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MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

"Evaluating the communication gap between enactivist theory, research, and human and robotic therapy addressing social interaction performance in persons on the autism spectrum"

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Abstract

How do persons on the autism spectrum socially interact? Motivated by the documented theory-to-research-to-practice addressing Autism Spectrum Disorder and after a series of meetings with professionals in the field (i.e., cognitive science, philosophy, engineering), I aimed in this master thesis to analyze and review publications discussing characteristics of the social interaction competence of persons on the autism spectrum from the perspectives of theory (i.e., Participatory Sense-Making), research (i.e., studies addressing visual and motor and social interaction performance), and therapy (i.e., human and robot therapies). This work is meant to facilitate the scientific communication between practitioners, engineers, and academics studying Autism Spectrum Disorder, and to promote the view that Autism Spectrum Disorder is not necessarily a disability, but rather an atypical form of development. As a trained psychologist with one and a half years of experience in applying principles of Applied Behavioral Analysis to teaching skills to children on the autism spectrum, I take advantage of my professional hands- on background to review the scientific and therapeutic fields and to make suggestions for experts in the field also from the perspective of an interventionist. The present work is addressed at academics investigating Autism Spectrum Disorder (including philosophers, psychologists, and engineers) and interventionists interacting with persons on the autism spectrum.

Among the paradigms in cognitive science, the *cognitivist* approach of Theory of Mind has led to argumentation for *impaired* mentalizing abilities of persons on the autism spectrum during social interaction, but this approach has been criticized for failing to capture the full "reality" of face-to-face social interaction. In contrast, the *enactivist* perspective on social interaction of Participatory Sense- Making hypothesizes a *particular* way of persons on the autism spectrum to socially coordinate and interact. Rather than on the particulars of states and transitions of the social interaction phenomenon, the enactivist framework focuses on the dynamics of movements and relationships and on the interaction rhythms characterizing the social unit formed by, e.g., a person on the autism spectrum and a person with typical development.

The Participatory Sense-Making theory by De Jaegher (2013) hypothesizes that persons on the autism spectrum interact and make sense of the environment based on their 'autistic' embodiment. In an attempt to verify whether recent evidence confirms this hypothesis, I review publications from the field of Psychology that investigate the motor and visual perception processes of persons on the autism spectrum, the way they make sense of the environment, and characteristics of their social interaction competence. The evidence I reviewed is indicative of a possible construct of an 'autistic' embodiment influencing sense-making and social interaction. However, given the restricted number of publications covered in my

review and further limitations identified within this selection, I cannot offer conclusive evidence for this hypothesis. Another finding of my review is that there seems to be a bidirectional relation between low-level processes (i.e., motor and sensory processes) and high-level processes (i.e., social interaction and language) in persons on the autism spectrum, but the nature of this relation is not definite. Another result of my literature review about the social interaction of persons on the autism spectrum is that they do actually *coordinate and synchronize* in their interactions with both, other persons and objects, but they do so *differently* than persons with typical development.

Different human and robot therapies aim to teach and improve social skills to/of persons on the autism spectrum. The results indicate robot-*mediated* therapy to be more *efficient* than human therapy in teaching social skills to children on the autism spectrum, but human interventionists to be more *skillful* than social robots at teaching social skills to children on the autism spectrum. I present arguments for the need to change the role of the robot in the therapy for persons on the autism spectrum to practicing only already acquired social skills. Robots could also be used as interactive social toys that provide human interventionists the opportunity to teach social skills to persons on the autism spectrum. Regarding human therapies for persons on the autism spectrum, my review shows human rhythm therapy to have the potential to address and improve social interaction as a process compared to behavioral therapy that limits social interaction competence only to social skills.

I found that the low number of studies providing informed recommendations to peer study fields documents the persistence of the communication gap, especially between applied research and therapeutic practice addressing the Autism Spectrum Disorder. For this reason, I call for scientists and practitioners in the field to address the assumed communication challenge: the enactivist philosophers to provide guidelines about what qualitative and/or quantitative evaluations (i.e., phenomenological and/or behavioral) can be applied to investigate the concepts of enactive social interaction, how to empirically study the phenomenon of social interaction, and whether and how the concept can be targeted and improved in a therapeutic context; and the call for engineers and interventionists working with persons on the autism spectrum to closely *collaborate,* in order to develop *ethical* robot-therapy designs that safeguard the human condition of everyone involved and affected.

Zusammenfassung

Wie funktioniert die soziale Interaktion bei Personen aus dem Autismus-Spektrum? Motiviert durch bestehende Lücken in Forschung und Praxis und nach mehreren Treffen mit Professionellen aus dem Feld der Autismus Forschung (d.h. aus den Kognitionswissenschaften, Philosophie, Ingenieurwesen), war es mein Ziel, in dieser Masterarbeit wissenschaftliche Publikationen zu analysieren, in denen Charakteristika der sozialen Fähigkeiten der Interaktion von Menschen aus dem Autismus-Spektrum aus der Perspektive der Theorie (d.h. „Participatory Sense-Making), Forschung (Studien in denen die visuelle, motorische und Fähigkeiten der sozialen Interaktion untersucht wurden) und Therapie (d.h. menschliche- und Roboter-Therapie) diskutiert werden. Diese Arbeit soll zudem die wissenschaftliche Kommunikation zwischen Praktikern, Ingenieuren und Akademikern, welche die Autismus-Spektrum-Störung erforschen erleichtern. Außerdem soll sie die Ansicht verbreiten, dass eine Autismus-Spektrum-Störung nicht zwangsweise eine Beeinträchtigung, sondern eher eine atypische Form der Entwicklung darstellt. Als trainierte Psychologin, mit anderthalbjähriger Erfahrung in der angewandten Verhaltensanalyse, die Kindern aus dem Autismus-Spektrum bestimmte Fähigkeiten beigebracht hat, will ich auch aus der Perspektive als Interventionistin, die Literatur aus dem wissenschaftlichen und dem therapeutischen Feld untersuchen, um anderen Experten aus dem Feld Vorschläge für deren zukünftige Forschungsansätze machen. Die vorliegende Arbeit ist daher an Akademiker, die die Autismus-Spektrum-Störung erforschen (inklusive Philosophen, Psychologen und Ingenieure) und an Interventionisten gerichtet, die im therapeutischen Setting, mit Personen aus dem Autismus-Spektrum arbeiten.

Unter den verschiedenen Paradigmen der Kognitionswissenschaften, spricht der kognitivistische Ansatz der "Theory of Mind" von eingeschränkten Fähigkeiten zur Mentalisierung bei Personen aus dem Autismus-Spektrum. Dieser Ansatz wird aber dahingehend kritisiert, dass hierbei nicht die gesamte Brandbreite der soziale Interaktion beschrieben wird. Im Kontrast dazu, steht die enaktivistische Perspektive der sozialen Interaktion. Im Sinne der hier postulierten „participatory-sense-making"- Hypothese, gibt es bestimmte Verhaltensweisen bei Menschen aus dem Autismus-Spektrum, sich sozial zu koordinieren und zu interagieren. Anstatt auf Besonderheiten von Zuständen und Übergängen, fokussiert sich der enaktivistische Ansatz auf die Dynamik von Bewegungen und persönlichen Beziehungen, außerdem auf den Rhythmus der Interaktion, der die soziale Einheit zwischen einer Person aus dem Autismus-Spektrum und einer Person mit typischer Entwicklung definiert. Die Participatory Sense-Making Theorie von De Jaegher (2013) postuliert, dass Personen aus dem Autismus-Spektrum, basierend auf ihrem "autistischen" embodiment, den Abläufen in ihrer Umwelt einen Sinn geben und mit ihr interagieren. In dieser Arbeit habe Ich Literatur aus dem Feld der Psychologie untersucht, in der die motorischen und visuellen Wahrnehmungsprozesse von Person aus dem Autismus-Spektrum, die Art und Weise wie sie ihre Umwelt verstehen und die Charakteristiken ihrer sozialen Kompetenzen zur Interaktion beschrieben werden, um zu überprüfen, ob kürzlich erschienene Forschungsergebnisse die Theorie von Jaeger verifizieren oder nicht.

Die Ergebnisse deuten darauf hin, dass ein mögliches Konstrukt eines „autistischen" embodiments existiert, welches die Art und Weise wie wir die Welt verstehen und mit anderen Menschen interagieren, beeinflusst. Da nur eine

limitierte Anzahl von Veröffentlichungen in dem Bereich existieren und wegen Limitationen innerhalb dieser Studien, kann ich dies aber nicht mit Bestimmtheit sagen.

Eine Konklusion meiner Untersuchung ist aber die, dass es eine bidirektionale Beziehung zwischen Prozessen auf niedriger Ebene (d.h. motorische und sensorische Prozesse) und auf höherer Ebene (d.h. soziale Interaktion und Sprache) zu geben scheint, welche aber nicht immer Auftritt. Eine andere Konklusion, die in dieser Masterarbeit über die soziale Interaktion von Personen aus dem Autismus-Spektrum präsentiert werden kann, ist die, dass sie tatsächlich ihre Handlung mit Personen und Objekten koordinieren und synchronisieren, aber sie tun es auf eine andere Weise als Personen mit einer typischen Entwicklung.

Verschiedene Therapieformen (d.h. Personen-zentriert, Roboter-zentriert) zielen darauf ab, Personen aus dem Autismus-Spektrum soziale Fähigkeiten beizubringen und diese zu verbessern. Die Roboter-zentrierte Therapie ist effizienter als die Personen-zentrierte Therapie in der Vermittlung von sozialen Fähigkeiten, an Kinder aus dem Autismus-Spektrum. Menschliche Therapeuten sind in diesem Kontext aber befähigter als soziale Roboter. Daher schlage ich vor, dass die Verantwortlichkeit von Robotern in der Therapie von Personen aus dem Autismus-Spektrum, auf das Üben von bereits erlernten sozialen Fähigkeiten, limitiert bleiben sollte. Der Roboter könnte als interaktives soziales “Spielzeug” verwendet werden, der dem menschlichen Therapeuten eine erweiterte Möglichkeit gibt, Menschen aus dem Autismus-Spektrum soziale Fähigkeiten beizubringen.

Bezüglich der Therapie von Personen aus dem Autismus-Spektrum, zeigt meine Untersuchung, dass die personen-zentrierte Rhythmustherapie das Potenzial besitzt, verschiedene Aspekte der sozialen Interaktion von Menschen aus dem Autismus-Spektrum zu adressieren und zu verbessern. Besonders im Vergleich zur behavioralen Therapie, welche die Kompetenz der sozialen Interaktion, nur auf soziale Fähigkeiten limitiert.

Ich konnte herausfinden, dass die geringe Anzahl von Studien, welche fundierte Empfehlungen abgeben verschiedene Studienfelder in den Augenschein zu nehmen, die Persistenz der Kommunikationslücke zwischen angewandter Forschung und der therapeutischen Praxis, gut dokumentiert. Deshalb, empfehle ich Wissenschaftlern und Praktikern des Feldes der Autismus Forschung, die existierenden Kommunikationslücken anzugehen. Das heisst, ich empfehle beispielsweise Philosophen aus dem Bereich des Enaktivismus, klare Richtlinien zu definieren, welche qualitativen und quantitativen Evaluationen (d.h. behavioral und/oder phänomenologisch) bei der Untersuchung von Konzepten von enaktivistischer sozialer Interaktion angewendete werden sollen. Außerdem, wie man das Phänomen der sozialen Interaktion empirisch untersucht und inwiefern oder ob diese Konzepte auf die Therapie abzielen und diese somit auch verbessern können. Außerdem, rufe ich Ingenieure und Interventionisten die mit Personen aus dem Autismus Spektrum zusammenarbeiten, dazu auf, dass sie im regen Austausch kollaborieren, um ethische Roboter-zentrierte Therapien zu entwerfen, welche dem Wohle der involvierten und von den Therapien beeinflussten Personen, dienen.

Acknowledgments

It has been a long and beautiful journey. I would like to thank my supervisor Paolo Petta for empathically and meticulously supporting the development of my academic skills ever since the beginning of the master thesis program, for always encouraging and assisting in my academic activities, and for engaging me in interesting and intellectually stimulant discussions about science and life. I reflected for days on the topics of our discussions.

I thank the professionals I met with to discuss aspects of my master thesis for their availability, patience, and interest: Markus F. Peschl, Matthew Ratcliffe, Christopher Frauenberger, and Nima Taheri-Nejad. The discussions prompted the formulation of the present master thesis concept.

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Professional Expertise

Throughout the content of the master thesis I provide my personal opinion as a behavioral interventionist pursuing the Registered Behavioral Credential (RBT- https://www.bacb.com/rbt/ - last accessed 18.06.2018). I detail now my experience and my expertise. I have a Bachelor in Psychology from the University of Bucharest. I carried out voluntary work at AITA (Association for Therapeutic Intervention in Autism Disorders, Bucharest, Romania-2014-2015), where I observed and supported one-on-one and group therapy for children on the autism spectrum, I assisted a child on the autism spectrum in kindergarten (Bucharest, Romania - 2014), and I applied behavioral principles of Applied Behavioral Analysis to teach skills to two children on the autism spectrum under the supervision of a BCBA (Vienna, Austria – 2016-2017).

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Through others, we become ourselves. Lev Vygotsky (1896–1936)

PART I. Motivation and Aims

1 Structure of the Master Thesis

This master thesis addresses the topic of social interaction performance in persons on the autism spectrum. After a report of an initial motivating round of expert interviews described in Appendix A Log of the Initial Meetings with Professionals and analyzed in Chapter 2 Evaluation of Initial Meetings with Professionals, I formulated the master thesis concept, which can be found in Chapter 3 Master Thesis Concept, and the Research Questions and Hypotheses, which can be found in Chapter 4 Research Questions and Hypotheses. In Chapter 5 Historical Perspective on the Diagnosis Criteria of Autism Spectrum Disorder, I present the diagnosis criteria of Autism Spectrum Disorder, I point out the changes in the evolution of the diagnosis criteria, and I analyze to what extent persons diagnosed according to DSM-IV still meet diagnosis criteria on the autism spectrum according to DSM-5. In Chapter 6 Social Interaction in Persons with Typical Development and in Persons on the Autism Spectrum, I discuss and compare the development of the abilities to interact of persons with typical development and of persons on the autism spectrum and characteristics of the social interaction performance of persons with typical development. From a philosophical and paradigmatic point of view, I contrast the cognitivist perspective of Theory of Mind and the enactivist perspective of Participatory Sense-Making on social interaction characteristics and performance of persons on the autism spectrum, taking side with the enactivist account of De Jaegher (2006, 2013) that argues for a unique way of persons on the autism spectrum to interact, based on their 'autistic' embodiment. The discussion about these theories can be found in Chapter 7 The Cognitivist and Enactivist Theories of Social Interaction. In the following three chapters (i.e., Chapter 8 'Autistic' Embodiment, Chapter 9 From Embodiment to Sense-Making, and Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum), I analyze recent publications from the field of Psychology discussing the concepts of 'autistic' embodiment, sense-making, and social interaction and coordination in persons on the autism spectrum. In Chapter 13 Human and Robot Therapy for Children on the Autism Spectrum and Chapter 14 Rhythm and Behavior Therapies, I critically discuss the effectiveness, skillfulness, and efficacy of human (i.e., rhythm and behavioral therapies) and robot interventionist in/at teaching and improving social skills of persons on the autism spectrum. In Chapter 15 The Communication Challenge, I assess the *communication and collaboration gap* between Theory, Therapy, and Research addressing social interaction in persons on the autism spectrum, and I offer my summary conclusions regarding conflicts and similarities between assumptions, methodologies, and definition of concepts of the fields of study and practice (Theory, Research, and Therapy) discussed in the present master thesis. In Chapter 16 Interdisciplinarity, I discuss the interdisciplinary aspect of this master thesis.

2 Evaluation of Initial Meetings with Professionals

This chapter is a synthesis and an analysis of a series of meetings with professionals I carried out at the outset of my master thesis work. A detailed log of the meetings is available in Appendix A Log of the Initial Meetings with Professionals. The main goal of this exercise was to discuss key topics of my first master thesis concept (see Appendix B My Former Master Thesis Concept). The outcome of the meetings led to the formulation of the final Master Thesis Concept explained in Chapter 3 Master Thesis Concept and the Research Questions and Hypotheses stated in Chapter 4 Research Questions and Hypotheses. Over a period of nine months I met with professionals from different fields (i.e., philosophy, cognitive science, computer science, and engineering) to discuss and analyze specific topics of relevance for my master thesis aims, to obtain feedback on the soundness of my developing master thesis concept, and to obtain the professionals' perspectives on the way children on the autism spectrum interact and on the building process of robots for children on the autism spectrum.

2.1 Analysis of the Meeting with a Computer Scientist/Cognitive Scientist

Markus F. Peschl is professor of cognitive science and philosophy at the University of Vienna. He carried out his studies in philosophy, cognitive science, and computer science and holds a PhD in Computer Science from the University of Vienna.

In our meeting, prof. Peschl compared the enactivist perspective on cognition to the cognitivist framework. The cognitivist paradigm takes a top-down approach on a phenomenon (i.e., from high-level processes, such as memory and cognition to low-level processes such as perception and sensation), while the enactivist paradigm takes a process and a bottom-up perspective (i.e., investigating how low-level processes, such as sensation and perception are involved in high-level processes). Prof. Peschl presented arguments to defend the idea that the enactivist paradigm is more relevant than the cognitivist paradigm in investigating a phenomenon. The process perspective of enactivism is interested in which and how different psychological phenomena of the human mind intertwine. The enactivist framework aims to explain how behavior emerges from the integration of the processes involved in the manifestation of the behavior. I address the bottom-up level of analysis in Section 7.2 Enactivism Theory and the term *emergence* is explained in Appendix C Glossary of Terms of the Enactivist Paradigm, term 4).

Relating to the robot-child on the autism spectrum interaction, Prof. Peschl identified key characteristics the social robot should have according to the enactivist theory in order to interact with the child on the autism spectrum. In particular, the robot should be able to perceive the sensory (tactile, olfactory etc.)

cues of the child. We did however not discuss further details of this idea. In addition, Prof. Peschl mentioned ethical issues that would need to be addressed when formulating suggestions for engineers and interventionists regarding the dyad robot-child on the autism spectrum interaction. I was therefore recommended to rather address the role of the robot as a *mediator* in the *triad*: child on the autism spectrum—robot—caregiver.

2.2 Analysis of the Meetings with a Historian and Philosopher of Science

Matthew Ratcliffe holds a PhD in History and Philosophy of Science from the University of Cambridge, and is the head of the philosophy department at the University of Vienna. His interests include philosophy and phenomenology of social interaction and the phenomenology of schizophrenia.

The first meeting with Prof. Ratcliffe was introductory and dealt with definitions of the concept of phenomenology of social interaction. Here, Prof. Ratcliffe informed me that my original approach to describe the unique social style of interaction of persons on the autism spectrum in their interaction with humans and with robots from a phenomenological perspective should rather be replaced with a behavioral approach that would allow me to compare the same characteristics of social skills of persons on the autism spectrum as they present themselves in the interaction with both humans and robots. The first questions addressed during the second meeting with Prof. Ratcliffe were whether it has been systematically documented in the literature for children on the autism spectrum to have been observed to be more sociable towards robots than towards humans, and what exactly distinguishes child-robot interaction from the one with humans. Moreover, Prof. Ratcliffe explained there are different patterns of interaction between the child on the autism spectrum and humans on the one hand, and the child on the autism spectrum and robots on the other, which hinder the comparison of these types of interactions at the same level. To be able to compare human-human and human-robot interaction, Prof. Ratcliffe suggested I define social interaction as observable social behavior (e.g., in terms of frequencies of imitation and eye contact) in contrast to phenomenological descriptions (that were discussed during first meeting). In the meetings, Prof. Ratcliffe further stressed the importance that I demonstrate and provide evidence for the transfer and generalization of social skills in persons on the autism spectrum after receiving robot-therapy. I discuss the acquisition and generalization of skills after therapy with humans in Subsection 13.4.1 Benefits of Human Therapy.

During second meeting, Prof. Ratcliffe pointed out a contradiction in my initial master thesis concept. There, I had argued on the one hand that children on the autism spectrum prefer the interaction with robots in favor of the interaction with humans, because they supposedly possess an inner motivation to interact with robots (i.e., understandable social mechanism), but not with humans (i.e., complex, dynamic social system). But at the same time, I had also asserted that children on the autism spectrum form social bonds and emotionally attach to their human caregivers, which implies that children on the autism spectrum also possess an inner motivation to interact with humans.

2.3 Analysis of the Meeting with a Philosopher in Computer Science

Christopher Frauenberger holds a Doctorate in Philosophy in Computer Science from Queen Mary, University of London and is a senior researcher at the Human Computer Interaction Department at the University of Technology, Vienna.

As a response to my initial master thesis concept, Christopher Frauenberger claimed from the literature that arguing for the existence of a particular style of interaction, as I first planned is not novel. He also claimed the literature acknowledges that persons on the autism spectrum *do* present a certain level of social skills, but researchers do not agree on the nature of these skills. Given the different perspectives on and the experiences in the domain of Autism Spectrum Disorder, such differences in approaches to the domain were to be expected — forming in fact one of the motivations to conduct this series of expert interviews. Similar to Prof. Ratcliffe, Christopher Frauenberger also explained how human-human and human-robot interaction cannot be compared at the same level. Christopher Frauenberger further mentioned the behavior of persons on the autism spectrum to be atypical and highly unpredictable, making it hard for caregivers to adapt to their behavior and for interventionists to provide guidelines for dealing with every situation.

Christopher Frauenberger recommended for me to include the field of Sociology in my study of Autism Spectrum Disorder and to follow up on anecdotal evidence describing the social experiences of persons on the autism spectrum. Moreover, Christopher Frauenberger advised me to include both quantitative and qualitative methodologies in the event of carrying out a planned case study concerning a child on the autism spectrum: Such a case study was approved by the Ethical Committee at the University of Vienna, but was not carried out in the end due to organizational issues. The application material is reported in Appendix G Proposal for a Single-case Study of a Pre-scholar on the Autism Spectrum.

2.4 Analysis of the Meetings with an Electrical and Computer Engineer

Nima Taheri-Nejad holds a doctorate in electrical and computer engineering from the University of British Columbia (UBC) and is an assistant researcher at the Technical University of Vienna.

The main topics of the discussions between me and Nima Taheri-Nejad were designing and building robots and their respective implications for the interaction with children on the autism spectrum. Nima Taheri-Nejad informed me of difficulties of building the hardware of a robot (e.g., constructing the robot's mouth is a key challenge on its own) and of the ethical and methodological necessity to test the robot with children with typical development and high-functioning adults on the autism spectrum before evaluating the performance in the interaction with children on the autism spectrum. Also because of this reason, Nima Taheri-Nejad showed restraint in aiming for complex roles for the robot in the interaction with children on the autism spectrum. He proposed the robot deployed in the interaction with children on the autism spectrum could be a *permanent aid*. The aim would be for the robot to mediate the interaction between children with typical development and children on the autism spectrum, so as to facilitate their interaction. Another suggested role of the robot is as *therapy aid/therapeutic tool*; the robot should be able to interpret the verbal and non-verbal language of the child to help address potential social issues by providing the interpreted information to the involved person with typical development in a therapeutic setting. Another suggested role for the robot is to serve as *data collector*, registering specific information about the behavior of the child on autism spectrum (e.g., vocalizations). This data would then be available for analysis by a human professional. Nima Taheri-Nejad put forward the idea to start experimenting with the role of the robot as a preferred toy, but was not decided on this aspect nor on the specific context in which the robot should be used.

Nima Taheri-Nejad suggested I aim for systematically identifying characteristics of the social interaction of children on the autism spectrum across individuals. While I do not provide such an overview (that would be challenging to assemble from available published material), I discuss publications investigating social interaction in persons on the autism spectrum and report social characteristics of persons on the autism spectrum in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum. Nima Taheri-Nejad also suggested and my master thesis supervisor consolidated the importance of "sufficiently modular (and capable) hardware" that would support a broader range of software deployments. Further, Nima Taheri-Nejad introduced me to the effect known as the "uncanny valley", where (imperfections in) the human-like appearance of a robot influence the emotional response of typically developed humans to it. In turn, I briefly informed Nima Taheri-Nejad about the latest updates of the neuroscientific literature on the social interaction of persons on the autism spectrum (e.g., that toddlers on the autism spectrum consistently attend more to the mouth than the eyes of a peer (Klin, Shultz, & Jones, 2015)), and I advised him about basic emotions the robot should display in the interaction with the child on the autism spectrum.

2.5 Personal Conclusions and Analysis

Contrary to my expectations as a student and novice researcher, I did not experience full alignment of approaches to the discussed topics across all interviews, nor did all peers offer specific instructions about the next steps to take. Moreover, I observed a number of both similarities and striking differences between the professionals' perspectives on the discussed topics.

The representatives of cognitive science and philosophy took the paradigms of enactivism and enactive intersubjectivity to best explain human social interaction for my purposes. While I considered the arguments made by Prof. Peschl to be insufficient for demonstrating any *higher* relevance of the enactivist paradigm in comparison to the cognitivist paradigm, I do believe—after analyzing the literature—the enactivist paradigm and its principles reflect the reality of the social interaction characteristics and competence of persons on the autism spectrum. Together with my supervisor, I reflected after the meeting with Prof. Peschl on the levels of analysis of the enactive and cognitive frameworks. I concluded the arguments provided by Prof. Peschl in favor of the enactivist framework are not sufficient because they do not explain at a fundamental level why the enactivist perspective should better describe the mechanisms and processes of a phenomenon or, in other words, why the bottom-up perspective should reflect reality *better* than the top-down perspective.

In my interaction with the representative of engineering, I observed a marked difference in approaching the design of a robot for children on the autism spectrum. As a result of my experience applying principles of Applied Behavioral Analysis (ABA) during my interaction with children on the autism spectrum and my communications with my supervisor, I was focused on clearly establishing the purpose, the role, the environmental context in which it would function, and the implications of any design *before* starting to implement the robot. In contrast, the representative of engineering expressed interest in the practical basic roles robots can and should fulfill in their interaction with children on the autism spectrum. Nima Taheri-Nejad's approach to the design of a robot was to start from the engineering limitations and the possibilities of building a robot for children on the autism spectrum. After building, the efficacy of the robot is to be tested in the context of the real environmental setting: The professional's approach to research follows the so-called waterfall model of building-releasing-testing. We addressed the differences of approaches by discussing issues of the building of a robot for children on the autism spectrum from an engineering, a therapeutic, and a psychological perspective. I believe both I and the Nima Taheri-Nejad benefited from our exchange of perspectives on the topic of robots for children on the autism spectrum.

Both representatives of cognitive science and philosophy in computer science approached the phenomenon of social interaction of children on the autism spectrum by aiming at understanding the social experience they have with humans, respectively with technologies. Also, both representatives of philosophy and philosophy in computer science clearly distinguished between the nature of the interaction of the child on the autism spectrum with robots and the one with humans. I analyze such differences between human and robot interaction in Section 13.4 Benefits and Limitations of the Human and Robot Therap. I also noted contrasting approaches to the topic of social interaction performance of children on the autism spectrum during my communication with the representative of philosophy in computer science. As a result of my personal experience of teaching skills to children on the autism spectrum by applying principles of Applied Behavioral Analysis, as well as from reading up on the behavioral psychology literature on the impaired or lack of social skills of persons on the autism spectrum (e.g., Frith (2012)) and their interaction with robots, I first focused on the importance of studying social interaction in persons on the autism spectrum without comparing it to that of persons with typical development because I believe persons on the autism spectrum to have an *atypical* manner of social interaction. Christopher Frauenberger's different professional and scientific background has led him to formulate a different perspective on the domain of Autism Spectrum Disorder and social interaction: In particular, he provides me with the work of the philosopher De Jaegher (2013) who argues for the existence of an 'autistic' embodiment (this body of work ended up forming a cornerstone of my master thesis work). I elaborate on the concept of 'autistic' embodiment in Chapter 8 'Autistic' Embodiment7.3. Even though the representative of philosophy in computer science claimed from the literature that the unique style of social interaction of persons on the autism spectrum has already been scientifically documented, the characterization of the exact nature of this style is in fact still pending. I investigate social interaction and coordination of persons on the autism spectrum in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum. In relation to Christopher Frauenberger's comment about the atypical and highly unpredictable behavior of persons on the autism spectrum, I did observe (considering my experience as a behavioral interventionist) persons with typical development present difficulties facing and adapting to the highly unpredictable behavior of children on the autism spectrum, but this aspect is less available for experienced interventionists and when the caregiver and the child on the autism spectrum have a closed relationship.

With regard to the human-robot interaction design, the representative of cognitive science pointed out that in the interaction with the child on the autism spectrum the robot should be receptive to the sensorial cues of the child. This perspective is in line with David Vernon's approach to social cognition. According to Vernon (2014), it is crucial for the social agent to be able to interpret the visual data with respect to the intentions and activities of other social agents.

2.6 Impact on the Master Thesis Concept

The outcome of the interviews guided the allocation of my resources to relevant and up-to-date concepts in the field and to the fleshing out of my master thesis concept. The representatives of philosophy and philosophy in computer science helped me identify and understand faults and omissions in my reasoning, identified missing pieces in my concept, and proposed further steps I should take. The outlined characterization of the enactivist framework and the list of recommended references provided by Prof. Peschl influenced the formulation of the performance measure for the literature search and selection of theories and experiments. Also related to literature search, I did not include, as recommended by Christopher Frauenberger the domains of sociology within the analysis of my master thesis because I believe the arguments from the enactive philosophy, comparative psychology, and human-robot interaction domains to be essential for the research questions pursued here.

Based on Prof. Ratcliffe's suggestion to define social interaction as social behavior that can be easily and systematically observed, I therefore characterize the social interaction phenomenon as social skills, but also as interpersonal processes. To solve faulty reasoning identified by Prof. Ratcliffe in my original master thesis concept, I re-oriented my focus towards the fields of *enactive* philosophy and *enactive* social interaction in persons with a typical development and in persons on the autism spectrum (discussed within the scope of RQ1; see Chapter 4 Research Questions and Hypotheses). The enactive approach takes both behavioral and phenomenological approaches to phenomena, but I mainly focus in the present master thesis on the former approach. Another reason for this choice was that I identified a resemblance between the principles of enactivism on social interaction phenomenon in persons on the autism spectrum and the personal observations of the way children on the autism spectrum interact in the therapeutic context. I introduce and discuss principles of enactivism and enactive social interaction in Section 7.2 Enactivism Theory.

As a consequence of Prof. Ratcliffe and Christopher Frauenberger's feedback that I cannot compare at the same level human-human and human-robot interaction, in the present thesis I do not compare these two types of interaction, but instead analyze the effectiveness, skillfulness, and efficacy of the human and robot interventionists (in a robot-mediated therapy) at/in improving and teaching social skills to persons on the autism spectrum (see RQ2 in Chapter 4 Research Questions and Hypotheses and Chapter 13 Human and Robot Therapy for Children on the Autism Spectrum). To elaborate on the Prof. Peschl's comment about the ethical aspect of a triadic interaction between the robot, the persons on the autism spectrum, and the person with typical development, I describe some of the ethical issues of robot-based therapies in Subsection 13.4.4 Limitations of Robot Therapy. Immediately related to this issue, I argue in Section 13.4 Benefits and Limitations of the Human and Robot Therap and in Section 13.6 Suggestions for Future Implementations of Robot-therapy for Children on the Autism Spectrum that the role of the robot should be limited to fulfilling the minor role of teaching basic social skills to children on the autism. As a result of the representative of cognitive science's recommendation to investigate the role of the robot as a mediator in the triad interaction child-robot-caregiver, I therefore investigate this role in Chapter 13 Human and Robot Therapy for Children on the Autism Spectrum. In relation to Christopher Frauenberger's comment about the difficulty of caregivers and interventionists to adapt to the highly unpredictable behavior of persons on the autism spectrum, I argue in Subsection 13.4.1 Benefits of Human Therapy that robots adapt less than humans to the behavior of persons on the autism spectrum in the therapeutic context.

As a result of all meeting with experts, we conceived of a preliminary qualitative study aimed at contributing required groundwork for the current master thesis: While the proposal did obtain clearance by the Ethics Committee of the University of Vienna of a single-case study of a pre-scholar on the autism spectrum, the study was finally not implemented because of scheduling issues. A complete copy of the approved application form, research proposal, informed consent of the legal guardian, and other relevant documents can be found in Appendix G Proposal for a Single-case Study of a Pre-scholar on the Autism Spectrum.

3 Master Thesis Concept

I present now a summary of the master's final thesis concept that incorporates lessons learned from the interviews with experts covered in the previous chapter. My analysis of the manner persons on the autism spectrum socially interact and coordinate is grounded in De Jaegher (2006)'s theory of Participatory Sense-Making and evidence from the field of Comparative Psychology. I hypothesize and assess the evidence for the existence of an 'autistic' embodiment of persons on the autism spectrum that influences the way they make sense of the world and the way they interact with another social agent. I move to the field of therapy to assess whether human and robot interventionists are effective in improving social skills of children on the autism spectrum and skillful and efficacious at/when teaching social skills to children on the autism spectrum. Finally, I assess whether there is a persisting communication gap between Theory, Research, and Therapy about Autism Spectrum Disorder.

4 Research Questions and Hypotheses

In this chapter I present the research questions (RQs) guiding the theoretical work of the master thesis, the scope, and aim of the research questions and the associated hypotheses.

RQ1. What are descriptive general and individual characteristics of the style of interaction of persons on the autism spectrum?

The purpose here is to identify characteristics of the social interaction performance of persons on the autism spectrum that are not necessarily impaired, but different from the characteristics of persons with typical development. In other words, the purpose is to accomplish the first steps to change the research perspective on the social interaction performance characteristics of persons on the autism spectrum towards one that values and investigates particular characteristics of the Autism Spectrum Disorder. To answer this question, I will describe and analyze the enactivist theory in general (see Section 7.2 Enactivism Theory) and of social interaction of persons on the autism spectrum from the perspective of De Jaegher (2006) (see Section 7.3 Participatory Sense-Making and Autism); compare the enactivist theory to Theory of Mind (see Section 7.1 Theory of Mind and Section 7.2 Enactivism Theory); present and contrast characteristics of the social development of persons with typical development and of persons on the autism spectrum (see Chapter 6.2 Development of Social Skills); and finally analyze the influence of 'autistic' embodiment on sense-making and social interaction of persons on the autism spectrum (see Chapter 8 'Autistic' Embodiment, Chapter 9 From Embodiment to Sense-Making, and Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum).
The covered fields of analysis are Philosophy and Psychology.

The hypothesis of RQ1 is:

H1) The 'autistic' embodiment is exclusively connected to the way persons on the autism spectrum make-sense of and socially interact in the world.

H1) is first formulated and evaluated in De Jaegher (2013). The author hypothesizes that the particular characteristics of the moving, perceiving, and emoting processes of persons on the autism spectrum relate to how they make sense of and socially interact in their world. In other words, the author explains that a different (from typical) embodiment implies a different sense-making and a different interaction and coordination in social encounters. The connection between phenomena is bidirectional, but De Jaegher does not provide a clear explanation of how processes are connected. In her work, De Jaegher sets out to explain and to provide evidence for preliminary relationships between the processes of embodiment, sense-making, and social interaction of persons on the autism spectrum, but further analyses are required.

I aim here to provide up-to-date evidence of the relationship between the concepts. The rationale for this H1) is related to my personal experience as a behavioral interventionist working with children on the autism spectrum and to the previously read literature (e.g., Garcıa-Pérez, Lee, & Hobson (2007), Klin, Jones, Schultz, & Volkmar (2003), and Mari, Castiello, Marks, Marraffa, & Prior (2003)); I concluded that persons on the autism spectrum react differently than persons with typical development to the social and non-social environment, and that the reaction might be related to differences in basic processes of moving and sensing.

RQ2. What are benefits and limitations of human and robot-mediated therapies with regard to the aims of teaching and improving social skills in children on the autism spectrum?

The purpose of RQ2 is to conclude which type of therapy is appropriate for which specific aims and actions set and taken during social therapy for persons on the autism spectrum. The scope of the related research is to analyze European Projects—the Euro-centrism of the projects selection is related to a greater expertize in European therapy practices due to my therapeutic experience in 2 European Countries (i.e., Romania and Austria)—and publications evaluating the effectiveness, skillfulness, and efficacy of human and robot interventionists when teaching and improving social skills of children on the autism spectrum (see Chapter 13 Human and Robot Therapy for Children on the Autism Spectrum) to provide my personal informed opinion as a behavioral interventionist with experience in interacting with children on the autism spectrum and to identify and analyze limitations and benefits of human and robot-mediated therapies designed to improve social skills for children on the autism spectrum (see Section 13.4 Benefits and Limitations of the Human and Robot Therap and Section 13.6 Suggestions for Future Implementations of Robot-therapy for Children on the Autism Spectrum).
The covered fields of analysis are Human-Robot Interaction and Psychology.

The hypotheses of RQ2 are:

H2a) Human interventionists are more effective than social robots in increasing the performance level of social skills of persons on the autism spectrum.

I characterize a system as *effective*, when it is successful in reliably achieving the intended results. By the phrase "the performance level of social skills", I refer to both social skills that can be systematically observed (e.g., waiting for turn, hand shaking) and social coordination and interaction abilities as defined by De Jaegher (2006) *and* to the social skills that are learned during therapy (near-transfer), but also applied in the real world (far-transfer). The rationale for this hypothesis is that human interventionists are better equipped with the general necessary qualities (e.g., better adapts and reacts to the complex and dynamic social world) of an interventionist that ensure near- and far- transfer of social skills.

H2b) Human interventionists are more skillful than social robots at teaching social skills to persons on the autism spectrum.

I characterize a system as *skillful* to teach social skills, when it possesses a broad range and depth of social skills that allows it to identify and produce in real time and with reduced latency the appropriate social cue the social partner requires. The rationale for this hypothesis is that human interventionists, compared to robots, are cognitive agents that have naturally and progressively accumulated the necessary social skills to act in a social interaction as expected by the social partner, and that the current status of developments in robotics does not allow for such social competence.

H2c) Social robots are more efficient than humans in teaching social skills to persons on the autism spectrum.

I characterize a system as *efficient*, when it robustly operates in an organized way and accomplishes the goal it was designed to fulfill with parsimonious use of resources. By the phrase "teaching social skills" I refer to the social capabilities that are taught only in a therapeutic context and that are easily and systematically observed and measured (e.g., eye-contact, pointing etc.) by interventionists and researchers. The rationale for the hypothesis is that robots can be programmed to meet this criteria given a systematic and appropriate (for the set targets) therapy design. Humans are prone to error, tiredness, and take time to learn the correct implementation of skills.

RQ3. What are benefits and limitations of the rhythm and the behavioral therapy designed to improve social skills in persons on the autism spectrum?

The purpose behind RQ3 is to evaluate which out of the rhythm and behavior therapies aimed at improving social skills for persons on the autism spectrum is most effective for addressing all aspects of the social skills (i.e., both social skills and the social rhythm flexibility and coordination as described by De Jaegher (2006)). Behavior therapy is well-established (Smith & Iadarola, 2015) and claimed to be effective (Makrygianni, Gena, Katoudi, & Galanis, 2018). Rhythm therapy is representative of the principles of Participatory Sense-Making Theory (De Jaegher, 2006). The scope of the related research work is to analyze and compare articles, reviews, and meta-analyses about the effectiveness of rhythm and behavior therapy to increase social skills in persons on the autism spectrum (see Section 14.1 Rhythm Therapy and Section 14.2 Behavior Therapy); to discuss and analyze limitations and benefits of the rhythm and behavior therapy; and to provide my personal expertise as a behavioral interventionist with experience in interacting with children on the autism spectrum about the benefits and limitations of the selected therapies, with the aim of informing and providing suggestions for empirical researchers and theoreticians in the field to support a better communication between fields (Section 14.3 Benefits and Limitations of Rhythm and Behavior Therapies).

The covered fields of analysis are Behavioral Psychology and Enactive Philosophy.

The hypothesis for RQ3 is:

H3) Persons on the autism spectrum present a larger improvement of social skills after receiving rhythm therapy than after receiving behavior therapy.

I define *social skills* both as observable and measurable social behaviors and as elements of social rhythm and coordination between social agents. The rationale for H3) is that rhythm therapy is supposed to target the development of the flexibility of the social rhythm (as described by De Jaegher (2006)), which is at the base of the development of social interaction described as synchronous rhythmic interaction.

RQ4. Do theory, research, and therapy sufficiently inform each other in order to advance in their shared purpose to investigate the characteristics of the Autism Spectrum Disorder and to provide effective and efficient treatment packages for persons on the autism spectrum?

The purpose of RQ4 is to assess the existence of any communication and collaboration gap between and across therapy, theory, and research. The scope of the related research work is to evaluate whether publications reviewed in this thesis connect their statements and findings to peer domains of theory, therapy, and research (see Chapter 15 The Communication Challenge and Appendix E Analyses of the Communication Gap between the Fields of Therapy, Research, and Theory Investigating Autism Spectrum Disorder).

The covered fields of study are Behavioral Psychology, Philosophy, and Human-Robot Interaction (therapy), Enactive Philosophy (theory), and Comparative Psychology (research) about Autism Spectrum Disorder.

The hypothesis of RQ4) is:

H4) There is a persisting communication gap between theory, practice, and research about Autism Spectrum Disorder.

I define *communication gap* as insufficient communication (i.e., authors do not provide recommendations to experts in the other fields) between involved parties that negatively influences the attainment of their shared goal. The rationale for H4) is that based on the documented theory-research-practice gap (Chown, 2015) and research-practice gap (Guldberg, 2017), recent publications (between 2013 and 2018) may still not connect their findings to the other fields of study and practice due to a communication challenge, whose causes and difficulties should be identified and addressed.

5 Historical Perspective on the Diagnosis Criteria of Autism Spectrum Disorder

Before going into the details and argumentation of the effort addressing the research questions stated in the preceding chapter, I describe the changes in diagnosis criteria for the Autism Spectrum Disorder over the past seven decades (from 1943 until 2013) and the current symptomatology description. The number of symptoms included in the diagnosis criteria first increased significantly from two to five, and finally were grouped into a disorder clustered under the term of *Autism Spectrum Disorder*; at the same time they were iteratively focused from a multiadic, to a triadic, and finally to a dyadic description of symptoms.

The first descriptions of the diagnosis of *Autism Spectrum Disorder* (ASD) were provided by Kanner (1943), who coined the term *Early Childhood Autism*, and Asperger (1944), who coined the term *Autistic Psychopathy*—later renamed to *Asperger Disorder* (Wing, 1981). Wing & Gould (1979) were the first to attempt a classification system of the Autism Spectrum Disorder—*socially impaired* and *sociable severely retarded children*—based on behavioral observations of the quality of social interaction, verbal and non-verbal language, and presence of repetitive stereotyped activities, regardless of intelligence levels, and on the scores of "formal tests or on educational achievement in the severely retarded range, regardless of the pattern of behavior and impairment" (Wing & Gould, 1979, p. 13).

The diagnosis criteria of Autism Spectrum Disorder were first published in the third edition of the Diagnostic and Statistical Manual of Mental Disorder (3rd ed.; DSM-3; American Psychiatric Association (1980, p. 87)). The Autism Spectrum Disorder comprised *Infantile Autism* and *Childhood Onset Pervasive Developmental Disorder (COPDD*). *Infantile Autism* was characterized by lack of response to other people; early onset of the disorder (before the age of 30 months); communication deficits; repetitive behaviors; and absence of delusions. COPDD was characterized by impairments in social interaction; impairments in at least three of the following areas: affect, anxiety, motor movement, hyper- and hypo- sensitivity; self-mutilation behaviors; later onset (after 30 months); and absence of delusions.

DSM-III-R (American Psychiatric Association, 1987) changed the diagnosis criterion of the *Autism Spectrum Disorder* to a triad of symptoms in the social area, the communicational area, and insistence on sameness of behavior, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior. Moreover, the term *Pervasive Developmental Disorder Not Specified Otherwise* was introduced instead of COPDD.

DSM-IV (American Psychiatric Association, 1994, p. 66) divided Autistic Disorders (a.k.a. *Pervasive Developmental Disorders*) into five subcategories: *Autistic Disorder*, *Rett's disorder*, *Childhood Disintegrative Disorder*, *Asperger's Disorder*, and *Pervasive Developmental Disorder not otherwise specified* (PDD-NOS). *Autistic Disorder* manifests itself as at least six impairments from the areas of social interaction, communication, restricted repetitive and stereotyped patterns of behavior, interests, and activities, and by an early onset of the disorder. *Asperger's Disorder* manifests itself as qualitative impairment in social interaction and restricted repetitive and stereotyped patterns of behavior, interests, and activities, difficulties in everyday areas of functioning, normal usage of language, and normal cognitive and adaptive behavior. The criteria do not overlap with other disorders such as *Pervasive Developmental Disorder* or *Schizophrenia*. *Pervasive Developmental Disorder Not-Otherwise Specified (PDD-NOS)* is diagnosed as a severe impairment in one of the following areas: social interaction, verbal and non-verbal communication, and stereotyped behavior, interests, and activities. The symptomatology should not fit the criteria for *Pervasive Developmental Disorder*, *Schizophrenia, Schizotypal Personality Disorder*, or *Avoidant Personality Disorder. Childhood Disintegrative Disorder* manifests as an apparently normal socio-communicational development until the age of 2 years, followed by clinically significant loss of skills in areas such as social interaction, communication, motricity, play and toileting, by deficits in the socio-communicational areas, and the presence of repetitive and restricted behaviors, activities, and interests.

DSM–5 (American Psychiatric Association, 2013a) diagnoses *Autism Spectrum Disorder* (ASD) as a dyad of symptoms in the areas of socio-communication and repetitive and restrictive patterns of behavior and activities manifested by the following (ibid, p. 50):

A. "persistent deficits in social communication and social interaction across multiple contexts",
B. "restricted, repetitive patterns of behavior, interests, or activities",
C. "symptoms must be present in the early developmental period (but may not become fully manifest until social demands exceed limited capacities, or may be masked by learned strategies in later life).",
D. "symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning."
E. "these disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay.".

The symptomatology is represented on a continuum along which the severity of the disorder is defined by criteria A and B: level 3 = requiring support; level 2 = requiring substantial support; and level 1 = requiring very substantial support. Along with the diagnosis, it should be specified whether the individual presents intellectual and/or language deficits, and other medical diagnosis. Individuals who present significant social communicational deficits, but do not present the full symptomatology of *Autism Spectrum Disorder* should be diagnosed with *Social Communication Disorder*.

Analyzing the differences between DSM-IV criteria and DSM-5 criteria, it seems that while under the DSM-IV criteria, the *Autism Spectrum Disorder* comprised four different pervasive developmental disorders: *Autistic Disorder*, *Childhood Disintegrative Disorder*, *Asperger's Disorder*, and PDD-NOS, the changes in the DSM-5, reunited all subcategories of DSM-IV into a single one: *Autism Spectrum Disorder*. This limitation to one disorder in DSM-5 is meant to (over)simplify the process of assigning a diagnosis to the client and to put the focus on the symptomatology of the disorder (American Psychiatric Association, 2013b). Also for simplification purposes, the introduced secondary criterion of severity then specifies the amount of support the person needs. Another point to make is that the DSM-5 facilitates early diagnosis of the Autism Spectrum Disorder when the symptomatology of the disorder does not exceed social demands (American Psychiatric Association, 2013b). In contrast, DSM-IV focused on the diagnosis of clients in their early adolescence/pre-school years.

Analyzing the changes of the criteria for the Autism Spectrum Disorder diagnosis across all DSM books, it appears that only the *Autistic Disorder* diagnosis presentation in DSM-IV partially meets the current criteria for Autism Spectrum Disorder diagnosis presentation specified in DSM-5. Although *The Childhood Disintegrative Disorder* manifests at a later developmental age (around age 2), it does not fit neither the *Autism Spectrum Disorder* diagnosis, nor *the Social Communicational Disorder* diagnosis described in DSM-5. The *Asperger's Disorder* described in DSM-IV as a disorder of both social interaction and repetitive behavior impairments, is also not equivalent to the description of the diagnosis criteria of *Autism Spectrum Disorder* in DSM-5. The symptomatology of *Pervasive Developmental Disorder not otherwise specified* (PDD-NOS) in the DSM-IV fits the symptomatology criteria of *Social Communicational Disorder* (SCD) in the DSM-5, but in the DSM-IV, PDD-NOS *is* an autistic disorder, while SCD in DSM-5 it is not any more. It is thus apparent that with the DSM-5 substantial changes in the diagnostic criteria for *Autism Spectrum Disorder* have been implemented.

Mazurek et al. (2017) designed a study that systematically and prospectively verified the concordance of the *Autism Spectrum Disorder* diagnosis criteria between the DSM-IV and the DSM-5 on a sample of 439 children. Their results show that 89% of the children that met the *Pervasive Developmental Disorder* diagnosis criteria for all subcategories in the DSM-IV continued to meet the criteria for *Autism Spectrum Disorder* in the DSM-5, 97% of the clients that met the DSM-IV *Autistic Disorder* Category continued to be diagnosed with *Autism Spectrum Disorder* according to the DSM-5, 20% of the clients that were diagnosed with *Asperger* Disorder in the DSM-IV no longer met the diagnosis criteria of *Autism Spectrum Disorder* in the DSM-5, and 75% of the clients that were diagnosed with PDD-NOS in the

DSM-IV, no longer met criteria in the DSM-5. These results suggest consistency in diagnoses across diagnosticians, but also that some clients that were previously diagnosed with *Autism Spectrum Disorder* were no longer diagnosed with ASD under the DSM-5. Another important result of the study is that girls are more affected by the changes included in the DSM-5 than boys. This finding has direct implications for comparative studies generalizing the results of the study to both genders of the population of persons on the autism spectrum.

In this chapter, I have discussed the definition of Autism Spectrum Disorder from a historical perspective. There are significant differences between the definitions of the condition in the DSM-IV and the DSM-5, and studies such as Mazurek et al. (2017) show that not all clients that were diagnosed under the DSM-IV criteria receive the same (or even: any) diagnosis under the DSM-5. Autism Spectrum Disorder is currently described in the DSM-5 as a neurodevelopmental disorder with symptomatology in the areas of social interaction, communication, and behavior. The person on the autism spectrum presents difficulties to socially interact and to communicate, and repetitive and restricted patterns of behavior and activities. The severity of the disorder is put on a continuum that evaluates the level of support the person on the autism spectrum needs.

PART II. Social Interaction Capabilities of Persons on the Autism Spectrum

6 Social Interaction in Persons with Typical Development and in Persons on the Autism Spectrum

In this chapter, I describe characteristics of social interaction performance of persons with typical development, I discuss and compare the social developments of persons with typical development and of persons on the autism spectrum, and I cover theories on the social interaction of persons on the autism spectrum. Before investigating whether and how the social interaction competence of persons on the autism spectrum differs from the social interaction competence of persons with typical development, it is important to describe regularities of the social 'world' of persons with typical development. I believe social interaction to presuppose the right interplay of 'social' factors: a physical or virtual space, at least one cognitive agent (a social agent that exists in time (has a continuity across past, present, and future) and space and can communicate with itself), and a set of culturally or biologically accepted rules that guide the back and forth exchange of social information. The agent participating in the social interaction must possess the minimum requirements to support it, these include *being cognitive* (Vernon, 2014, p. 10). Social interaction is a complex phenomenon that develops from birth, from a reflex-like response to the contextually embedded social response in the coupled interaction of the infant with the caregiver (Shultz, Klin, & Jones, 2018). I argue the enactivist social interaction theory of De Jaegher (2006) best reflects the reality of the way persons socially interact, because it addresses and describes the bodily coordination of the face-to-face direct interaction of persons and evaluates the social agent, the interaction process of the social unit, and the environment in which the interaction takes place. The concept of *participatory sense-making* by De Jaegher refers to the coordination of the sense-making of social agents through their bodily interaction, which leads to the generation of a particular kind of sense-making that is available only within the interaction of the social agents.

In the following, I discuss basic functional and psychological requirements of a cognitive agent and why cognitive processes are key for social interaction. To this end I take David Vernon's work (2014) as main reference. But first, I would like to briefly introduce the researcher: David Vernon is a software engineer and currently working as a professor at the Carnegie Mellon University Africa in Rwanda. David Vernon's research areas are computer and robotic vision, AI, and cognition in autonomous agents. The work of Maturana and Varela on autopoiesis and Husserl's and Heidegger's philosophy of phenomenology influenced David Vernon, motivating his aim to develop and empirically validate a cognitive architecture that would follow the principles of *enactivism*. Enactivism is a philosophical current that argues that cognitive processes are not only a characteristic of the mind of the acting agent, but some cognitive processes also arise out of the interaction of the cognitive agent with the environment and other social agents (Rowlands, 2010). More information on this paradigm can be found in Chapter 7.2 Enactivism Theory.

Vernon (2014) argues that cognitive agents analyze the available information about past, current, and future states of the agent and use the present and past information to predict future states, the consequences of those states, and the impact of the state of the environment on the anticipated future state. There are four fundamental elements cognitive agents make use of: *action*—involves movement towards a goal, *goals*—the end state of the action, *intention*—commitment to reach the goal, and *attention*—“understood in the sense of intention-guided perception” (Vernon, 2014, p. 198).

During successful social interaction, the cognitive agent interprets “a wide variety of visual data that conveys information about the activities and intentions of other agents” (Vernon, 2014, p. 199). That is because cognitive agents expect of their cognitive interlocutors in a social interaction the same abilities of inference to predict and understand their needs and goals, representative of general cognitive processes they possess (Vernon, 2014). Indeed, according to Vernon it is key that a cognitive agent knows for example what behavioral cues provide information about their partner’s emotional state. A cognitive agent understands which cues are social—and relevant for the social interaction—by following culturally learned patterns of interactions or by reflexively responding to specific social cues (e.g., by perceiving biological motion) (Vernon, 2014). Vernon outlines the following enactivist principles for responding to a cognitive agent in a social interaction (note that these differ from the principles described above about the predictive abilities of cognitive agents employed in a social interaction):

When a social stimulus is perceived, the perceiving agent experiences bodily states that are culturally associated with the perceived stimulus. In turn, the other agent perceives these bodily states and tends to imitate them. Associated with the imitated bodily states, corresponding affective states are experienced. The level of compatibility between the affective and cognitive states and the bodily states influences the social performance of the agent. In this way, agents are able to bodily understand the other’s state in a social context (Vernon, 2014, p. 200).

Vernon (2014) describes two forms of social interaction processes occurring between two cognitive agents: *instrumental helping* and *collaboration*: *Instrumental helping* refers to the unidirectional attending to the intentions of another cognitive agent to achieve a goal. This implies that the helping agent has a personal motivation for assisting the other agent, infers that the agent needs help, and understands the other agent's goal and plan of action. *Collaboration* represents the process during which two cognitive agents cooperate towards achieving the same goal. The agents agree on the same intentions and the same goal, "share their attention, and engage in joint action" (Vernon, 2014, p. 201).

Vernon (2014) presents two methods through which persons interact socially: During social interaction, a person on the one hand *infers* the next states and goals of actions of their social partner; and/or the person bodily *perceives* the social cues of their social partner. These two methods might seem contradictory because they are representative of two opposing theories on social interaction (i.e., ToM, respectively the Enactivist Paradigm), but to the extent of my understanding, with the described method of inferencing employed in social interaction, Vernon did not only refer to the fundamental principle of ToM, but he also assumes the inferencing abilities to be a fundamental property of the cognitive agent that allows it for example, to make predictions about future states of the environment and itself based on present and past states. Since in the environment social interaction occurs, the cognitive agent will also exercise their inferencing abilities to predict the states of the social partner. Out of the two social interaction processes of instrumental helping and collaboration, I will now discuss the latter in more detail, since this master thesis focuses on social collaboration between two cognitive agents, i.e., between a person on the autism spectrum and a typically developed person.

6.1 Collaboration

According to Vernon (2014, p. 207) a successful collaboration between two cognitive agents implies that both engage in joint action; have shared intentionality, shared goals, and joint attention. They should both have the ability to read social cues and infer goals, and both have the motivation to collaborate. *Joint action* presupposes that both agents are committed to participate in the joint activity, have the same goal and intentions, provide mutual support, and are mutually responsive to the intentions and actions of the other. Having *shared intentions* implies that the cognitive agents intend to pursue *a shared goal*, but may have partially individual sub-plans towards attaining that goal. Cognitive agents *monitor* the progress along the plan of actions and support the social partner in following the plan if necessary. *Joint attention* implies "a coordinated and collaborative coupling" (Kaplan & Hafner, 2006, p. 144) between two cognitive agents having a shared goal. In order to successfully engage in joint attention, both agents must recognize the other as an intentional cognitive system, must be able to detect the element in the focus of attention, and must be able to change the attentional focus.

Collaboration thus is an interactional process that involves a wide range of complex skills, including, but not limited to: recognizing the agency of the social partner, monitoring the progress of the activity, and being able to attend to the other's activity.

6.2 Development of Social Skills

In this subsection I address the development of social skills, with a focus on early social processes of the infant and the toddler, and the developmental disruptions of persons on the autism spectrum. Based on a review of seminal papers and recent associated neurological and experimental evidence, Shultz et al. (2018) explicate how infants acquire social skills, highlight the role of the caregiver in developing the social skills of infants, and present a hypothesis for the atypical development of social skills in persons on the autism spectrum. This work is highly relevant for my research because the authors take an explicitly *interactionist* perspective on the interaction between an infant and a caregiver that follows the principles of the *enactivist* paradigm I pursue. The key take-away message of this subsection is that the infant quickly becomes an *active* participant in their interaction with their caregiver, by shifting from a reflex-like response to a meaningful reaction to the social cues of the caregiver.

At birth, reflexive visual orienting is supported by the subcortical visual system, which responds differently to different characteristics of visual stimuli (Farroni, Csibra, Simion, & Johnson, 2002). Around the age of 2 months, reflexive orienting responses are overridden by a volitional orientation preference controlled by the cortex (Shultz et al., 2018). During this period, infants begin to smile in response to faces (Messinger & Fogel, 2007); mothers spend more time showing charged emotions than neutral ones (Lavelli & Fogel, 2005); and infants expect adults to socially react and to be active agents in interaction (Tronick, Als, Adamson, Wise, & Brazelton, 1978). At the age of 3 months, crying acquires an interactive and intentional role (Ostwald & Murry, 1985) and reflects the infant's psychological state (Lieberman, 1985). At the age of 1 year, the child is able to understand others' intentions (Shultz et al., 2018) and can show the disposition for helping others even when no reward is given (Warneken & Tomasello, 2009). During the first year, the caregiver and the infant form a social unit that starts with the caregiver adapting to the behavior and interaction rhythm of the child, which supports the infant to also respond to the social cues of the caregiver (Shultz et al., 2018). Over this period, infants present a preferential biological orientation towards sounds, sights, and smells of the caregiver (Bushneil, Sai, & Mullin, 1989) and reflexive patterns of behavior (Moro reflex, palmar grasp reflex, etc.) that trigger child-caregiver interaction. At the age of 14-18 months, toddlers differentiate between animate and inanimate systems, begin to understand what a cognitive agent is, and are able to understand the goals, actions, and intentions of other cognitive agents within the limits of their array of executed and known actions (Falck-

Ytter, Gredebäck, & Hofsten, 2006). They infer an adult's action and finish it themselves if the adult failed to successfully reach the goal of the action (Meltzoff & Decety, 2003). At the age of 2 years, the child seems to be driven by intrinsic motivation to participate in simple collaboration tasks with adults (Warneken, Chen, & Tomasello, 2006). Between the age of 2 and 3 years, toddlers can successfully engage in cooperation tasks with other children (Brownell, Ramani, & Zerwas, 2006). Between the age of 3 and 4 years, children learn to *solve* complex cooperation tasks (Meyer, Bekkering, Paulus, & Hunnius, 2010). By the age of 3 and a half years, they have *mastered* complex cooperation tasks and are able to switch roles and teach new partners (Ashley & Tomasello, 1998).

The infant-caregiver social unit starts to function when both social partners respond to the social cues of the other. Shultz et al. (2018) explain how the social skills of the infant develop to support the infant-caregiver social unit: Signaling behaviors of the child function in a bidirectional way—to orient the infant towards the caregiver, to attract attention, and to obtain response from the caregiver (Shultz et al., 2018). For example, neonatal crying triggers the arrival of the caregiver in close physical proximity, signals the child's psychological and/or physiological state, but also encourages interaction (Shultz et al., 2018). Another possible signaling system, the neonatal facial musculature, which is able to produce almost all facial expressions, might not bear a meaning at the beginning, but the response of the caregivers embeds the expression of the child in a specific socio-emotional context, which facilitates future facial mimics of the infant to be contingent on the correct social context (Lozoff, Brittenham, Trause, Kennell, & Klaus, 1977).

The caregiver has the important role to embed the actions of the infant in the associated social context. The first random behaviors of the child and their reflexes have a survival role only if the caregiver responds to the behavior (Lozoff et al., 1977). For example, crying attracts the caregiver's attention, brings the infant and the caregiver in close physical and auditory contact (Bell & Ainsworth, 1972), and increases joint eye-contact possibilities (Peláez-Nogueras et al., 1996). Another example is when the caregiver imitates the behavior of the child, which elicits the infant's attention and eye contact, and in turn encourages further responses of the caregiver (Malatesta & Izard, 1984). Caregivers adapt their behavior to the capabilities of the infant and provide social meaning to the infant's behaviors: Shultz et al. (2018) exemplify aspects of the coupling behavior between the caregiver and the infant: Caregivers adapt to the infant's rhythm when they use exaggerated and slow facial expressions and speech patterns that are well-perceived by the infant's restricted perceptual capacities (Lozoff et al., 1977).

When first social attempts are successful, increasingly complex social skills are built on the already acquired social skills. Shultz et al. (2018) describe the acquisition of the social skills as an iterative process, where social skills of higher sophistication are an effect of simple social skills, and become the cause of even more complex social skills (Hall, 2012). Shultz et al. (2018) argue for an active role of the infant in the social interaction, based on the observation in the literature that infants understand and create a causal link between their own actions and the events in the environment. The learned associations define the range of the quality of abilities acquired later. As already mentioned, the developmental transitions of infants are from a reflex-like response to a volitional social acting: "[L] earned, volitional behaviors replace, emerge from, and/or depend upon behaviors that were initially spontaneous or reflexive." (Shultz et al., 2018, p. 8). Developmental transitions are guided by the adaptation process of the caregiver and infant to each other's actions.

In contrast to the development of persons with typical development, both older children and adults on the autism spectrum still present impairments in the social adaptive actions that for persons with typical development are present in their infancy only. Studies have observed differences in frequency of vocalizations and gaze to faces (Filliter et al., 2015), attention to and engagement with objects (Elsabbagh et al., 2013), mutuality of infant-caregiver interaction (Campbell, Leezenbaum, Mahoney, Day, & Schmidt, 2014), and social smiling and joint attention (Lambert-Brown et al., 2015) between persons on the autism spectrum and persons with typical development. Shultz et al. (2018) identified a common variable among studies, which is that behavior differences between persons on the autism spectrum and persons with typical development at an early age become more pronounced with age: The authors propose that persons on the autism spectrum do not overcome some social developmental milestones, given that social limitations observed in infants with typical development are still present at a later age in persons on the autism spectrum. This observation is a key argument for their hypothesis that development be iterative, and that the development of early actions constrain future actions (Gibson & Pick, 2000).

Eye-looking patterns also show an atypical development in persons on the autism spectrum. Shultz et al. (2018) assert that social processes such as preferential orientation, social engagement, and social adaptation, developed within the first months in toddlers with typical development are the key problematic processes in the development of Autism Spectrum Disorder. Levels of eye gaze during the first months are higher in infants on the autism spectrum than in infants with typical development, and the underlying biological and behavioral mechanisms of infants on the autism spectrum are atypical (i.e., atypical rate of change in eye-looking). In contrast, infants with typical development show a decrease in the levels of eye gaze at 2 months. Based on available evidence, authors propose the hypothesis that reflex-like orienting be also present in children on the autism spectrum, but that later, more complex, phases of preferential eye-looking are disrupted. This hypothesis puts the scientific focus on the study of the transition from reflexive/'experience expectant' (mostly subcortically mediated) to an interactive/'experience dependent' phase (mostly cortically mediated) (Johnson & Morton, 1992).

The work of Shultz et al. (2018) bridges between old and new evidence by combining seminal papers with more recent empirical and neuro-scientific work. In their review, the authors formulate a model of how the human mind and body develop by being "remarkably attuned to the social world" (Shultz et al., 2018, p. 14). From early life moments, the infant and the caregiver form a social unit, in which each actor is an active agent, responds to the other's actions, and provides an opportunity for response for their social partner, which also allows the interaction to take 'a life of its own'. Shultz et al. (2018) observe that at least in the case of eye gaze, persons on the autism spectrum do not seem to present the same developmental pattern for preferential eye gaze as persons with typical development. Based on this finding, the authors advocate the study of disruptions in the transition from reflex-like responses over volitional interactive responses to social interaction in persons on the autism spectrum.

7 The Cognitivist and Enactivist Theories of Social Interaction

The aim of this subsection is to describe and analyze characteristics of the social interaction performance of persons on the autism spectrum according to the Theory of Mind (Premack & Woodruff, 1978) and the enactive perspective on social interaction of De Jaegher (2006, 2013). These theories are representative of the cognitivist and the enactivist frameworks of social interaction. Theory of Mind states that children on the autism spectrum present an impaired ability to think about the point of view of others, which can be used to explain their observed deficits in social abilities (Baron-Cohen, Leslie, & Frith, 1985; Frith, 2012). The enactive perspective on social interaction by De Jaegher (2006, 2013) hypothesizes that persons on the autism spectrum and persons with typical development employ different ways to make sense of the social context at differing social interaction rhythms, leading to difficulties in understandings during social interaction. Given that Theory of Mind has been criticized to not describe the bodily face-to-face interaction of persons on the autism spectrum (Bottema-Beutel, 2017), I have chosen the perspective of enactivism to characterize social interaction performance in persons on the autism spectrum.

7.1 Theory of Mind

In this subsection, I discuss the origins and development of Theory of Mind (or, as it is sometimes known the "Theory Theory" (Ratcliffe, 2007)), principles of Theory of Mind as applied to the Autism Spectrum Disorder, and limitations of this cognitivist framework on social interaction. Theory of Mind states that a cognitive agent makes inferences about the mental states of others (Premack & Woodruff, 1978). The observed deficits in social abilities of persons on the autism spectrum are explained by their impairment to think about imputed mental states of other persons (Baron-Cohen et al., 1985). However, a pioneering researcher in the field, Frith (2012) admits that the theorized ability to mentalize does not explain all social skills (e.g., exceptions could be imitation, emotional contagion, social facilitation etc.) employed by persons on the autism spectrum during social interaction.

The pioneering work of Premack & Woodruff (1978) on primates and Theory of Mind (ToM) led to a series of papers on the development of Theory of Mind in children. Theory of Mind postulates that a social agent is able to think about the mental states of oneself and of another cognitive agent (Premack & Woodruff, 1978). Two types of tasks were developed to investigate the presence of ToM abilities in children: *elicited-response* tasks and *spontaneous-response* tasks. Scott, He, Baillargeon, & Cummins (2012) explain that in both types of tasks it is investigated the false belief knowledge of the participant (usually a child) about a fictional or real agent involved in a scenario. Authors further explain the differences are that in elicited-response tasks, participants are asked direct questions, and in spontaneous-response tasks, participants' spontaneous behavior as a response to the unfolding scenario is measured (e.g., violation-of-expectation and anticipatory-looking tasks). One of the first examples of elicited-response tasks are the *false-belief tests* created by Wimmer & Perner (1983): A child stores a piece of chocolate in a cupboard. The child goes outside to play, and his mother changes the location of the chocolate. The participant with typical development in the study is now asked about the location the child would look for the chocolate when returning from play. The results showed that most four year old children responded incorrectly to the question (i.e., stating that the child would look for the chocolate at the new location). Studies applying the spontaneous-response task concluded that children as young as 1-2 years old have an understanding of the other's mental states (Baillargeon, Scott, & He, 2010; Luo, 2011; Scott & Baillargeon, 2017). The contradicting evidence of children not passing the false-belief test until the age of 4 and the possible understanding of the other's mind already in toddlers led to researchers differentiating in their work between explicit and implicit abilities to mentalize (e.g., Naughtin et al. (2017)). I describe now the development of Theory of Mind. I begin by discussing the seminal work of Alan M. Leslie (1987). Alan M. Leslie is a Scottish psychologist and Professor of Psychology and Cognitive Science at Rutgers University, is interested in the design of the cognitive system early in development, and generally uses spontaneous-response tasks to study infant's cognitive development. Leslie (1987) argues that understanding the mind of others is associated with a specialized mental mechanism—the Theory of Mind Mechanism (TOMM). This mechanism is posited to consist of decoupling from the reality of a situation in order to take on a fictional perspective. Tyler (2015) presents that "TOMM is part of the core architecture of the human brain, a domain-specific processing stream adapted for understanding the behavior of others" (ibid., p. 140). Alan Leslie takes children to display a form of 'decoupling' at around 18 months of age while engaging in pretend play, which is seen to later develop into the ability to think about the mental states of others. Alan Leslie further hypothesizes that children on the autism spectrum do not present this ability to "decouple" from reality.

Similarly, Baron-Cohen (1995) argues the ability to mentalize to be innate and universal of humans. The ToM system is theorized to include four components: the intentionality detector (ID), the eye-director detector (EDD), the shared attention mechanism (SAM), and a theory of mind mechanism (TOMM). According to Baron-Cohen, failure to successfully develop the core elements of the ToM system would impact the ability to mentalize. The principles of Theory of Mind have been applied specifically to understand the social symptomatology of Autism Spectrum Disorder. Baron-Cohen et al. (1985) report in their seminal study that the majority of children participants on the autism spectrum did not pass the false-belief test, which was interpreted as an impairment of the ability to mentalize. Uta Frith (1989) argues in her book that at least a part of the mentalizing difficulties observed in children on the autism spectrum are linked to the observed social impairments. On the downside, employment of ToM to explain symptomatology of the Autism Spectrum Disorder and their causes has met difficulties and limitations. In a more recent publication, Frith (2012) concedes that ToM accounts for only a fraction of the socio-communicational impairments of Autism Spectrum Disorder. That is because social interaction processes require abilities employed in other areas than in ToM. Frith states that "imitation, emotional contagion, conformity, stereotype formation, social facilitation, reputation management, agency detection, to name only a few" (2012, p. 2079) are social processes not explained by the mentalizing abilities More generally, Theory of Mind is a cognitivist account assuming that persons take on a third-person perspective to mentalize and to theorize about social interaction and the mind of the others. As well as Frith, Bottema-Beutel (2017) argues that the third person perspective on social interaction has failed to provide valuable insights into characteristics of face-to-face social interaction. Explicit mentalizing does not align with the characteristics of usual social interaction, and supporters of ToM do not explain how implicit mentalizing is involved in social interaction (Schilbach et al., 2013). Rowlands (2010) explains the defining ideas of the so-called *Cartesian framework* of cognitive theories to be the assumption that mental processes occur exclusively in the head of the cognitive agent, and that the mind of the individual not to be a physical entity: He argues that cognitive science has turned towards new perspectives of mental phenomena that are embodied, extended, enacted, and embedded. These new perspectives argue for mental processes to happen mostly in the brain, but also partly in the body, and/or partly in the environment. A cognitive agent's actions on the environment transform the information from *available* to *active*, and the outcome of this process of active information is taken to supplement or complement other cognitive processes. Rowlands thus argues that actions on the environment be not only causing cognitive processes, but are also *constitutive* of them.

Theory of Mind thus is a cognitivist account of social interaction for persons with typical development as well as for persons on the autism spectrum. But, ToM largely does not explain the sphere of social interaction abilities of persons with typical development and of persons on the autism spectrum: this is why I now orient my attention to the *enactivist* theory of social interaction, which focuses on and analyzes the direct and bodily social interaction of cognitive agents.

7.2 Enactivism Theory

In this subsection I introduce basic principles of the enactivist paradigm and of the enactive social interaction theory of De Jaegher (2006). The choice to discuss the enactivist theory of social interaction, instead of the ToM Theory is not to be taken as indication of me considering the enactivist perspective to explain best social interaction of persons on the autism spectrum. Given the limitations of ToM and after continuous evaluation of the cognitivist and the enactivist paradigms during my master programme, I agree with the principles of the enactivist perspective, but I do not completely exclude ToM's ability to explain at least a part of the social interaction processes. The theory of De Jaegher (2006) on social interaction of persons on the autism spectrum hypothesizes that the social symptomatology of persons on the autism spectrum is the outcome of a different biology, structure of the brain etc. and a different way to make sense of the world than persons with typical development. This would result in the interaction between a person on the autism spectrum and a person with typical development to be atypical or uncommon because both agents have a different social interaction rhythm that affect their understanding of the world of their social partner.

I refer the reader to see Appendix C Glossary of Terms of the Enactivist Paradigm for a glossary of the terms that are used to explain the principles of the enactivist paradigm.

The development of the enactivist paradigm begins with reports of limitations of cognitivist principles in the areas of autonomous robotics (Beer, 1990) and situated artificial intelligence (Agre, 1988; Suchman, 1987). The cognitivist principles could not be successfully implemented in the design and implementation of efficient robots and user interfaces, because the cognitivist model of "sense-model-plan-act" could not allow the robots to perform "simple" interactions within the noisy and partially known environment (Di Paolo, Buhrmann, & Barandiaran, 2017). The alternative bottom-up approach for modelling the robots consisted in a combination of functional layers of control: from the simplest layer (functional loops) to the more complex (interaction of several sensorimotor layers for the interaction with the environment) (ibid). In the bottom-up approach, the focus is on the connection between the body of the robot and the environment in which it is situated. This approach was applied to understand human cognition (ibid). For example, intelligence is described as "fluid and flexible sensorimotor coupling" (idem, p. 16). This principle is similar to the tenets of the enactive approach, which postulate that "cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided" and that "perception consists in perceptually guided action" (Varela, Thompson, & Rosch, 1991, p. 173). Another insight of the embodied and situated understanding of cognitive systems is the primacy of action in cognitive processes and that cognition is grounded in the sensorimotor coupling of the system (Noë, 2004). The enactive perspective has been recently applied to various disciplines: intersubjectivity and social cognition (De Jaegher & Di Paolo, 2007), socio-cognitive development (Fuchs, 2013), enactive person based approaches to autism (De Jaegher, 2013), and on schizophrenia (Kyselo, 2016).

I present now principles of the enactivist framework. Enactivism describes cognition as embodied action (Bottema-Beutel, 2017): Perception and action are taken to work inseparably to enable the formation of cognitive structures (De Jaegher, 2006). In other words, "perception consists in perceptually guided action and … cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided” (Maturana & Varela, 1987, p. 173). Sensorimotor knowledge is explained as “the way in which the nervous system links sensory and motor surfaces” (ibid). According to enactivism, when we perceive an object, we act on it through specific movements of reaching out to the object, lifting it up, turning it on its sides, etc. This exploratory process is guided by our sensory modalities that tell us how to explore the object and where to act (Rowlands, 2010, p. 72). It is during and as a result of the exploratory process that we perceive the object and we identify it. Different researchers formulate their theories on how (part of) cognitive processes are based on sensorimotor knowledge. In the case of visual perception, O’Regan & Noë (2001) explain that as we explore an object, our mind creates “sensorimotor contingencies” (idem., p. 940) of the object. Having formed sensori-motor expectancies associated with an object, the mind does not need to create internal representations of it, rather, the object out in the world acts as an external model. We then do not need to exercise the ability to explore the object any more, as the sensori-motor contingencies allow us to perceive the object instantly. Accordingly, De Jaegher & Di Paolo (2007) discuss how enactivism assumes a continuous interdependency between the cognizer and the environment it enacts. They define this coupling as “the amount of influence that a system’s variables have on another’s parametrical conditions” (2007, p. 490). The cognizer, defined by its sensori-motor patterns, interacts with the environment. The cognitive agent brings forward individualistic aspects of the perceived world, and in turn is constrained by its perspective on that particular environment. Each organism enacts its own world: it does not simply detect the world as it is, rather, it actively accesses only those elements that are relevant for the survival of the identity of the organism. In this way, the organism is also situated in its own environment. As the structure of the organism automatically brings forth its world, there is no need to store mental representations of the world. The world also constrains the perspective of the organism on the world, by specifying only those characteristics of the organism that are adaptive to the environment. In a different environment, the organism might develop other adaptive behaviors. While meaningfully interacting with the environment, the organism learns rules, which allow it to recognize specific structures in the environment. In comparison to the cognitivist rules that are designed to solve external tasks, the enactivist rules allow the organism to recognize those tasks that are solvable by its internal structure (De Jaegher, 2006).

I present now limitations of the enactivist theory. The enactivist theory fails to explain how the organism maintains its own identity while always being coupled with the environment in which it is embedded. It is also not clear where the boundary between the environment and the organism lies, what exactly are characteristics of the environment and what are individual characteristics of the organism. Some answers to these questions are provided by the *interactionist* theory (Bickhard (2009a, 2009b, 2016)); this theory (instead of the enactivist theory) is not the focus of my master thesis because I found the related publications towards the end of the scientific process supporting the writing of this master thesis. A problematic aspect the enactivist perspective brings forth is the need for change of the traditional definition of what cognition is (Di Paolo et al., 2017) to include extracranial and extrabodily processes (Walter & Kästner, 2012). The latter authors propose that researchers should first answer the question "what kind of concept should we expect "cognition" to be?" (Walter & Kästner, 2012, p. 14), and they already introduce a few answers (i.e., cognition as a *natural kind*; cognition as an *umbrella concept*; cognition as a *nominal concept*; cognition as a *cluster concept*; and cognition as a *family concept*). However, further investigations are necessary to reach a definite new definition of cognition.

To summarize, the enactivist paradigm puts the focus on the interdependency between the cognizer and the world in which it is situated. In this way, the cognizer perceives the world through its particular embodiment (idealism), but the world also influences how and what the cognizer can perceive (realism).

7.3 Participatory Sense-Making and Autism

Having introduced the enactivist paradigm, I can now continue with presenting the theory of De Jaegher (2006) of Participatory Sense-Making on social interaction of humans. This theory shifts the perception of the general understanding of social interaction performance of persons on the autism spectrum from impaired social interaction abilities to simply an atypical way to interact that is different than the way persons with typical development interact. As a result of my own professional interaction with children on the autism spectrum, I have had the opportunity to observe modes of interaction and of "being in the world" of children on the autism spectrum that appear to align well with the enactivist perspective of De Jaegher. I observed that children on the autism spectrum perceive, react to, and interact with the world differently from typical children. It was often the case that it was easier to enter atypical social games preferred by the child on the autism spectrum (e.g., running towards the same place or pulling and releasing the drapery puller), than to encourage the involvement of the child in typical activities.

I remind the reader to consult Appendix C Glossary of Terms of the Enactivist Paradigm for a glossary of the terms that are used to explain the principles of the Participatory-Sense Making theory.

Hanne de Jaegher is a philosopher of the mind and of cognitive science and currently a research fellow at the University of the Basque Country. Her scientific interests include how we think, play, and live. De Jaegher (2006) applies the enactivist framework to the field of *social interaction* and *social cognition. Social cognition* is the general term that defines forms of cognition of the agent's actions, intentions, emotions, and particularly the relation of these processes to other agent's processes, and *social interaction* refers to two or more autonomous agents co-regulating their sensori-motor couplings, that results in the interaction acquiring an autonomy of its own (De Jaegher, Di Paolo, & Gallagher, 2010). The principles of sense-making, autonomy, emergence, and experience make it possible to study the interaction between cognitive agents as a temporally extended unit and the autonomous agents. The methods of enactive social interaction are gesture and conversation analysis and interaction studies, (Bottema-Beutel, 2017).

Behavior is defined to be purposeful and expressive (Gallagher, 2001). Gallagher proposes that humans have innate *embodied skills* such as: “imitation, intentionality detection, eye-tracking, the perception of goal-related movements, and the perception of meaning and emotion in movement and posture” (Gallagher, 2001, p. 90). De Jaegher (2006) acknowledges the key role of embodied social skills for understanding the “mind” of others, but she argues these skills not to have to be necessarily innate, instead social interaction and coordination to be fundamental for this process.

Still, the question of how social meaning/understanding is achieved through interaction is yet to be answered. De Jaegher (2006) argues *temporal coordination* within social coordination and interaction to be key. According to her, the capacity to socially understand each other “is [mostly] given by the ability to engage in coordinated interaction through the rhythmic capacity” (De Jaegher, 2006, p. 148). The rhythm capacity “is the capacity to flexibly, temporally coordinate through and in the interaction with another person” (De Jaegher, 2006, p. 146). Moreover, the rhythm capacity is taken to be constrained by the individual’s moods, neurophysiologies, emotions, and the space of the interaction, and to be positively influenced by the relationship or the history of interaction between the social agents. Rhythm flexibility is proposed as a measure of how well a person is able to interact socially. To have a social skill is defined as the “flexibility to deal with the regularities (and irregularities) of the social domain provided by the actions of the others” (De Jaegher, 2013, p.7). De Jaegher (2006) observes that basic mechanisms of social interaction—*functional coordination* and *interactional coordination*—complement each other; the rhythm interaction flexibility designates the overall ability to socially interact.

De Jaegher (2006) proposes the term *participatory sense-making* to describe “the coordination of intentional activity in interaction, whereby individual sense-making processes are affected and new domains of social sense-making can be generated that were not available to each individual on [their] own” (De Jaegher & Di Paolo, 2007, p. 497). Coordination affects sense-making. Individual sense- making is conceived as an active process of understanding the world by making use of expressive and purposeful behaviors. Movements are both tools and methods of sense-making. During social interaction, individual sense-makings coordinate bodily, and in this way coordination of actions in a sustained social interaction influences individual sense-making. De Jaegher (2006) argues the interaction between a person on the autism spectrum and a person with typical development to be characterized by the difficulty of *both* social agents to adapt to the interaction rhythm of the other.

Furthering this line of reasoning, De Jaegher (2013) sketches an enactive account of Autism Spectrum Disorder. She argues that particularities of moving, sensing, and emoting of persons on the autism spectrum relate to the way they make sense of the world, explain repetitive and atypical activities persons on the autism spectrum are known to engage in, which are taken by the author as examples of the way they make sense of the world, and she further argues these activities to have certain sensorimotor correlates. She also argues that persons on the autism spectrum present a reduced social rhythm flexibility that is translated into difficulties in participatory sense-making. According to De Jaegher, sensorimotor processes of persons on the autism spectrum, especially those that involve a temporal aspect, influence coordination and interaction in social encounters; this leads to a different involvement in the participatory sense-making with persons with typical development. Children on the autism spectrum present difficulties with intersubjectivity engagement (Hobson & Lee, 1998; Hobson, 2002). Given such and other literature reports, De Jaegher (2006) concludes that persons on the autism spectrum and their interactional partners with typical development bring in different interaction rhythms and both lack the social flexibility to adapt to the other's rhythm.

I believe the theory of Participatory Sense-Making of De Jaegher (2006) to be well argued and clear in the presentation of the thesis (i.e., movements are tools and methods of individual sense-making), the anti- thesis (i.e., social interaction regulates through coordination of movement), and the synthesis (i.e., participatory sense-making occurs when social agents coordinate their sense-making in interaction through coordination of movements). However, I identified a few aspects that need further development. De Jaegher fails to provide clear guidelines and criteria for researchers to empirically test social interaction through the lens of this theory. Social Interaction, Embodiment, Sense-making, and Coordination of bodily movements are complex phenomena that encompass a wide range of other phenomena. To my understanding, De Jaegher's take on Participatory Sense-Making theory, the presented examples, and her recommendations for further investigations, all appear to promote a behaviorist and a phenomenological perspective to study the phenomenon, but the information is not clear. An issue of De Jaegher (2006; 2013) theory is that the author does not clarify how the abilities to bodily coordinate, to synchronize in interaction, and to increase the flexibility of the social rhythm—as it is described as skills—are acquired and developed in humans. For example, as already mentioned, De Jaegher (2006) asserts that the embodied social skills do not necessarily have to be innate, but she does not further explain exactly how persons could *acquire* such skills and whether these skills can be improved or otherwise modified. Finally, De Jaegher argues that persons are able to interact and coordinate in social interactions because they are situated in a meaningful frame, but this idea does not explain why persons are able to coordinate and socially interact in the first place. Another point in this line of critique is the observation of Chien (2017) that the theory of Participatory Sense-Making does not explain how humans recognize social cues, or, as Chien puts it, “the “social-ness” of the signal” (Chien, 2017, p. 133).

The theory of Participatory Sense-Making of De Jaegher (2006) is discussed also in other publications. De Jaegher, Peräkylä, & Stevanovic (2016) expand the initial theory to the field of interactional sociology to discuss the autonomy of social agents and how co-creation of meaningful action is brought about. Fantasia, De Jaegher, & Fasulo (2014) argue for the fundamental role of cooperation in interaction and the implications for Autism Spectrum Disorder. Bottema-Beutel (2017) analyzes the corpus of interactional research on Autism Spectrum Disorder through the lens of the enactivist account of social interaction (the work of De Jaegher (2006) on Participatory Sense-Making included) to identify characteristics of the way persons on the autism spectrum interact: The author finds the literature to be lacking in coverage of the social and linguistic processes in the everyday social interaction dynamics of persons on the autism spectrum. Recently, *Discourse Analysis* (DA) and *Conversation Analysis* (CA) have been applied to study social interaction and communication in persons on the autism spectrum to fill the identified gap. The work of Bottema-Beutel (2017) presents the results of research employing DA and CA methodologies, and identifies shared characteristics of the social interaction and communication of persons on the autism spectrum across these publications. One conclusion is that persons on the autism spectrum employ atypical interactional resources and coordinate with features of the environment that are less salient for persons on the autism spectrum (Bottema-Beutel, 2017). For example, persons on the autism spectrum use echolalia (atypical interactional resource) to coordinate with other persons (Sterponi & Shankey, 2014). Another example, Bottema-Beutel & Smith (2013) showed that an adolescent on the autism spectrum coordinates more with elements of the interaction that lead to a successful completion of the activity than with affiliative elements. Another conclusion is that persons on the autism spectrum engage more readily with partners that use and are responsive to atypical interactive patterns (Bottema-Beutel, 2017). Sterponi & Fasulo (2010) showed that a child on the autism spectrum responded with positive affect and willingness to interact when his mother followed the child’s interactional lead and incorporated in her speech similar verbal patterns to the one of the child. Bottema-Beutel also concluded that in some cases, different interactional patterns and priorities of the interlocutors might intervene (Bottema-Beutel, 2017). For example, in Sterponi & Shankey (2014), the mother takes a didactic role and interrogates the child to test their knowledge. Bottema-Beutel (2017) argues it is important to analyze whether the person on the autism spectrum is constantly put in the position of a student tested about their knowledge. The author argues this role might not be happily fulfilled by the persons on the autism spectrum because they might feel constrained and ignored. The final conclusion is that persons on the autism spectrum might enact meaning differently from interlocutors, and that they might present difficulties enacting the meaning created within the development of complex social interactions (Bottema-

Beutel & White, 2016). Authors state that both partners must be attuned to the social activity, and that they need to have a common social experience and a similar socio-cultural knowledge.

To summarize, this section describes the proposal of Participatory Sense-Making of De Jaegher (2006). The author does not aim to give an account of Autism Spectrum Disorder, but to describe characteristics of the social interaction performance of persons on the autism spectrum from an enactivist perspective. De Jaegher (2013) hypothesized that persons on the autism spectrum socially interact based on their embodiment and their sense-making. The way persons on the autism spectrum socially interact is different that the way persons with typical development interact because each brings into the social interaction a different social rhythm that hinders social understanding and co-creation of meaning. Through the lens of the theory of Participatory Sense-Making, authors observe in the literature that persons on the autism spectrum employ atypical interactional resources, coordinate with elements of the social interaction that lead to the accomplishment of the goal of the interaction, and engage eagerly with persons that use atypical interactive patterns in the social interaction.

8 ‘Autistic’ Embodiment

This chapter is concerned with identifying general and individual descriptive characteristics of motor and perceptual processes of persons on the autism spectrum. The literature points to differences in the way persons on the autism spectrum move and visually perceive than persons with typical development. The identified characteristics of the motor and perceptual processes contribute to the understanding of a possible ‘autistic’ embodiment. The work presented in this chapter, in Chapter 9 From Embodiment to Sense-Making, and in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum is concerned with testing the hypothesis that the ‘autistic’ embodiment is connected with the way persons on the autism spectrum make sense of their world and with the way they interact with social agents. In this chapter I discuss ‘autistic’ embodiment, in Chapter 9 From Embodiment to Sense-Making I discuss sense-making in autism, and in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum I discuss social interaction of persons on the autism spectrum. As stated in H1), I hypothesize The ‘autistic’ embodiment is exclusively connected to the way persons on the autism spectrum make-sense of and socially interact in the world. The formulation of this hypothesis is based on the work of De Jaegher (2013), who evaluated the validity of a similar hypothesis. The theoretical evidence presented there included comparative studies with a low sample size (e.g., Mari et al. (2003)) and theoretical studies of controversial evidence (e.g., Markram & Markram (2010)). I aim to assess whether more recent evidence makes for a stronger or a weaker case for the existence of, for example, an ‘autistic’ embodiment, and of the links between the concepts. I do not aim to obtain a definite answer with regard to the targeted hypothesis, but rather to review and assess the latest state of the art in the literature. That is because I believe it to be difficult to investigate the relationship between embodiment, sense-making, and social interaction because the concepts encompass multiple complex phenomena that are not entirely described in behavioral terms.

De Jaegher (2013) calls ‘autistic’ embodiment “the particular ways in which the biology, neurophysiology, affective, and sensorimotor structures and skills of people with autism differ from those of non-autistics (ibid, p.8). I discuss ‘autistic’ embodiment by referring only to characteristics of the motor and visual perception processes of person on the autism spectrum. I chose to investigate motor processes because they are fundamental for normal functioning of organisms. Impairments in this area can severely affect acting in the world and social interaction. Visual processes form the basis for the development and functioning of higher cognitive processes; understanding how persons on the autism spectrum perceive visually and how this differs from persons with typical development is a key step towards understanding higher processes, such as social interaction. While investigating only two processes of the embodiment of persons on the autism spectrum places clear limits on the general understanding of the ‘autistic’ embodiment that can be obtained, the core aim of this chapter is to contribute as a stepping stone for further investigations in this direction.

8.1 Motor Abilities of Persons on the Autism Spectrum

Although motor impairments have not been included in the diagnosis criteria of Autism Spectrum Disorder, they have been continuously reported in the literature. Researchers are interested to create the motor profile of persons on the autism spectrum, and dyspraxia is considered to be representative of the disorder. The aim of the present review is to evaluate whether persons on the autism spectrum present different motor characteristics in comparison to persons with typical development. I detail and analyze the nature of the motor characteristics in each group. My aim is not to evaluate whether motor differences between persons on the autism spectrum and persons with typical development are fundamental—i.e., lead to different embodiments—but to identify such differences and assess whether they *may* be due to different embodiments. The resulting picture is that key differences between persons on the autism spectrum and persons with typical development appear to exist for multiple motor qualities such as, coordination, balance, and fine and gross motor characteristics. Moreover, such differences can be observed not only in comparison to other developmental disorders (e.g., ADHD) and persons with typical development, but also *within* the autism spectrum.

For the review of motor skills of persons on the autism spectrum, I carried out a search and selection procedure according to specific criteria. For the comparative studies, quantitative requirements were: a sample size greater than 20 and at least one control group. For theoretical studies, the criterion was summative nature (e.g., meta-analysis, review). The search platform employed was Google Scholar (first five pages), the publication timeframe considered was between 2013 and 2018, and the key words employed in the search were: “motor”, “autism”, and “disorder”. I cover three comparative studies and one theoretical study. The comparative study by Kaur, Srinivasan, & Bhat (2018) does not match the inclusion criteria because the sample size is smaller than 20. Their holistic approach combines a battery tests against a motor coordination paradigm that provides further valuable evidence for the purpose of the current review. For a summary description of the selected publications, see Table 1 – Overview of Publications Investigating Movement Processes in Autism Spectrum in Appendix D Supplementary Information about the Studies Analyzed in Chapter 8‘Autistic’ Embodiment.

8.1.1 Theoretical Background Presented in the Studies

The theoretical literature discussed in the selected studies is comparable with regard to how the studies report general motor impairments of persons on the autism spectrum. Motor impairments of persons on the autism spectrum are documented in the areas of fine (McPhillips, Finlay, Bejerot, & Hanley, 2014) and gross motor skills (Pan, Tsai, & Chu, 2009), dyspraxia (Carmo, Rumiati, Siugzdaite, & Brambilla, 2013), and motor coordination (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). Another motor area, hysteresis in persons on the autism spectrum, has not been studied before. Amaral, Romero, Kloos, & Richardson (2017) are the first to investigate hysteresis in persons on the autism spectrum**.** Both Amaral et al. (2017) and Esposito & Pasca (2013) report Autism Spectrum Disorder to be described in the literature as a disorder with high variability between and within individuals on the spectrum; thus, Esposito & Pasca (2013) underscore the need to develop methods for stratifying the disorder in order to better understand it, and Amaral et al. (2017) suggest that the best method to account for the observed variability is to study the disorder in a relational context. Although studies (e.g., Jansiewicz et al. (2006)) report motor impairments to be predictive of the autism spectrum diagnosis, both Esposito & Pasca (2013) and Ament et al. (2015) point out the lack of any study indicating the existence of a unique motor profile of the persons on the autism spectrum.

8.1.2 Defining Key Terms Explaining Motor Abilities

There is a terminological consensus among research groups describing characteristics of the same motor behavior of persons on the autism spectrum, which could be related to the use of battery tests that evaluate motor characteristics similarly, but also because motor processes can be systematically observed and based on the acquired descriptive knowledge, easy to be quantified and examined. *Dyspraxia* is the impaired ability to imitate motor sequences or gestures and is discussed in Kaur et al. (2018), Ament et al. (2015), and Esposito & Pasca (2013). P*raxis* is impaired general motor ability, both not attributable to basic motor or perceptual impairments (Heilman & Rothi, 2003).and is discussed in Kaur et al. (2018) and Ament et al. (2015). Amaral et al. (2017) are the only authors that discuss *hysteresis*, and they define it as adaptive change of behavior to the continuous change the environment sustains.

8.1.3 Methodological and Procedure Characteristics of Studies

For details on the psychometric characteristics of the utilized battery tests, please see Table 2 in Appendix D Supplementary Information about the Studies Analyzed in Chapter 8‘Autistic’ Embodiment. In general, the studies applied standardized tests and/or motor paradigms to evaluate motor impairments of persons on the autism spectrum. Using both standardized tests and a motor paradigm can provide a holistic perspective on the differences between experimental and control groups. Such an example is Kaur et al. (2018), who applied BOT – 2 (Bruininks-Oseretsky Test of Motor Proficiency, Second Edition) (Bruininks & Bruininks, 2005), SIPT – BMC (Sensory Integration and Praxis Tests - Bilateral Motor Coordination Subtest) (Ayres, 1989), and a motor coordination paradigm to assess motor characteristics (i.e., gross and fine motor performance, praxis, bilateral motor coordination including solo and social motor coordination, and interpersonal/social synchrony) of pre-scholars and scholars on the autism spectrum. The administration of BOT – 2 included instructing participants using photos—suitable and useful for young children and for non-verbals on the autism spectrum. Moreover, throughout the procedure of the study, the investigators provided participants with instructions adapted to their verbal and interactional needs (e.g., visual demonstration of the instruction, use of simple verbal instructions or of pictures). For the scoring procedure of the behaviors observed during the administration of SIPT - BMC, a trained doctoral student and the investigators coded the actions of the child. The motor coordination paradigm was designed to evaluate how children coordinate their body movements, when alone and in a social interaction. This paradigm consists of simple and complex actions performed in social and solo contexts (e.g., solo complex clapping, social complex marching, and solo simple drumming). The selected actions employ both fine and gross motor skills. Kaur et al. performed second-to-second coding of the behaviors and calculated the coefficient of variation (CV) to assess consistency of movement (lower CV = greater consistency) and movement rates (the number of events per second). As BOT - 2, the MABC - 2 (Movement Assessment Battery for Children -2nd edition) (Henderson, Sugden, & Barnett, 2007) subscales employed by Ament et al. (2015) (i.e., Manual Dexterity, Balance, and Ball Skills) allows the investigation of gross and fine motor characteristics and was applied to participants on the autism spectrum. In turn, Amaral et al. (2017) focused on the study of hysteresis. White foam cubes of increasing and decreasing sizes (between 2 and 20 cm) were slid on a table for the child to pick and place on a marked place on the surface of the table. The ascending/descending phase was terminated when the participant picked up 5 cubes in a row with two hands/with one hand. In order to demonstrate adaptation to a changing environment (aka hysteresis), picking-up styles must change at critical points (from the use of one to two hands and the other way around). This means that the transition in the ascending phase must occur at a larger cube size that in the descending phase. The procedure was applied in both, solo (hidden presence of the investigator) and social contexts. Finally, Esposito & Pasca (2013) carried out a desktop research and a literature analysis of evidence about motor impairments of persons on the autism spectrum.

8.1.4 Participants in the Studies Investigating Motor Processes in Persons on the Autism Spectrum

The sample sizes of the studies varied between 12 and 56 pre-scholars and primary scholars on the autism spectrum. The sample size of the matched controls was between 12 and 81 persons with typical development, and one study recruited a group of 63 participants with ADHD. Out of 121 participants on the autism spectrum from all studies, only 17 were females. All studies included female participants. Regarding the diagnostic criteria employed, only Kaur et al. (2018) report their participants on the autism spectrum to have been diagnosed according to the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS - 2) (Lord et al., 2012); Ament et al. (2015) report that both participants with ADHD and on the autism spectrum were diagnosed according to the DSM-IV criteria. Most participants on the autism spectrum and with ADHD in Amaral et al. (2017) were taking psychotic medication and had co- morbidities.

Ament et al. (2015) chose a convenience sampling and Kaur et al. (2018) randomly selected the participants on the autism spectrum out of the population of children on the autism spectrum (no further information on the characteristics of the population are given). The group of participants with typical development in Kaur et al. (2018) were selected according to the convenience criterion. Amaral et al. (2017) do not report the type of participant sampling method used: It therefore cannot be concluded whether the results can be generalized to the population.

8.1.5 General Differences between Groups

Three out of four studies conclude there are differences between the motor performances of persons on the autism spectrum and typically developed persons. Ament et al. (2015) apply three conditional logistic regression models to compare the TD (typically developed) and DD (developmental disability) groups, ASD (Autism Spectrum Disorder) and ADHD groups, and ASD co-morbid ADHD and ASD without co- morbid ADHD groups. Ament et al. (2015) observed there are significant differences of the performances on the MABC-2 between the ASD ($M = 4.14$, $SD = 2.19$), the ADHD ($M = 6.38$, $SD = 2.67$), and the TD group ($M = 8.90$, $SD = 2.52$). They further concluded that participants on the autism spectrum present more severe overall motor impairments than participants diagnosed with ADHD. The Kruskall-Wallis test (the results were not significant with $p>0.05$) employed by Kaur et al. (2018) revealed a significant group effect between the LASD (low IQ participants on the autism spectrum), the HASD (high IQ participants on the autism spectrum), and the TD group for BOT-SF ($\chi2(2)=21.76$, $p<0.001$), body coordination ($\chi2(2)=23.67$, $p<0.001$), fine manual ($\chi2(2)=19.93$, $p<0.001$), and manual dexterity ($\chi2(2)=21.10$, $p<0.001$) components of BOT-2; for rhythmicity ($\chi2(2)=8.13$, $p=0.017$), mirroring ($\chi2(2)=12.25$, $p=0.002$), overflow ($\chi2(2)=10.33$, $p=0.006$), and total error scores ($\chi2(2)=18.17$, $p<0.001$) and time for completion ($\chi2(2)=18.17$, $p<0.001$) on SIPT-BMC; for 9/12 movements for movement variability: social simple clap ($\chi2(2)=16.72$, $p<0.001$), solo complex clap ($\chi2(2)= 9.75$, $p<0.008$), social complex clap ($\chi2(2)= 11.52$, $p<0.003$), social simple march ($\chi2(2)=13.36$, $p<0.001$), solo simple march ($\chi2(2)=12.8$, $p<0.002$), solo complex march ($\chi2(2)= 14.12$, $p<0.001$, social complex march ($\chi2(2)= 14.36$, $p<0.001$), social simple drum ($\chi2(2)=16.8$, $p<0.001$), and solo simple drum ($\chi2(2)=7.65$, $p<0.002$); and for 8/12 movements for movement rate: solo simple clap ($\chi2(2)= 6.55$, $p<0.04$), social simple clap ($\chi2(2)=10.23$, $p<0.006$), solo complex clap ($\chi2(2)= 7.22$, $p<0.03$), social complex clap ($\chi2(2)=14.58$, $p<0.001$), solo simple march ($\chi2(2)= 12.99$, $p<0.002$), social simple march ($\chi2(2)= 10.97$, $p<0.004$), solo complex march ($\chi2(2)=5.85$, $p<0.05$), and social complex march ($\chi2(2)=11.23$, $p<0.004$). Esposito & Pasca (2013) present evidence for a wide range of motor impairments of persons on the autism spectrum, such as head lag and fine motor skills. The analysis of data of Amaral et al. (2017) does not provide information as to whether there are significant differences in the transition points between groups. However, the results point to the lack of hysteresis in persons on the autism spectrum in the social condition.

8.1.6 Similar Performances between Groups

Amaral et al. (2017) report both the ASD (Autism Spectrum Disorder) and the TD (typically developed) group to present evidence of hysteresis in the solo experiment. The majority of participants in both groups (i.e., 60% in the TD group and 66% in the ASD group) changed the grasping style on a larger cube size in the ascending than the descending phase. Hysteresis was not associated with mental-flexibility to the task, which differentiates hysteresis from perseveration. The results indicate that both groups can adapt to a changing environment by taking into account multiple variables.

Other similarities in performance between groups can be also observed in Kaur et al. (2018). Both, the LASD (low IQ) and the HASD (high IQ) groups demonstrated poor performance of fine and manual dexterity on the BOT-2, an equally larger variability of movements for almost all actions in the motor paradigm than the TD group, and an equal movement rate for almost all actions in the motor paradigm. Kaur et al. conclude that fine motor skills but not gross motor skills are associated with both LASD and HASD. Another reported result is that differences were not encountered between the TD, LASD, and HASD groups in movement variability for the solo simple clap and the solo and social contexts of complex drum.

8.1.7 Persons with Typical Development Motor Profile

Amaral et al. (2017) report T-tests and mixed-design ANOVA to reveal that participants with typical development were able to adapt their behavior (i.e., changing from one-hand to two-hands for picking increasing/decreasing sized cubes) at key moments during both the solo and the social experiment; the transition from one grasping style to the other was higher in the ascending than the descending phase. However, the value of the effect size is not stated, and the reader cannot evaluate the strength of the findings. The other studies do not report distinct motor characteristics of participants with typical development: Their performance reflected the mean performance in the battery tests.

8.1.8 Persons with ADHD Motor Profile

Ament et al. (2015) report that before Bonferroni correction, manual dexterity on MABC-2 was significantly associated with the ADHD diagnosis, with every 1 point decrease in the score of the item being associated with a 20, 2 % increase (CI 1.6, 42.2 %; p = 0.031) in the likelihood for an ADHD diagnosis. Authors conclude that ADHD participants might present impaired action selection associated with holding and manipulating small objects.

8.1.9 Persons on the Autism Spectrum Motor Profile

The motor impairments are representative and predictors of the autism disorder. Esposito & Pasca (2013) argue that motor symptoms in persons on the autism spectrum manifest at an early developmental stage, are pervasive, heritable, and persistent. They also present evidence that motor characteristics are predictive of communicational scores (e.g., Bhat, Galloway, & Landa (2012)). In contrast to Esposito & Pasca (2013), Ament et al. (2015) show that motor impairments are predictive of a developmental disorder (e.g., ADHD, ASD). Every point decrease on the MABC-2 scores is predictive of developmental disorders, and scores on the Aiming, Balance, and Catching components and items are predictive of the Autism Spectrum Disorder. For example, every 1-point decrease in balance item scores was associated with a 39, 1% likelihood the participant had a diagnosis on the autism spectrum compared to the ADHD group. However, no subscale or item scores were predictive of the diagnosis of autism spectrum co- morbid ADHD compared to the group diagnosed with autism spectrum without co-morbid ADHD. Also, diagnosis, and not IQ, correlated to praxis errors, time and movement variability in Kaur et al. (2018). Given these and other studies' findings (e.g., Gizzonio et al. (2015)), Kaur et al. (2018) recommend dyspraxia to be representative of Autism Spectrum Disorder.

Ament et al. (2015) observe an association between low scores on the aiming, catching, and balance subscales of the MABC-2 and an increased likelihood of an autism spectrum diagnosis. Kaur et al. (2018) also observe a reduced performance of the participants, but they also differentiate within the autism symptomatology: high IQ (HASD) and low IQ (LASD). Post-hoc Mann-Whitney U tests revealed that LASD obtained lower scores on body coordination and BOT-SF, mirroring and total errors, and took the longest time to execute actions than the HASD in SIPT-BMC. Both HASD and LASD presented higher movement variability for clapping and drumming and slower movement rates in executing clapping and marching. The LASD group presented greater rhythmicity, mirroring, overflow, and total errors and slower movement rates for most actions compared to the TD group. The HASD group presented higher overflow errors and slower movement rates for solo complex clap and social simple and complex march actions compared to the TD group.

8.1.10 Personal Analysis and Conclusions

I present here strong and weak points of the selected publications, and I identify future actions that need to be taken to advance the understanding and investigation of motor impairments of persons on the autism spectrum. The results of the covered studies indicate *possible* unique, representative motor characteristics of persons on the autism spectrum as different from the typically developed, but also *within* the autism spectrum. Persons on the autism spectrum present difficulties with body coordination and balance, fine and gross motor skills, praxis, increased movement variability, and longer execution time. Also, it seems that participants on the autism spectrum with a low IQ are characterized by most mirroring and total errors and longest time to execute actions.

A low number of female participants was reported in all selected studies. There is a 3:1 male-to-female ratio of persons being diagnosed with Autism Spectrum Disorder (Loomes, Hull, & Mandy, 2017), and although this means that female participants with an Autism Spectrum Disorder diagnosis are harder to recruit, the females on the autism spectrum population are underrepresented in these studies, a key aspect that limits any generalization of results to the female population. Regarding individual studies, Amaral et al. (2017) reported that most participants with ADHD and on the autism spectrum had co-morbidities and were taking medication. Taking psychotic medication and having co-morbidities can have an influence on performance on task, depending on the main effects and the side effects of the medication, and the symptoms of the co-morbidity; it is thus important for studies to also state the effect of the medication and the co-morbidities on the performance evaluated in the study. Considering the limitations of a small sample size, very low number of female participants, and no information on the sampling method in Amaral et al. (2017), generalizing findings to the population of persons on the autism spectrum, and in particular to the population of females on the autism spectrum, is not possible. Regarding interpretation of results of similar performance in hysteresis between the ASD and the TD group, Amaral et al. (2017) do not provide any explanation for using a minimal threshold of 50% correct responses as criterion for concluding that the sample and the population of ASD and TD showed hysteresis.

The model analysis of Ament et al. (2015) comparing performance between ASD co-morbid ADHD and ASD without co- morbid ADHD allowed the study of a possible influence of co-morbid ADHD on performance of the ASD group, but in anticipation of possible significant differences between the two groups and considering limitations of the regression models, the authors should have also used a regression model comparing ASD co-morbid ADHD group to TD and ADHD group.

While Esposito & Pasca (2013) conclude there may not be any single universal motor characteristic of persons on the autism spectrum disorder, Ament et al. (2015) conclude that multiple motor impairments might be representative of ASD, and ADHD. The study by Esposito & Pasca (2013) can be described as a presentation of professionals' opinion about the current state of the art of the literature on motor impairments of persons on the autism spectrum and the implications of these impairments for the diagnosis criteria of the disorder and for further studies. Even though the arguments are not supported by a wide range of analyzed articles, professionals' opinion is important to orient new directions and efforts in research.

In general, a limitation across studies I observed is that the reviewed comparative studies do not report the concurrent validity of the applied standardized tests to evaluate whether and to what degree, for example, the scores obtained on MABC-2 (Henderson et al., 2007) can be compared to the scores obtained on BOT-2 (Bruininks & Bruininks, 2005).

The findings of the reviewed studies match findings in other studies (e.g., Gizzonio et al. (2015)) and literature reviews (e.g., Cook (2016)). According to Cook (2016), persons on the autism spectrum present stability issues while standing and walking, atypical kinematics, poor fine motor control (in handwriting tasks), and delayed preparation and execution times for goal-directed and point-to-point actions. Although Cook (2016) summarizes results from a larger number of studies than my review, which could lead to drawing conclusions that are more representative of the state of the art of the field, the author does not analyze the selected publications for methodological and data analysis weaknesses and strong points as I did.

In conclusion, even though single actions were studied in isolation, they do form the basis for further normal development of complex actions: Understanding how single motor characteristics influence play, social interaction, and even other low-level phenomena, such as perception and sensation, is key. Further studies should combine types of measurements (e.g., standardized tests, experimental tasks, and kinematic measures) and delineate subgroups of persons on the autism spectrum that present specific motor characteristics and other factors (e.g., intelligence, verbal abilities) to identify motor characteristics representative of the Autism Spectrum Disorder. But there also are characteristics of the motor system of persons on the autism spectrum that do not differ from that of persons with typical development (e.g., Amaral et al. (2017)). Another suggestion is that future studies should consider sampling more females. Finally, studies investigating the influence of medication on performance during studies are necessary in persons on the autism spectrum as Esposito & Pasca (2013) also recommend.

8.2 Perception Abilities of Persons on the Autism Spectrum

Visual perception is an important basis for the development and functioning of higher cognitive processes; therefore, understanding how persons on the autism spectrum perceive visually and how this differs from persons with typical development is a key step towards understanding higher processes, such as social interaction. Visual perception characteristics in persons on the autism have been increasingly studied over the last few decades (Perreault, Habak, Lepore, Mottron, & Bertone, 2015). Local and global mechanisms are the most extensively studied processes of visual perception in persons on the autism spectrum (Guy, Mottron, Berthiaume, & Bertone, 2016). Previous literature has advocated either a local bias of the visual mechanisms of persons on the autism spectrum (Baldassi et al., 2009), or no enhanced local visual processing nor a deficit in global visual processing, but a slow global processing (Hallen, Evers, Brewaeys, Noortgate, & Wagemans, 2015). The aim of my following review is to identify and characterize any reported substantial differences between the visual perception of the persons on the autism spectrum and persons with typical development. My review does not compare and discuss visual processing as a whole. Four articles on the visual perception of persons on the autism spectrum were selected according to the following inclusion criteria: The publications were identified through the Google Scholar Platform and screened to match the criteria of: sample size bigger than 20, use of a control group, and publication date between 2013 and January 2018. The keywords of the search were: "autism", "visual perception", and "disorder". Both, comparative and theoretical studies were selected. While the detailed results of this review are not consistent, the resulting picture is that it appears that overall the studies do support the existence of differences between the visual mechanisms of persons on the autism spectrum and persons with typical development, a local-to-global interference in persons on the autism spectrum, and the already documented global-to-local interference in persons with typical development (see Subsection 8.2.2 Theoretical Background about Visual Processing of Persons on the Autistic Spectrum). However, in the light of the inconsistent results and the identified methodological, data analytic, and interpretational limitations, it is difficult to conclude that the observed differences in the visual processing of participants on the autism spectrum reflect fundamentally different ways to visually perceive their outside world. A possible solution for this difficulty is to include all studies that match the selection criteria of the current review with the additions of selecting those studies that analyze which skills are predictive of the Autism Spectrum Disorder and that investigate also other groups than persons with typical development.

For a more detailed summary of the aims, methodologies, and results of the reviewed studies, please see Table 3 in Appendix D Supplementary Information about the Studies Analyzed in Chapter 8'Autistic' Embodiment.

8.2.1 Defining Key Terms Explaining Visual Perception Abilities

There is general agreement in the literature I reviewed on the nomenclature of the underlying mechanisms of visual perception. Local and global visual performance are defined in terms of the sizes of the stimuli and/or by the employed visual mechanisms. Guy et al. (2016) distinguish between *local* ("small" letters in the Navon Task (Navon, 1977); detailed processing) and *global* performance ("larger" letters of the Navon Task; gestalt processing). Guy et al. (2016), Nayar, Voyles, Kiorpes, & Martino (2017) and Perreault et al. (2015) agree that local processing implies detailed and attentive processing to local characteristics; Nayar et al. (2017) further add it is slower and effortful, and Perreault et al. (2015) state that local information is added sequentially. Guy et al. (2016), as well as Nayar et al. (2017) and Perreault et al. (2015) agree global processing is a gestalt integration of information. Nayar et al. (2017) add it is a rapid and automatic process; Nayar et al. (2017) and Perreault et al. (2015) agree that the shape of the pattern is integrated with reference to its center. Guy et al. (2016) and Nayar et al. (2017) also describe the local-to global and global-to-local forms of interference, where one mechanism is influenced by the other. Perreault et al. (2015) identify three *levels* of visual perception: *low-level*, for extraction of elementary visual features; *mid-level*, for integration of non-social patterns; and *high-level*, for integration of social information. Schauder, Park, Tadin, & Bennetto (2017) discuss visual motion perception, which is usually tested depending on stimulus contrast and size.

8.2.2 Theoretical Background about Visual Processing of Persons on the Autistic Spectrum

The literature reports different paradigms that employ different visual processing mechanisms of persons on the autism spectrum (i.e., influence of cognition processes on perception or influence of perception on its elements). Guy et al. (2016) and Nayar et al. (2017) identify Weak Central Coherence (WCC) (Happé & Booth, 2008; Happé, 1996) and Enhanced Perceptual Functioning (EPF) (Mottron & Burack, 2001) as two predominant theoretical frameworks that aim to explain visual perception of persons on the autism spectrum. Perreault et al. (2015) discusses only EPF.

Apart from the presented paradigms, there are divided research results that either provide evidence for a local processing bias or concordance of over-use of local processing style with difficulties in the global processing mechanism. For example, Hallen et al. (2015) report a detailed-processing style of persons on the autism spectrum, while Joseph, Keehn, Connolly, Wolfe, & Horowitz (2009) report that persons on the autism spectrum make use of a local processing style only in some visual tasks. For symmetrical stimuli, the global mechanism is not believed to be the default visual processing style as in the case of persons with typical development (Behrmann, Thomas, & Humphreys, 2006).

With regard to visual motion integration, the literature is dispersed. Schauder et al. (2017) distinguish between two theories of perception of motion for persons on the autism spectrum. The *Gain control mechanism* model (Newell, 1993) hypothesizes there is an atypical high response to high-contrast stimuli in persons on the autism spectrum. In contrast, Schwarzkopf, Anderson, Haas, White, & Rees (2014) argue in favor of the *increased receptive field size* theory, with reference to larger population receptive fields from the extrastriate visual area. Some authors (e.g., Robertson, Martin, Baker, & Baron-Cohen (2012)) postulate impaired motion coherence, while others (e.g., Manning, Tibber, Charman, Dakin, & Pellicano (2015)) sustain an enhanced motion integration.

8.2.3 Methodological and Procedure Characteristics of the Studies

Different methodologies and different experimental stimuli have been applied to study visual perception of persons on the autism spectrum. The experimental design of Nayar et al. (2017) consists in the use of Kanizsa Illusory Contours (KIC) (Kanizsa, 1976) in a match-to-sample task.

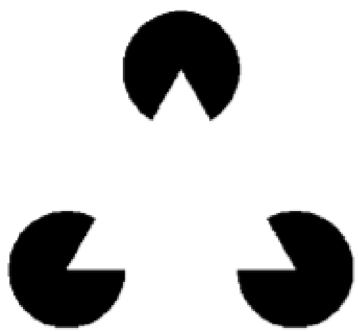

Figure 1 - Kanizsa Illusory Contour (KIC). Depicted is the Kanizsa triangle used in Nayar et al. (2017) *to perceive the triangle's illusory contours; the white space of the Pac Man Configuration must be perceived as corners corresponding to a triangle. Reproduced from "Kanizsa subjective figures capture visual spatial attention: evidence from electrophysiological and behavioral data", by Senkowski, Rottger, Grimm, Foxe & Herrmann, 2014, Neuropsychologia, 43, p.873, Fig.1. Copyright 2004 by Elsevier Ltd.*

KIC (aka Pac-Man Configurations) is a visual illusion that evokes the perception of a triangle due to the Pac-Man-shaped forms inducers (Figure 1). The reaction time and accuracy of responses and touching behaviors were recorded via a touch-screen interface, and the looking behaviors were recorded by an eye- tracking device. There were two conditions: the *basic KIC* condition—during which a shape had to be matched to the target KIC out of a field of 2 KICs—and the *"noise" KIC* condition—during which the shape had to be matched to the target KIC out of an array of individual "Pacmans". If the child looked away from the screen, tracking was terminated and the trial was excluded:

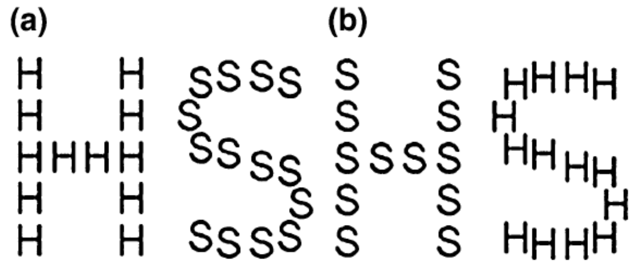

Figure 2 - Hierarchical Stimuli in the Navon Task: (a) consistent global letters and (b) inconsistent local letters. Reproduced from "A Developmental Perspective of Global and Local Visual Perception in Autism Spectrum Disorder", by Guy et al., 2016, J Autism Dev Disord, p. 5, Fig. 1. Copyright 2016 by Springer Science + Business Media New York.

Guy et al. (2016) applied the Navon task (Navon, 1977) (see Figure 2) in their study. The Navon task consists of four hierarchical letters and four conditions, which include the *global* letters and the consistent or inconsistent *local* letters. The role of the participant is to identify the local or global letter, as instructed. Guy et al. (2016) were able to identify simple local, and simple global processing styles, as well as local-to-global and global-to-local interferences.

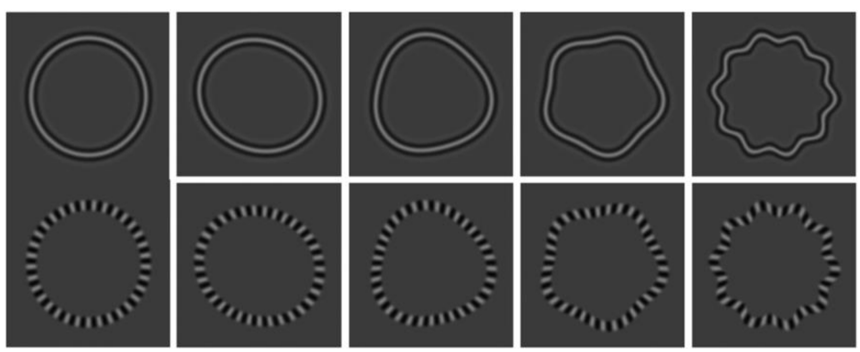

Figure 3 - Luminance-defined and Texture defined RFP (Radial Frequency Patterns). The top row depicts luminance-defined RFP of 0, 2, 3, 5, and 10 bumps defined as radial frequencies, and the bottom row depicts texture defined RFP of 0, 2, 3, 5, and 10 bumps defined as radial frequencies Reproduced from "Behavioral evidence for a functional link between low- and mid-level visual perception in the autism spectrum", by Perreault et al., 2015, Neuropsychologia, 77, p, 383, Fig.1. Copyright 2015 by Elsevier Ltd.

The experimental design of Perreault et al. (2015) allows to study the influence of the low-level characteristics on the mid-level processing of the stimuli. They chose a two interval-forced choice paradigm employing a *distractor* (a circle) and a *target*—a circle deformed by a certain number of Radial Frequency Patterns (RFPs) (see Figure 3). The target contained 2, 3, 5 or 10 RFPs. Based on the definitions of terms of Perreault et al described in Subsection 8.2.1 Defining Key Terms Explaining Visual Perception Abilities and the background of the study described in Subsection 8.2.2 Theoretical Background about Visual Processing of Persons on the Autistic Spectrum, the targets with 2, 3, and 5 RFPs are hypothesized to be processed in a global manner, usually achieved by focusing on the center of the stimuli, while the target with 10 RFP is hypothesized to be processed in a local manner, by sequentially integrating each RFP.

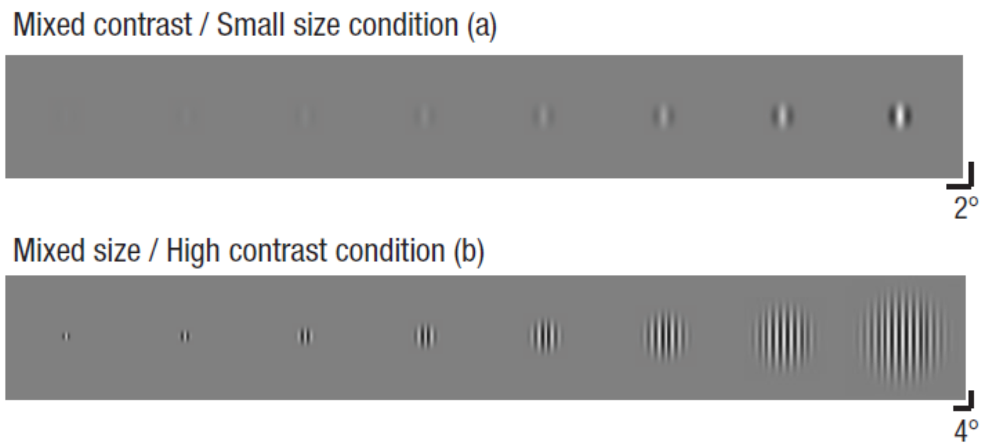

Figure 4 - Visual Motion Tasks According to Size and Contrast. Reprinted from "Larger Receptive Field Size as a Mechanism Underlying Atypical Motion Perception in Autism Spectrum Disorder ", by Schauder et al., 2017, Clinical Psychological Science, 5, p. 828, Fig. 1d. Copyright 2017 by the Author(s).

The task of the participant in Schauder et al. (2017) was to establish the direction of drifting grating stimuli presented in a 2D space (see Figure 4). Schauder et al. designed their task and stimuli to test two established hypotheses, response gain control (Newell, 1993) and receptive field size (Schwarzkopf et al., 2014), about the perception of movement of persons on the autism spectrum. Their experimental design contained three conditions: mixed contrast/small size, mixed size/high-contrast, and mixed-size/low-contrast. To validate the response gain control hypothesis (Newell, 1993), the authors expected group differences at high-contrast and all sizes stimuli. To validate the receptive field size hypothesis (Schwarzkopf et al., 2014), Schauder et al. (2017) expected group differences across all stimulus contrasts and small sizes stimuli. An important aspect of the design was that the presentation and the duration of appearance of the stimuli on screen was set according to Weber–Fechner law (Fechner, 1860). This law refers to two related laws in psychophysics (i.e., the Webber law and the Fechner law). It was Fechner that formulated the complete theory, which stipulates that the relation between the actual change in a physical stimulus and the perceived change is logarithmic. If a stimulus measure varies as a geometric progression, the corresponding perception is altered in an arithmetic progression.

8.2.4 Participants of the Studies Investigating Visual Perception in Persons on the Autism Spectrum

The studies reported a size sample between 20 and 40 school-aged children and adolescents on the autism spectrum. Out of a total of 228 participants, only 19 were females. Nayar et al. (2017) and Schauder et al. (2017) did not recruit any females. The ASD (Autism Spectrum Disorder) group was evaluated according to the DSM-IV-TR criteria. Nayar et al. (2017) report that 6 out of 28 participants from the ASD group did not match the DSM-5 criteria. Nayar et al. (2017) and Schauder et al. (2017) report that participants in the ASD group took psychoactive medication, and all research groups but Nayar et al. (2017) report that participants were checked for normal vision before administration of task. Most studies report sampling of convenience, but Schauder et al. (2017) do not report how participants were recruited.

8.2.5 Data Analysis in the Studies Investigating Visual Perception in Persons on the Autism Spectrum

The data analysis of the results was carried out differently across studies. Guy et al. (2016) combined multiple statistical tests. Besides mixed-design and repeated measures ANCOVA, they applied multiple regression models to verify the effect of interference. In this way, the observed developmental differences are not influenced by large intra-subject variability. Nayar et al. (2017) and Perreault et al. (2015) ran ANOVA tests. Perreault et al. (2015) applied the Tukey post-test to assess whether RFP conditions were perceived differently by participants. Schauder et al. (2017) carried out a psychophysical and computational analysis. They also ruled out procedural differences as reason for differences in the results reported by Foss-Feig, Tadin, Schauder, & Cascio (2013).

8.2.6 Differences of the Performance between Persons on the Autism Spectrum and Persons with Typical Development

Nayar et al. (2017) and Perreault et al. (2015) note differences in the global condition. Nayar et al. (2017) report significant differences between groups in looking behaviors in the global condition (basic KIC), such that participants on the autism spectrum looked less at the KIC center than participants with typical development (Bonferroni-adjusted post hoc group comparisons within basic KIC and KIC-noise conditions: $F(1,44)=56.85$, $p>0.01$ and $F(1,44)=59.73$, $p>0.003$,respectively); no significance was observed for touching behaviors. Perreault et al. (2015) observe significant differences between groups for both, luminance (only for 2 RFP ($F(1,57)=7.81$, $p<.01$, $\eta^2_{partial}=.12$) and 3 RFP ($F(1,57)=7.54$, $p<.01$,

$\eta^2_{partial}$ =.12) and texture conditions (for all RFP conditions - $F(1,57)=16.38$, $p<.05$, $\eta^2_{partial}$=.22), with the performance of the ASD group lower than the TD group. As Perreault et al. explain, RFP with deformations fewer than 10 are integrated globally. There are some differences between groups reported in the local conditions of some studies. Perreault et al. (2015) report mixed results: there are no significant differences for the local-texture condition, but some for the local-luminance condition (5 and 10 RFP). Schauder et al. (2017) also report differences between groups, but only in mixed contrast/small size conditions.

8.2.7 Indistinguishable Visual Performance Characteristics of all Tested Groups

The studies report similar performances between the ASD group and the TD group. Guy et al. (2016) report similar development of the global and local reaction times between groups and no significant differences in the local condition without interference. Perreault et al. (2015) report similar performance within groups—the perceptual threshold decreased in the luminance condition, and it increased in the texture condition as the number of RFP increased. In Schauder et al. (2017), both groups did worse with increasing stimulus size and high-contrast, and both improved their performance with increasing stimulus size and low-contrast.

8.2.8 Visual Perception Profile of Participants on the Autism Spectrum

All authors report worse performance of the ASD group in comparison to the TD group. Perreault et al. (2015) report worse discrimination performance for all texture RFP and only for 2 and 3 RFP luminance. Schauder et al. (2017) report reduced motion detection discrimination performance across all contrast levels. Guy et al. (2016) report the ASD group had a slower performance in the global condition, and Nayar et al. (2017) obtained a medium size effect for participants on the autism spectrum making more errors than controls in the KIC + noise condition.

Guy et al. (2016) conclude that participants in the ASD group presented a local-to-global interference, a slower performance in baseline global condition, and no significant differences from TD group for global-to-local conditions. Guy et al. interpret their results within established theories on the perception of persons on the autism spectrum: they favor the bottom-up explanation to account for the registered differences in visual perception tasks. Guy et al. (2016) reject the hypothesis of the ASD group presenting a bias for local information; they observe that the ASD group variable is not a predictor of local/global reaction time. They also reject the hypothesis of the local bias to increase with age; the results show the exact opposite—reaction times for both conditions decreased with age.

Nayar et al. (2017) also found a local-to-global interference. Moreover, authors conclude that the ASD participants present neither a local nor a global processing style. They take their results to fail to provide evidence for neither the WCC nor EPF theory. At the same time, Nayar et al. acknowledge a study design limitation: in the KIC + noise condition, participants possibly engaged in visual search rather than discrimination and matching.

Perreault et al. (2015) conclude the ability of persons on the autism spectrum to discriminate globally a circular pattern to be dependent on the type of local characteristics (luminance, texture) and on the number of RFP. They report the discrimination thresholds of the participants on the autism spectrum to be higher across all RFP conditions for texture, but equal for 5 and 10 RFP in the luminance condition. The study authors themselves interpret their results as evidence for the EPF theory of persons on the autism spectrum.

Schauder et al. (2017) obtain results that oppose those reported in Foss-Feig et al. (2013): The atypical motion sensitivity for the smallest stimulus size in ASD encountered by Schauder et al. (2017) is considered evidence for the receptive field theory. However, reduced stimulus sensitivity in the mixed size/high-contrast or mixed-size/low-contrast condition was not observed. The authors provide an alternative account for their results that is related to attentional and eye fixation movement differences, since receptive fields are associated to better integration of local information (Anton-Erxleben & Carrasco, 2013).

8.2.9 Personal Analysis and Conclusions

I systematically presented information about selected articles across all important aspects of the studies: theoretical background, experimental design, method, results, participants, and discussion. I now analyze these reports.

Nayar et al. (2017) state the observed variety of methodologies and experimental stimuli used to investigate visual perception in persons on the autism spectrum may contribute to the inconsistency of results observed in the literature, but the research group also introduces a rarely used methodology. However, the introduced methodology accounts for the unnecessary use of the motor skills of persons on the autism spectrum in other visual tasks. A highlight of the procedural aspect in Nayar et al. (2017) was to terminate the tracking when the child looked away from the screen, as persons on the autism spectrum might engage in self-stimulatory behaviors that would disengage them from the task at hand.

Although Guy et al. (2016) fail to report how their study relates to other studies that applied the Navon task to participants on the autism spectrum, the use of the Navon task facilitates this comparison of their results to previous studies that used this task. Moreover, Guy et al. did not account for the influence of race on the performance in the Navon task, as reported in (McKone et al., 2010). In contrast to Guy et al. (2016), the experimental design of Nayar et al. (2017) allows the study of only two types of visual processing mechanisms. In the *basic KIC* condition, participants had to always match a shape with the target KIC shape: a condition that makes use of the global mechanism. In the *"noise" KIC* condition, participants had to match the shape to the target shape of the KIC from an array of distractors: a condition that registers local-to-global interference. Also, in comparison to the Navon Task used by Guy et al., the use of KICs in the experimental design of Nayar et al. does not support a systematic analysis of the individual types of visual perception mechanisms (i.e., local and global) and their interferences. Also, the data analysis by Nayar et al. (2017) addresses the stated hypotheses and research questions, but they analyzed only the correctly-matched trials. But beyond that, valuable information about differences in processing might have been observed also in the incorrect conditions.

A limitation of the methodological design of Perreault et al. (2015) is that authors do not provide any argumentation for choosing three RFPs levels (i.e., 2, 3, and 5) to study the global processing mechanism and only one level of the RFP number (i.e., 10) to study the local processing mechanism. Perreault et al. also do not provide an interpretation of the differences in performance of persons on the autism spectrum between 2, 3, 5, and 10 RFP within the ASD group and the TD group. Consequently, the overall significance and meaning of the reported differences in performance (i.e., that the ASD group performed well for the 2 and 3 luminance-RFP global condition, and worse for 5 RFP-global condition) remains unclear. Another limitation of the study of Perreault et al. (2015) is that the authors did not assess whether the performance on the task improved as a result of the participant becoming more familiar with and learning how to respond to previous trials; especially since the long duration of sessions (i.e., between 1 h 30 min and 2 h) could have led to a high rate of learning.

The inexistent or low number of recruited female participants in all selected studies raises significant issues with extrapolating the results to the female population and puts forward the need to prioritize an equal number of both genders in the sample size. Moreover, the reporting of Nayar et al. (2017) that a small number of participants on the autism spectrum diagnosed according to DSM-IV-TR criteria did not match the DSM-5 criteria raises issues with regard to the compatibility of diagnosis between DSM-IV and DSM-5. The final point is that given the limitations of the participant's selection in all studies, it is not possible to extrapolate the following findings to the population of pre-scholars and adolescents on the autism spectrum, especially to the female population.

In the studies I covered, participants on the autism spectrum show local-to-global interference only for some reported results (Guy et al., 2016; Nayar et al., 2017): this can be taken to also indicate some global impairment. However, the local-to-global and global-to-local interference is calculated differently in each of the studies I reviewed, which limits the possibility to conclude a general finding about the interference effect in visual perception of persons on the autism spectrum across studies. As a result, the consistency between reported results could on the one hand be interpreted all the more positively, because both methodologies investigated the same construct, or, on the other hand, not favorably, as the different analyses may have addressed different aspects of the phenomenon. Another finding was that the visual perception of persons with typical development was characterized by a global mechanism bias (Guy et al., 2016; Nayar et al., 2017). Also, the identified specificity of performance differences between groups for the mixed contrast/small size conditions in Schauder et al. (2017) does suggest some difference between mechanisms of visual perception in persons on the autism spectrum and persons with typical development: But while the detection of such differences is valuable empirical evidence, it still is but an intermediary step towards an understanding of the *nature* of the differences; e.g., whether persons on the autism spectrum have an enhanced ability to perceive visually.

Given the identified limitations of the studies covered, I conclude that the results are suggestive of differences between the visual perception of persons on the autism spectrum on the one hand, and of persons with typical development on the other, but the apparent nature of these differences is not consistent. In particular, the provided evidence is not strong enough to conclude that the observed differences in visual perception mechanisms would indicate a different embodiment of the persons on the autism spectrum.

Some of the selected authors place their findings in one of the two theories of perception in persons on the autism spectrum: WCC or EPF. WCC postulates that persons on the autism spectrum present deficient higher-order processes controlling perceptual integration of single elements; in other words, due to impairments of higher-level processes they tend to perceive more the individual elements rather than the whole. On the other hand, EPF postulates that it is due to the increased and enhanced autonomy of perception that persons on the autism spectrum have a preference for local processing. Thus, the theoretical frameworks are oppositional due to the described mechanisms employed during perception; WCC takes a top-down approach—argues for impairment of higher-level processes that influences perception—, while EPF is oriented in the bottom-up direction—argues for atypical perception processes that influences its mechanisms.

Different conclusions on the characteristics of the visual perception of persons on the autism spectrum were obtained in other work: A recent review of the visual perception characteristics of persons on the autism spectrum states that “the general consensus is that individuals with ASD ‘see’ the world differently, possibly with a local bias at the expense of global processing” (Little, 2018, p. 2). However, as D’Souza, Booth, Connolly, Happé, & Karmiloff-Smith (2016) point out, the local bias-global impairment combination is an oversimplification of the variety of abilities that are operationalized differently across different tasks. Little (2018) also concludes that persons on the autism spectrum present an increased risk of having oculomotor problems, refractive errors, and strabismus. Given the identified risk of developing vision problems, she suggests that common behaviors of persons on the autism spectrum (e.g., avoidance of eye gaze, seeking types of visual stimulation) may be associated with impaired vision.

Future meta-reviews targeting the visual perception of persons on the autism spectrum should apply more strict inclusion criteria than the selected studies (including: bigger sample size, stronger methodological design, and randomized selection of participants) and should cover a larger number of studies. Another suggestion is that further research should focus on identifying whether the local style in association with a global impairment is generally observed in persons on the autism spectrum.

8.3 General Personal Analysis and Conclusions

In this chapter, I investigated characteristics of the 'autistic' embodiment of persons on the autism spectrum. I looked into how persons on the autism spectrum move and visually perceive the environment. In Section 8.1 Motor Abilities of Persons on the Autism Spectrum, I concluded that persons on the autism spectrum present differences in their movement characteristics from persons with typical development in areas such as fine and gross motor skills, body coordination, movement variability, execution time, and movement variability. Aiming, Balance, and, Catching scores were predictive of the Autism Spectrum Disorder. In Section 8.2 Perception Abilities of Persons on the Autism Spectrum, I concluded that persons on the autism spectrum present differences in the way they perceive their environment from persons with typical development, but the nature of reported differences is not consistent across studies. Studies suggest a local-to-global interference in persons on the autism spectrum. The findings of the reviews covered are insufficient to suggest an 'autistic' embodiment, also because the number of analyzed publications is too low and the studies present limitations of their experimental methodology, data analysis, and data interpretation.

Overall, I collected the following characteristics of the motor and visual processes of persons on the autism spectrum that hint towards the existence of an 'autistic' embodiment:

1. The perceptual and motor characteristics of persons on the autism spectrum have underlying neurological characteristics that differ from the function and structure of the brain of persons with typical development.

Motor impairments are associated with observed abnormal brain connectivity of persons on the autism spectrum (Just, Keller, Malave, Kana, & Varma, 2012; Thompson et al., 2017), manifested as poor long-range connectivity between cortico-cortical structures or cortico-subcortical structures (Mostofsky et al., 2009). Studies report that praxis and imitation errors in Autism Spectrum Disorder could be related to impairments in bilaterally distributed praxis network and poor long-range connectivity between the motor and visual brain areas (Mahajan, Dirlikov, Crocetti, & Mostofsky, 2016; Nebel et al., 2016). Poor long-range neural development was also reported by Kovács (2000) to explain visual processing differences in persons on the autism spectrum. Both HASD and LASD present overflow errors in comparison to the TD group (Kaur et al., 2018). It is argued that this result is associated with poor inhibitory control neurons from the cerebral cortex and delayed functional segregation of upper and lower limb areas from the motor cortex (Nebel et al., 2016). Kéιta, Guy, Berthiaume, Mottron, & Bertone (2014) also report that an excitatory/inhibitory signaling balance at the origin of abnormal lateral or feedforward connectivity within primary visual areas could be the cause of the differences in processing luminance and texture information. Schwarzkopf et al. (2014) signal also differences in the visual areas, which consist in atypical large receptive fields populations in extrastriate visual areas. However, as Kaur et al. (2018) also observe, the neuroscientific evidence is still limited and further research using fMRI is necessary.

2. Motor impairments of persons on the autism spectrum may be associated with a specific genetic profile.

Motor impairments of persons on the autism spectrum are heritable (Esposito & Pasca, 2013). Bhat et al. (2012) provide evidence for the presence of motor impairments among siblings on the autism spectrum. Buja et al. (2018) show that damaging de novo mutations of persons on the autism spectrum are significantly associated with motor impairments within the disorder.

3. The motor and perceptual characteristics of persons on the autism spectrum are not a consequence of other phenomena (e.g., social or cognitive).

In contrast to the group of persons diagnosed with ADHD, Ament et al. (2015) concluded that motor impairments of persons on the autism spectrum are not a consequence of the social symptomatology. However, Amaral et al. (2017) find social interaction, and not individual characteristics, to significantly change the style of grasping of objects. These two findings can be interpreted as two sides of the same coin. To explain my point, I remind the reader that De Jaegher (2006) discusses how both, social interaction and individual embodiment, can influence the dynamics of interaction and the sense-making of the individual. It seems that motor impairments alone influence sense-making of the individual on the autism spectrum (bottom-up influence), while hysteresis is influenced by social interaction and the presence of another person (top-down influence).

4. Persons on the autism spectrum have unique motor characteristics.

The results of Ament et al. (2015) show that persons on the autism spectrum have specific motor impairments in the static balance and catching areas. Both areas require in-the-moment spatial and temporal integration of elements (Whyatt & Craig, 2012), which further support walking, running, and playing sports (Ament et al., 2015).

In conclusion, the evidence points to differences of the motor and visual characteristics of persons on the autism spectrum from persons with typical development. Persons on the autism spectrum have unique motor characteristics. There is no consensus about the nature of the differences in the visual perception of persons on the autism spectrum. Motor and perceptual impairments appear to have a specific underlying neurology and possibly a unique genetic profile. The related neuro-scientific and genetic evidence however is limited and has not been analyzed.

Future reviews should cover larger numbers of publications, should exclude studies presenting methodological limitations as identified here, should select studies that analyze characteristics predictive of the Autism Spectrum Disorder, should compare the characteristics of the processes of persons on the autism spectrum to the characteristics of persons with other neurological diagnostics, and should cover the underlying neurological and genetic substrates of the motor and visual processes.

De Jaegher (2006, 2013) discusses of an ‘autistic’ embodiment, but the findings covered in this chapter are not sufficient to conclude whether a discussion of an ‘autistic’ embodiment, significantly different from the embodiment of persons with typical development is justified. However, my results show that further investigations is warranted and may provide supporting evidence.

9 From Embodiment to Sense-Making

In Chapter 8 I discussed characteristics of the motor and visual perception processes of persons on the autism spectrum, characteristics that are representative of the 'autistic' embodiment according to De Jaegher (2013). Next on the agenda is discussing how persons on the autism spectrum make sense of the world around them. In this chapter I discuss theoretical and practical evidence regarding particular ways persons on the autism spectrum make sense of their social environment, particular ways in which they act that are inherently relevant for them, and the link between low-level processes—representative of a particular embodiment—and high-level processes—indicative of the way persons on the autism spectrum interact, think, and communicate. I searched for publications on PubMed, Google Scholar, and Scopus no older than 3 years (2015-2018). The types of publication I selected were meta-analyses, comparative studies, doctoral theses, and books. The resulting picture is that it appears there is no consensus about the nature of the link between low-level and high-level processes in persons on the autism spectrum.

According to the enactivist paradigm, the body defines the interaction potential with the external environment, and the external environment influences brain, body, and mind. The biological and psychological structures of body, brain, and mind reflect what type of information we require from the environment and how the information is perceived. Consequently, persons on the autism spectrum that present specific patterns of sensing, perceiving, and moving could make sense of the world uniquely. In my practical experience as an interventionist for children on the autism spectrum, I observed that children on the autism spectrum are interested in different aspects of the environment than persons with typical development. Some children on the autism spectrum are not interested in fashion (e.g., preference for a color or for a piece of garment) the way persons with typical development are. Children on the autism spectrum engage in repetitive activities (e.g., toggling the light), present an intense and atypical preoccupation with specific activities, objects (e.g., always running to a specific place in the room), and atypical play (e.g., spinning the wheels of toy cars). In these, the children engage in the specific activities even when alone in the room. When possible, they would always perform the respective activity, occasionally also interrupting another for their preferred one. Donnellan, Hill, Leary, & others (2013) argue that professionals and caregivers should consider such symptoms as meaningful, non-volitional, neurological symptoms of the disorder, and not as symptoms of laziness or non-compliance that must be changed. Indeed, I also believe these activities to serve a specific purpose for persons on the autism spectrum. As interventionist, it is important to reflect upon the function of the behavior and the importance of the behavior for the child on the autism spectrum before considering whether to work towards its extinction.

To evaluate the connection between embodiment and sense-making, one should demonstrate that the specific activities that are typical of or relevant for children on the autism spectrum is underlined by the 'autistic' embodiment (De Jaegher, 2013). An area in which there is evidence that individuals on the autism spectrum derive pleasure from their specialized activities or thinking styles is restricted interests and repetitive behaviors (De Jaegher, 2013): These cardinal diagnosis criteria according to DSM-5 are organized into four categories: *stereotyped motor movements*; *use of objects or speech* (e.g., lining up toys, flipping hands, echolalia); *insistence on sameness* (e.g., need to dress with similar/same clothes everyday); *highly restricted, fixated interests abnormal in intensity or focus* (e.g., turning wheels to a car, repeatedly opening/closing doors); and *hyper- or hypo-reactivity to sensory input or unusual interest in sensorial characteristics of the environment* (e.g., being in constant motion, apparent lack of appropriate emotional reaction to injuries). One could assume that since persons on the autism spectrum repeatedly engage in the same activities and behaviors, they do it as a consequence of a personal motivation. They could do these activities because they enjoy them (e.g., sensation seeking activities), to alleviate pain, or to satisfy an internal need (e.g., hyper-/hypo- sensitivity to specific stimuli). Even though these activities can be time-consuming and therefore impact further development (Naguy & Yahya, 2018), in my own interactions with children on the autism spectrum I have observed that it can also increase social responsiveness when other persons are involved in the activities.

9.1 The Link between Low-level Processes and High-level Processes

I now present evidence for the existence of a link between low-level processes and high-level processes that are representative of the way persons on the autism spectrum make sense of their environment. Empirical findings suggest a link between maladaptive motor stereotypy and atypical sensory integration. Shafer, Newell, Lewis, & Bodfish (2017) hypothesize manifestation of maladaptive motor stereotypy to be indication of low motor complexity. Shafer et al. further hypothesize that low motor complexity is caused by abnormal sensorimotor integration. Ruddock et al. (2015) observed in a double-jump reaching task with and without inhibitory constraints that participants with neurodevelopmental disorder faced significant problems in anti-jump trials where inhibitory control is required. These results suggest that persons with a neurodevelopmental disorder might present difficulties with integrating sensorial feedback to predict motor movement.

Speech perception in persons on the autism spectrum differs from persons with typical development; it is influenced by different temporal processing and atypical integration of multisensory stimuli. Stevenson et al. (2017) show that abnormal audiovisual sensory integration of social stimuli mediates the relationship between temporal processing of multisensory information and speech perception in scholars on the autism spectrum. There is a distinguishing unidirectional link: temporal processing of multimodal sensory information correlates negatively with audiovisual integration of social stimuli and influences speech perception. This relation has been obtained in participants on the autism spectrum only: Different stimuli were used in the temporal processing task and in the multisensory integration task, and significant results were consistently obtained. Stevenson et al. (2017) point out that the observed sensory integration abnormalities may also extend to the general sensory embodiment of the person on the autism spectrum. They interpreted the findings within both, established top-down (e.g., Weak Central Coherence Theory (Happé, 1994)) and bottom-up theories (e.g., Enhanced Perceptual Theory (Mottron & Burack, 2001)) of the perception of persons on the autism spectrum and concluded that both approaches obtain a cohesive understanding of the perception of speech in persons on the autism spectrum.

In persons on the autism spectrum, balance skills are correlated with receptive language skills. Hannant (2018) studied the relationship between sensorimotor skills and visual perception in relation to receptive language in 18 pupils on the autism spectrum and 18 pupils with typical development matched in age and verbal-IQ. Hannant (2018) observed a medium to large size effect of the correlation between receptive language and balance (sensorimotor skills) in participants on the autism spectrum ($r=.56$, $p=.008$). Moreover, visual perception and balance skills correlated only in participants on the autism spectrum, while in persons with typical development visual perception significantly correlated with receptive language ($r=.57$, $p=.007$).

Moseley & Pulvermüller (2017) analyze the hypothesis that Autism Spectrum Disorder be a disorder of movement and action perception integration within the enactivist framework. They argue that the documented differences of persons on the autism spectrum in sensori-motor characteristics at the brain and behavioral level could be the cause of differences observed elsewhere in higher cognitive processes, for example in working memory and semantic processing (Shebani & Pulvermüller, 2013). Moseley & Pulvermüller employ the term *action perception circuits* to refer to physiological brain processes represented by the activation of both motor and sensory areas during language processing. For example, Moseley & Pulvermüller state from the literature that babbling is a basis of language development and implies the activation of both, frontal motor areas and posterior auditory neurons (cf. Garagnani, Wennekers, & Pulvermüller (2008), cited in Moseley & Pulvermüller (2017)). Following the concept of Hebbian connections as described in Palm, Knoblauch, Hauser, & Schüz (2014), concurrent activation of motor and sensory neurons is taken to evoke correlated activity: based on this, Moseley & Pulvermüller hypothesize that concurrent activation should strengthen connections between sensorial and motor areas. The authors further hypothesize that if sensori-motor brain systems and their connections to other regions were impaired (e.g., language), then persons on the autism spectrum may present problems with semantic processing involving motor systems. Moseley & Pulvermüller present evidence for such reduced activity in motor systems and behavioral deficits of persons on the autism spectrum when processing action words (e.g., Moseley et al. (2013)) and argue such hypo-activation of the motor system to be the cause of behavioral limitations when processing action words. In conclusion, Moseley & Pulvermüller propose Autism Spectrum Disorder to be treated as a movement and action-perception integration disorder.

To summarize, the way persons on the autism spectrum act in the world (i.e., motor stereotypy) may be an indicator of lower behavioral motor complexity, caused by atypical sensorimotor integration. The way persons on the autism spectrum perceive speech correlates with their balance skills and is influenced by their atypical integration of multi-modal stimuli. In persons on the autism spectrum, processing of action words comes with a hypo-activation of the motor brain regions, which translates into movement impairment.

9.2 Nature of the Link between Sensorial Processes and Social Interaction

In previous section, I reported evidence for the link between sensorial processes, sensorial integration and high-level processes. I now discuss the nature of this link with a focus on social interaction processes: The resulting picture is that researchers have proposed multiple hypotheses about how sensorial processes and social processes are connected.

Thye, Bednarz, Herringshaw, Sartin, & Kana (2017) report persons on the autism spectrum to present difficulties perceiving specific visual characteristics of the stimuli (i.e., complexity, frequency, fast- moving) that are specific to the dynamic and fast-paced flow of social interaction (see also Perreault et al. (2015) in Section 8.2 Perception Abilities of Persons on the Autism Spectrum). For example, difficulties of children on the autism spectrum to perceive visual cues (Wass et al. (2015) in Thye et al. (2017); see also my review in Section 8.2 Perception Abilities of Persons on the Autism Spectrum) can impede joint and eye gaze performance and face perception in social interaction by affecting perception of visual cues that are associated with social reward, “making the cause and effect of social interactions unpredictable” (Thye et al., 2017, p. 3).

Thye et al. (2017) further suggest that while other sensorial processes themselves may not be impaired in persons on the autism spectrum (e.g., biological motion perception, auditory perception), there may be issues with how the information coming from these sensorial sources is integrated in highly complex social contexts. In turn, integration of multimodal sensorial information can have a cascading effect on the social development. Thye et al. cite studies (e.g., Brandwein et al. (2015) and Collignon et al. (2013))

reporting difficulties of persons on the autism spectrum with processing visual information accompanied by auditory information. This aspect is crucial in social contexts, where persons talk and use mimic and gestures to convey meaning. Such difficulty can impact language processing and emotional recognition. Biological motion perception by persons on the autism spectrum remains itself a controversial subject. Even so, against mixed findings, Bolis & Schilbach (2017) favor recent evidence that while persons on the autism spectrum present intact biological motion perception given the right motivation (Cusack, Williams, & Neri, 2015), they do also present difficulties with interpersonal action perception in tasks that additionally includes auditory cues from the communication between two agents (Von Der Lühe et al., 2016).

Another hypothesis is that persons on the autism spectrum do not only present difficulties with processing basic social information, but also with processing social information in a manner that generates the expected social responses (Bolis & Schilbach, 2017). Persons with high-autistic traits are not simply taken to be "blind" to social information, but are assumed to update their beliefs that influence decision making to a lesser extent than persons with low-autistic traits (Sevgi, Diaconescu, Tittgemeyer, & Schilbach, 2016). Bolis & Schilbach (2017) thus conclude that the actual difficulty of persons on the autism spectrum might lie within the "propensity" to use the social information when generating social actions.

The overarching provisional consensus thus regards the relevance of the bidirectional connection of sensorial and social processes: Bolis & Schilbach (2017) state that "it may be the coupling and the inextricable interplay of sensory and motor functions (within an individual) rather than selective deficits thereof – and whether or not a given partner in a social interaction is more or less similar to the autistic person (at the interpersonal level), which play an important role in the development and manifestation of cardinal characteristics of autism" (ibid, p. 3). Thye et al. (2017) concur, even though the level of evidence remains low (dated evidence, correlational studies). They argue in favor of persons on the autism spectrum to present an atypical hierarchical processing style in social contexts, characterized by reduced employment of top-down processes and excessive employment of bottom-up sensorial processes. For example, persons on the autism spectrum would appear to present oversensitivity to auditory stimuli because of difficulties in filtering out background noises, and difficulty in processing only auditory speech in social contexts. Another tentative example of reduced employment of top-down processes would be difficulties in extracting and evaluating emotional cues from speech prosody, which could limit the ability to understand the intention of the social partner by missing out on socio-emotional cues of the conversation. The atypical way persons on the autism spectrum make sense of their social interactions may thus be related to difficulties at: the low level (i.e., atypical processing of visual characteristics of social stimuli); the level of how multiple low-level stimuli are integrated (i.e., auditory stimuli accompanied by visual stimuli are not integrated properly), or the high level (i.e., atypical integration of social stimuli, which generates atypical social responses).

9.3 Nature of the Link between Motor Processes and Social Interaction

In this section, I research the nature of the relation between motor and social processes in persons on the autism spectrum.

Casartelli, Molteni, & Ronconi (2016) support the ideas behind the concept of *motor cognition* and apply the concept to the study of Autism Spectrum Disorder. The concept is grounded in neuro-scientific studies (e.g., Casartelli & Chiamulera (2015)) that link specific cortical motor systems not only to kinematics of human movement, but also to social cognitive processes. Two phenomena have been proposed to explain motor cognition: *motor resonance* and *motor interference*. Motor resonance holds that humans and animals understand both observed and executed action by accessing the same internal motor representations. By this Casartelli et al. explain, humans are held to be able to *directly and bodily* understand "the mind" of others. Casartelli et al. take motor resonance to be impaired in Autism Spectrum Disorder. They cite evidence (e.g., Cattaneo et al. (2007)) for persons on the autism spectrum having difficulties understanding the goal of another person's actions while observing them (i.e., without accessing information on the context and/or function of the object). Motor inference refers to the influence the observation of another person's action has on the concomitant congruent or incongruent executed action (Stanley, Gowen, & Miall, 2007). It is hypothesized that persons on the autism spectrum are insensitive to the interference effect, neither with human nor robotic or virtual agents (Cook, Swapp, Pan, Bianchi-Berthouze, & Blakemore, 2014). Moreover, Casartelli et al. (2016) conclude from earlier studies (e.g., Pierno, Mari, Glover, Georgiou, & Castiello (2006)) that the *facilitation effect*—kinematics of an action being influenced by the observation of an action or a gaze at the target, taken as evidence for motor cognition processes—is also impaired in persons on the autism spectrum. To provide an explanation for the observed conspicuous behavior , Casartelli et al. (2016) hypothesize that either persons on the autism spectrum extract, encode, and translate typical social cues into "internal motor representations" in an atypical way, or that persons on the autism spectrum are altogether not influenced by typical social cues. They report these hypotheses requiring further consistent study. With regard to the influence of social cues during a task, Amaral et al. (2017) report that persons on the autism spectrum present different dynamics in hysteresis in social tasks *only*, i.e., in the presence of an experimenter during the task.

Researchers conclude specific brain regions to be involved in both motor and social processes of persons on the autism spectrum: One perspective is that motor systems are involved in both social processes and in motricity and that structural differences of the motor systems impact social cognition. Another perspective is that the role of the mentalizing system (i.e., a brain region that corresponds to both, motor processes and social cognition) is to differentiate between self and other during social interaction.

9.4 Personal Analysis and Conclusions

The way persons on the autism spectrum make sense of the environment is inherently relevant for themselves. This manner describes what aspects from the environment are important for persons on the autism spectrum, which might impede typical interaction with the environment. Given this, these processes should not be immediately targeted for change by interventionists, but first understood and if possibly replaced with an appropriate behavior for the social context.

The aims of my investigation in this chapter was to identify evidence for a different kind of sense-making of persons on the autism spectrum and to evaluate the link between low-level processes representative of the ‘autistic’ embodiment and high-level processes representative of an ‘autistic’ sense-making. Theoretical and experimental evidence does suggest a link between maladaptive motor stereotypy and difficulties with sensory integration. Audiovisual integration and balance skills are also linked to receptive skills. In this regard, not all studies identify bottom-up influences. Whether it is a matter of top-down or bottom-up influence is difficult to research, as processes are interconnected and their performance depends on each other.

With regard to the link between sensorial processes and social interaction, the hypotheses I covered are that low-level processes (i.e., audio-visual cues) influence high-level processes (i.e., social understanding), that the distinguishing difference of persons on the autistic spectrum lies in the mode of integration of low-level processes, and that there is a reduced employment of top-down processes.

With regard to the link between motor processes and social interaction, the behavioral and neuroscientific evidence in support of the theory of motor cognition (Casartelli et al., 2016) is insufficient and dated, and the connection between the motor and social characteristics (i.e., whether it is a bidirectional influence, or only social cues influencing motor performance) as well as the differences between motor resonance and motor interference remain unclear: For example, the motor interference paradigm holds that the social cue influence motor performance, but it is not explained why the same mechanism could not be present also in the motor resonance paradigm. While Bolis & Schilbach (2017) and Casartelli et al. (2016) both conclude that persons on the autism spectrum might process social information in atypical ways, they disagree on the underlying mechanisms. The argumentative starting points also differ: Casartelli et al. set out from the idea that the cortical motor systems can play a role for both action kinematics and social processes (Casartelli & Chiamulera, 2015), and anomalies in the motor system may impact social cognition in persons on the autism spectrum (Gallese, Rochat, & Berchio, 2013). Bolis & Schilbach (2017) conclude from a fMRI study that both motor regions and regions that cover social cognition (i.e., the mentalizing system) get activated when observing other persons in a social interaction. The motor area might generate a mental representation of the action and the person might mimic the behavior, but it is the activation of the mentalizing system that is taken to differentiate between self and other.

A next step would be to research the association between low-level processes and specific social contexts: as Thye et al. (2017) suppose, impairments may occur at different levels (sensorial, perceptual, attentional) for different social contexts.

10 Social Coordination and Synchronization of Persons on the Autism Spectrum

So far, evidence points to differences of the motor and visual perception characteristics between persons on the autism spectrum and persons with typical development. However, the nature of these differences is not consensual across the literature. There appears to be a link between low-level processes and high-level processes of social interaction and communication of persons on the autism spectrum, but this link is supported by weak evidence (see Chapter 8 'Autistic' Embodiment and Chapter 9 From Embodiment to Sense-Making). Moreover, I observed in the literature (e.g., Bolis & Schilbach (2017) and Casartelli et al. (2016)) the directionality and nature of this link is not definite. De Jaegher (2006) hypothesizes that "people with autism have difficulty with connecting, and more specifically with participatory sense-making. This implies that they have trouble with interaction and coordination and that the underlying rhythmic capacity of their interactions is hampered" (De Jaegher, 2006, p. 169).

To investigate social interaction and coordination as described by De Jaegher, I cover in this chapter characteristics of the social interaction and coordination of persons on the autism spectrum and the link with embodiment and sense-making. I searched for theoretical and comparative studies (PhD theses, Master theses, meta-analyses, reviews, books, articles etc.) no older than 3 years (2015-2018) on the Google Scholar, PubMed, and Scopus research platforms. Most covered publications investigated coordination of persons on the autism spectrum with an object or another person. The resulting picture is that it appears that not all participants on the autism spectrum present difficulties in all areas of coordination and social interaction: Some results do not point to a correlation between coordination and social skills in persons on the autism spectrum; other results indicate that difficulties in coordination of persons on the autism spectrum may be related to reduced social flexibility in the interaction.

According to the principle of coupling as explained by De Jaegher (2006), the dynamics of one system are affected by the states of the other system; I assume person-person coordination, person-person coordination mediated by an object, and person-object coordination to represent different dynamics of different types of interacting systems that should be investigated and reported separately. Because of this aspect, I structured the following sections according to the type of coordination the participants on the autism spectrum engage in. The inclusion of evidence discussing coordination with an object is related to the hypothesis of De Jaegher (2006) that there is a bidirectional influence between motor coordination with another person and social interaction. Atypical motor coordination with an object might influence the dynamics of the coordination with another person, and this influence might manifest different for persons on the autism spectrum compared to persons with typical development.

10.1 Face-to-face Coordination

In this section I cover three studies of face-to-face coordination between a person on the autism spectrum and a person with typical development during social interaction. The resulting picture is that it appears that participants on the autism spectrum present difficulties with synchronization (defined as simultaneous execution of actions) and typical coordination with another person (defined as whole-bodily coordination).

10.1.1 Importance of Studies

Kaur et al. (2018) aim to advance the understanding about the impairments of social synchrony in persons on the autism spectrum by applying a set of comprehensive measures to study the phenomenon. Fitzpatrick et al. (2017a) aim to evaluate the importance of social motor synchronization to understanding the differences of the social interaction characteristics of persons on the autism spectrum. Romero et al. (2018) aim to resolve the issue of contradicting evidence by researching subtle nonverbal communication involved in social interaction of persons on the autism spectrum.

10.1.2 Personal Analysis: Similarities and Differences between Studies

The researchers use different terminology to refer to components of social interaction and social coordination, and the approach taken by Romero et al. (2018) differs markedly from those of Kaur et al. (2018) and Fitzpatrick et al. (2017a). Kaur et al. (2018) measured *bilateral motor coordination* on the Bilateral Motor Coordination Subtest of the Sensory Integration and Praxis Test (SIPT-BMC), where children imitate actions executed by the clinician. Rhythmicity, mirroring, and overflow errors of the movements were analyzed. The same authors also measured *interpersonal synchrony*. It can only be hypothesized from the procedure of the experiment and from the documented work by Kaur et al. of Fitzpatrick et al. (2017b) that interpersonal synchronization between persons is evaluated in Kaur et al. (2018) as simultaneous execution of bodily actions. In contrast, Fitzpatrick et al. (2017a) employed a motor control drumming task, language and cognitive battery tests, and three social motor tasks: Two social motor coordination tasks involved coordination of objects, faces, and bodies: *synchrony* (the movements were to be performed at the same time as another person; measured according to the level of coherence) and *imitation* (the movements were to be imitative of the demonstration); the third was an *interpersonal hand-clapping* task (an interactive two-person movement game in a setting closer to real social interaction). In addition, Romero et al. (2018) measured *social cognition competence* as scores of 4 ToM tests and *social motor coordination* by analyzing the whole-bodily interaction of the clinician and the study participant while communicating. The mean scores from three verbal and one non-verbal ToM tasks were summed and used as the ToM score (mean=3.316, standard deviation=0.938, range=0.667-4). Whole-body interaction is analyzed as the degree of social motor coordination (e.g., coherence between gestures, turn-taking) and variability of movements. Romero et al. (2018) define social interaction as a dynamical, complex interaction that includes implicit and explicit characteristics, but the authors do not expand on the terminological difference between explicit and implicit social characteristics. Romero et al. used time-series analysis to evaluate whole-body movement, and social attention is measured in a joint attention task.

Fitzpatrick et al. (2017a) observed past evidence reports several factors as key elements of a successful social interaction and development such as, coordination of bodies observed in turn-taking and joint action, synchronization, imitation, and motor skills. While Kaur et al. (2018) and Fitzpatrick et al. (2017a) argued for *social motor coordination* and *interpersonal motor coordination* abilities as indicators of successful social interaction, Romero et al. (2018) investigated the exact nature of the link between coordination and social interaction to assess whether these processes reflect underlying mechanisms or whether disruption in one process leads to disruption in the other. To be more exact, Romero et al. (2018) assessed whether *social cognition* measured with Theory of Mind (ToM) tasks is embodied (i.e., whether the ability to interact—social cognition—correlates with coordination—whole-body movements—observed during social interaction between a high-functioning child on the autism spectrum and a clinician).

Bilateral motor coordination and *interpersonal synchrony* variables in Kaur et al. (2018) are defined similarly, but measured differently from the *imitation* and *synchronization* variables in Fitzpatrick et al. (2017a). Kaur et al. measure interpersonal synchrony as the percentage of time the child synchronizes their movement with the clinician; Fitzpatrick et al. measure synchronization as the level of coherence between movements. The imitation variable of bilateral motor coordination is measured by Kaur et al. as the percentage of errors in the movements of the child, while Fitzpatrick et al. measured *imitation* as the level of coherence of the movements between social partners. Fitzpatrick et al. and Romero et al. (2018) similarly measured *interpersonal motor coordination* and *social motor coordination* as the levels of coherence between movements in a face-to-face interaction between the participant and the clinician.

Fitzpatrick et al. (2017a) and Kaur et al. (2018) analyze the interaction only from the perspective of the child on the autism spectrum, while Romero et al. (2018) investigate the relationship from both sides (i.e., the side of the child and the side of the synchronization expert). To the study of Fitzpatrick et al. participated 45 children on the autism spectrum (39 males; 6 females) diagnosed according to DSM- IV- TR (confirmed by ADOS-2) and 53 children typically developed (40 male, 13 female). The reported mean age of participants on the autism spectrum is 8.65 years old (range 6-10 years old) and the reported mean age of participants with typical development is 8.3 years old (range 6-10 years old). The applied sampling method was convenience sampling. The sample of Romero et al. included 28 high-functioning children on the autism spectrum, diagnosed according to DSM-IV-TR (confirmed by ADOS- 2). The reported mean age of participants is 8.55 years old (standard deviation is 1.35 years). The applied sampling method was convenience sampling. The study of Kaur et al. (2018) included 12 participants diagnosed with high-functioning autism (12 males; mean age 7.44 years +/- 0.57), 12 participants diagnosed with low-functioning autism (2 females, 10 males; mean age 8.74 years +/- 0.59), and 12 matched participants with typical development (3 females, 9 males; mean age 7.75 years +/- 0.55). The diagnosis of participants on the autism spectrum was given by a clinical psychologist; there is no mentioning of the diagnosis criteria applied. The sample was randomly selected.

10.1.3 Results and Interpretation of Results

The results of Kaur et al. (2018) show that both LASD (low IQ) and HASD (high IQ) children spent less time in synchrony with their adult partner compared to controls. The authors suggest that the perception- action coupling impairments of persons on the autism spectrum—according to (Whyatt & Craig, 2013), such impairments influence spatio-temporal aspects of movement control and social communication and cognitive skills—could account for the poor social synchrony of participants on the autism spectrum. As reported also in Section 8.1 Motor Abilities of Persons on the Autism Spectrum, LASD members generally present higher error rates in rhythmicity, mirroring, overflow, as well as larger total errors, as well as slower movement rates for most imitated actions compared to the TD group. The HASD group presented higher overflow errors and slower movement rates for solo complex clap and social simple and complex march actions compared to the TD group. It seems that participants on the autism spectrum with a low IQ were characterized by most mirroring and total errors and longest time to execute actions.

One of the hypotheses researched by Fitzpatrick et al. (2017a) is that participants on the autism spectrum demonstrate lower synchronization ability and more variable and less coordinated motor ability than participants with typical development: This hypothesis is confirmed. The authors observed that all study participants had lower coherence scores (index of poor movement synchrony) in the imitation than the synchrony task. This is attributed by the authors to the resources employed in the task: While imitation is taken to involve execution of actions from memory, synchronization is assumed to employ skills of sustained attention to the other person’s actions. According to this view, the observed difference of coherence scores between tasks could be due to difficulties related to the memory load required during imitation. Fitzpatrick et al. (2017a) stress the importance of the manner in which a movement is executed or the resources that are employed in imitation and synchronization: Participants on the autism spectrum obtained different coherence scores than persons with typical development, with a larger difference in the synchrony battery than the imitation battery. This is taken to be related to the increased ecological validity of the synchrony battery, which requires more real-life like social monitoring. Moreover, in the interpersonal hand-clapping task, the participants on the autism spectrum obtained lower coherence scores (index of poor movement synchrony) than the controls. Fitzpatrick et al. report social synchrony to have been most coherent in interpersonal hand clapping, moderate in synchrony task, and lowest in the imitation task. Given that participants on the autism spectrum showed most coherence in the task with highest ecological validity, the authors argue that the obtained results could be due to increased familiarity with the pat-a-cake game played during the social interaction task, and to the participants on the autism spectrum having a preference for sameness. Moreover, during the interpersonal hand-clapping task, the experimenter may have compensated for the difficulties in interaction of the participant on the autism spectrum. In single-handed drumming, participants on the autism spectrum had higher movement period and higher movement variability; but amplitude was not significantly different. In bimanual drumming, they had lower coherence of the movements. Drumming movements of participants on the autism spectrum were slower and more variable in terms of spacing and timing than for persons with typical development. The study authors report that the movement measures rely on rhythmic timing of movements. Moreover, coherence of movement was lower for anti-phase than for in-phase movement.

Second, Fitzpatrick et al. (2017a) hypothesized a relationship between synchronization ability and motor ability, but only interpersonal hand clapping correlated negatively with single-handed drumming period, period SD and amplitude SD, and correlated positively with in-phase drumming coherence. The relationship between motor and social characteristics thus is not straightforward. The study authors explain the observed correlation as pertaining to the rhythmic nature of both processes that unfold in time and space. Given this aspect, motor and social processes may have similar underlying mechanisms. In comparison to the other social tasks, the interpersonal task incorporates a higher degree of rhythmic movements and movement initiation. There could be different patterns of movements executed during imitation, synchrony, and interpersonal clapping, but motor coordination measure could also be unique to the interpersonal social context because of the timing characteristic of each process. Fitzpatrick et al. conclude that children on the autism spectrum present difficulties synchronizing in a social context and urge future research on the relationship between the level of impairment in synchronizing and impairments in social skills.

Romero et al. (2018) stress that future studies should differentiate whether persons on the autism spectrum *can* interact and the *manner* in which they do. This aspect is also discussed and encouraged by Fitzpatrick et al. (2017a). It is noteworthy that researchers investigate whether social cognition—evaluated as ToM scores—is embodied.

Romero et al. (2018) measured general social interaction competence as scores to 4 ToM tests. They report from the literature that the abilities of persons on the autism spectrum to attribute mental states to others are impaired, even though some participants managed to pass ToM tests. Previous literature reported by the authors (e.g., Tager-Flusberg (2007)) states that ToM does not explain the full symptomatology of persons on the autism spectrum, that lower scores on ToM tests are not unique for them and are not observed in all persons on the autism spectrum, but the authors still chose to apply ToM tests in their task to study social cognition participants on the autism spectrum. They hypothesized an association to exist between the dynamic motor movement measures (ADOS) and the traditional measures to evaluate impairment in Autism Spectrum Disorder (ToM).

The results of Romero et al. (2018) indicate that children on the autism spectrum coordinate their bodily movements with a clinician better than randomly expected. This coordination was mutual (i.e., there was neither lagging nor leading of the interaction from the side of the child). The participants on the autism spectrum presented healthy levels of motion variability, which is contrary to past evidence (e.g., Fitzpatrick, Diorio, Richardson, & Schmidt (2013)) reporting higher levels of movement variability. The complexity of their movements matched the one of the clinician. The study authors argue that future research should also investigate whether the clinician controls or compensates for some of the impairments of the child during social interaction; the present results indicate that the interaction with the clinician was coordinated, mutual, normally variable, and complex.

The dynamical structure of bodily movements and the whole-body interaction between the child and the clinician correlated with scores on the ADOS-2 restricted and repetitive behavior (RRB) subscale (the more deterministic the child's movement variability, the higher the RBB score). Additionally, higher coherence of movements between the child and the clinician was associated with lower RBB scores.

Principal component analysis identified a relationship between bodily movement measures, joint attention, and ToM scores. The first component showed a relationship between RRB, ToM, child DFA (detrended fluctuation analysis: a scaling of different time-scales of movement) and coherence of movements between the child and the clinician. The study authors were especially interested in the subscale of *insistence on sameness* because it is seen in the literature as a response to a lack of order in the environment or as the need of imposing order (Cuccaro et al., 2003). The increase in the RRB measures are associated with an increase in the child's DFA measures, which is taken to correspond to an increase in control (Van Orden, Kloos, & Wallot, 2011) and a decrease in synchronization ability with the clinician. These results are translated to the need of the child on the autism spectrum to maintain control in the interaction regarding both, verbal and non-verbal aspects of the interaction. The correlation of ToM scores with scores on ADOS in this factor (r=.41 at .5 s coherence) validate previous results (i.e., Fitzpatrick et al. (2013)) that associate increased levels in the synchronization task to the ability to impute beliefs to other people. For Romero et al. (2018), these results do indicate that higher social cognition is to a certain extent embodied. Also based on previous evidence, the authors suggest that children on the autism spectrum might present difficulties in coordinating with another person as a consequence of their lack of flexibility, which negatively influences social rapport (Miles, Nind, & Macrae, 2009) and has further negative consequences for the ToM deficit (Baron-Cohen et al., 1985; Roelofs, Wingbermühle, Egger, & Kessels, 2017). In the second factor of the analysis, ToM and social attention scores load with the social affect on the ADOS-2 subscale: this is taken to explain the low capacity of children on the autism spectrum to sustain a communication high on informational content. As reported by Romero et al. (2018), the limitations of their study are the lack of a control group and the possible compensation for the observed social difficulties of the participant on the autism spectrum by the clinician. Even so, this study is important because it encourages to consider a dynamical perspective on social interaction. The authors obtained healthy levels of interaction variability, which is contrary to what most other studies have observed so far.

10.1.4 Personal Analysis and Conclusions

The presented studies contribute relevant information to the status of the literature and inform future studies. To summarize, participants on the autism spectrum appear to be less engaged with and present lower coherence scores than their partner with whom it is assumed they are in synchrony. Participants on the autism spectrum with low IQ score present most errors when imitating the behaviors of another person. The coordination between a person on the autism spectrum and an adult with typical development presents typical levels of variability and complexity, but the level of flexibility—measured as the score on the Repetitive Behaviors Subscale—is predictive of the successful interaction. There is evidence pointing to a link between the 'autistic' embodiment and social interaction characteristics and between the sense-making of persons on the autism spectrum and the way they socially interact: There is a correlation between drumming motor skills—a particular impairment of persons on the autism spectrum—and social coordination and between social coordination and social cognition abilities.

One limitation across studies I observed is that the studies I surveyed did not measure or define concepts similarly, which makes reporting the result in a coherent manner difficult. Turning to limitations of the individual studies, although Kaur et al. (2018) provide the interpretation that low quality of synchrony in participants on the autism spectrum is accounted by their perception-action coupling impairments, they do not provide further information about how exactly impaired perception-action coupling in participants on the autism spectrum could account for the observed reduced duration of social synchrony. Also, the authors fail to report baseline results for the coordination of actions of participants on the autism spectrum to a metronome beat. A key aspect of the study of Fitzpatrick et al. (2017a) is that the authors draw attention to the importance of *how* movements unfold at the right time to support social interaction. A related important finding is that there might be different *types* of movement patterns employed in different social activities. This aspect can orient future work to investigate associations between types of movement and synchronization types. Romero et al. (2018) argue that a correlation between ToM test scores and dynamical movements analysis results would clarify whether the two perspectives share underlying sub-processes or whether the level of social interaction is related to the level of social cognition abilities, but they do not provide any philosophical account for how and why such interpretation of the correlation would form a sound research analysis, given that ToM and embodiment are differently rooted philosophical perspectives. Romero et al. likewise do not explain how the selected methodology and analysis is meant to match the set research aims and hypotheses. The absence of a control group in Romero et al. (2018) makes it impossible to draw conclusions between persons on the autism spectrum movement variability and persons with typical development movement variability. While the obtained results (i.e., that social cognition is embodied) could have significant implications for future research and for the general understanding of cognition, the authors do not themselves comment on this aspect, nor on the philosophical and methodological background of their analysis.

It is important that future studies investigate also the side of the partner with typical development in the interaction, and how they attend to the person on the autism spectrum, because it has been recognized that adults with typical development might compensate for the interactional difficulties of children on the autism spectrum: future studies should analyze the degree and the type of influence the clinician might have on the interaction with the child on the autism spectrum.

10.2 Face-to-face Coordination Mediated by an Object

This section covers face-to-face coordination between a person on the autism spectrum, a person with typical development, and an object during social interaction. The resulting picture is that it seems that in such settings, participants on the autism spectrum generally coordinate and jointly synchronize with another person successfully, but some characteristics of these processes are atypical.

10.2.1 Importance of Studies

The research aim of Brezis et al. (2017) is to address limitations of previous studies investigating social interaction in participants on the autism spectrum that focus on the content of the interaction and use observational methods of investigation. To this end, the study pays more attention to the timing of the interaction and to breakdowns of the communication; also, it uses the mirror paradigm, which is seen to have a higher ecological validity. Brezis et al. (2017) investigate the relations between *motor skills*, *social skills*, and *synchronization* in object-mediated interactions between an adult on the autism spectrum and an expert social agent or an object, in comparison to those with a person with typical development. In contrast, the work of Curioni, Minio-Paluello, Sacheli, Candidi, & Aglioti (2017) builds on previous literature that reports a connection between impaired synchronization abilities in persons on the autism spectrum and their social skills. The authors aim to investigate the influence of the levels of autistic traits on the possible roles during synchronization (i.e., Leader or Follower) and to provide supplementary evidence for the connection between synchronization roles and synchronization success.

10.2.2 Personal Analysis: Similarities and Differences between Studies

There are some important methodological and theoretical differences between Brezis et al. (2017) and Curioni et al. (2017) in their task to investigate social interaction and coordination in persons on the autism spectrum with another person, which is mediated by an object.

To the study of Brezis et al. (2017) participated 34 high-functioning participants on the autism spectrum (31 male, 3 female; mean age 2.3 years, range 1.6-3.75 years) and 35 participants with typical development (28 male, 7 female; mean age 2.15 years, range 1.58-3.75 years). The diagnosis of participants on the autism spectrum was confirmed by following the diagnosis criteria of ADOS. The selection procedure of participants was convenience sampling. In the study of Curioni et al. (2017), 16 pairs of same sex, adult participants (1 person on the autism spectrum and 1 person with typical development) participated to both social and non-social tasks. The mean age of participants on the autism spectrum was 26.1 years (range 18-42 years) and the mean age of participants with typical development was 29.6 years (17-49 years). 9 pairs knew each other previous to the experiment, the remaining 7 were given 1h to familiarize with each other. All participants with typical development knew the diagnosis of their social partner. The selection procedure of participants was convenience sampling.

Brezis et al. (2017) take a bottom-up approach by taking into consideration that impairments in sensory-motor coordination, such as imitation, might be key disabilities of persons on the autism spectrum that impact social connectedness. On the other side, Curioni et al. (2017) take into consideration both bottom-up and top-down influences to assess the relationship between social interaction and coordination. They look at both predictive and sensori-motor monitoring processes as well as higher order social functions to be pylons of social interaction. The bottom-up perspective on interpersonal coordination consists of prediction, imitation or complementing of the partner's movements (Sebanz, Bekkering, & Knoblich, 2006) and modulating one's own movements to signal intentions (Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016).

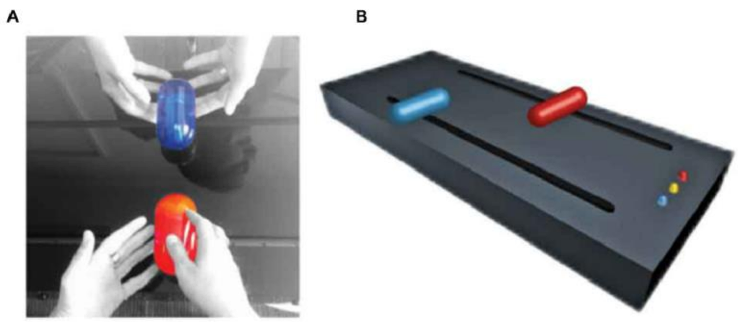

Figure 5 - The Mirror Game. A) Participants are instructed to hold each one handle and to create parallel movement by taking turns leading, following, or jointly improvising, B) The Mirror Game Console with its parallel tracks and handles. Reproduced from "Patterns of Joint Improvisation in Adults with Autism Spectrum Disorder ", by Brezis et al, 2017, Front. Psychol, 8: p. 3, Fig. A and B. Copyright by CC BY.

Brezis et al. (2017) organized two experiments: The Mirror Game (MG) between two persons and between a person and a dot on the screen. MG is a collaborative game designed to support joint movements between participants. *Joint Improvisation (JI)* was investigated in the MG between two persons (see Figure 5). All participants played against an expert improviser with significant experience in contact improvisation and in working with persons on the autism spectrum. Players sit across at a table holding handles that could be moved along parallel tracks. The game comprised of three rounds: Leading, Following, and JI. In the Leading round, the participant lead the movement, in the Following round, the participant followed the movement of the partner, and in the JI round, the participant was assumed to jointly move with their partner. After each session, all participants provided a rating for the easiest and hardest round and answered an open question about their experience of the game, followed by a game questionnaire inquiring about their affective experience and their subjective view of their partner's responsivity. *Motor abilities* of participants were evaluated according to two motor questionnaires and an imitation battery based on Fitzpatrick et al. (2013), in which participants were asked to imitate five sequences of three motions performed by the experimenter: with or without an object, on their body, or in space.

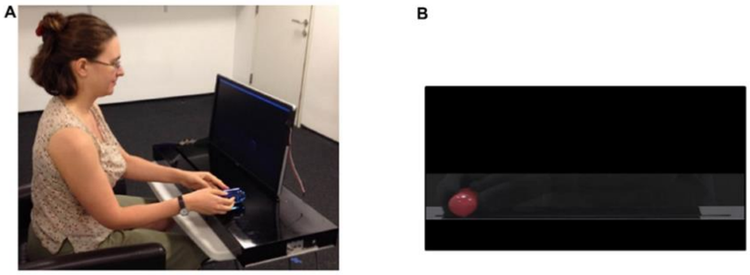

Figure 6 - The Motor Task of the Mirror Game. A) The participant sits in front of the mirror game console and a screen fitted to the size of the track, B) a moving or static handle was displayed on the screen, and the participant was instructed to follow it. Reproduced from "Patterns of Joint Improvisation in Adults with Autism Spectrum Disorder "by Brezis et al., 2017, Front. Psychol, 8: p. 6, Fig. A and B. Copyright by CC BY.

Motor skills were also tested in a battery of specially designed motor tasks (see Figure 6). The motor tasks tested the ability of participants to move their handle according to the position of the red dot on a screen and their maximum velocity while moving the handle of the console. Participants held a handle of the console and faced a screen fitting the second track. On the screen it was displayed pre-recorded positions and movements of the dot representative of the red handle. *Social skills* were evaluated according to questionnaires testing empathic tendency, emotional recognition, and ability to recognize one's own emotions. Following MG, all participants completed a Naturalistic Conversation task, during which participants engaged in a casual conversation with the experimenter. The conversation was video recorded, and the number of looks, headshakes/nods and smiles, and affective engagement and flow were annotated.

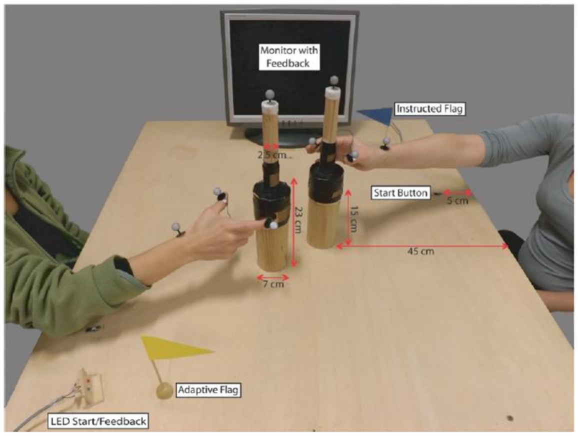

Figure 7 - Setup of the Social Interactive Task: in this picture, participants perform an opposite trial, meaning that the participant on the right will grasp the upper part of the bottle-shaped object via a precision grip, while the participant on the left will grasp the lower part of the bottle-shaped object with a power grip. Reprinted from "Autistic traits affect interpersonal motor coordination by modulating strategic use of role-based behavior" by Curioni et al., 2017, Molecular Autism, 8, p. 3, Fig. 6. CC 4.0 International License.

The study of Curioni et al. (2017) included a social interactive task and a non-social interactive task. The non-social task is described in Subsection 10.3.2 Personal Analysis: Differences and Similarities between Studies**.** The purpose of the social interactive task was to test individual motor behavior and pair coordination. Participants were asked to grasp a bottle-shaped object as synchronously as possible with their partner (see Figure 7). Participants were either told where to grasp the bottle (*instructed condition*) or required to on-line adapt to their partner's movements (*adaptive condition*). In half of the sessions, participants were asked to perform movements opposite to those of their partner. Participants sat at a table equipped with start buttons, go/feedback LEDs, bottle-shaped objects, and a monitor to provide task instructions and performance feedback. The bottom part of the object-shaped bottle was designed to be grabbed with a power grip and the top part of the bottle-shaped object was designed to be grasped with a precision grip (see Figure 7).

Synchronization in Brezis et al. (2017) was evaluated by calculating co-confident motion values (CC): the percentage of CC segments and CC duration (in sec). During CC, the players formed a coupled unit co-creating motion, rather than adhering to a Leader-Follower pattern (Noy, Dekel, & Alon, 2011) and displayed similar, jitter-less motion patterns (Brezis et al., 2017). In persons with typical development, CC correlates with increased heart rate and a subjective feeling of belongingness (Noy, Levit-Binun, &

Golland, 2015). Brezis et al. also calculated motion velocity and motor complexity of the motor coordination performance of the participant. *Motor skills* of participants were calculated as the scores in battery tests evaluating basic motor and coordination skills, motor planning and dyspraxia, and imitation. *Social skills* were calculated as the scores in battery tests. Brezis et al. correlated the social skills scores and the motor scores with the synchronization abilities in the MG to evaluate whether the ability to bodily coordinate correlates with social skills and motor skills. In Curioni et al. (2017), individual motor behavior was analyzed as reaction time and movement time, and pair coordination was analyzed as difference between movement times (i.e., grasping asynchrony) and between reaction times.

Both Curioni et al. (2017) and Brezis et al. (2017) believe synchronization to be an important factor in the quality of social interaction, and while it is measured differently, the shared understanding of the synchronization between two persons is one of action executed similarly at the same time. However, differently from Brezis et al. , Curioni et al. believe interpersonal coordination an established component of social interaction that already employs motor, cognitive, and social skills. This idea is also reflected in the methodology selected by Curioni et al. , who analyze coordination only and not also the relation to social skills, as Brezis et al. do.

10.2.3 Results and Interpretation of Results

Brezis et al. (2017) evaluated the level of motor skills in the mirror game for both participant groups. While motion complexity did not differ between groups, motion velocity did: participants on the autism spectrum were faster in the Leading round, and persons with typical development were faster in Following round. Likewise, motion complexity of the expert did not differ by group or by round, but motion velocity did: In the Leading round only, the synchronization expert was faster in her interaction with the persons with typical development than with the participants on the autism spectrum.

Brezis et al. (2017) hypothesized that participants on the autism spectrum would have lower or null CC rates and shorter duration of CC, and that participants on the autism spectrum would have less complex motion than persons with typical development. The first hypothesis is partially confirmed, the second hypothesis is rejected. Results indicate that for the participants on the autism spectrum the probability to attain CC was higher than chance, but this level was more attenuated in the Following condition. Participants on the autism spectrum did not differ from persons with typical development in their ability to attain CC during the JI round, which is considered the hardest to coordinate (Noy et al., 2011). Brezis et al. cautiously interpret this finding as possibly being due to a methodological issue: Participants might have not coordinated their actions jointly at all, but rather taken turns as Leader and Follower. This issue illustrates the difficulties in investigating social coordination, as persons may substitute one pattern

(Leader-Follower) for another (Joint Interaction). Even so, the reported findings align with the earlier results obtained by Noy et al. (2011). Persons with typical development had a significant increase in CC frequency in the Following round compared to Leading [$t(34) = 5.26, p < 0.001$] and Joint Interaction [$t(34) = 5.00, p < 0.001$] rounds, an effect not observed in participants on the autism spectrum. Brezis et al. interpret the finding as connected to increased difficulties of participants on the autism spectrum in the Following round, caused by imitation impairments (Edwards, 2014) and reduced synchronization (Fitzpatrick et al., 2016). The duration of the CC period was shorter in the case of the adults on the autism spectrum than adults with typical development across all rounds. For both groups, the probability of attaining CC increased with increasing motion velocity. The expert knew which of the participants were on the autism spectrum and moved more slowly when leading the interaction with them than with persons with typical development. Brezis et al. suggest it might have been this reduced velocity of movements imposed by the expert that could have led to the found lower percentage of attaining CC in participants on the autism spectrum. But even when controlling for velocity, participants on the autism spectrum had a lower probability of attaining CC than persons with typical development.

Brezis et al. (2017) found no difference in complexity of movement across the different groups. Participants on the autism spectrum did not show any repetitive behavior characteristics of their disorder. In contrast to the findings covered in Section 10.1 Face-to-face Coordination here participants on the autism spectrum were found capable of reaching CC with an expert in synchronization, but they could not maintain the same characteristics of synchronization as participants with typical development when following the movements of an expert: These differences cannot be completely explained in terms of differences in velocity of movement differences.

As third hypothesis, Brezis et al. (2017) assumed that the synchronization skills displayed during the MG by participants on the autism spectrum would correlate with their social skills. The hypothesis was rejected. Results indicate participants on the autism spectrum performed poorly on the social tasks. Moreover, the social skills of adult participants on the autism spectrum did not predict their ability to attain CC. Brezis et al. infer from this finding that synchronization and social interaction form two different domains, and even when participants on the autism spectrum should present characteristics of successful socio-motor synchronization, they might still have problems in social interaction. Other interpretations of the observed results identified by the study authors are that the sample size may be too small to support reliable detection of a correlation, or that the social tests that were applied were not sensitive enough. Alexithymia in study participants on the autistic spectrum did predict CC rates, but not in persons with typical development.

As already stated, the affective experience of participants in Brezis et al. (2017) was also evaluated. All participants rated the Following round most difficult, followed by Joint Interaction, and Leading. While a clear absolute majority (74%) of participants with typical development rated the Following round most difficult, only a relative majority (45%) of participants on the autism spectrum did likewise. Participants on the autism spectrum who perceived Following as most difficult reported difficulty in predicting the expert's motion pattern, difficulty in staying focused and responding fast and reported the expert's movement was too fast. Participants with typical development reported similarly for this condition. For the Joint Interaction round, some participants on the autism spectrum understood they had 'to let go' of control, but found this step difficult. Participants on the autism spectrum were less likely to want to continue the game when the experimenter was perceived as less responsive to their movements. Brezis et al. (2017) interpret this finding as a possible genuine difficulty of persons on the autism spectrum to perceive the other person's willingness to interact. Participants on the autism spectrum who perceived Leading as most difficult reported they had difficulty in creating motion or taking the lead. By contrast, participants with typical development found the Leading round easiest because of its high degree of control of self-movements. For participants on the autism spectrum, positive ratings of the game and the movements of the expert were correlated with greater CC frequency during Following and Joint Interaction rounds.

Curioni et al. (2017) hypothesized that depending on the assumed role and the level of autistic traits, participants would differently recruit prediction and adaptation strategies in order to facilitate coordination. The results of Curioni et al. indicate that during the social task, the higher the level of autistic traits of the participant, the less they waited for the partner's movement. In the Follower condition and in comparison to persons with typical development, participants on the autism spectrum did not wait for the Leader of the interaction to start moving. This result is interpreted as a faster reaction time of participants on the autism spectrum after having received the instructions, combined with a lack of need of information from the Leader partner.

Moreover, Curioni et al. (2017) observed that the higher the autistic traits, the less participants modulated their movement duration according to their role. In the Leader condition, participants took a longer period of time to perform movements than in the Follower condition, and this effect was observed more pronouncedly in participants with low level of autistic traits. Curioni et al. interpret this finding as a modulation of movement patterns according to role in order to ensure coordination and synchrony between participants. In the Leader role, participants with low autistic traits increased their movement duration to ease synchronization for their partner. In the Follower role, participants with low-autistic traits had shorter movement durations to keep up with their partner showing increased movement velocity.

Curioni et al. support the assumption of Vesper, Wel, Knoblich, & Sebanz (2011) who state the lack of adjustment of motor behaviors according to role during synchronization in participants with Asperger to be not due to difficulties in understanding the implications of the other's role, but rather due to a reduced ability in applying strategies to aid the other in their task.

10.2.4 Personal Analysis and Conclusions

The study of Brezis et al. (2017) is relevant for the scientific landscape because it provides evidence that while adults on the autism spectrum can synchronize their sensor-motor patterns with a synchronization expert, some characteristics in their synchronization patterns do differ from the ones of persons with typical development. The results suggest that motor skills do not completely predict percentage of CC, and synchronization skills measured as CC levels are not correlated with social skills. The work of Brezis et al. (2017) extends the focus to the possible influence of positive affect on the duration of CC and on the general ability to socialize. Moreover, this study reveals the importance and significance of carrying out interviews with participants on the autism spectrum after the task, as these can reveal additional reasons for specific observed events during the interaction the study does not measure. The interviews also document the personal experiences of participants on the autism spectrum and the differences from those of participants with typical development. The study contradicts previous evidence suggesting a link between movement skills and coordination skills or between movement skills and social skills.

The study by Curioni et al. (2017) is relevant for the research landscape because it modulates performance according to level of autistic traits and not diagnosis. Curioni et al. do not provide an explicit reason for putting the participants in the study on a continuum from low to high autistic traits. Given the observed differences in coordination between groups (i.e., that participants on the autism spectrum do not wait for the movements of the Leader-partner), and the obtained results in previous studies where persons with typical development presented no differences in coordination with another person with typical development between aligned and opposite rounds (Sacheli, Tidoni, Pavone, Aglioti, & Candidi, 2013), it can be concluded that the coordination between two persons with typical development differs from the interaction between a person with typical development and a person on the autism spectrum.

The covered studies indicate that motor coordination of persons on the autism spectrum presents normal complexity, but increased motion velocity. Contrary to expectations, participants on the autism spectrum succeeded to jointly synchronize in a social coordination, but some characteristics of the synchronization differ from the one of persons with typical development (e.g., shorter synchronization duration). What is interesting is that social skills of participants on the autism spectrum did not correlate with their ability to jointly synchronize.

Participants on the autism spectrum had most difficulties in the Follower Condition. Just as participants with typical development in the study of Brezis et al. (2017), participants on the autism spectrum also had a lower probability to attain CC in the Follower condition, but for participants with typical development only, the probability to attain CC increased in the Follower condition in comparison to other conditions. In Curioni et al. (2017), participants on the autism spectrum waited the least in the Follower condition for their partner's movement. Moreover, the synchronization expert led faster in interactions with persons with typical development than in persons on the autism spectrum. This finding illustrates extant methodological issues.

10.3 Coordination with an Object

I discuss the results of two studies: Kostrubiec, Huys, Jas, & Kruck (2018) and Curioni et al. (2017) that show an atypical coordination of persons on the autism spectrum with an object. The resulting picture is that it seems the ability of persons on the autism spectrum to coordinate with an object is influenced by the role fulfilled during coordination (i.e., Leader, Follower), by the type of phase (i.e., in-phase or anti- phase), and by the type of coordination (i.e., spontaneous or intentional).

10.3.1 Importance of Studies

Coordination deficits in persons on the autism spectrum have been reported for infants (Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998), children (Dawson & Galpert, 1990), and adolescents (De Marchena & Eigsti, 2010). Kostrubiec et al. (2018) pushes forward the status of the literature on the characteristics of social interaction and motor coordination in persons on the autism spectrum, by focusing on assumed essential characteristics of motor coordination such as efficacy and stability. The importance of the study of Curioni et al. (2017) was explained in Subsection 10.2.1 Importance of Studies.

10.3.2 Personal Analysis: Differences and Similarities between Studies

Kostrubiec et al. (2018) aim to verify the hypothesis that motor coordination is an important characteristic of social interaction. They take *coordination* to refer "to the concerted action of perceptual motor components—as for example limbs, eyes, head, or trunk—and underlie[s] the production of any bodily motion" (Kostrubiec et al., 2018, p. 210). To exemplify coordinated behavior, authors present the evidence of Teitelbaum et al. (1998) reporting coordination deficits in infants on the autism spectrum regarding the limbs, pelvis and shoulder griddle during the execution of primary motor patterns, such as rolling, crawling etc. and Dawson, Hill, Spencer, Galpert, & Watson (1991) reporting deficits in smiling and eye contact in infants on the autism spectrum.

Essential properties of coordination are *stability*—strongly interconnected components resist internal or external perturbations—and *accuracy*—not defined by the study authors, but I will explain in the below dedicated paragraph how it was analyzed. Coordination in healthy participants tends to follow two stable coordination patterns: *in-phase* (in synchrony) and *anti-phase* (in alternation). Anti-phase is documented to be less stable and accurate (Kelso, Scholz, & Schöner, 1986) and more attention-wise (Temprado, Zanone, Monno, & Laurent, 2001) than in-phase. Motor coordination is documented to increase mutual trust (Fischer, Callander, Reddish, & Bulbulia, 2013) and empathy (De Coster, Verschuere, Goubert, Tsakiris, & Brass, 2013) between participants. Based on this relation between coordination and social behavior, Kostrubiec et al. (2018) assumed a relation between social and perceptual-motor coordination deficits in Autism Spectrum Disorder.

In the study by Kostrubiec et al. (2018), 20 high-functioning children on the autism spectrum (18 males; mean age 10 years; diagnosis according to DSM-IV) and 21 participants with typical development (18 males; mean age 11) participated. The recruiting method of participants was convenience sampling. For information about the characteristics of the participants in Curioni et al. (2017), please see the Subsection 10.2.2 Personal Analysis: Similarities and Differences between Studies.

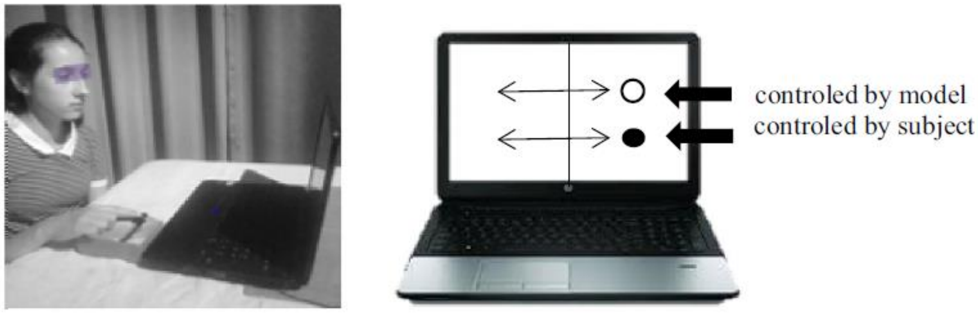

Figure 8 - Motor Coordination with a Dot Task. Left: the participant is instructed to follow horizontally the movements of a circle displayed on a laptop screen, Right: computer screen displaying the horizontal oscillations of the participant (black circle) and the model (white circle). Reproduced from "Age-dependent Relationship Between Socio-adaptability and Motor Coordination in High Functioning Children with Autism Spectrum Disorder" by Kostrubiec et al., 2018, J Autism Dev Disord, 48, p.214, Fig.2. Copyright 2017 by Springer Science+Business Media, LLC.

Kostrubiec et al. (2018) research *motor coordination with a dot* in persons on the autism spectrum in relation to their *socio-adaptive skills*. Kostrubiec et al. applied a coordination task to study motor coordination and questionnaires to study socio-adaptability, verbal capacity, reasoning capacity, and social interaction. In the coordination task (see Figure 8), participants had to horizontally and from left to right move a green circle by oscillating a slider with the index. Study authors organized four experimental conditions: *spontaneous oscillation* (the participant was instructed to move the green circle at his/her own pace), *spontaneous coordination* (a red circle was present above the green circle; the participant was instructed to oscillate the green circle), *0° intentional coordination/in-phase coordination* (the participant is instructed to keep the green circle below the red one), and *180° intentional coordination/anti-phase coordination* (the participant is instructed to do the opposite movement to the red dot).

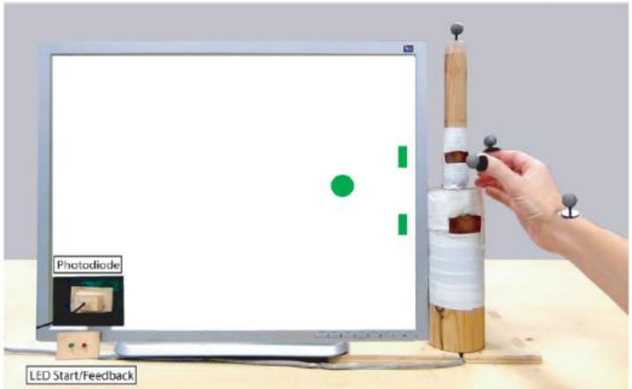

Figure 9 - Setup of the Non-Social Task. The picture displays a congruent trial in which the participant will grasp the upper part of the bottle-shaped object via a precision grip, and the dot will move towards and stop at the upper green target. Reproduced from "Autistic traits affect interpersonal motor coordination by modulating strategic use of role-based behavior" by Curioni et al., 2017, Molecular Autism, 8, p. 8, Fig 6. CC 4.0 International License.

The purpose of the non-social task in Curioni et al. (2017) was to test whether autistic traits modulate motor behavior and coordination abilities in all participants. The participants had to grasp the same bottle-shaped object as in the social task (for details about the methodological setup of the social task, please see Subsection 10.2.2 Personal Analysis: Similarities and Differences between Studies), but this time in synchrony with a dot that moved on a screen either to the upper or lower part of the bottle-shaped object (see Figure 9). Participants' grasping location was either spatially congruent (in-phase) or incongruent (anti-phase) with the dot's position on the screen. As in the social task, participants had one of two different roles: instructed or adaptive.

In Kostrubiec et al. (2018), motor coordination with a dot is measured according to the *relative phase* (RP), which is the difference between the phases of two oscillating structures in a system, where 0° is for in-phase and 180° for anti-phase. In this case, the RP value was calculated as the difference between the positions of the human-controlled and model-controlled circles (i.e., the red circle). The stability of the coordination pattern is indicated by the RP variance. RP variance inversely scales with coordination stability and was given by the circular variability index and transformed to SD. The pattern accuracy is measured according to the *absolute error* (AE), which is the difference between the required and produced RP. A high value of AE is equivalent to low accuracy and means the child participant lagged the stimulus. The complexity of RP fluctuations was given by the value of *Apen*. Apen is the logarithmic likelihood that 'similar' vectors of observations are not followed by additional 'similar' vectors in medium-sized, stationary time series. Apen can take a value as a natural number between 0 (full predictability) and 2 (unpredictability). In contrast, in Curioni et al. (2017), motor coordination with a dot was measured as values of accuracy (percentage of trials when participant grasped the bottle-shaped object in the correct location), grasping asynchrony (trial-by trial absolute time interval between participant's grasp time and dot's stop time reaction time), reaction time (interval between delivery time of auditory instructions and start button release time), and movement duration (interval between start button release time and grasp time).

10.3.3 Results and Interpretation of Results

Kostrubiec et al. (2018) predicted that participants on the autism spectrum would have less stable, less accurate, and less complex patterns of coordination. This hypothesis was falsified for spontaneous coordination tasks: The results indicate that scholars on the autism spectrum did not encounter difficulties to coordinate spontaneously with a dot. There were no differences in stability, complexity, and accuracy between scholars on the autism spectrum and controls. Both groups presented a smaller *variability of relative phase* (the structure of fluctuations in motor signals) and a smaller *absolute error of RP* (the difference between the produced and required RP) than the highest values (180° and 360°). There were however differences between groups when specific coordination patterns were intentionally required (in- phase or anti-phase). For participants on the autism spectrum the values for both RP absolute error and RP variability were higher in the spontaneous coordination than in either in-phase and anti-phase intentional coordination; controls results were highest in the spontaneous coordination, lower in the anti-phase, and lowest in the in-phase intentional condition. Controls obtained more stable patterns in the 0° phase (in-phase), than in the 180° phase (anti-phase). There appears to exist a relation between stability and pattern selection. The results show higher general accuracy in the intentional condition than in the spontaneous condition for both groups, however in persons with typical development coordination patterns are influenced by the type of phase, while this was not the case for participants on the autism spectrum. The study authors interpret these results as either a deficit in error perception or a maladaptation to social demands. Further discussion refers to the difficulties of participants on the autism spectrum with intentionally focusing on the required element in the environment, due to sensory overload.

With regard to the complexity of movements, in Kostrubiec et al. (2018) participants with typical development presented a higher Apen in the spontaneous condition compared to the180° intentional condition, while participants on the spectrum did not present significant differences. There was a higher similarity between the model (i.e., the red circle) and the controls pattern than the pattern of participants on the autism spectrum. From a developmental point of view, the results indicate for both groups that older children (14 years old) produce more stable, accurate, and complex patterns than younger ones (8 years old).

Kostrubiec et al. (2018) report an age-dependent relation between intentional coordination (0° and 180°) and socio-adaptive skills. However, their analysis does not identify the type of relationship (causality and directionality). A correlation between diagnosis severity and coordination difficulties was also documented. However, these findings, authors report are not representative of Autism Spectrum Disorder, as there are also persons who have coordination difficulties associated with social impairments without being on the autism spectrum. Further results in Kostrubiec et al. indicate that persons on the autism spectrum can coordinate in a spontaneous and intentional task both in-phase and anti-phase, however the complexity, accuracy, and stability of the coordination patterns differ across tasks. The accuracy of coordination is higher in the intentional task than the spontaneous task, and participants on the autism spectrum do not present differences in coordination in the intentional task between in-phase and anti-phase as persons with typical development do. The complexity of coordination did not differ between the spontaneous and the intentional task, nor did it for persons with typical development. For both groups, the qualities of coordination were found to increase with age.

Participants on the autism spectrum in Curioni et al. (2017) presented a general motor impairment and a slower movement rate than persons with typical development in the repetitive motion task. Curioni et al. hypothesized that participant's motor skills would predict the Mirror Game motion parameters. The hypothesis is partially confirmed. For the group on the autism spectrum, general motor skills were predictive of CC in the Following condition. Also, in the repetitive motion task, velocity was positively correlated with CC in the Following condition for both groups. However, the authors conclude motor impairments not to be predictive of the attainment of CC in participants on the autism spectrum, given that even when controlling for motor differences, participants on the autism spectrum still showed less frequent CC than persons with typical development. Another result of Curioni et al. is that the higher the level of autistic traits, the further participants were affected by the interference effect of the opposite movement of a dot. Curioni et al. interpret these results as evidence of difficulties with executive function abilities in persons on the autism spectrum (i.e., ignoring the dot's movement and target location and inhibiting the tendency to follow the trajectory of the dot).

10.3.4 Personal Analysis and Conclusions

The study of Kostrubiec et al. (2018) investigated characteristics of motor coordination of persons on the autism spectrum with a dot and whether and how their performance differs from the one of persons with typical development. One limitation is that the authors do not explain their choice of coordination variables and do not state and explain the extent to which the obtained results can be applied to everyday social and object coordination. Another methodological issue concerns the fact that the study authors correlated scores from the coordination paradigm with socio-adaptive test scores, but assessment of social skills with the application of tests has low ecological validity.

The studies covered in this section present conflicting evidence: Kostrubiec et al. (2018) report that participants on the autism spectrum are *not* influenced by the type of phase of the coordination task (i.e., in-phase or anti-phase), and Curioni et al. (2017) document an interference effect that influenced participants on the autism spectrum in coordination with a dot in anti-phase. Participants on the autism spectrum are able to spontaneously and intentionally coordinate with a dot, but the accuracy of coordination is higher in the intentional task. Moreover, differences in coordination between the participants on the autism spectrum and the control groups were encountered in the intentional coordination task. Last, for persons on the autism spectrum, motor skills are reported to be predictive of the abilities to jointly synchronize in the Follower condition only.

11 General Conclusions on Social Interaction of Persons on the Autism Spectrum

Following the example of De Jaegher (2013), I researched the hypothesis that the social style of interaction of persons on the autism spectrum depends on their embodiment and their sense-making. The hypothesis implies a *particular* way of interacting of persons on the autism spectrum.

In Chapter 8 ‘Autistic’ Embodiment, I addressed characteristics of the motor and visual perception processes of persons on the autism spectrum. I concluded that persons on the autism spectrum present impairments in the areas of fine and gross motor skills, body coordination, movement variability, execution time, and movement variability. Aiming, Balance, and, Catching scores were predictive of the Autism Spectrum Disorder. Also, persons on the autism spectrum present a local-to-global interference.

In Chapter 9 From Embodiment to Sense-Making, I addressed evidence investigating a link between low-level processes, such as sensorial and motor processes and high-level processes such as social interaction and language, but the nature of the link between low-level processes and social interaction is not clear. Considered hypotheses are that low-level processes (i.e., audio-visual cues) influence social understanding, that the difference lies within the mode of integration of the low-level processes, or that there is a reduced employment of top-down processes.

In Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum I addressed coordination, synchronization, and social interaction between a person on the autism spectrum, a person with typical development, and/or an object. The studies covered investigate different aspects of social interaction and coordination in persons on the autism spectrum using different methodologies and analyzing different variables.

To summarize the collected evidence about the social coordination of persons on the autism spectrum with another person defined as simultaneous execution of movements towards the same goal: The coordination between a person with typical development and a person on the autism spectrum presents healthy levels of motion complexity and motion variability (Romero et al., 2018). On the downside, persons on the autism spectrum spend less time in joint coordination (Kaur et al., 2018), and their interaction with a person with typical development presents different levels of coherence, depending on the type of coordination: lowest for synchronization, higher for imitation, and highest for the interpersonal hand clapping task (Fitzpatrick et al., 2017a). Studies found different results with regard to predictors of coherence of movements: bimanual drumming in Fitzpatrick et al. (2017a) is found to be predictive of lower coherence scores, while an indirectly proportional relation between coherence of movements and scores on the Repetitive and Restricted Behavior (RBB) subscale (the higher coherence of movements, the lower the RBB score) is reported in Romero et al. (2018).

Regarding collected evidence about social coordination with another person mediated by an object according to the role fulfilled in the interaction, studies show that when taking the Leader role in coordination, persons on the autism spectrum present a reduced movement duration (i.e., are faster) than persons with typical development in the same role. Taking the Follower role, persons on the autism spectrum present a faster reaction time and do not wait for the Leader of the interaction to finalize the execution of movements. Also, there was no significant increase for persons on the autism spectrum in the probability to attain CC in the Follower condition like persons with typical development presented. Persons on the autism spectrum did not present differences from persons on the autism spectrum with regard to the probability to attain CC in Joint Interaction Condition. Future studies should consider the velocity of the movements of the social partner in the interaction with persons on the autism spectrum as an influencing and relevant variable within their experimental design. Persons on the autism spectrum present a lower probability to continue the coordination with the social partner when perceived as less receptive to the movements of the person on the autism spectrum. Positive ratings of the experience of the social interaction with the synchronization expert correlated with a higher probability to attain CC in Follower and Joint Interaction condition.

Regarding collected evidence discussing the coordination of persons on the autism spectrum with an object (i.e., Curioni et al. (2017) and Kostrubiec et al. (2018)), purposeful coordination with an object is characterized by lower variability of movements, higher accuracy of movements, typical complexity, and a slower movement rate than persons with typical development. Motor impairments are predictive of the ability to attain CC in the Follower round only.

12 Implications for RQ1

The evidence presented so far about the 'autistic' embodiment, sense-making, and social interaction suggests differences of the motor and visual perception processes, of the language, motor stereotypy, and social interaction of persons on the autism spectrum from persons with typical development. Persons on the autism spectrum move differently, visually perceive the world differently, and interact and coordinate in a social interaction atypically. However, the evidence is inconsistent across studies and the low number of publications I reviewed does not allow for a definite answer as to whether researchers can meaningfully discuss about an 'autistic' embodiment, 'autistic' sense-making, and an 'autistic' social interaction. The covered evidence is not sufficient to draw an informed conclusion regarding my stated research question RQ1 and my research hypothesis H1) (i.e., The 'autistic' embodiment is exclusively connected to the way persons on the autism spectrum make-sense of and socially interact in the world.). Further studies are needed that analyze unique characteristics of persons on the autism spectrum in comparison to persons with typical development and persons with other neurodevelopmental disorders.

An important point to document is that not all findings in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum support the principles of the theory of Participatory Sense-Making by De Jaegher (2006) that are directly linked to H1). In relation to the principle that there is a bidirectional relation between social interaction and social coordination, Romero et al. (2018) referred to the reported flexibility of coordination to be predictive of the social interaction of persons on the autism spectrum, but Brezis et al. (2017) report that social skills of participants on the autism spectrum are not correlated with their ability to synchronize. Moreover, while Romero et al. (2018) report a correlation between social coordination and social cognitive abilities—measured as scores to ToM tests, Fitzpatrick et al. (2017a) report that only interpersonal hand clapping correlates with drumming motor skills. The last finding does not completely agree with the principle of mutual influence between social interaction and social coordination as only some aspects of social interaction in Fitzpatrick et al. (2017a) correlated with social coordination ability. Another important hypothesis in De Jaegher (2006) is that the interaction between a person on the autism spectrum and a person with normal development is faulty: The expert in synchronization in Curioni et al. (2017) leading the interaction with persons on the autism spectrum presented a slower movement velocity than with persons with typical development. This finding further agrees with De Jaegher (2006)'s hypothesis that the dynamics of the social interaction between persons on the autism spectrum and persons with typical development are different than the dynamics of the social interaction between persons with typical development.

Given that not all results in the current state of the art of the literature on the social coordination and interaction competence of persons on the autism spectrum agree with the hypotheses set and explained by De Jaegher (2006, 2013), I believe future studies should directly target to evaluate the validity of the hypotheses of De Jaegher.

PART III. Therapy for Persons on the Autism Spectrum

13 Human and Robot Therapy for Children on the Autism Spectrum

I discussed so far aspects of the social interaction competence of persons on the autism spectrum as presented in theoretical and empirical research. In this chapter I assess the effectiveness, skillfulness, and efficacy of human and robot interventionists (the last in a robot-mediated therapy) in/at improving and teaching social skills of/to persons on the autism spectrum by analyzing results of two European Projects H2020 (i.e., DREAM and BabyRobot). I discuss in detail only these two European projects because in these projects leading academics from different organizations and countries collaborate and because the project proposals underwent screening by the European Committee according to high academic standards; consequently, the quality, impact in the real-world, and relevance of these academic researches is high. I also discuss limitations and benefits of human and robot therapy. This chapter deals with Research Question RQ2 and its hypotheses. H2a): I hypothesize that Human interventionists are more effective than social robots in increasing the performance level of social skills of persons on the autism spectrum. I could not conclude whether this is the case, given the low number of selected publications and the identified limitations of the selected publications. H2b): I hypothesize that Human interventionists are more skillful than social robots at teaching social skills to persons on the autism spectrum. The hypothesis is confirmed. H2c): I hypothesize that Social robots are more efficient than humans in teaching social skills to persons on the autism spectrum. The hypothesis is confirmed.

13.1 The EU H2020 DREAM Project

In this section, I cover the definition of the robot-therapy, the methodology and procedures employed in the European Project DREAM, which aims to evaluate the effectiveness of the human and robot therapy for improving social skills in children on the autism spectrum, and I analyze reported empirical results. The resulting picture is that it appears that robot-mediated therapy is a promising intervention that might be at least as effective as human therapy in improving social skills in children on the autism spectrum. However, I also identify methodological, procedural and data interpretation limitations of the experiment that limit the significance of these results.

Figure 10 - The Nao Robot. Reprinted from "Can Human–Robot Interaction Promote the Same Depth of Social Information Processing as Human–Human Interaction?", by M. Kim, Kwon, & Kim, *2018, Int J of Soc Robotics, 10, p. 35, Fig.1. Copyright 2017 by Springer Science+Business Media B.V.*

"Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders" (DREAM - https://www.dream2020.eu/ - last accessed 13.09.2018) is a project supported by the European Union (project No. 611391) that started in 2014 and is scheduled to end in 2018. The consortium of the project is formed of seven teams of psychotherapists and engineers from Sweden, Belgium, Romania, and UK. One of the general key aims of the project is to investigate the child on the autism spectrum-robot interaction. To this end, the project measures the variables turn-taking, joint attention, and imitation in the interaction with the Nao robot (Gouaillier et al., 2009) (see Figure 10) and a human interventionist.

Autism Spectrum Disorder is defined in the project according to the DSM-5 criteria. The consortium presents the principles of Theory of Mind (ToM) (e.g., Baron-Cohen (1995)) to argue that children on the autism spectrum might favor technologies over human interaction. For a description of the principles of ToM, please see Section 7.1 Theory of Mind. The project collaborators opt for a *Robo-mediator* approach to deliver therapeutic treatment. In this approach, the robot is used as a key mean for delivering the treatment and for enhancing positive-outcome. In the project's Deliverable 1.1 (Costescu, David, Dobrean, Liu, et al., 2014), it is asserted the Robo-mediator approach to be associated with faster and better gains compared to the classical human-client therapeutic interaction (ibid, 7). However, the authors do not provide scientific evidence to support this claim. In the case of the *Robo-Assistant* approach, the robot acts as a facilitator of the therapeutic process, but is not a crucial component for treatment success, and could be easily replaced by other agents. In contrast to the Robo-Assistant approach, in the Robo- Mediator Approach the robot is a *key* component. The stated motives of the study author for the adoption of the Robo-Mediator Approach are related to the physical characteristics of the robotic platform (i.e., the anthropomorphic embodiment and object-like simplicity), software characteristics (i.e., information is presented in a gradually increased complexity manner), and the general manner of interaction with robots (i.e., robots are stated to be predictable and controllable): I have to note that while these arguments can be seen to speak in favor of Robot Intervention over Human Intervention, they do not support the choice of the Robo-Mediator over other types of Robot therapies.

13.1.1 Definition of the Robo-Mediated Intervention

In this subsection, I offer more detail on the robo-mediated intervention as characterized in the DREAM Project and on what skills of the participant child are targeted by the therapy design.

The therapeutic intervention implemented in the DREAM project targets three basic *psychological processes* described in the DREAM Deliverable 1.3 (Costescu, David, Dobrean, Matu, et al., 2014a), turn-taking; imitation; and joint attention that are key for social interaction. See Section 7.3 Participatory Sense-Making and Autism for information about the social interaction process of persons on the autism spectrum. *Imitation* is a basic mechanism of social learning through which a person reproduces an observed behavior. Costescu, David, Dobrean, Matu, et al. (2014a) assert that persons on the autism spectrum present impairments when imitating facial expressions, gestures, actions with or without objects, and overall imitation skills. *Joint attention* is conceptualized as a basic process of social learning and of social cognition involving gaze shifting and eye contact with the social partner (Krstovska-Guerrero & Jones, 2013). The authors report from the literature (e.g., Meindl & Cannella-Malone (2011)) persons on the autism spectrum to have impairments in the areas of eye contact, gaze shifting, and pointing to draw attention to an object. *Turn-taking* is involved in social interaction and social communication, during which a person’s social or communication turn is respected, after which the floor is taken by another social agent. Children on the autism spectrum are taken to present impairments in these areas (Bellini, Peters, Benner, & Hopf, 2007).

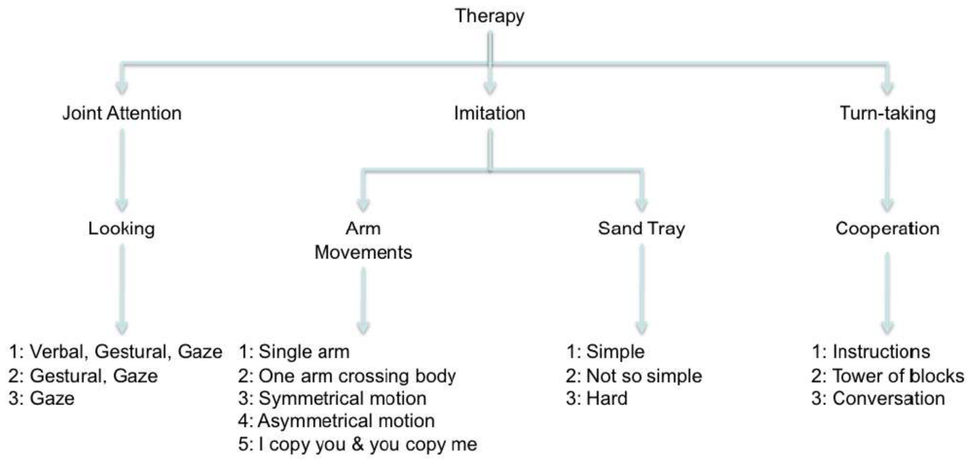

Figure 11 - The tasks in the DREAM Project that evaluate joint attention, imitation, and turn-taking skills. Reproduced from D1.1 Intervention Definition, by Costescu, David, Dobrean, Liu, et al., 2014, Project No. 611391, p. 10, Fig.1. In the public domain

These three psychological processes are taught as 16 exercises organized in different *tasks*. For a scheme of these tasks, please see Figure 11. Imitation is taught and evaluated in tasks targeting imitation with object (functional and symbolic play), imitation without an object, and imitation of emotional gestures; joint attention is taught and evaluated in tasks targeting the child's ability to orient their attention to an object after the robot turned its head towards an object, after the robot turned its head and pointed to the object, and after the robot turned its head, pointed, and vocalized an instruction and the child's ability to imitate these episodes to direct the robot's attention to an object. To evaluate turn-taking skills, the authors introduced a sorting game with facial expressions played on the Sandtray (Baxter, Wood, & Belpaeme, 2012).

In Deliverable 1.2 and Deliverable 1.3, it is stated the interaction of the robot with the child on the autism spectrum is described in terms of elementary actions (i.e., robot movements and sensory cues picked up and processed by the robot) (Costescu, David, Dobrean, Matu, et al., 2014b) and the goals pursued by the robot with the use of these actions (i.e., the expected change in the environment, the response of the child of the therapist) (Costescu, David, Dobrean, Matu, et al., 2014a). The DREAM consortium chose to employ the Nao Robot (Gouaillier et al., 2009) developed by SoftBank Robotics (previously Aldebaran Robotics) (see also Figure 10). Nao is a 58 cm-tall robot, weighting 5.6 kg humanoid robot. It is equipped with an inertial sensor, two cameras for face detection and environment recognition, four head-mounted microphones and two loudspeakers for processing sound and speech, full color RGB (Red, Green, Blue) eyesight for expressive communication, two sonars for exploration, eight force sensitivity resistors for adaptive walk, and twenty degrees of freedom for flowing movements. To monitor the child's facial expressions, behaviors, and the objects he/she interacts with at any location in the experimental room, three RGB-D (RGB- depth) cameras are installed in the experimental room and directed at the child. To provide the robot additional information from the real-world frame reference to compare with the information from its own real-world frame reference, the fourth RGB-D is placed above the experimental table, facing the robot.

The behavior of the child and the state of the environment are described from the robot's perspective. The robot's perception is abstracted and characterized in terms of *perception primitives* used to determine the child's behavior in relation to the therapy environment, employing Cartesian coordinates. Each perception primitive is a set of parameters that corresponds to particular robot perceptions. For example, the robot's action *Detect mutual gaze* is associated with the perception primitive *checkMutualGaze()*: returns a value of true or false depending on whether the child and the robot are looking at each other; *Facial expression recognition* employs the perception primitive *identifyFaceExpression (x, y, z, expression_id*): the emotion identifier (happy, sad, angry, or fearful) of the therapist or of the child is returned in the *expression_id* parameter. "Emotions" here are coded on the basis of facial, vocal, or postural cues. Descriptions of the behavioral grind according to which the robot codes the "emotions" are not given. The robot is equipped with built-in 25 of such perception primitives that are employed to recognize: the child's perception of the environment; the child's position in reference to the therapy environment; the child's head, body, and hand pose; the content of the child's speech; the child's facial expression; and any objects the child should be holding.

The robot has seven built-in *action primitives* that are activated by perception primitives. Examples of action primitives are: *say (text, tone)*—the robot speaks the message *text* in a *tone* that reflects one of four "emotions" (happy, sad, angry, or fearful)—, *moveHand(handDescriptor, x, y, z, roll*)— the action specifies the robot to move its hand to a location given by the coordinates x, y, and z and to orient the hand at that point; the hand to be moved is specified by the *handDescriptor* argument (either left or right)—, *and moveHead(x, y, z)*—causes the robot to move its head so that its gaze is directed at a location given by the coordinates x, y, and z. The full specifications of the DREAM robot's behavioral repertory are stated in the DREAM Deliverable 1.2 (Costescu, David, Dobrean, Matu, et al., 2014b).

13.1.2 Methodology of Experiment 1

Within the DREAM Project, two experiments were so far carried out. Experiment 1 (term set here for referencing purposes) explained in Deliverable 2.1.2 (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a) investigates the effectiveness of the Robot-enhanced therapy (RET) in comparison to the Standard Human Treatment (SHT). I chose to discuss and analyze this experiment because it is directly linked to

Hypotheses H2a), H2b), H2c). Experiment 2 (term set here for referencing purposes) described in Deliverable 2.2.1. (Costescu, David, Dobrean, Matu, Szentagotai, et al., 2015) and Deliverable 2.3.1. (Costescu, David, Dobrean, Matu, & Szentagotai, 2015b) evaluates the efficacy of RET to improve social skills in persons on the autism spectrum. The preliminary results of Experiment 2 discuss 14 participants out of the scheduled 60. This experiment does not directly link to the hypotheses of my master thesis, and the last version of the deliverable dealing with Experiment 2 was published later in the process of analyzing the data from this project. In Experiment 1, 7 children participants on the autism spectrum aged between 3 and 5 years were selected from the Autism Transylvanian Association (Cluj-Napoca, Romania) so far to undergo intervention. The authors report the results of only 5 children. The inclusion criteria consisted in children having been diagnosed on the autism spectrum according to the DSM-5 criteria or the ADOS score (Lord et al., 2012), presenting difficulties in at least two of the targeted areas of the intervention (i.e., turn-taking, joint attention, and imitation), and enjoying interacting with the robot.

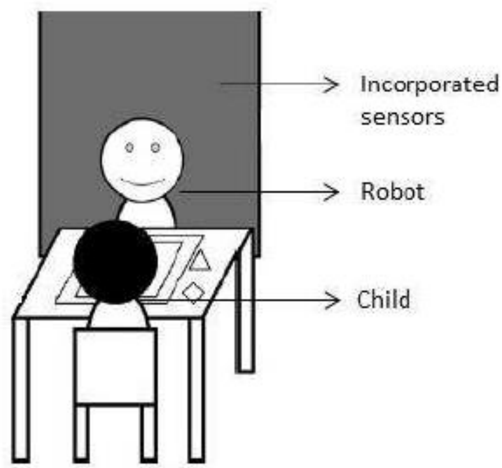

Figure 12 - Design Setup for Experiment 1 of the DREAM Project. During Robot-enhanced Therapy, the child is instructed to sit at a table across the robot. Reprinted from D1.1 Intervention Definition, by Costescu, David, Dobrean, Liu, et al., 2014, p.27, Fig.2. In the public domain

In the RET condition, the Nao Robot sits on or at the table in front of the child (see Figure 12). In the Standard Human Treatment (SHT) condition, the interventionist sits in front of the child. The only difference between RET and SHT is that in the RET condition, a robot is interacting with the child at the table, and in the SHT condition, a human is interacting with the child at the table. The same tasks (see Figure 11) are taught to the child during both SHT and RET. In addition to the cameras and sensors of the Nao Robot, video cameras and sensors are installed in the experimental setting behind the robot. In both conditions, a third person is present at all times during the experiment to mediate the interaction between the therapist and the child participant (i.e., to connect tasks in the protocol and to provide the prompt to the child). The Nao Robot's movements are controlled by an operator sitting in the right part of the experimental room using the Wizard of Oz (WOZ) paradigm. This means that the robot is not autonomous, but is instead fully teleoperated by the hidden operator. In a WOZ experiment, a human 'wizard' mimics the functions of a system (Gould, Conti, & Hovanyecz, 1981) by operating remotely the robotic system. WOZ paradigm is used by "researchers and designers to obtain feedback on functionalities that would otherwise require significant resources to be implemented" (Schlögl, Doherty, & Luz, 2015, p. 593) and allows the evaluation of user experiences and interaction strategies without building a fully functional system (Gould et al., 1981). In Deliverable 6.3.3. (Baxter et al., 2017) of the DREAM Project, it is stated that a benefit of the WOZ paradigm is that the controller choses the actions of the robot, which assures that the robot is always adapted, in this case, to the therapeutic context. Authors do not mention why WOZ was applied in Experiment 1of the DREAM Project, or why, in Experiment 2 of the DREAM project, authors apply a supervised semi-autonomous robot. In Deliverable 6.2. (Baxter et al., 2016), authors argument the methodological change by providing evidence from literature (i.e., Scassellati, Admoni, & Matari (2012)) that for a long-term use, the WOZ framework is not a sustainable paradigm.

As documented in Deliverable 2.1.1 (Costescu, David, Dobrean, Matu, & Szentagotai, 2015c), a single- case alternative treatments design was used to evaluate the effectiveness of the robo-mediated therapy (= Robot-enhanced Therapy, RET). Single-case experimental designs are useful quasi-experimental methods that emphasizes repeated measures of individual behavior and where the participant serves as his/her own control (Hayes, Barlow, & Nelson-Gray, 1999). They are aimed at verifying the efficacy of an intervention when there are low research funds and low number of participants (Kratochwill, 1992). Graph analysis is the central method of analysis employed.

13.1.3 Procedure of Experiment 1

In Experiment 1, the child participant underwent therapeutic intervention as defined in Subsection 13.1.1 Definition of the Robo-Mediated Intervention provided by a human interventionist followed by the Nao robot, or the other way around.

Instruction
Provided by the interactional partner (robot or human) Dependent on the task - imitation task: “Do like me!” - turn-taking task: “Now it is your/my turn.” - JA task: looking; looking +pointing; looking + pointing + saying “Look!”

Response
Provided by the child Dependent on the task - imitation task: moving arms/objects and making sounds in similar ways as the interactional partner - Turn-taking task: waiting with his/her hands still when it is the turn of the interactional partner - JA task: looking in the direction indicated by the robot

Consequence
Provided by the interactional partner (robot or human) Depending on the child’s answer - If the answer is correct then the child receives positive feedback: “Well done!” - If the answer is incorrect then the child receives negative feedback: “Try again!”

Figure 13 - The teaching structure of tasks in Experiment 1. The interventionist provides the person on the autism spectrum an instruction, and after evaluating the quality of the response of the child, it provides a positive or negative feedback. Reproduced from D2.1.2 Tasks for social robots on developing social skills (Wizard of Oz system) by Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p.11, Table 1. In the public domain

The implemented teaching plan applies principles of Discrete Trial Teaching (DTT) (covered in more detail in Section 14.2 Behavior Therapy). During the task, the child participant had to answer correctly instructions given by the interventionist. All three tasks of Experiment 1 (i.e., imitation, joint attention, and turn-taking) follow the same structure of teaching according to principles of DTT (Figure 13). Each block of DTT teaching contained three presentations of the same instruction, with an optional extension to the fourth one. Whenever the child responded correctly and independently (no prompt required) to the first two instructions, the child was given the instruction the third time to answer independently (no prompt was provided). Both, the Nao robot and the human interventionist, provided reinforcement contingent to positive answers of the child. In case of negative response to any of the first two instructions, the human mediator prompted the child at the third presentation of the instruction. The prompted response is not an independent response. After the prompted response to the third instruction, the child was offered a fourth trial to answer correctly and independently.

The performance of each child was assessed over a number (6-8) of sessions, until a stable baseline level/measure (BM) was obtained. Following this phase, children participants underwent RET “for approximately 8 sessions”, SHT for approximately 8 sessions, and RET or SHT “for approximately 4 sessions", "depending on which of the treatments worked better for each child" (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p. 9). Each session lasted 5 to 20 minutes and was delivered daily. BM evaluated the child's familiarity with the principles of the DTT format and the baseline of the targeted skills of the children participants.

13.1.4 Coding Procedure in Experiment 1

The behaviors of the children on the autism spectrum were recorded, annotated, and scored according to a behavioral grid, where behaviors were given a natural number from 0 to 2 reflecting the level of correctness and completeness of the response of the child: 0 was given to an incorrect response, 1 to a partially correct and complete response, and 2 to a fully correct and complete response.

Rating	*Meaning*	*Description*
0	*Intense noncompliance*	*The child walked away from the place in which the robot/adult interaction took place*
1	*Noncompliance*	*The child refused to comply with the experimenter's request to play with the robot/adult*
2	*Neutral*	*The child complied with instructions to help the robot/adult after several prompts from the experimenter.*
3	*Slight interest*	*The child required two or three prompts from the experimenter before responding to the robot/adult.*
4	*Engagement*	*The child complied immediately following the experimenter's request to help the robot/adult.*
5	*Intense engagement*	*The child spontaneously engaged with the robot/adult.*

Figure 14 - Rating System of the Engagement Task used in Experiment 1 of the DREAM Project. Engagement of the participant on the autism spectrum is evaluated based on the range of behaviors of walking away from the robot (intense noncompliance) and spontaneous engagement with the robot (intense engagement). Reproduced from D1.1 Intervention Definition, by Costescu, David, Dobrean, Liu, et al., 2014a, p. 9, Table 1. In the public domain.

The authors of the study also coded and scored the *general engagement* of the child in each task according to the rating system (from "intense noncompliance" coded as 0 to "intense engagement" coded as 5; see Figure 14) of Pop, Pintea, Vanderborght, & David (2014). Authors also coded and scored stereotypical behaviors, frequencies of positive and negative emotions displayed during the interaction with the robot or the child, utterances contingent to the interaction, verbal initiations congruous to the interaction, eye contact with the robot/human interventionist (measured in duration – the number of seconds during which the child looked at the upper region (not necessarily at the eyes) of the robot; success criterion – more than 3s)., rational/irrational beliefs (defined by Dryden & DiGiuseppe (2003)), adaptive behaviors (seeking help from the interventionist, seeking comfort, and orienting behaviors) and maladaptive behaviors (behavioral distraction/avoidance, demands, and aggression).

13.1.5 Results and Interpretation of Results of Experiment 1

The presentation of results of Experiment 1 reported in Deliverable 2.1.2. (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a) did not include any actual data of the applied test, statistical threshold or other statistical measures. Moreover, the reporting of results was incomplete; it was not clear what the performance/level of improvement of participants after receiving SHT or RET[1] was.

13.1.5.1 Turn-Taking Skills

Regarding improvements of the turn-taking skills in children on the autism spectrum, the study authors conclude that most children benefited to a similar extent from both SHT and RET, compared to the BM, with the only exception of Participant 3 (out of 5), who not only had lower performance during RET, but also higher performance compared to the maximum level of performance for primary outcomes in BM. Given the high baseline performance of Participant 3 in BM compared to the maximum level of performance, the authors explain Participant 3 did not benefit from RET to the same extent as from SHT because “less space for improvement was available for this child” (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p. 9) or, in other words “a possible ceiling effect” occurred (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p. 9). Another finding is that RET “led to” a bigger performance of the eye contact skills than SHT. Moreover, in the RET condition, children participants benefited from increased performance of the imitation skill. Also, RET led to more frequent stereotype, maladaptive, and adaptive behaviors than SHT. The authors see the result that RET led to more frequent stereotype and maladaptive behaviors as an opportunity for interventionists to address possible problematic behaviors of children on the autism spectrum that might appear in their interaction with the robot.

The summary of findings compiled by the authors reports that both RET and SHT have similar positive effects on increasing turn-taking skills in children participants on the autism spectrum, and in addition RET was associated also with increased eye-contact. At the same time, RET is also associated with more adaptive and maladaptive behaviors than SHT, to which authors recommend practitioners could interpret it as an opportunity to reinforce adaptive behaviors and decrease the frequency of the maladaptive behaviors.

[1] I also failed to find any other publication collecting these results through the website of the DREAM Project (https://www.dream2020.eu/publications/ — last accessed 13.09.2018).

13.1.5.2 Joint Attention

Regarding improvements of the joint attention skills in children on the autism spectrum, the results cover only the first two phases of the experiment (i.e., the sessions where only RET or only SHT is applied). Both the RET and SHT conditions led to similar results for general joint attention, in most cases superior to BM, "[w]hen space for improvement was available" (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p. 21), or, in other words when the performance of the participant in BM was not close to maximum level of performance: "children with the highest need of improvement benefited from both interventions to a similar extent" (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a, p. 22).

13.1.5.3 Imitation

Regarding improvements of the imitation skills, in four out of five children high levels of imitation skills were already present in the baseline condition. This is offered as a main reason why neither after RET nor SHT participants on the autism spectrum obtained performance improvements. Further, the study authors provide the additional suggestion that children with a high skills baseline did not benefit from RET because of the predictive and repetitive manner to act of the Nao robot: the authors suggest this could be because the Nao robot displayed a low number of social behaviors, which did not encourage interaction outside the given interaction patterns of the therapy (e.g., the robot did not provide feedback to the child's story, or it did not include the child's name in the verbal interaction).

13.1.5.4 Secondary Behavioral Outcomes

In relation to secondary outcomes, RET was associated with better performance on verbal utterances and eye contact, but not engagement, than SHT or BM. The study authors suggest that the limited engagement could be due to the highly structured manner of interaction of the robot boring the children: The participants were familiar with the limited number of behaviors of the robot and able to predict them. Regarding behavioral outcomes, some children presented an increase in stereotype and maladaptive behaviors during the RET condition, compared to both SHT and BM. The study authors explain that the increase in the frequency of appearance of stereotype and maladaptive behaviors could be related to the slowness of the robot compared to the one of humans triggering frustration manifested as a disruptive behavior. The authors suggest that interventionists can use this opportunity to control the frequency of maladaptive behaviors and encourage the adaptive behaviors. They also argue that the increased frequency in the maladaptive behaviors might be related to the delayed reaction time of the robot (or other technical issues), which in turn might have generated frustration in the children participants.

The study authors found also an increase in the number of adaptive behaviors during RET, compared to both SHT and BM, and they explain that the increase in the frequency of appearance of these behaviors to be related to the novelty of the robot in the therapy that could have triggered spontaneous initiation of interaction in the child participant on the autism spectrum with the therapy human mediator to inform him/her about characteristics/behaviors of the robot. Also, the majority of children expressed more positive emotions during RET than in either SHT or BM.

Overall, the study authors conclude that neither SHT nor RET were demonstrated to affect the development of imitation skills, in comparison to baseline levels, but that SHT was associated with a higher improvement of imitation skills than RET. In addition, authors report that RET might not lead to increasing performance of imitation skills for high-functioning children on the autism spectrum. Regarding the targeted secondary outcomes, RET and SHT were found by the authors to be equally effective in many researched areas; eye contact, verbal utterances, and maladaptive and adaptive behaviors, were higher for RET than SHT.

The authors suggest that further research should focus on specific questions about the effect of the RET and SHT therapy and not only whether one therapy is more effective than the other. For example, a particular question could be how quickly the positive effects are installed as a result of RET and SHT sessions, but also how quickly the novelty of the RET setting wears off with the children. Research should also opt for randomized clinical trials rather than single case experiments. Finally, the authors raise the issue of handling of technical breakdowns.

13.1.6 Personal Analysis and Conclusions

In the preceding sections, I presented results of a preliminary study carried out in the context of the European DREAM Project. I now critically evaluate the results and limitations of the experiment. The resulting picture provided by the authors is that it appears for RET to be a promising intervention that might have at least the same effectiveness as SHT and be associated with positive emotions of the children participants.

Discussing about the methodology of Experiment 1, the study authors changed the employed selection criteria between the publications of the DREAM Deliverable 2.1.1. (Costescu, David, Dobrean, Matu, & Szentagotai, 2015c) and Deliverable 2.1.2 (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a). The criterion requiring the child participant to enjoy interaction with the robot was excluded; in addition, the minimum interaction time of the child with the robot was lowered from 15 to 5 minutes. In this regard, I have to remark that enjoyment of the interaction with the robot is a criterion that is directly related to the ethical issue of always considering the well-being of the child first. Another point about the methodology of Experiment 1 is related to the employed experimental design. Criticism of the single case experimental design is related to *order effects* (i.e., the ordering of the interventions affects the results) (Byiers, Reichle, & Symons, 2012), *carry-over effects* (i.e., performance improvements measured after an intervention may in fact be due to some previous intervention), *irreversibility* (i.e., the dependent variable is affected by the removal of the independent variable), and *ethical problems* (i.e., withdrawal of intervention can raise ethical problems) (Badia & Lammers, 2004). Not all of the mentioned critiques can be avoided, but authors should interpret their findings in light of these limitations, and in the case of ethical problems, they should inform the legal guardians of the participants and/or the participants to the study of this ethical aspect. The deliverable 2.1.2 (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a) fails to explicitly address any of these limitations, it is however mentioned that each child participant was randomly assigned one of the two interventions (i.e., RET or SHT), an aspect that in fact also addresses the order effects limitation. In order to deal with the carry-over effects limitation, the authors of the study could have analyzed the data to assess whether the improvement in performance could at least in principle have been due to the influence of the former applied intervention.

Turning to the results of the study, it is important to first state that in Deliverable 2.1.2 the terms *efficacy* and *effectiveness* of robot therapy are used interchangeably. Another point is that if the interpretation for the results of Participant 3 was sound (i.e., that Participant 3 benefited more from SHT than from RET because of the "possible ceiling effect"; see Subsection 13.1.5.1 Turn-Taking Skills), then no improvement should have been observed in the SHT condition, too. Likewise, the conclusion drawn by the authors that children with higher prior turn-taking skills compared to the ceiling effect in BM would benefit less from RET is based on just this single case, and until the preliminary results are corroborated, these results and their corresponding interpretation should be taken with due caution. Authors of Deliverable 2.1.2 report in the compiled summary of findings that for primary outcomes in joint attention skills children with low joint-attention baseline skills benefited from SHT and RET equally, but it is not detailed whether all cases in SHT and RET did elicit skills improvements or not, so that it cannot be ascertained whether the therapy conditions led to the intended effects (for the small sample size). Also for Joint Attention condition, the stated summary is for RET and SHT to have had similar positive effects in improving skills of children participants on the autism spectrum (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a); but when presenting this conclusion in the Section *General discussion and conclusions* of Deliverable 2.1.2. (p. 26), Costescu, David, Dobrean, Matu, & Szentagotai (2015a) do not mention as they did in the previous Chapter *Joint Attention (JA)* of Deliverable 2.1.2. (p. 19) that this result applied only for children with a low joint-attention baseline skills. Another point to make is that the stated claim in Subsection 13.1.5.3 Imitation of a wider range of social behaviors of the robot to improve the imitation abilities of the participants on the autism spectrum is not scientifically corroborated: Another interpretation of the study findings could rather be related to the design of the therapy program: I believe that therapeutically significant results could perhaps be obtained with a therapy program characterized by more complex imitative behaviors (e.g., to imitate placing a driver puppet in a toy car, pushing the car, and then extracting the driver from the car). I observed that authors of the Deliverable 2.1.2 provide interpretations to different results that discuss contrasting attitudes of the child participant towards the robot, and they do not explain i.e., how the child can both be curious or enthusiast about (due to the novelty of the robot, which led to increased frequency of appearance of adaptive behaviors in children participants on the autism spectrum) and bored of the robot (due to the observation that participants on the autism spectrum were less *engaged* in the interaction with the robot) (see Subsection 13.1.5.4 Secondary Behavioral Outcomes).

In conclusion, I found serious issues with both, the reporting and the interpretations offered in the DREAM Deliverable 2.1.2 (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a); the results of any single small preliminary study need to be considered with due caution. In addition to that, another aspect of importance for future investigations put into evidence is the impact of the prior skill levels of patients on the effects of the types of therapy applied, as here it does appear that the different types of therapy, i.e., RET vs. SHT, have different consequences for children on the autism spectrum with different skills.

13.2 The EU H2020 Project BabyRobot

In this section, I present and analyze the methodology, procedure, and results of two exploratory pilot user studies carried out by researchers from the European Project BabyRobot that evaluate the effectiveness of the robot therapy for improving social skills in children on the autism spectrum. The main conclusion of the user cases is that children react differently when interacting with robots.

BabyRobot is a European Horizon 2020 Project (No. 687831) carried out by a consortium of Research Organizations, Higher or Secondary Education Establishments, and Private for-profit entities from the UK, Greece, and France. The general aim of the BabyRobot Project (from 2016-01-01 to 2018-12-31, ongoing project; http://babyrobot.eu/ - last accessed 13.09.2018) is to model human-robot communication, in particular the processes: sharing attention, establishing common ground and forming shared goals. The goals of the BabyRobot Project (C. Tzafestas et al., 2017) are:

G1) to create robots that analyze and track human behavior over time in the context of their surroundings in order to establish common ground and intention-reading capabilities.

G2) to define, implement and evaluate child-robot interaction (typically developing and children on the autism spectrum) application scenarios for developing specific socio-affective, communication and collaboration skills.

G3) to push forward the state of the art in core robotic technologies mainly in the areas of motion planning and control in constrained spaces, gestural kinematics, sensorimotor learning and adaptation.

Figure 15 - the Humanoid Robot Kaspar. Reproduced from "KASPAR – a minimally expressive humanoid robot for human–robot interaction research", by Dautenhahn et al., 2009, Applied Bionics and Biomechanics, 6, p.370, Fig.1. Copyright 2009 by Taylor & Francis.

The Baby-Robot project employs two robots: the Zeno robot, to address Human-Robot Interaction and Communication (in *Work Package* (WP) 4) and Child-Robot Communication and Learning (in WP5) and the Kaspar robot (see Figure 15), to investigate child-robot collaboration, multiparty communication and learning (in WP6). For the purpose behind RQ2, I address the content of the Deliverable 6.1 in WP6 that deals with G2), and I describe the interaction of the Kaspar robot with children on the autism spectrum. The Kaspar robot has been designed and developed by the University of Hertfordshire's Adaptive Systems Research Group, in Hertfordshire, Anglia. Also, it has been developed for use as therapeutic toy for children with autism to teach them social and communication skills by Professor Kerstin Dautenhahn and her team (Dautenhahn et al., 2009). Kaspar is a social robot that is 60 cm tall, equipped with 18 Force-Sensing Resistors (FSR) pressure sensors placed on several points on the hands, arms, shoulders, torso, head and feet to detect tactile interaction, 11 degrees of freedom in the head and neck, 5 in each arm and 1 in the torso, a silicon-rubber mask on the structure of the face, video cameras where the eyes are, eye lids that can open and shut, and a mouth that smiles and opens (Dautenhahn et al., 2017).

Dautenhahn et al. (2017) present in Deliverable 6.1 the first study ("Use Case 3") entitled "What I see is what I know". The general aim of Use Case 3 is to investigate whether the semi-autonomous robot Kaspar can assist children on the autism spectrum in developing their visual-perspective taking skills, social interaction, and collaboration skills. Dautenhahn et al. explain that in the first year of the BabyRobot Project the focus is on designing and testing tasks applied in the interaction between a child participant on the autism spectrum and the Kaspar robot used in a WOZ setup (for a definition and additional information on the WOZ paradigm, see Subsection 13.1.2 Methodology of Experiment 1) in the second year the focus is on testing the tasks with the Kaspar robot in a semi-autonomous mode, and the third year focuses on developing the tasks. Three exploratory pilot *user studies* that I refer to them here as USs: US1, US2, and US3 were conducted during the development of the interaction scenarios and the definition of the tasks of Use Case 3 to test the feasibility of some of the new concepts of the tasks and the intended set-up procedures. The aim of US1 is to test whether low functioning children on the autism spectrum understand that what they see on a computer screen next to the Kaspar robot represents what the robot "sees" through its cameras that are placed where its eyes are. The aim of US2 is to test the full setup and procedures of all the tasks of Use Case 3 with a typically devolving child. The aim of US3 is to test the set-up and procedure of Use Case 3 with three children with autism aged 9-11 in a special education school. For the purpose behind RQ2 and its hypotheses, I describe in the following Sections US1 and US3.

13.2.1 Methodology of the User Studies US1 and US3

Three children aged between 3 and 5 years participated in the user study US1 and three children aged between 9 and 11 years participated in US3. The children varied in their cognitive abilities, e.g., out of the participants in US3, two were partially verbal, while one was (fully) verbal.

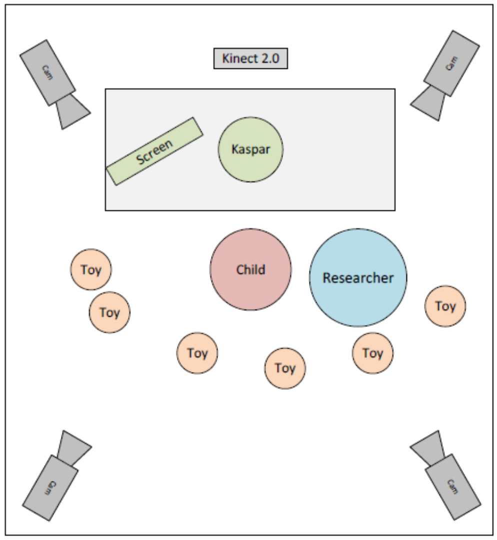

Figure 16 - Experimental Setting of Use Case 3. The child is seated in front of the Kaspar robot at a table and next to a Researcher. Reproduced from D6.1 Use Case 3 Specification and Initial Report on Multi Party Child-Robot Collaboration and Learning, by Dautenhahn et al., 2017, p. 14, Fig.1. In the public domain.

The experimental setting in US1 and US3 is the same as the experimental setting formulated for the planned Use Case 3 experiment (see Figure 16). US1 and US3 were conducted in a familiar room for the children participants on the autism spectrum in two schools in different towns in Hertfordshire, UK. It is also mentioned that US3 was organized in a special education secondary school. Kaspar was placed on a table and connected to a screen placed near it that showed what the robot "saw" through the cameras in its eyes. An investigator sat next to the table and next to the child.

Figure 17 - The wireless keypad controlling Kaspar, the social robot to perform certain activities. Reproduced from D6.1 Use Case 3 Specification and Initial Report on Multi Party Child-Robot Collaboration and Learning, by Dautenhahn et al., 2017, p.31, Fig.2. In the public domain.

In US3, Dautenhahn et al. (2017) report the robot Kaspar was controlled according to the Wizard of Oz paradigm. In both US1 and US3, the robot was also operated remotely via a wireless remote control (a specially programmed keypad, see Figure 17), either by the investigator or by the child (depending on the child's ability). The remote control controlled some of the activities the robot Kaspar could display. The experimental set-up aimed at providing a safe and predictable environment for children participants on the autism spectrum to freely interact with a single robot and a human investigator. The experimental session ended when the child indicated that he/she wanted to leave the room, when he/she became bored, or when he/she lost interest in the activity.

Dautenhahn et al. describe 11 tasks that are applied within the context of the User Case 3 experiment. Out of these 11 tasks, some of them (it is not reported which and how many) were carried out by the children participants with Kaspar within US1 and US3. The tasks of User Case 3 are: *Task 1 "Show me an animal & I'll make the sound"* (the child must place at an appropriate distance from the eyes/face of Kaspar a stuffed animal, and Kaspar will name the animal), *Task 2 "I'll ask for the animal, you find me the animal"* (Kaspar names an animal, and the child participant must find the mentioned stuffed animal and place it at an appropriate distance from the eyes of Kaspar), *Task 3 "Make me look and I'll tell you what it is"*(the child participant controls via the wireless keypad the direction of Kaspar's head to make it look at specific stuffed animals present in the experimental room and Kaspar names the animals present in its field of view), *Task 4 "I'll tell you what I want to see & you need to show me"* (Kaspar says the name of the stuffed animal it wants to see, and the child participant must orient Kaspar's head towards the place of the animal), *Task 5 "Collaborative control to meet a common goal"* (Kaspar says the name of the stuffed animal it wants to see, and two children participants must work together to orient Kaspar's head), *Task 6 "What you see is not the same as what I see"* (the child participant is given a cube with pictures of animals on it; when Kaspar asks to see an animal, the participant presents Kaspar with the picture of the requested animal, while the opposite side of the cube presents the child with the picture of another animal), *Task 7 "You need to agree for me to play"* (two children participants collaborate to decide on which stuffed animal to show Kaspar for it to name), *Task 8 "I spy with my little eye…"* (the child participant must point to the animal Kaspar is looking at), *Task 9 "What can we see?"* (a physical separator device is placed on the table between Kaspar and the child that allows three visibility states: visible to both Kaspar and the child participant, visible to the child only, and visible to Kaspar only; the investigator places the animal in one of the three positions, and Kaspar asks the child participant about the visibility of the stuffed animal), *Task 10 "Who can see what?"* (the setup of this Task is similar to Task 9, with the addition that stuffed animals are placed in all visibility positions; Kaspar asks the child participant about the visibility of each animal), and *Task 11 "Where will I look?"* (with Kaspar watching, the child places a toy into a container with a lid on top of it; after a few minutes, Kaspar "goes to sleep" and the child participant is encouraged to change the position of the animal into another container; when Kaspar wakes up, the child is asked where Kaspar "expects" the animal to be).

13.2.2 Procedure of US1 and US3

Figure 18 - A child participant interacting freely with Kaspar in US1. Reproduced from D6.1 Use Case 3 Specification and Initial Report on Multi Party Child-Robot Collaboration and Learning, by Dautenhahn et al., 2017, p.32, Fig.3.(middle). In the public domain.

Figure 19 - The investigator showing the child participant in US1 what Kaspar "sees" through its cameras. Reproduced from D6.1 Use Case 3 Specification and Initial Report on Multi Party Child-Robot Collaboration and Learning, by Dautenhahn et al., 2017, p.32, Fig.3.(left). In the public domain.

Figure 20 - A child participant shows Kaspar a stuffed animal. Reproduced from D6.1 Use Case 3 Specification and Initial Report on Multi Party Child-Robot Collaboration and Learning, by Dautenhahn et al., 2017, p. 33, Fig.6 (right). In the public domain.

In US1 (Dautenhahn et al., 2017), the child was encouraged to interact freely (see Figure 18), but also to play games with Kaspar: moving toys into and out of the robot's field of view. The experimenter showed the child how to check what Kaspar can and cannot see by looking at the screen (see Figure 19), asked the child if the robot can "see" the toys, and let the child control the wireless keypad controlling the direction of Kaspar's head. In US3 (Dautenhahn et al., 2017), the participants were encouraged to interact with Kaspar following the structure of pre-defined tasks of Use Case 3 (for an example, see Figure 20).

13.2.3 Results of US1 and US3

In US1, out of the three children, one did not seem to understand the concept of a display of what the Kaspar robot "sees". Another child managed to understand the concept towards the end of the session, with the help of the experimenter. The third child understood the concept from the beginning. For the rest of the session, the third child participant engaged with the robot in other game activities.

In US3, the first child participant was at first hesitant to interact with the robot, but after a few minutes chose to come in the experimental room to interact with the robot. The second child participant gradually became more comfortable with the interaction and started interacting verbally with the robot and the investigator. The third child participant interacted freely with the researcher and the robot from the beginning. All three children finished a different number of game tasks in their interactions with the robot.

13.2.4 Interpretation of Results of US1 and US3

In US1, not all children understood that what the robot "saw" was what it was being displayed on a screen. In US3, authors report children participants on the autism spectrum interacted differently with the robot, with some being reluctant at first, while others being very open and eager to interact. All children participants engaged with the robot in the end, but their first reaction was not always to approach the robot and to engage with it.

General conclusions of the US1 and US3 provided by Dautenhahn et al. (2017) are that: structured game scenarios require a high degree of flexibility because it leads to sustained engagement with children on the autism spectrum; low-functioning children on the autism spectrum, especially those with low verbal abilities need to be addressed precise instructions that are formulated in simple language and repeated several times; the speech of children participants on the autism spectrum with low verbal abilities is difficult to understand, and this challenge is especially relevant for the implementation of the speech recognition feature of the robot; the erratic/unpredictable behavior of children on the autism spectrum represents a challenge for interventionists developing an accurate tracking feature of the robot; and investigators should expect that not all children participants on the autism spectrum will be able to finish all of the pre-defined tasks.

13.2.5 Personal Analysis and Conclusions

Dautenhahn et al. (2017) do not mention in Deliverable 6.1. and in relation to US1 the levels of cognitive ability of the participants in association with their success or difficulty with the task. Considering this reporting limitation, I believe it is impossible to assume whether in any participant to the study the cognitive ability could have influenced the performance on the task. I observed from the content of Deliverable 6.1. that the general conclusions provided by Dautenhahn et al. (2017) about US1 and US3 do not follow from the results presented.

13.3 Further Studies

Some of the studies presented in this section (i.e., Yun, Choi, Park, Bong, & Yoo (2017) and Bekele, Crittendon, Swanson, Sarkar, & Warren (2014)) provide additional evidence (besides the one presented in Experiment 1 of the DREAM Project) to the H2a) hypothesis investigated in this chapter (i.e., Human interventionists are more effective than social robots in increasing the performance level of social skills of persons on the autism spectrum.) and all of the studies presented in this section provide examples of the limitations and benefits of robots therapy (discussed in Section 13.4 Benefits and Limitations of the Human and Robot Therap). One such example is that although during robot-therapy children participants on the autism spectrum display stronger positive emotions than during human therapy, there are still pending urgent technical issues of the experimental setup of the robot therapy to ensure the optimal therapeutic setting for persons on the autism spectrum. Not all studies directly target limitations and benefits of the robot therapy, but some authors mention relevant observations that were obvious after carrying out the experiment.

13.3.1 Aim of the Studies

The aim of the study of Yun et al. (2017) is to compare the effectiveness of robot-therapy and human therapy aimed at improving facial expression recognition and eye contact in children on the autism spectrum. The aim of the pilot feasibility study of Bekele et al. (2014) is to empirically test the feasibility and usability of a closed-loop adaptive robotic system providing joint attention prompts and within-system adaptation of these prompts and to compare the child performance to look at a target after receiving prompts from robots and humans. Chevalier et al. (2017) assess whether the sensory profile of children on the autism spectrum (overreliance on proprioceptive cues and a hypo-reactivity to visual cues / hypo-reactivity to proprioceptive cues and an overreliance on visual cues) influences their capability to imitate or initiate arm movements for their partner to imitate. The study of E. S. Kim et al. (2015) gauges the potential clinical utility of the social robot Pleo in a therapeutic intervention for persons on the autism spectrum, by comparing affective valence during interaction with the robot versus the interaction with the adult human.

13.3.2 Participants

To the study of Yun et al. (2017) participated 15 male subjects on the autism spectrum aged between 4 and 7 years old. 8 participants were randomly assigned to the Treatment Group (TG; treatment was offered by a robot) and the remaining 7 to the Control Group (CG; treatment was offered by a human). To the study of Bekele et al. (2014) participated 6 children on the autism spectrum (ASD) and 6 with typical development (TD) aged between 2 and 5 years. To the study of Chevalier et al. (2017) participated 12 subjects on the autism spectrum (mean age: 11.7+/- 2.6 years; 2 females). Based on the results of the questionnaire and the experimental setup applied in the study, participants were assigned to two groups: Group G1 with the children CH3, CH5, CH8, CH10, and CH11 (characteristic of an overreliance on proprioceptive cues and a hypo-reactivity to visual cues) and Group G2 consisting of CH1, CH2, CH4, CH6, CH7, CH9, and CH12 (characteristic of a hypo-reactivity to proprioceptive cues and an overreliance on visual cues). To the study of E. S. Kim et al. (2015) participated 24 high-functioning children on the autism spectrum (3 females) aged between 4.6 and 12.8 years (M=9.4, SD=2.4). In all presented studies participants were recruited according to the convenience sampling method.

13.3.3 Description of the Method and Procedure

The designed behavioral intervention program of Yun et al. (2017) targets eye contact and facial emotional recognition and follows the principles of DTT (for more information about DTT, see Appendix F Glossary of Terms of the Applied Behavioral Analysis Intervention, term 1)). The social skills training program consisted of eight session lasting between 30 and 40 minutes with three sets of types of the interaction: 1) therapist- observer-robot, 2) child-robot, and 3) therapist observer - child. Each session consisted of an *Instruction Phase* (during which the robot interacted only with the therapist - observer) and a *Practice Phase* (during which the robot interacted individually with the child and the therapist - observer). The instruction protocol for the session started with the robot greeting and making eye contact with the interactional partner. If the interactional partner (therapist -observer in the Training Phase and child participant in the Practice Phase) made appropriate eye contact, the robot provided a Reward (RW) and proceeded to the next task (i.e., facial emotion recognition task). When the interactional partner did not make eye contact, the robot provided Encouragement (EN); if after three consecutive attempts the child participant did not make eye contact with the robot, the robot remained in Pause (PA) mode until clearance to further interact from the observer –therapist was obtained. In the facial emotional recognition tasks, the robot displayed a set of facial movements that were expected to be interpreted as facial emotional expressions and asked the social partner to name them.

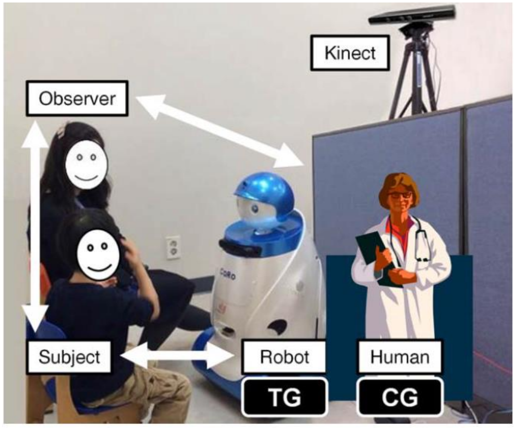

Figure 21 - Experimental setup for TG (treatment group; interacting with robot) and CG (control group; interacting with human interventionist). Reproduced from "Social Skills Training for Children with Autism Spectrum Disorder Using a Robotic Behavioral Intervention System" by Yun et al.*, 2017, Autism Research, 10, p.1314, Fig.9. Copyright 2017 by International Society for Autism Research, Wiley Periodicals, Inc.*

The therapist - observer recorded the child participant's correct and incorrect responses. The same procedure with RW, EN and PA was applied to this task also. The experimental setting is depicted in Figure 21.

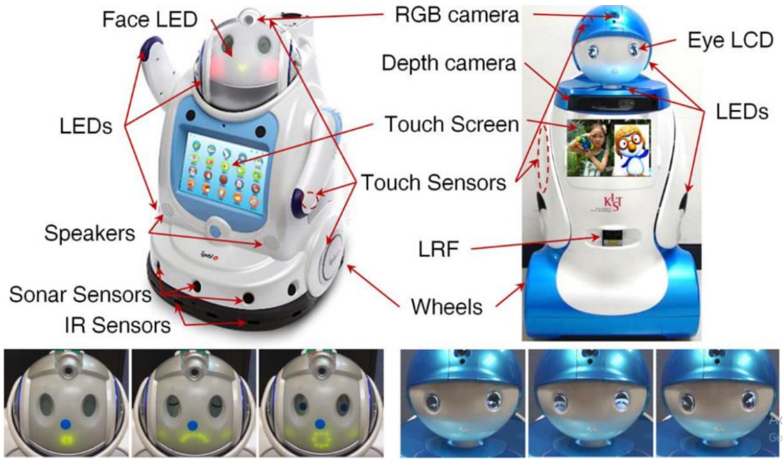

Figure 22 - Short description of iRobiQ (left) and CARO (right) and three examples of the "emotions" displayed. Reproduced from "Social Skills Training for Children with Autism Spectrum Disorder Using a Robotic Behavioral Intervention System", by Yun et al.*, 2017, Autism Research, 10, p.1315, Fig.4. Copyright 2017 by International Society for Autism Research, Wiley Periodicals, Inc.*

Two robots were chosen for the facilitator role in the interaction: iRobiQ (see Figure 22 left) and CARO (see Figure 22 right). iRobiQ was developed by Yujin Robot Co., Ltd. (Seoul, South Korea) for commercial purposes. It is a 45 cm tall robot that displays different movements of the mouth that are associated with movements of the four emotions: happiness, sadness, surprise, and shyness (see Figure *22* left). CARO was developed by the Center for Robotic Research at the Korea Institute for Science and Technology (Seoul, South Korea). It is a clinical assistive robot and able to display different movements of the eyeballs that are associated with the emotions happiness, sadness, surprise, and anger (see Figure 22 right).

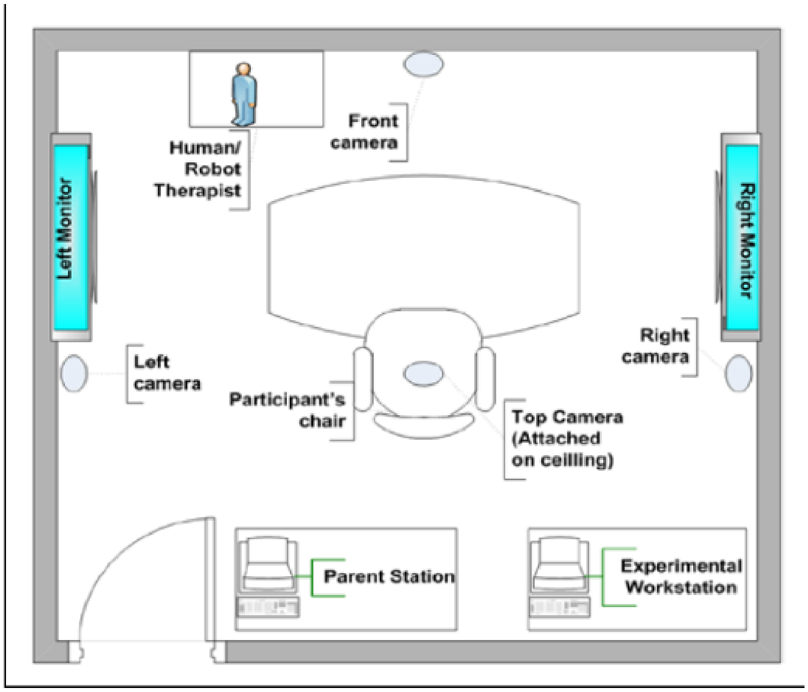

Figure 23 - Experimental Setting of a Feasibility Study Pilot. Reproduced from "Pilot clinical application of an adaptive robotic system for young children with autism", by Bekele et al., *2014, Autism, 18, p. 601, Fig.1. Copyright 2014 by the Author(s).*

Bekele et al. (2014) designed a component-based distributed architecture where systems interact via a network in real time (see Figure 23). Its components are: a) the humanoid robot Nao (see Figure 10) that provides real-time prompts, b) a head-tracker system for gaze inference composed of a network of spatially distributed infrared cameras c) a child-sized cap with light emitting diode (LED) lights) d) a camera processing module (CPM) providing real-time gaze inference data and e) two target 24-inch monitors that could be activated contingent on the child's behavior to look at them in a response to joint attention prompt. The child participant was invited to the experiment room and given time to explore it and the robot. Afterwards, the child was seated in the chair at a table and the child-sized cap was placed on her/his head. The child was presented with four total blocks presented by the human administrator (two blocks) and the Nao robot (two blocks). Each block consisted of four trials. The child was instructed to look at one of the two mounted computer monitors. Six predetermined prompt levels (PLs) were organized (e.g., “least-to-most” hierarchy: verbal + gaze => verbal + gaze => verbal + gaze + point=> verbal + gaze + point=> verbal + gaze + point + audio clip at target=> verbal + gaze + point + audio clip at target + video onset at target). If the child responded correctly at any given step of the PL, verbal reinforcement followed by a 10s video was provided. Inferred gaze to target within the trial and 8s window after presentation of prompt was coded as accurate response.

The proprioceptive and visual profile of participants on the autism spectrum in Chevalier et al. (2017) was assessed according to results to the Adolescents/ Adults Sensory Profile (AASP) (Brown & Dunn, 2002) Questionnaire and an experimental setup. AASP assesses the sensory processing preferences of individuals in terms of neurological thresholds for stimulation (high/low) and self-regulation strategies (active/passive) (Dunn, 1999). The questionnaire was filled out by the caregivers of the participants to the study. Authors mention that although the questionnaire is not designated for the targeted sample, they still chose to apply this questionnaire because of the feedback of the caregivers that the questionnaire also suits their children and teenagers. Chevalier et al. (2017) assumed that the participants to the study in the group G1 would struggle more to imitate his/her partner, would struggle more to initiate movements for his/her partner to imitate, and would present slower improvements in his/her imitation skills across the sessions that participants from the group G2. The hypothesis was confirmed. Participants interacted in Chevalier et al. (2017) both with a human partner and the robot Nao. There were seven sessions per participant. The session were held in a private room of care centers. In the human sessions, the child participant was placed in front of the human experimenter, and in the robot sessions the child was sited at a table, on top of which Nao was sitting. During phase A, the child had to imitate the arms movements of their partner. The movements are a combination of the left and right arms in one of the five positions: Down (D), Up (U), in front (F), in ψ (P), and in T form (T). The movements were randomly executed to a learning effect after repetitions of movements. The human social partner executed the movements in real time, and for the robot, the movements were computed. The child participant was reinforced for correct imitation and corrected when necessary. During phase B, the human/robot partner imitates the gross arm movements of the child.

Figure 24 - Interaction with a confederate and the Pleo Robot. Reproduced from "Potential Clinical Impact of Positive Affect in Robot Interactions for Autism Intervention", by E. S. Kim et al., *2015, 2015 International Conference on Affective Computing and Intelligent Interaction (ACII), p. 34, Fig. 1 (top). Copyright 2017 by Springer Science+Business Media B.V.*

Figure 25 - Pleo, the dinosaur robot. Reproduced from "Potential Clinical Impact of Positive Affect in Robot Interactions for Autism Intervention", by E. S. Kim et al., *2015, 2015 International Conference on Affective Computing and Intelligent Interaction (ACII), p. 35, Fig. 2. Copyright 2017 by Springer Science+Business Media B.V.*

In a randomized crossover design in E. S. Kim et al. (2015), children participants took part in interactions with a confederate—a researcher who guided the interactions—and either a robot or adult interaction partner (see Figure 24). The interactions (lasting 6 minutes) were semi-structured and targeted activities such as, building block toys, petting the robot, and performing a secret handshake with the adult. The participant robot to the study was Pleo: a commercial toy dinosaur robot (18 × 10 ×20 cm, 3.2 kg; see Figure 25) manufactured by Innvo Labs, in Hong Kong and Nevada. Authors modified the robot to play pre-recorded, synchronized motor and audio behaviors, triggered through the robot's infrared receiver by a television remote control. The robot was controlled using the WOZ paradigm. The robot was able to "express" positive (e.g., excitement and joy) and negative (e.g., disappointment or dislike) emotions by vocalizing context-appropriate sounds (e.g., "Oooooh" for interest and "Awwww" for disappointment).The primary dependent variable of the study is *affective valence displayed by the child* and was coded and scored according to a Likert scale from 1 (intense negativity: frustration, unhappiness) to 5 (intense positivity: enthusiastic).

13.3.4 Results

After the first treatment session in Yun et al. (2017), the percentages of eye contact increased dramatically in comparison to baseline (20% for TG and 17.4% for CG, $p>0.05$), with the percentage in TG (96.46%) higher than the one in CG (68.57%). Over the sessions, the percentage gradually decreased in TG and generally maintained in CG. The switch from IRobiQ and CARO did not have a clear effect on the eye contact performance. After the eighth session, the frequency of eye contact increased significantly in both groups compared to baseline (77.92% in TG and 73.81% in CG, $Z= -2.52$ and -2.37, respectively, $p <0.05$). In both groups, performance of facial emotion recognition significantly increased from the first to the fourth session ($Z= -1.992$, $P=0.046$ in the TG; $Z= -2.264$, $P=0.024$ in the CG), while there were no significant increases between the fifth and eighth sessions when the robot was changed ($Z= -1.625$, $P=0.104$ in the TG; $Z= -1.761$, $P=0.078$ in the CG).

In Bekele et al. (2014), children on the autism spectrum spent an average of 52.8% (standard deviation (SD) = 21.4%) of the robot condition looking at the robot compared to an average of only 25.1% (SD = 18.7%) of the human condition looking at the human administrator. The duration of gaze toward robot in participants with typical development yielded a mean of 54.3% (SD = 17.7%) across all trials, whereas the duration of gaze toward the human administrator across all trials yielded a mean of 33.6% (SD = 16%). Success rates of looking at the correct monitor were calculated as the percentage of trials successfully completed prior to activation of the monitor. In a majority of both robotic (ASD = 77.08%; TD = 93.75%) and human sessions (ASD = 93.75%; TD =100%), children were finding targets prior to monitor activation. However, the ASD group had significantly less accuracy prior to activation than the TD group (mean difference = 16.67%, $p < 0.05$). Both children in the ASD group (Human: 26.4%, SD = 11.7%; Robot: 40.9%, SD = 20%; $p < 0.05$) and TD groups (Human: 20.1%, SD = 4.8%; Robot: 29.5%, SD = 15%; $p < 0.05$) required more prompting leading to accurate response in the robot conditions than in the human conditions. The ASD group ultimately required, more prompting in the robot trials than the TD group, although the difference was not statistically significant.

Chevalier et al. (2017) report that due to disruptive behavior, the results of one participant were not included in the analysis. In phase A, authors found a significant main effect of the groups on the number of the imitated movements ($F(1; 9) =34.94$; $p <0.01$). Children from group G1 imitated fewer movements than the children from group G2 (G1: M = 51.34, SD = 17.25; G2: M = 87.14, SD = 35.04). With regard to the imitation scores, authors found a significant main effect of the scores on the groups ($F(1; 9) = 17.65$; $p < 0.01$). Children from group G2 were more successful than children from group G1 (G1: M = 23.09, SD = 26.81; G2: M = 79.79, SD = 20.25). Authors note that even if this result is not significant, children participants from G1 still seemed to have a higher score in the sessions with the human partner than participants in G2. In phase B, free initiation of movements was not significantly different between the groups on the whole experiment ($F(1; 5) = 0.08$; p = ns); however, authors observed that the free initiation increased in both groups, with G2 higher than G1. Authors also report that the participants from G1 encountered more difficulties understanding they had to initiate movements, and that the robot was imitating them; they often imitated the robot because the robot was slightly moving from the noise based on skeleton data of the RGB-D camera. Analyzing the individual behavior of children participants, authors observe that most participants showed enthusiasm when interacting with the robot.

Affect was more positive in E. S. Kim et al. (2015) during the robot than the adult condition ($t(23) = 5.1$, $p <$ 001, d = 0. 93). More positive affect during robot than adult interaction was associated with ADOS calibrated severity score: higher ADOS calibrated severity scores indicated greater autism symptom severity($r(22) = .43$, $p < .05$), especially in the social affect domain ($r(22) = .46$, $p < .05$).

13.3.5 Interpretation of Results

Yun et al. (2017) concluded that participants on the autism spectrum increased in their performance of eye contact and recognition of facial emotion expression similarly after receiving both human-therapy and robot-therapy.

Bekele et al. (2014) conclude that children on the autism spectrum spent significantly more time looking at the humanoid robot (52.8%, SD = 21.4%) than the human administrator (25.1%, SD = 18.7%). Both children on the autism spectrum and children with typical development ultimately responded accurately following prompts delivered by a humanoid robot and a human administrator. However, both groups of children required high levels of prompting to successfully orient in the robot condition. The reasons provided by authors for these aspects refer to unclear or suboptimal instructions and unfamiliarity with the manner of presenting instructions of the robot; authors believe for the latter reason an important point to consider is whether robots are capable of performing sophisticated actions: eliciting responses from individuals, and adapting their behavior human-like. Finally, authors state that the mere introduction of a humanoid robot that performs simple behaviors can impact change and relevance to participants on the autism spectrum.

Chevalier et al. (2017) conclude that the sensorial profile of participants on the autism spectrum impacts their ability to imitate and to initiate movements to be imitated. Participants with hypo-reactivity to visual motion and an overreliance on proprioceptive information (group G1) were less likely to initiate movement and had a slower improvement in their imitation skills that children participants with an overreliance on visual motion and a hypo-reactivity to proprioceptive information (group G2). Authors do not elaborate on the reasons for the found connection between sensorial profile and the imitation ability of persons on the autism spectrum, but they do recommend robots used in a therapeutic setting to be equipped with a module for online detection of the sensorial profile of persons on the autism spectrum; however, the description of the practical role of this module are not specified (i.e., how the module should achieve its purpose). Another conclusion is that the experimental set-up in Phase B affected the participant's understanding of the aim of the task, because they were unwilling to stand in front of the RGB-D camera for them to be correctly tracked.

E. S. Kim et al. (2015) observed more positive affect during the robot than the adult condition. Authors report that this finding suggests that robots may be intrinsic reinforcements, or preferred interaction partners over the human social partners; this finding suggests a potential advantage of the robot-intervention. Moreover, therapeutic robots may be especially benefic to lower-functioning children on the autism spectrum.

13.4 Benefits and Limitations of the Human and Robot Therapies

As a result of discussions with representatives of relevant fields (e.g., philosophy and philosophy in computer science), I present in this section some key differences between robot therapy and human therapy that are relevant for understanding how these kinds of therapies address specific social characteristics of persons on the autism spectrum. In doing so, I focus on benefits and limitations of human and robot therapy. Being myself a psychologist pursuing the Registered Behavioral Technician Credential (http://www.bacb.com/rbt/ - last accessed 14.09.2018; awarded by the *National Commission for Certifying Agencies* (NCCA) in Washington, DC; The NCCA standards are consistent with *The Standards for Educational and Psychological Testing* (AERA, APA, & NCME, 1999)), with experience in applying principles of Applied Behavioral Analysis to teach skills in one-on-one interactions with three children on the autism spectrum, this analysis also reflects my personal informed opinion on the interaction between children on the autism spectrum and human or robotic interventionists.

13.4.1 Benefits of Human Therapy

I first focus on strong points of human therapy in improving and teaching social skills of/to children on the autism spectrum.

The ethics team of the DREAM project (cf. Section 13.1 The EU H2020 DREAM Project) challenged the original perspective of the DREAM Consortium, according to which children on the autism spectrum would enjoy interacting with robots more than with humans: Richardson et al. (2018) present qualitative evidence that children on the autism spectrum prefer the activities of e.g., spending time in the nature, engage with other beings, and show interest in human relationships more than interactions with technologies and robots. They point out that the general rationale of studies that investigate whether persons on the autism spectrum favor robot interaction over the human interaction starts from the observation that children on the autism spectrum present difficulties interacting with humans. But also according to the conclusions drawn in Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum of this thesis, participants on the autism spectrum are in fact capable of motor coordination and synchronization in social interaction, even though they present different characteristics of these processes than persons with a normal development. These findings complement the results presented by Richardson et al.

The advantage of human therapy in comparison to robot-mediated therapy is upheld also by MSc Alex Stefan, a Romanian behavioral interventionist with five years of experience in working with children on the autism spectrum and a founding member of the Association “Aripi Albastre”, Bucharest, Romania (organization that provides therapy for children on the autism spectrum): “I don’t think these kinds of [social] skills can be learned without “one-on-one” interaction with a real person” (Alex Stefan, 14.07.2016, translated from the Romanian language by me; Original text: “Nu cred ca se pot invata astfel de abilitati prin lipsa interactiunii “unu la unu” cu o persoana reala”; the answer is part of the questionnaire organized by me for the purpose of her academic semester project during her master in cognitive science that aimed to investigate the effectiveness of serious games for improving social skills in children on the autism spectrum). Alex Stefan meant to refer to the specific and defining characteristics of human interaction (e.g., highly dynamic, intuitive, complex, fast, and rich in social cues) and its unique contributions to the development and improvement of skills of clients on the autism spectrum that the human-robot interaction cannot provide.

Human therapy is associated with *optimal outcomes* of persons on the autism spectrum, where: the notion of “optimal outcome” refers to the person losing the diagnosis on the autism spectrum (Fein et al., 2013). Representative studies typically report about one tenth of their sample size of children on the autism spectrum to lose their autism diagnosis (Moulton, Barton, Robins, Abrams, & Fein, 2016; Zachor & Itzchak, 2010). To qualify as optimal outcome, a child must be able to demonstrate both near-transfer and far-transfer of skills learned during the intervention, i.e., generalization of skills to similar tasks as well as to real-life situations. McCleery(2015) supports the idea that generalization and transfer of skills is dependent also on the type of strategy and therapeutic program persons on the autism spectrum follow.

Zachor & Itzchak (2010) assess the effect of the type of human intervention approach (Applied Behavioral Analysis (ABA) or Eclectic) on outcome in cognitive, language, and adaptive skills and on changes in autism diagnosis. During the experiment, one group of participants on the autism spectrum received ABA therapy and the other group of participants on the autism spectrum received Eclectic therapy. Their results indicate that both groups improved significantly regardless of the type of intervention, and 9% of participants lost their autism spectrum classification. After a search for publications discussing optimal outcome in children on the autism spectrum after receiving robot therapy (selection criteria: Google Scholar, first 5 pages, keywords: "autism", "robot therapy", and "optimal outcome", timeframe: 2014-2018), I could not find any that discusses the topic of optimal outcome.

In my personal experience, the children on the autism spectrum I interacted with were obviously seeking their caregiver's attention (e.g., by taking the hand of the caregiver, by positioning themselves in close proximity to the caregiver and looking them in the eyes, by laughing and looking at them), in order to engage with them in some meaningful activity. Over multiple therapy sessions, I and Eva Szulyovszky (Board Certified Behavior Analyst (BCBA): a graduate-level certification in behavior analysis) verified a children on the autism spectrum's interest towards games presented on a tablet for therapeutic purposes. In all occasions, the child showed signs of boredom, impatience, and no signs of interest. While I cannot conclude that children on the autism spectrum *prefer* the interaction with humans over the one with robots or technologies, I can state that children on the autism spectrum do search for and show positive emotions during interaction with their human caregiver. Moreover, the documented preference to interact with technologies and robots might in any case not necessarily be applicable to all children on the autism spectrum.

13.4.2 Limitations of Human Therapy

Human therapy is not perfect, it also has weaknesses in improving and teaching social skills of/to children on the autism spectrum.

Humans are prone to errors and mistakes, in general and in their professional conduct. Therapy for children on the autism spectrum usually implies a strict predesigned therapy program human interventionists must follow; this design allows interventionists to target the same behavior of the client and to identify the exact cause for possible difficulties or delays of the progress of the client, to apply the therapeutic principles (that are grounded in scientific studies (e.g., Skinner (1938)) in a coherent manner across different interventionists and caregivers that would ensure the best outcome, and to systematically improve the behavior of the client to minimize the effort and the anxiety the client might feel in association with the teaching process. Repetitively applying therapy principles requires increased monitoring of one's own behavior and not just the behavior of the child. This process e.g., includes the allocation of required personal resources for therapy activities that the interventionist may not always be able to provide, due to general mood, well-being, personality, external influences, etc. Moreover, newly trained interventionists in particular make mistakes at the beginning of their professional career that might set back the evolution of the person on the autism spectrum. Such issues can e.g., be related to faulty application of therapy guidelines, failure of identifying targeted behaviors, or a lack of automation of applying principles in a fast and correct manner. If not detected and addressed, e.g., because of poor supervision or lack of communication with their colleagues, the effects of their professional misconduct may have long-term consequences for the professional career of the interventionist and the progress of the client.

Generally, after an autism diagnosis, the child needs a team of therapists to help them develop different skills. Such teams include hospital and community services, as well as speech and language therapists (Lavelle et al., 2014). The costs of therapy are high, depend on the severity of the autism diagnosis and increase with the age of the patient (Barrett et al., 2012). In Europe, the economic burden of Autism Spectrum Disorder is substantial; for example, in UK, annual costs for children on the autism spectrum increase with age (2–3 years: £6,815; 4–17 years: £29,767; ≥18 years: £49,804) (Taneja, Sharma, Bhatt, & Bhutani, 2017). In the USA, families with children on the autism spectrum spend $3020 more on health care, $14 061 more on non-health care, and $8610 more on school than a family with a child that is *not* on the autism spectrum (Lavelle et al., 2014).

13.4.3 Benefits of Robot Therapy

Robot therapy also holds specific potential and actual strong points in improving and teaching social skills to children on the autism spectrum.

Costescu, David, Dobrean, Liu, et al. (2014) identify in their EU H2020 DREAM project (cf. Section 13.1 The EU H2020 DREAM Project) some advantages of robot-mediated therapies: Robots present the same information repeatedly without fatigue, maintaining the same presentation format—which may improve the chances of the person on the autism spectrum to understand the task. Robots can be programmed to gradually increase the difficulty and complexity of a task in an accurate manner. Robots are predictable, controllable, and can be programmed to train a wide range of social and communication behaviors. The positive influence of the robot therapy for children on the autism spectrum has been stated also by Bekele et al. (2014), Chevalier et al. (2017), and E. S. Kim et al. (2015), the latest sustaining a positive influence especially for low-functioning children on the autism spectrum.

Another assumed advantage of robot therapy is that robots might teach social skills at a significantly lower cost compared to human therapy. Rabbitt, Kazdin, & Scassellati (2015) state however that the cost of these robots vary considerably, depending on the robotic form. To give an example, Rabbitt et al. explain that a system designed in a laboratory may cost tens of thousands of dollars, but adapting commercially available toys is often significantly less (e.g., several hundred dollars). Moreover, there are other costs associated with implementing the robot-therapy: programming the robot, maintenance, repairs, and training clinical staff to use the robot etc. While these cost-related concerns are valid, Rabbitt et al. conclude from literature (e.g., Jason & Ferrari (2010)) that the cost of living with a mental disorder is placing a huge financial burden on the individual and the society. Please refer to Subsection 13.4.2 Limitations of Human Therapy for additional information on the costs of living (therapy included) for persons on the autism spectrum. Systematic analyses are necessary to include all factors that allow for a comparison between the costs of human therapy and the costs of robot therapy for persons on the autism spectrum, but preliminary results point to the lower costs of robot therapy.

Children participants on the autism spectrum seem to display more frequent (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a) and more intense positive emotions (E. S. Kim et al., 2015) and more frequent adaptive behaviors (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a) in the robotic condition than in the human condition. Examples of positive emotions are that the child laughed, smiled and was enthusiastic while interacting with the robot. One example of adaptive behaviors is given by Costescu, David, Dobrean, Matu, & Szentagotai (2015a) in Deliverable 2.1.2 of the DREAM Project: as a response to the novelty of the robot in the therapy; children on the autism spectrum sought more often than in the human condition the attention of the adult mediator. Likewise, Dautenhahn et al. (2017) also report in Deliverable 6.1. of the BabyRobot Project that a child on the autism spectrum (out of 3) started interacting verbally with both, the robot and the human interventionist.

13.4.4 Limitations of Robot Therapy

Robot therapy also has weak points regarding the targeted improving and teaching social skills of/to children on the autism spectrum.

Before discussing some key scientific and technical issues, it is important to document that there are numerous fundamental ethical issues that have to be addressed before promoting any robot-based therapy. S. G. Tzafestas (2016) covers several of these ethical issues that have to be discussed when investigating scenarios in which humans interact with socially assistive robots: Even and in particular also in otherwise successful deployments, it must not be overlooked that children and elder people in particular may feel anxious when the robot is removed from the environment because of degradation or technological failures (*attachment/ personification issue*). The person interacting with the robot might think that the robot can assist them in all the ways a human can (*deception issue*). Users must be fully informed about the practical limitations and the benefits of the robot (*awareness issue*). The autonomy of the user and the robot should be balanced in the interaction (*authority issue*). The robot might wrongly perceive persons as authorized to receive the client's personal information (*privacy issue*). Interaction with a socially assistive robot might lead to lower time spent in the interaction with a human (*human-human interaction issue*). Finally, responsibility in case of harm during the interaction must be clear at all times (*justice and responsibility issue*). Prof. Peschl (see also 2.1 Analysis of the Meeting with a Computer Scientist) also explicitly advised that researchers should first investigate the effects of a robot-mediated therapy to minimize the ethical issues that arise in the direct robot-human interaction.

Turning to scientific issues, the manner of interaction of the robot may not match the interactional needs and the manner of interaction of children on the autism spectrum. In the DREAM project's Deliverable 2.1.2, Costescu, David, Dobrean, Matu, & Szentagotai (2015a) explain that children participants on the autism spectrum with a high baseline of imitation skills might not benefit more from RET (Robot Enhanced Therapy) than from SHT (Standard Human Therapy), exactly because of the predictive and stereotype manner of interaction of the robot that has been also identified as an advantage in the previous subsection. Here, the authors propose that participants did not engage significantly with the robot because they were bored by the predictive robotic manner of interaction. In addition to the breadth of competence, sufficient skillfulness of the robot is also an issue: Costescu, David, Dobrean, Matu, & Szentagotai identified the possibility that participants presented an increased number of maladaptive behaviors during RET because of the overly slow manner of interaction of the Nao robot employed in their empirical study (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a).While, as discussed in Section 13.2.5 Personal Analysis and Conclusion, some interpretations offered in the literature are faulty, it still is very important to further investigate the idea that the predictive, slow, and stereotypical manner of interaction of a robot has significant negative impact on aspects of the social interaction dynamics of a child on the autism spectrum. Also, Dautenhahn et al. (2017) conclude in Deliverbale 6.1 of the BabyRobot Project that the design of the program controlling the robot's interaction should be both structured and highly flexible, in order to support sustained interaction: The resulting picture thus is that it may be important for the robot to be able to interact in *both*: a repetitive and stereotype manner to make the child feel safe, and a flexible manner of interaction to sustain engagement of the child on the autism spectrum to the interaction.

Possible technical issues of the robot are crucial aspects to consider in the interaction with children on the autism spectrum. Reported technical issues come from Dautenhahn et al. (2017) in the BabyRobot

Project. Authors point out the importance of robust speech recognition capabilities of the robot to be able to cope with individual characteristics of speech of children on the autism spectrum, such as grammatical errors or pronunciation issues. Moreover, the robot must be able to accurately track the highly unpredictable behavior of children on the autism spectrum, in order to detect and “understand” it. Yet another class of considerations regards technical failures, as appeared during the interaction that delayed the reactive system of the Nao robot in the social interaction (Costescu, David, Dobrean, Matu, & Szentagotai, 2015a). Technical breakdowns can occur at critical moments, e.g., when the child has a sensorial breakdown. It is very important that such issues are addressed first-hand, and until they can be safely excluded, a human interventionist needs to be always present in the therapy room.

13.5 Implications for RQ2

In this chapter, I have presented methodologically limited quantitative and qualitative results about the effectiveness and efficacy of robot and human therapy in teaching and improving social skills in children on the autism spectrum and about the skillfulness of human and robot interventionists at teaching social skills. In particular, my analysis discussed limitations and benefits of human and robot therapy. I integrated preliminary results of the current DREAM and BabyProject European Projects, results of recent studies, and anecdotal evidence from my personal experience as a behavioral interventionist working with children on the autism spectrum. I discuss in this section the implications of the presented findings and conclusions for the RQ2.

Regarding my hypothesis H2a), I assumed that Human interventionists are more effective than social robots in increasing the performance level of social skills of persons on the autism spectrum. Given the low number of selected publications and the identified limitations of the selected publications, I could not provide a conclusive evaluation. However, evidence points to a similar performance of the social interaction abilities of persons on the autism spectrum after receiving robot- and human-therapy. Similar to Experiment 1 in the DREAM Project, Bekele et al. (2014) and Yun et al. (2017) also compare the social performance of the participant on the autism spectrum after receiving robot and human therapy, but there are methodological differences between studies. Yun et al. (2017) investigated facial expression recognition and eye contact, while Costescu, David, Dobrean, Matu, & Szentagotai (2015a) investigated imitation, turn-taking and joint attention, and Bekele et al. (2014) targeted the ability of participants on the autism spectrum to follow verbal and eye gaze to identify an element in the environment provided, after receiving prompts from a robot and a human. Bekele et al. (2014) and Costescu, David, Dobrean, Matu, & Szentagotai (2015a) both implemented the Nao robot to interact with participants, while Yun et al. (2017) changed the robot (iRobiQ, then CARO) within the block of sessions, but this aspect did not influence the performance of participants on the autism spectrum. Yun et al. (2017) analyzed the results of the highest number of participants (i.e., 15) aged between 4 and 7 years, followed by Bekele et al. (2014) with 6 aged between 2 and 5 years, and finally Costescu, David, Dobrean, Matu, & Szentagotai (2015a) with 5 aged between 3 and 5 years. Although the number of participant differs, the studies analyzed and published the results of participants within the same age range. Besides methodological differences, there are methodological limitations. For a full description of the discussed limitations, please see the Methodology, Results and Discussion sections pertaining to Section 13.3 Further Studies. The general result across studies is that persons on the autism spectrum present similar levels of performance of their social skills (i.e., eye contact, recognition of facial emotion expression, turn-taking and joint attention, following eye gaze) after receiving robot-therapy and human-therapy. The exceptions were for the level of imitation skills and level of prompting for following eye gaze, with higher levels of imitation skills after receiving human therapy and higher levels of prompting in the robot condition. A final important point to make is that human-therapy only I found to be associated with optimal outcome in persons on the autism spectrum.

To compare the results of my review with the results of others in the literature, I discuss now the systematic review by Pennisi et al. (2016), whose results agree with the set hypothesis H2a). Pennisi et al. attempted to answer the question of whether social robots can be an effective tool in autism therapy: The review was authored by PhD students in cognitive science and clinical physiology and by PhD graduates in clinical physiology, bioengineering, child and adolescent neuropsychiatry, medicine, and robotics. There is no information mentioned about the stakeholder's interest. 28 studies published between 2005 and 2014 were reviewed. The chosen eligibility criteria consisted in studies with original experiments (surveys and theoretical studies were explicitly excluded), studies with a group on the autism spectrum, and a minimum sample size of the participants on the autism spectrum of 3. Such small sample size of course does not allow for parametric data analysis, and Pennisi et al. consequently state their findings to serve as hypotheses for further investigations. Another limitation of the eligibility criteria employed is the inclusion of studies without a control group. After reviewing the total of 28 studies that compare robot- therapy effectiveness with the one of human-therapy with regard to improving social behavior, imitation, joint attention, and frequency of repetitive behaviors, Pennisi et al. conclude that participants on the autism spectrum often presented a better performance in the robot condition than in the human condition. In particular for social behaviors (i.e., eye contact, manipulation, and touch), a number of eight out of sixteen studies report that in some experimental conditions a robot is better than a human interventionist to improve social behavior in children on the autism spectrum. A problem Pennisi et al. observed in all reviewed studies is that they did not employ a large number of subjects; twenty five studies had a sample size between four and six participants. Also, a total of two out of four studies showed that children on the autism spectrum improved their performances in joint-attention tasks in the robot condition. Finally, four out of six studies showed that children on the autism spectrum improved their performances in imitation tasks in the robot-condition. My own analysis included evidence from two European Projects H2020 and two articles targeting the effectiveness of human and robot therapy with regard to improving social skills in children on the autism spectrum, while Pennisi et al. analyzed the higher number of 26 studies in total; in addition, the publications covered by Pennisi et al. do not appear to suffer from validity issues such as I encountered. Both our analyses found the sample sizes of the groups to be small. Given the higher number of studies reviewed by Pennisi et al. and the more rigorous inclusion criteria for selection of studies, I believe the review of Pennisi et al. to be more comprehensive and more representative of the state of the art of the literature about the effectiveness of robot therapy for improving social skills for persons on the autism spectrum than the review I presented.

Related to my hypothesis H2b), I assumed that Human interventionists are more skillful than social robots at teaching social skills to persons on the autism spectrum. The hypothesis is confirmed. The current technological status of assistive robots does not match human social abilities. One example is that humanoid robots do not have the physical mobility of humans, and therefore most robot therapies take place at a table, which can limit the acquisition and generalization of skills because typical human-human interaction does not take place only at the table. The human-human interaction is dynamic, natural, fast and automatic, and humans understand and communicate social cues through bodily interaction: During face-to-face social interaction, the trained human interventionist quickly adapts to the changing needs of the child, interprets subtle social and emotional cues of the child, and is able to deal with breakdowns or hyper/hypo-reactive responses to sensorial cues. In contrast, robots interact in a highly structured manner, which can provide the child on the autism spectrum a safe and predictable environment, but can also bore the child; in addition, some children on the autism spectrum have difficulties understanding the robot's behavior. It is perhaps due to these reasons that as Richardson et al. (2018) put it, persons on the autism spectrum actually prefer to interact with other biological beings, especially humans, rather than with robots. Moreover, the persons on the autism spectrum are not always open to interact with robots. Dautenhahn et al. (2017) did present in Deliverable 6.1 of the BabyRobot project that children on the autism spectrum had different reactions towards the Kaspar robot, with some being reluctant and others open to interact from beginning.

Related to my hypothesis H2c), I assumed that Social robots are more efficient than humans in teaching social skills to persons on the autism spectrum. The hypothesis is confirmed. Human interventionists make mistakes during therapy and take time to learn the therapy procedures, which can delay the progress of the child. In comparison, it should be possible for the robot interventionist to be programmed to teach specific behaviors in a regular and consistent manner. However, reality differs, because next to significant open challenges in computational cognitive modeling and programming, robots can also present technical failures during interactions. In conclusion, H2c) can be accepted, *with the remark* that engineers should further improve the software of a robot to reduce breakdowns in the interaction.

13.6 Suggestions for Future Implementations of Robot-therapy for Children on the Autism Spectrum

My findings presented in this chapter are merely indicative, but they provide a concrete basis to orient further investigations in the field. Based on these findings, I make in this section suggestions for engineers when building robots for therapeutic purposes and for therapists when designing robot therapies for persons on the autism spectrum.

There are technical issues engineers should address to improve the potential of robots in the person on the autism spectrum-robot interaction, such as the robot displaying real-time movements or higher flexibility and repertoire of social behaviors. In general, to interact in a more flexible and a completely autonomous manner with a person on the autism spectrum, a robot must be prepared for high-risk high-consequence social interactions. Chevalier et al. (2017) recommend robots to be equipped with a module for online detection of the sensorial profile of persons on the autism spectrum, since their study shows that performance of persons on the autism spectrum differs according to specific sensorial profiles. The seminal work of Scassellati (2001) also provides guidelines for engineers for building robots that are capable of autonomous interaction that I believe to be important for any future attempts of engineers to construct robots that are embedded in the real-life human social interaction. For example, a robot must react in real time and with insignificant latency to social cues (Scassellati, 2001, p. 22): this agrees with how, as discussed in Section 7.3 Participatory Sense-Making and Autism, De Jaegher (2006) stresses that interaction rhythm is crucial for successful social interaction. Another provided guideline by Scassellati is that the perceptual system of the robots must recognize the relevant, at least basic, multimodal, and invariant social structures in an instructional social context. In addition to recognizing important social cues, the robot must be able to produce the expected social responses that can be recognized and interpreted by humans through a socially appropriate appearance and conduit. However, the appearance of the robot must also reflect its capabilities, so as to not lead other social agents to expect more from its functionality than possible (Scassellati, 2001, p. 22).

Until further technological advancements allow robots to interact in an autonomous and free manner, I suggest the role of a robot should be at most a *therapy aid*: The robot should teach a limited number of skills to persons on the autism spectrum to allow the child to practice skills, but the majority of teaching should be done by the human interventionist. After exercising with the robot, a human interventionist should embed and practice the targeted skills in the natural context of the social context. Another role of the robot I suggest is that of an *interactive social toy*, motivating interactions between human interventionist and the client on the autism spectrum. The human interventionist can take advantage of social behaviors displayed by the robot to, e.g., prompt the child to imitate the behavior of the robot, teach additional skills in relation to the displayed behavior, or embed the behavior of the robot in the proper and natural context in which both the robot, the client, and the interventionist can further their interactions. Nima Taheri-Nejad (cf. Section 2.4 Analysis of the Meetings with an Electrical and Computer Engineer) likewise suggested that robots should not fulfill a major role in the therapy, and identified some possible useful roles: as permanent aid (i.e., to ease the interaction of persons on the autism spectrum with the "world of persons with typical development"), therapeutic tool (i.e., as interpreter of the behavior of the child on the autism spectrum and translator to facilitate the understanding of persons with typical development of the "world of persons on the autism spectrum"), and as data collector of the behavior of the child.

14 Rhythm and Behavior Therapies

This chapter is the second part of my discussion about therapies aimed at improving social skills for persons on the autism spectrum. In this chapter, I discuss characteristics, limitations, and benefits of the rhythm and behavioral human therapies for persons on the autism spectrum. This chapter deals with RQ3 and the hypothesis H3) Persons on the autism spectrum present a larger improvement of social skills after receiving rhythm therapy than after receiving behavior therapy. This hypothesis could not be ultimately assessed because I did not find publications that compare the effectiveness of rhythm and behavioral therapy *in one experimental design*. Search criteria included: Search Platform Google Scholar (first 5 pages); keywords: “autism”, behavioral therapy”, “rhythm therapy”, “effectiveness”; timeframe 2014- 2018. The resulting picture is that behavior therapy is effective in improving social skills for children on the autism spectrum, but the effectiveness decreases with increasing age of participants. Another finding is that dance and music therapy are also effective in improving social skills, but the evidence assessing music therapy is conflicting.

14.1 Rhythm Therapy

In this section, I describe principles of music and dance therapy, representative of rhythm therapy, and I report published evidence assessing the effectiveness of rhythm therapy for improving social skills in persons on the autism spectrum. By the term *rhythm therapy* I refer to the therapy that targets the development of rhythm flexibility during social interaction or that supports the development of social skills by engaging in rhythmic interactions.

De Jaegher (2006) recommends among others, rhythm therapies to be suitable for increasing the flexibility of the social interaction rhythm of persons on the autism spectrum. To recapitulate, the works of De Jaegher (2006, 2013) and De Jaegher & Di Paolo (2007) investigate how people understand each other by coordinating their individual sense-making according to a particular social rhythm. Unmatched interactional rhythm between the social agents leads to uncoordinated individual sense-making in a social interaction, which in turn impacts the quality of social interaction. De Jaegher (2006, 2013) argues that persons on the autism spectrum present a different interactional rhythm and a reduced interactional flexibility than persons with typical development. Given its principles and its aims, it is hypothesized rhythm therapy to increase the flexibility of the social rhythm of persons on the autism spectrum, which in turn would support successful interaction with persons with typical development (De Jaegher, 2006, 2013). However, given that this therapy does not directly target rhythm flexibility, but rather synchronous rhythmic social interaction, which is documented to be its fundament (see Subsection 14.1.1 Presentation of Dance Movement and Music Therapies), it is not obvious that any measured effectiveness of dance and music therapies (taken in this master thesis as examples of rhythm therapies) should necessarily be due to an increase in rhythm flexibility.

14.1.1 Presentation of Dance Movement and Music Therapies

In this subsection I analyze the rhythm therapies: dance and music therapy.

Dance Movement Therapy (DMT) is an embodied treatment approach that focuses on imitation of the social agent's motor behavior to build a social relationship (McGarry, 2011). According to Koch, Mehl, Sobanski, Sieber, & Fuchs (2015), the aim of DMT is to improve attunement abilities and to develop advanced forms of intersubjectivity, such as self-other distinction. Koch et al. describe principles and procedures of DMT: The therapist mirrors non-stereotypic behavior of the client, which is assumed to increase social awareness in the client of the contingencies between their behavior and the therapist's behavior, which in turn increases the possibility the client synchronizes with the therapist. Synchrony is defined in the context of DMT as a general movement coordination, and mirroring is done through *attunement*—synchronous movement—and *disruption of attunement*—different timing in movement.

Music therapy incorporates various musical approaches and programs in a therapeutic format, including instrument playing, movement to the beat of the music, musical composition etc. American Psychological Association (2015) states that music therapy represents "the use of music as an adjunct to the treatment or rehabilitation of individuals to enhance their psychological, physical, cognitive, or social functioning. Music therapy involves singing, writing music, performing music, listening to music, and lyric analysis, among other techniques." (ibid, p. 681). Musical engagement presupposes interplay of emotions, senses, and cognition, which supports a dynamical interaction between the body, mind, and the environment (Maes, Leman, Palmer, & Wanderley, 2014). In music therapy, therapists apply the concept "musical attunement", which is the moment-by-moment use of improvised music that is sensitive to the child's body and mind expression (J. Kim, Wigram, & Gold, 2008). The therapist matches the child's rhythmic movements and dynamic forms of expression until a shared musical foundation between the therapist and the child is established (J. Kim et al., 2008). The established foundation encourages the child to initiate or join in the musical activities (J. Kim et al., 2008). Musical interactions become synchronized and regulated through timing coherences, melody form, and intra- and inter-subjective intensity (Schumacher & Calvet, 2008).

14.1.2 Evaluating the Effectiveness of Rhythm Therapy

Koch et al. (2015) investigated the feasibility of a dance movement therapy based on movement mirroring. Koch et al. hypothesized that DMT improves well-being, body awareness, self-other distinction, empathy, and social competence in persons on the autism spectrum. To the study, 31 young high- functioning adults on the autism spectrum (23 men, 7 females; mean age of 22 years) participated. Participants were diagnosed with high-functioning autism or Asperger's syndrome according to the International Classification of Diseases, 10th Revision (ICD-10) (World Health Organization, 2010). Authors did not exclude from the study participants with co-morbidities or participants taking medication. Participants were recruited according to the method of convenience sampling. The therapy was applied 1h per week for 7 weeks.

Participants were assigned to one of the two groups: treatment or experimental group (EG; n=16) and control group (CG; n=15) according to their sex, age, and severity of diagnosis. The groups were taught by the same therapist and co-therapist. The therapy program consisted in 7 sessions of 1h each applied weekly. In the intervention group, exercises consisted in a warm-up exercise (about 10 min), dyadic movements in which participants lead and followed the Leader of the interaction (15-20 min), baum- circle (Baum, 1991) during which a person‘s expressive movement is imitated in attunement by the rest of the group (20 min), and a verbal processing part during which participants set down and reflected on their experience (10-15 min). Out of 16 participants in the intervention group, 10 attended all seven therapy sessions. The control group did not receive any intervention, but completed the same pre- and posttest questionnaires applied also to the intervention group. The applied questionnaires investigated psychological well-being, body awareness, self-other awareness, empathy, and social skills. Therapists also completed questionnaires evaluating the mirroring modalities behavior (i.e., modal and counter movement) of participants in the intervention group, as formulated by Eberhard-Kaechele (2012).

Univariate ANOVA analysis revealed significant difference between treatment and control group, with participants in the treatment group presenting a higher performance on well-being ($F(1, 27) = 2.95$, $p = .049$, $d = .63$), body-awareness ($F(1, 29) = 2.95$, $p = .049$, $d = .62$), self-other awareness ($F(1, 28) =3.93$, $p = .029$, $d = .72$), and social skills ($F(1, 29) = 3.49$, $p = .036$, $d = .67$). There was no significant difference for empathy. The size effects of the results is medium to large (between .61 and .91). The majority of participants reported experiencing an enjoyable and entertaining time during the therapy sessions and a preference to continue the therapy, if possible. The results of the questionnaire filled by therapists indicate the majority of participants used predominantly modal mirroring (i.e., in-phase synchronization). Participants lead and followed the interaction in an equal manner. Koch et al. (2015) report that limitations of the study are the reduced power of the test; the lack of clinical randomization of the participants; that participants were not blinded to the intervention; the use of self-reports scales for participants on the autism spectrum; and that the mirroring variable was not controlled to evaluate whether this variable only lead to significant differences in skills. Even so, Koch et al. conclude that DMT is a feasible therapy program that improves body awareness, self-other awareness, psychological well-being, and social skills in persons on the autism spectrum.

Another publication that evaluated the effectiveness of rhythm therapy is the meta-analysis of Li (2016). In this meta-analysis, inclusion criteria comprised, among others of the guidelines: that the selected study investigated the effectiveness of music therapy for children on the autism spectrum diagnosed according to the DSM-5, DSM-IV, or ICD-10 criteria and aged up to 21 years; that studies had a control group with participants on the autism spectrum or a within-subject crossover design; that the dependent variables targeted psychological processes reported in the description of the autism diagnosis symptomatology; and that the study was published between 2004 and 2016. A total of 11 studies were analyzed that included 229 participants. The intervention lasted 30 min and 50 min, and it was administered for up to 20 weeks. The results of this meta-analysis corroborate that music therapy is an effective intervention for children on the autism spectrum, with an average effect size that was medium to large (d =.73). Li observed music therapy as especially effective for improving the level of nonverbal communication skills (d = .67), followed by verbal communication skills (d = .55). In contrast, music therapy was not found to have any significant impact on social skills. However, Li acknowledges that the small number of covered publications targeting specific skills may have influenced the results. Another limitation of the study is the reduced allowed lower limit of the sample size of just 3 participants accepted in this meta-analysis.

The final publication is the review of James et al. (2015). Authors also reviewed the effectiveness of music therapy for improving skills in persons on the autism spectrum. The inclusion criteria of their meta-review comprised of experimental or quasi-experimental design and a minimum sample size of 1. James et al. cover publications from the period between 2004 and September 2013. A total of 12 studies was included in the meta-analysis. Most studies were found to report positive outcomes of music therapy for some participants on the autism spectrum regarding communication and social interaction, with the remainder reporting mixed outcomes. No study reported negative outcomes. Most studies focused on an early age of the participants, and only a single one on an adult population. A methodological limitation of the studies covered is the lack of reporting of treatment integrity data or follow-up procedures of the treatment, such as generalization or maintenance: Future studies should aim for fuller coverage of the age range and provide more detailed information, such as language impairment, diagnosis severity, and IQ of the participants.

14.1.3 Personal Analysis and Conclusions

In the previous section, I presented studies discussing the effectiveness of Dance Movement Therapy (DMT) and Music Therapy. De Jaegher (2006) hypothesizes that persons on the autism spectrum present a different social rhythm than persons with typical development, which directly affects the coordination of sense-making of the individual worlds. Rhythm therapies might target the development of rhythm flexibility in a social interaction. The resulting picture is that dance therapy is effective for improving social skills in verbal persons on the autism spectrum and in persons diagnosed with Asperger.

Koch et al. (2015) conclude that DMT improves body and self-other awareness, psychological well-being, and social skills in persons on the autism spectrum. Evidence evaluating the effectiveness of music therapy presents conflicting results. The meta-analysis of Li (2016) reported that music therapy is not effective for improving social skills, but the review of James et al. (2015) reported positive outcome in the area of social interaction in 7 out of 12 studies. Li and James et al. selected publications from the timeframe between 2004 and 2016, 2013 respectively for James et al.; it follows that the meta-analysis of Li is more recent and it is expected to include more recent results published in the literature. Both studies evaluated a high number of publications: Li included 11 publications in the analysis, while James et al. included 12. Limitations of both study analyses is the low inferior limit of the sample size (1 for James et al. (2015) and 3 for Li (2016)), which makes it impossible to generalize the results of these studies to the targeted population of persons on the autism spectrum. Both studies report an on-going need for more rigorous experimental designs (e.g., randomized control trials) and follow-up effects of the treatment (e.g., generalization and maintenance).

The general impression is that music and dance therapies are effective therapies for increasing social skills in persons on the autism spectrum. However, it can be observed that there is a high need for more rigorous experimental designs, and for a higher number of studies addressing the effectiveness of rhythm therapy. Over a range of around a decade, only about a dozen studies were found to be eligible for the inclusion criteria of the analyses of the analyses of Li (2016) and James et al. (2015).

14.2 Behavior Therapy

I describe in this section principles of the behavior therapy and analyze evidence assessing the effectiveness of this therapy for improving social skills in persons on the autism spectrum. I chose to discuss Behavioral Therapy because therapy models based on Applied Behavioral Analysis (ABA) have proven to be effective interventions in fields such as education, clinical psychology (for persons with developmental disorders such as Autism Spectrum Disorder), behavioral medicine, organizational behavior management and because of its strong focus on social impact (i.e., solving socially important problems in socially important settings) (Slocum et al., 2014). Another reason is related to my experience as an interventionist applying principles of Applied Behavioral Analysis in my work with children on the autism spectrum, which allows me to provide first-hand and relevant feedback and suggestions. The resulting picture is that behavioral therapy is effective for improving social skills in young children on the autism spectrum, but the effectiveness of the therapy decreases with increasing age of the client.

14.2.1 Presentation of Applied Behavioral Analysis Therapy

Applied Behavioral Analysis (ABA) is a psychological intervention that can be applied to analyze human behavior to understand and influence it. ABA is based on the seminal work of Skinner (1938), who documented that the frequency of appearance of a behavior is influenced by its consequences. Skinner observed on animals that when a preferred consequence (i.e., reinforcement) follows a behavior, then the likelihood of appearance of that behavior increases, and when a disagreeable consequence follows a behavior (i.e., punishment), the likelihood of appearance of the targeted behavior decreases. The Behavior Analyst Certification Board[2] (2012) (BCBA) define ABA as "the design, implementation, and evaluation of instructional and environmental modifications to produce socially significant improvements in human behavior" (ibid, p. 3). ABA interventions are based on the direct observation and measurement of behavior and its environmental context. According to BCBA, ABA implements the practice of *functional assessment and analysis* of the functional relations between the behavior and environmental factors, that consists in identifying contextual factors, motivating operations, antecedent stimuli, positive reinforcement, and other consequences (for a detailed explanation of some of these terms, please see Appendix F Glossary of Terms of the Applied Behavioral Analysis Intervention) to help people develop new behaviors, increase or decrease the frequency of appearance of existing behaviors, and increase the frequency of appearance of new behaviors under specific environmental conditions. BCBA reports that "the practice of behavior analysis expressly excludes psychological testing, diagnosis of a mental or physical disorder, neuropsychology, psychotherapy, cognitive therapy, sex therapy, psychoanalysis, hypnotherapy, and long-term counseling as treatment modalities" (idem). An important component in ABA is *data collection and analysis* (Cooper, Heron, & Heward, 2014): The interventionist must document the observed behavior of the client, the consequences and antecedents of the behavior for further analysis.

[2] https://www.bacb.com/about-behavior-analysis/ - last accessed 18.09.2018

ABA has been especially applied to toddlers to increase the performance at later developmental stages. Early Intensive Behavioral Intervention (EIBI) is an intensive therapy for young children that applies the principles of behavioral analysis to increase skills (e.g., imitation, language, motor skills, and social skills) and to decrease stereotypic behavior (MacDonald, Parry-Cruwys, Dupere, & Ahearn, 2014). EIBI was first implemented by Lovaas (1987) and constituted of up to 40h of one-to-one therapy per week for the duration of 2-3 years (Smith, 2011). The EIBI program implemented by Lovaas (1987) focused on Discrete Trial Teaching (for an explanation of the term, see Appendix F Glossary of Terms of the Applied Behavioral Analysis Intervention, term 1)), which focuses on a repeated and fast manner of teaching, using a specific instruction, and minimizing unnecessary contextual details (Roane, Fisher, & Carr, 2016). For example, the child has in front of them a set of three pictures, the instructor says “Touch the car”, and if the child touches correctly the picture of a car, the instructor reinforces the child verbally and/or gives access to a preferred item; if the child does not respond or responds incorrectly, the instructor gives feedback (e.g., “Try again”), then presents the instruction again and offers the child a prompt to respond correctly. In other words, the instructor reinforces correct responses and ignores or punishes other behaviors by increasing the time spent in the task.

14.2.2 Evaluating the Effectiveness of Behavior Therapy

Makrygianni et al. (2018) investigated in a meta-analysis the effectiveness of ABA therapy in improving IQ, receptive and expressive language, and adaptive behavior for children on the autism spectrum. 29 publications were included that evaluated interventions applying ABA principles and intervention techniques, rather than specific ABA treatments; used an experimental or quasi-experimental design; included a sample of children diagnosed with autism spectrum, with PDD, or PDD-NOS (the reference for diagnosis criteria is not mentioned); provided child assessments on at least one of the targeted skills for participants on the autism spectrum; used specific standardized or non-standardized intelligence, language, and adaptive tests; provided both pre- and post-treatment assessments; and the minimum duration of the treatment was of seven months. The publication period of the studies was between 1987 and 2015. The results in Makrygianni et al. indicate that ABA interventions are very effective in improving intellectual abilities; moderately to very effective in improving communicational and receptive and expressive language skills; and moderately effective in improving IQ scores evaluated as non-verbal abilities, in adaptive behavior, and socialization. These results are in line with the results reported previously in the literature. One out of the three tests applied to evaluate potential publication bias obtained significant results with regard to the adaptive behavior (socialization included) and the IQ scores provided by verbal tests. Publication bias constitutes a major threat to research validity because of a tendency to accept studies that report significant effects and to reject findings with inconclusive or insignificant results (Rothstein, Sutton, & Borenstein, 2005). Makrygianni et al. report a high variability of the methods used for applying ABA therapy, which poses a particular challenge for their evaluation. This particular meta-analysis is the only one published since 2012 to evaluate the performance of participants both before and after the treatment; it also evaluates the largest number of studies (i.e., 29), and analyzes a large number of variables of the treatments (i.e., 8 variables). Mentioned limitations of the meta-analysis of Makrygianni et al. are: the reduced sample size of the selected publications (i.e., between 4 and 29 participants), no randomized controlled trials, reduced homogeneity of the studies (e.g., differences in age and characteristics of participants, parental involvement etc.), no inclusion of a control group in the studies, and lack or a reduced number of studies that investigated specific targeted behaviors of the child performance.

MacDonald et al. (2014) evaluated the effectiveness of EIBI aimed at improving cognitive skills, joint attention, play and stereotyped behavior skills in 83 children on the autism spectrum aged of 1 to 3 years of age. The study assesses changes in performance evaluated pre- and post-treatment as well as according to the age-appropriate typical development, using a direct observation tool called ESAT (MacDonald et al., 2006). ESAT consists of video assessments of behaviors that are considered developmental milestones (i.e., joint attention initiation and responding) and are measured as performance to tasks such as *following a point to pictures* (i.e., the examiner points to a single picture in the page of a book, and the child participant must look at the picture for 5s), *response definitions* (i.e., the child looks at the object pointed by the experimenter within 5s), *toy activation task* (i.e., the experimenter turns on a mechanical toy placed out of reach for the child participant and observes the child participant if he/she observed the toy for 15s and 5s after the mechanical toy is turned off), *book presentation task* (i.e., the experimenter presents the child with a book, and asks him/she "What do you see?"; the child is observed while looking at the pictures in the book for 20s) etc. All children were enrolled in an EIBI treatment program employed both in individual and in group teaching. Targeted skills included social skills, such as eye contact in response to being named, waiting, imitation, and joint attention. Children received between 20 and 30 hours of EIBI per week and were evaluated pre-treatment and post-treatment (at 7 and at 15 months). The ESAT subtests consisted of: one test evaluating eye contact ability in response to name calling; 3 tests evaluating joint attention initiation; 3 tests evaluating responding to a gaze shift or a point, 4 cognitive tests; and a 5 minutes free play session. The results report that 1-year olds presented the largest changes in general performance, followed by the 2-years old, and finally the 3-years old children. Accordingly, MacDonald et al. conclude that better improvements after receiving EIBI can be achieved when children enter at a younger age (i.e., until their second birthday). 1-year olds presented an increase of performance in all targeted areas, but for stereotypy movements. 2-year olds presented an increase of performance in all areas except stereotypy and play. For 3-year olds and older there was only an increase of performance in responding with joint attention to pointing, eye contact, and cognitive performance. MacDonald et al. suggest that the structure of the play session (i.e., that the children were not prompted on multiple occasions to play appropriately with the toys) contributed to the lack of improvements for 2 and 3-year old participants: While children with typical development did not require more than one prompt ("It is time to play!"), more prompts should have helped children on the autism spectrum to sustain engagement during the play session.

14.2.3 Personal Analysis and Conclusions

Recent literature points to different degrees of effectiveness of ABA in relation to specific types of skills and the age of participants on the autism spectrum. A current representative meta-analysis shows ABA interventions to be highly effective for improving intellectual abilities, moderately to highly effective for improving communicational skills, and moderately effective for improving social skills. MacDonald et al. (2014) points to degrees of effectiveness of ABA according to age of participants at entrance of the therapy: the older the children, the less effective EIBI is. This study show an increased methodological rigor by explicitly reporting behavioral observations at pre- and post-treatment to evaluate performance, along with the use of absolute developmental references. In spite of around 30 years of research on ABA, the current methodological status of the experiments still lacks, for example a bigger sample size and randomized control trials to increase the strength of evidence about the effectiveness of ABA.

14.3 Benefits and Limitations of Rhythm and Behavior Therapies

This section discusses limitations and benefits of the rhythm and behavior therapy with regard to improving social skills for persons on the autism spectrum based on my professional experience as an interventionist working with children on the autism spectrum and based on the evidence reported in the previous sections.

14.3.1 Benefits of Rhythm Therapy

Considering the discussed limitations of Theory of Mind (see Section 7.1 Theory of Mind) and the proposal of the enactivist social theory that solves these issues (see Section 7.2 Enactivism Theory and Section 7.3 Participatory Sense-Making and Autism), one important benefit during rhythm therapy is that social interaction is characterized as interactional, dynamic, bodily, and situated. Since social interaction skills are core deficits of the symptomatology of the Autism Spectrum Disorder diagnosis, therapies that aim to improve the direct and bodily synchronization and social interaction between agents are essential. Examples of such therapies are music and dance therapy; they target important social processes: synchronization, (musical) attunement, and social awareness. In these therapies, the interventionist synchronizes with the client on the autism spectrum. The resulting synchronous movement initiated by the interventionist represents a foundation that encourages the client on the autism spectrum to initiate further social acts or to support the interaction. In support of this benefit of rhythm therapy, Hobson (1993) argues that "a conceptual grasp of the nature of 'minds'…is acquired through an individual's experience of affectively patterned, intersubjectively coordinated relations with other people" (ibid, p. 4–5).

Another benefit of the rhythm therapy solves an issue I encountered in my experience as an interventionist interacting with children on the autism spectrum. I personally experienced the documented unmatched social rhythm between a person with typical development and a person on the autism spectrum (De Jaegher, 2006) during my interaction with a child on the autism spectrum when I felt I was not able to socially "connect" with the child or to be on the same page; the interaction felt clumsy, difficult, and synchronous. Rhythm therapy targets the *whole bodily interaction* between social agents and has the potential to target and improve the flexibility of the social rhythm of the interaction between a person with typical development and a person on the autism spectrum in comparison to *individual social skills* (i.e., clear-cut social behaviors, such as waiting for one's turn in a game, or making eye contact) targeted by the behavior analysis.

14.3.2 Limitations of Rhythm Therapy

Rhythm therapy is not perfect, it also has weaknesses in improving social skills of persons on the autism spectrum.

One such limitation is related to the experimental design of rhythm therapy; it is difficult, perhaps impossible to evaluate whether there is a direct influence of therapy variables (i.e., the exercises that focus on the experience of participants on the autism spectrum) on the development of social skills, such as rhythm flexibility, social attunement, synchronization ability. For example, in Koch et al. (2015), authors cannot conclude whether the *Baum-circle* exercise yielded the greatest impact on the development of synchronous abilities of participants on the autism spectrum because the exercise included whole- bodily movements between the 16 participants of the intervention group that are difficult to analyze in a quantitative manner. In this case, the DMT could only be investigated as a whole. In general, it could be difficult for therapists to assess improvements in social synchronization abilities in a rigorous methodological design, other than subjective scales (as it was carried out in Koch et al. (2015)) because the targeted psychological processes of the rhythm therapy mostly arise out of the interaction between two social agents; and for these processes, the current scientific and methodological status of the literature does not provide sufficient methodologies to evaluate such complex social interactions in the live interaction, but only in a laboratory context. An important implication of these limitations is that it may be hard for interventionists to evaluate the level of improvement of social skills and whether to set up new therapy goals for the client.

14.3.3 Benefits of Behavior Therapy

Behavior therapy also holds specific potential and actual strong points in improving social skills in persons on the autism spectrum.

The hierarchical teaching manner of ABA therapy has the advantage that the client on the autism spectrum learns a basis of social skills that could support further interactions. For example, the person on the autism spectrum learns to say "Hello" to the new person that entered the room, which in turn could trigger further interaction from the social partner to ask "How are you?". Learning this basis of social skills may decrease the likelihood that the person on the autism spectrum feels uncomfortable when not acting appropriately in a typical social context. Another important benefit of ABA therapy is that it is a scientific practice and, thus, prone to improvements (J. Leaf et al., 2016) that focus more on the dynamical interaction between the person on the autism spectrum and the person with typical development and on the needs of the person on the autism spectrum.

14.3.4 Limitations of Behavior Therapy

Behavior therapy is not perfect, it also has weaknesses in improving social skills of persons on the autism spectrum.

ABA might not be best suited for teaching social skills to persons on the autism spectrum because it is *reductionist* of the social interaction phenomenon, meaning that the focus is only on individual and limited social skills and not on the whole process of social interaction, and as described in Section 7.2 Enactivism Theory and Section 7.3 Participatory Sense-Making and Autism, social interaction is an interrelationship. Literature also states that ABA programs put an emphasis on language, communication, and cognitive skills, at the expense of other developmental areas, such as social skills (Makrygianni et al., 2018). During my interaction with children on the autism spectrum, I observed that teaching social skills (e.g., response to name) to children on the autism spectrum, especially to the older ones (i.e., 6 years old) is different from teaching how to socially interact. An explanation for this aspect is possibly related to the hierarchical manner of teaching of ABA. The targeted behavior is broken down into smaller behavioral components and every subcomponent is taught until the targeted behavior is learned. However, the social interaction phenomenon as described by the enactive account (see Section 7.2 Enactivism Theory and Section 7.3 Participatory Sense-Making and Autism) is complex and hard to decompose into instances of behavior only. I also observed that the complexity of the social interaction context the child on the autism spectrum is situated in increases with age and cognitive development; this aspect makes it harder to apply ABA to teach increasingly complex social skills.

Although ABA is focused on individual social skills, and not on the social interaction phenomenon as a whole, it is expected from a good interventionist to have a specific “feeling” of the social interaction with the child on the autism spectrum, to anticipate the social ways of the child (aspect that can only be achieved within the synchronous and attuned social interaction) to guide the social interaction towards a positive one for the child. However, this “feeling” is not openly discussed within the framework of ABA.

The core element in ABA therapy is the reinforcement that increases the likelihood of appearance of the targeted behavior. Behavioral interventionists are trained to think first of the reinforcement of the behavior—which could be current interests and activities of the child—and then of the instruction or the skill to teach. It is often the case during ABA therapy (especially at the beginning of the therapy) that reinforcement is not related to the nature of the taught skill. Providing the child with a reinforcement that is not necessarily related to the social task at hand is unnatural because the child may associate the learned social behavior to a consequence that would not follow in the “real world”. Things are a bit different for naturalistic ABA programs, that embed the behavior in the natural environment and the reinforcement of the behavior is the natural consequence of the targeted behavior. However, simulating the real situation within the context of the therapy (that usually happens in a closed location such as the room of the child on the autism spectrum) is most of the time not possible or difficult to do. The positive outcome is that when the child’s progress increases, the child is not always reinforced for their behavior up to the point of not being reinforced at all. However, for the child on the autism spectrum to initiate and respond to social interaction without expecting a specific reinforcement is hard to achieve and may take years of practice.

Considering the information discussed in Section 7.3 Participatory Sense-Making and Autism, social interaction is a dynamic, on-going process that cannot be reduced to the three term contingency of DTT (antecedent-behavior-consequence) usually applied in the behavioral therapy. For example, when a behavioral interventionist assesses the antecedent and consequence of behavior, it does not consider the possibility that multiple cues could have triggered the behavior or could have increased the probability of appearance of the behavior. It is also often the case that persons on the autism spectrum have delayed reactions to events in the social environment, which obviously influence the evaluation of the association between the behavior, the antecedent, and the consequence.

14.4 Implications for RQ3

I presented so far in this chapter evidence discussing the effectiveness of rhythm and behavior therapy for improving social skills for persons and children on the autism spectrum. I discuss in this section the implications of the presented findings and conclusions for the RQ3 of this Master Thesis. I hypothesized (H3)) that Persons on the autism spectrum present a larger improvement of social skills after receiving rhythm therapy than after receiving behavior therapy. This hypothesis could not be assessed because I did not find studies that evaluate and compare the effectiveness of both rhythm and behavior therapy. However, the limited evidence points to behavior therapy being most effective for younger children under the age of 2 years old. The evidence discussing the effectiveness of music therapy is conflicting.

PART IV. Reflections

15 The Communication Challenge

In this chapter I evaluate whether theory, research, and therapy are sufficiently informing each other in order to advance in their purpose to investigate characteristics of the Autism Spectrum Disorder and to provide effective and efficient treatment packages for persons on the autism spectrum (RQ4). I hypothesized (H4)) that There is a persisting communication gap between theory, practice, and research about Autism Spectrum Disorder. The hypothesis is partially confirmed.

Literature has already pointed out a research-practice gap (Guldberg, 2017) and research- to- practice- to- theory gap (Chown, 2015). To evaluate the status of RQ4, I verified publications I read for the purpose of the current master thesis that were published between 2013 and 2018 to check if the authors connect their findings and/or make recommendations based on their findings to the other fields of study and practice; a negative evaluation would imply a *persistent* communication gap between the fields of Theory, Research, and Practice that, in turn could reflect a communication challenge. I included in the analysis all studies directly investigating aspects of the Autism Spectrum Disorder. I excluded reviews and meta-analyses because these publications did not publish information about the communication status between the investigated fields of study and the field of practice. A limitation of this analysis is that I did not further investigate into the included publications by the reviews and meta-analyses the communication status. For Theoretical papers, I checked whether the theoretical principles were supported by research evidence and whether the authors recommended (updates to) a specific therapeutic design. For Research papers, I checked whether the results are integrated within a theoretical framework and whether they provide recommendations to specific existing therapies or therapies in general for persons on the autism spectrum. For Therapy papers (i.e., papers empirically investigating the effectiveness of therapies), I checked whether the authors place the description of the targeted therapy within a theoretical paradigm and the results inform, confirm, and/or update theoretical principles and research results. The reader is referred to Table 4, Table 5, and Table 6 in Appendix E Analyses of the Communication Gap between the Fields of Therapy, Research, and Theory Investigating Autism Spectrum Disorder to see the examined publications and the result of the evaluation. Overall, I evaluated 10 Theoretical papers, out of which 6 discussed implications for both therapy and research (see Table 4). I evaluated 13 Research papers, out of which only 2 discussed implications for both theory and therapy (see Table 5). I evaluated 4 Therapy papers, out of which 2 discussed implications for both research and theory (see Table 6).

15.1Personal Analysis and Conclusions

I presented so far in this chapter the results of my evaluation of Theory, Research, and Therapy papers investigating Autism Spectrum Disorder. Based on the results of my evaluation of a communication gap, I present in this section conclusions to the findings, and I also analyze the nature of the communication gap as I observed it between the fields of study and practice.

The results indicate that most authors of Theoretical Papers relate their findings to the findings in peer fields, but authors of Research Papers relate their findings the least. In half of the Therapy Papers, authors connect the findings to peer fields. It appear that the assumed communication gap is restricted to the fields of Research and Therapy.

I noticed differences in theoretical principles and methodologies between the fields of study and practice: Psychology investigating social interaction in persons on the autism spectrum and Philosophy (i.e., Participatory Sense-Making Theory). One such difference is that Philosophy does not communicate sufficiently with Psychology to establish how philosophical concepts and principles can be investigated in an experimental psychological setting and based on the research outcomes whether there is a need for updating and how to update theoretical principles. As discussed in Section 7.3 Participatory Sense-Making and Autism and in Chapter 11 General Conclusions on Social Interaction of Persons on the Autism Spectrum, the theory of Participatory Sense-Making of De Jaegher (2006, 2013) and its hypothesis that there is a connection between an 'autistic' embodiment, sense-making, and social interaction are well-argued from a philosophical point of view, but difficult to empirically investigate as the concepts discussed in the hypothesis describe complex phenomena (e.g., social attunement, interactional coordination, embodiment). On the other side (i.e., Psychology informing Philosophy), most of the findings of Psychology research papers are not integrated within a theoretical framework; thus the theory cannot be updated based on recent evidence although the psychological field shows progress by investigating social coordination between cognitive agents also from the 2nd person perspective, methodological design that follows the principles of social interaction of the Participatory Sense-Making Theory discussed in this master thesis. The need for authors of Psychology papers investigating social interaction stating whether the results confirm or contradict principles of a theoretical paradigm is urgent as I observed Psychology papers present evidence that do not fully agree to the principles of the enactivist framework on social interaction of De Jaegher (2006, 2013). For more information please see, Chapter 11 General Conclusions on Social Interaction of Persons on the Autism Spectrum.

Another issue is that Research and Therapy and Theory and Therapy do not communicate sufficiently leading to continuous development of therapies that is based on recent empirical and theoretical findings.

De Jaegher (2006) discusses the concepts of interaction, bodily coordination, participatory sense-making etc., but does not provide a *clear* account as to whether and how these concepts can be improved in a therapeutic setting. The author hints towards the idea that the flexibility of the social rhythm can be improved, but it is *not clear* which therapy strategies should be applied. Interventionists need clear guidelines that would allow them to design a therapy plan that allows systematic observation of behavior or to assess the progress of phenomena that are difficult to describe. Also, both the fields of Research and Therapy should communicate to a greater extent to establish which social skills should be targeted in a therapeutic context and which should be further investigated in an empirical research. For example, the Brezis et al. (2017) demonstrate that the affective experience of persons on the autism spectrum influences the social coordination performance with a person with typical development. Given this finding, therapies can target the persons on the autism spectrum's perception on the social coordination. The client can be encouraged to communicate their experience while interacting and to compare it with the experience of the social partner to establish a common ground. Considering the other side (i.e., Therapy and Research), interventionists should also inform researchers about difficulties to target and improve specific phenomena. For example, rhythm therapies present difficulties with understanding which therapy practice leads to which therapy outcome (discussed in Subsection 14.3.2 Limitations of Rhythm Therapy). Research can further investigate this difficulty.

15.2 Suggestions for Experts

In an attempt to address the communication gap, I provide suggestions to professionals in relevant fields of study and practice to consider. First, philosophers should provide recommendations to researchers how the theoretical principles can be empirically investigated and to interventionists how they can be integrated within the therapeutic setting. Second, the researchers should relate the results of their studies to a specific theoretical paradigm about Autism Spectrum Disorder and should confirm or suggest updates to the theoretical principles; they should also, based on the results of their studies provide recommendations to interventionists how to update the therapy design. Third, interventionists should keep the scientists and theoreticians informed about the effectiveness of the therapeutic strategies and should point to therapy issues that need further empirical or theoretical investigation.

15.3 Implications for RQ4

I discuss in this section the implications of the findings presented in the previous sections for the RQ4 of this Master Thesis. I hypothesized (H4)) that there is a persisting communication gap between theory, practice, and research about Autism Spectrum Disorder. The hypothesis is partially confirmed. There is a persisting communication gap, but only from the side of Research and Therapy; most authors in the Research field do not relate the findings of their studies to peer fields (i.e., Theory and Therapy) and in half of the evaluated Therapy papers authors do not connect the findings to peer fields. The resulting picture is that it seems that Research papers connect the least their findings to the other fields.

Given the documented persisting communication gap, I believe there is a challenge for Theory, Research, and Therapy to communicate their findings across fields and to provide recommendations to experts in the peer fields. The importance of addressing the assumed communication challenge is related, for example to the possibility of interventionists making an informed choice when designing therapies for persons on the autism spectrum that is based on relevant knowledge from the scientific field (e.g., which skills to target for improvement and how to teach them), that Chown (2015) says would lead to interventions being more efficacious and effective. Consequently, theoreticians could formulate and update the paradigm's principles based on recent and relevant empirical studies, and perhaps solve limitations and issues of the theoretical paradigm. Finally, researchers could focus their resources on investigating for example, urgent issues in therapy practices related for example, to different strategies employed by different interventionists to teach a skill.

16 Interdisciplinarity

In this chapter, I discuss the interdisciplinary aspect of the current master thesis and conflicts and similarities between approaches, methodologies, and definitions of concepts in the domains and fields of study investigating social interaction competence of persons on the autism spectrum.

The topic of social interaction competence of persons on the autism spectrum is complex because there are many phenomena that comprise social interaction. One can argue that a social act is when a child imitates the caregiver's behavior to cut a plastic banana during pretend play. Another social act could be when a person responds with *Hello* to the greeting of another person. Social interaction refers also to the back-and-forth dynamic of gestures and bodily positions developed during social interaction. Also, social interaction can be studied from multiple perspectives (i.e., from the 2nd perspective of the social agents involved directly in the interaction; from the 3rd perspective of the observer of the social interaction; and from the 1st perspective of the experience of one agent in the interaction). Given the complexity of the social interaction phenomenon, some researchers study only social skills, while others attempt to study social interaction as a whole. To understand the complexity of the phenomenon of social interaction of persons on the autism spectrum, it is key researchers discuss perspectives from different fields of study (e.g., biological, neuroscientific, psychological, philosophical etc.). This interdisciplinary approach already started to develop and was taken also in this master thesis: I took the perspectives of Philosophy, Psychology, and Human-Robot Interaction to understand how persons on the autism spectrum interact, to identify characteristics of their manner of social interaction, and to assess the effectiveness and efficacy of interventions and the skillfulness of interventionists targeting and teaching social skills for persons on the autism spectrum. Within the Philosophy field I distinguished between Theory of Mind (the Cognitivist Approach) and Participatory Sense-Making (the Enactivist Approach); within the Psychology field I analyzed studies investigating mostly psychological processes involved in social interaction competence of persons on the autism spectrum in comparison to persons with typical development; within the Human- Robot Interaction field I discussed the potential of robot therapy for improving social skills in persons on the autism spectrum in comparison to human therapy. An integrated interdisciplinary perspective on aspects of the social interaction phenomenon of persons on the autism spectrum can lead to a more comprehensive understanding that is not available to the disciplinary approach.

I provide now a short presentation of how the disciplines approaching the study of social interaction performance of persons on the autism spectrum interacted throughout the current master thesis. For my purpose of investigating social interaction performance in persons on the autism spectrum I argued for the philosophical enactivist perspective of Participatory Sense-Making that hypothesizes a unique social interaction style of persons on the autism spectrum, and to evaluate this hypothesis I reviewed evidence reflecting the current state of the art of the psychological literature evaluating whether there is a connection between embodiment, sense-making, and social interaction of persons on the autism spectrum. Also based on my experience as a behavioral interventionist pursuing the RBT credential that interacted with children on the autism spectrum, I identified and discussed limitations and benefits of the human and robot therapy design aimed at improving social skills in persons on the autism spectrum.

There are two opposite perspectives across the Research, Therapy, and Theory fields on how to describe social interaction competence in persons on the autism spectrum. The conflict can be observed between robot therapy, behavioral psychology, and behavioral therapy on one side and rhythm therapy and the enactivist perspective on the other side. Robot therapy, behavioral psychology, and behavioral therapy define social interaction as social skills that can be systematically measured, and defined in a clear manner. The advantage of this perspective is that research can easily evaluate the nature of social skills, can compare the performance of the skills between different groups of persons, and therapy can target the improvement of the social skills in a progressive and easy to follow manner. The main disadvantage is that this approach is reductionist of the social interaction phenomena. On the other side, rhythm therapy and enactivism define social interaction as an interpersonal whole-bodily synchronization of movements and sense-making between two attuned social agents. The advantage of this approach is that it aims to investigate the social interaction phenomena as a whole and tackles more social processes that deal with the 2nd person perspective of the interaction that takes place in the real world. The disadvantage of this approach is that field still requires major methodological advancements.

It appears to be a match between the social interaction phenomenon described by philosophical principles of enactivism and the way it is investigated by some authors in the psychological field. Coordination is described within the enactivist paradigm as the juxtaposition of two behaviors that have the same goal. In some empirical research, coordination is named and measured differently across studies, but it is defined similarly with how the concept is described by the enactivist paradigm. For example, Brezis et al. (2017) and Fitzpatrick et al. (2017a) name the social coordination process *synchronization*, but Brezis et al. measure it by calculating the value of the co-confident motion (CC), while Fitzpatrick et al. measure it as the level of coherence between movements. Another similarity is that enactivism views social interaction as a whole process that arises out of the social interaction between individual social agents, while Brezis et al. (2017) and Romero et al. (2018) also investigated in their studies social interaction between a person on the autism spectrum and a person with typical development by looking at both sides of the social interaction.

Some experimental results in the Psychology Field are in line with the philosophical principles of enactivism of social interaction. The principles of enactive social interaction state that low-level processes such as sensory-motor patterns influence high-level processes, which in turn depict how the agent understands and interacts with the world. In my analysis in Chapter 9 From Embodiment to Sense-Making, I demonstrate characteristics of visual perception and motor processes of persons on the autism spectrum influence the way they perceive the social environment and they interact and coordinate in a social interaction.

I observed another similarity between the practices of rhythm therapy and the assumptions of the enactivist framework. During music therapy, the interventionist matches the child's rhythmic movements and their dynamics of expression to establish a musical foundation that supports social interaction between the interventionist and the child (J. Kim et al., 2008). Similarly, the theory of enactivist social interaction of De Jaegher (2006) argues that the adhesive of social interaction is the social rhythm that guides social interaction between the social agents.

17 Conclusions

The main aim of the current master thesis was to evaluate the communication gap between the fields of Enactive Social Interaction, Psychology, and Human and Robot Therapy investigating social interaction in children on the autism spectrum. The motivation for this aim was supported by the already documented communication gap in the literature between fields of study and practice investigating Autism Spectrum Disorder (e.g., see Guldberg (2017)).

A secondary goal of the master thesis was to argue for the enactivist perspective on social interaction of persons on the autism spectrum of De Jaegher (2006) that argues for a *different* and not impaired way of persons on the autism spectrum to socially interact. First, I presented limitations of the cognitivist framework of Theory of Mind describing social interaction in persons on the autism spectrum by arguing that the cognitivist approach takes a 3rd person perspective on social interaction that does not provide sufficient information about the direct and bodily social interaction between cognitive agents. Then, I presented and analyzed principles of the enactivist framework on social interaction. The enactivist framework of participatory sense-making argues that the coordination of movements between cognitive agents influences the coordination of individual sense-making. The main contribution of the Participatory Sense-Making theory is that the way persons on the autism spectrum socially interact is not seen as impairment, but as different. The focus is put on the unmatched social rhythm of the interaction between the person on the autism spectrum and the person with typical development. Another contribution of the enactivist framework is that it hypothesizes a unique connection between the embodiment, sense-making, and social interaction of persons on the autism spectrum.

Then, I evaluated whether we can talk of an 'autistic' embodiment (see Chapter 8 'Autistic' Embodiment) that influences the sense-making (see Chapter 9 From Embodiment to Sense-Making) and the social interaction of persons on the autism spectrum (see Chapter 10 Social Coordination and Synchronization of Persons on the Autism Spectrum) by analyzing recent publications in the psychological field. The most important finding is that the result of the analysis indicate an influence of low-level processes (i.e., sensorial and motor processes) on high level processes (i.e., communication and social interaction) in persons on the autism spectrum. Another conclusion is that based on the low number of publications I analyzed, I was not able to assess H1) that The 'autistic' embodiment is exclusively connected to the way persons on the autism spectrum make-sense of and socially interact in the world. Further analyses investigating the same hypothesis should consider assessing publications from a broader area of disciplines that investigate which characteristics of the low- and high-level processes are predictive of the Autism Spectrum Disorder and should compare the characteristics not only with persons with typical development, but also with persons with other neurodevelopmental disorders. Another important conclusion is that the coordination between a person with typical development and a person on the autism spectrum presents healthy levels of motion variability and complexity, but persons on the autism spectrum spend less time in synchronization than persons with typical development.

Another secondary goal was to evaluate the effectiveness, skillfulness, and efficacy of human and robot interventionists in/at improving and teaching social skills to persons on the autism spectrum. The motivation for this goal was to evaluate which therapy fits for which specific kinds of goals of the therapy for persons on the autism spectrum by identifying limitations and benefits of the therapies. I hypothesized (H2a)) that Human interventionists are more effective than social robots in increasing the performance level of social skills of persons on the autism spectrum.. The results concerning this hypothesis present limitations; I could not provide a conclusive evaluation. I hypothesized (H2b)) that Human interventionists are more skillful than social robots at teaching social skills to persons on the autism spectrum.. The hypothesis was confirmed. I hypothesized (H2c)) that Social robots are more efficient than humans in teaching social skills to persons on the autism spectrum.. The hypothesis was confirmed. I also hypothesized (H3)) that Persons on the autism spectrum present a larger improvement of social skills after receiving rhythm therapy than after receiving behavior therapy. This hypothesis could not be evaluated. The main suggestion I provide for engineers and for interventionists designing robot therapy is that until further technological developments and ethical issues of assistive robots are addressed, the robot should only be applied in the therapy setting to exercise social skills in a structured and clear manner with persons on the autism spectrum. After practice, the interventionist can embed the social skills in the natural setting of the social context. Another possible role of the robot is to be a toy that triggers and supports the interaction between the client on the autism spectrum and the interventionist. The robot can display social skills that would serve as an interactional bridge between the interventionist and the client and that would encourage communication, imitation, and interaction. Another important conclusion is that the behavioral therapy's approach to teach social skills in a highly structured and hierarchical manner does not encompass the different aspects of social interaction as described by the enactivist framework, but rhythm therapy has the potential to do so.

Finally, I evaluated whether there is a communication gap between therapy, theory, and research addressing social interaction in persons on the autism spectrum. I hypothesized (H4)) There is a persisting communication gap between theory, practice, and research about Autism Spectrum Disorder. The hypothesis was partially confirmed. It was the vast majority of research papers that did not connect their results with Theory and Therapy.

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19 Appendices

Appendix A Log of the Initial Meetings with Professionals

1. Log of the Meeting with Computer Scientist/Cognitive Scientist Prof. Markus F. Peschl

Overall Communication

I had a meeting with Prof. Peschl on November 13, 2017. We had a discussion about the cognitivist and the enactivist paradigms of cognition and about the interactions of children on the autism spectrum with robots. The meeting was informative and relevant because it encouraged me to reflect on the manners of research the discussed paradigms entail and to identify the next steps to carry out for my master thesis work. Prof. Peschl argued for the enactive stance for understanding the human mind and described the perspective of the enactivist paradigm on researching a phenomenon. He also briefly stated his opinion about interactional dynamics characteristics between the robot and the child on the autism spectrum.
I prepared for the meeting by formulating key questions about the enactivist theoretical and methodological approaches to social cognition. I asked what the characteristics of a social robot interacting with a child on the autism spectrum within the enactivist framework are, and what the scientific arguments for supporting one paradigm of cognition over another are.

Expertise in Autism Spectrum Disorder

Prof. Peschl had little knowledge of Autism Spectrum Disorder. I explained the diagnosis criteria, the characteristics of the disorder, and the scope and aim of the Applied Behavioral Analysis (ABA) therapy.

2. Log of the Meeting with Historian and Philosopher of Science Prof. Matthew Rattcliffe

Overall Communication

I had two brief meetings with Prof. Ratcliffe on March 20 and April 25, 2017. We communicated clearly, and there were no major disagreements or misunderstandings of the other's perspective.
Prior to the first meeting, I prepared an introduction into my educational and professional background, a summary of my former master thesis concept, and a list of questions about the field of phenomenology, the *intersubjectivity* concept, and the content of his book "Rethinking commonsense psychology" (Ratcliffe, 2007). During the short introductory meeting, we discussed the definition of the

intersubjectivity concept and the perspectives of folk psychology and of phenomenology on social interaction. Prior to the second meeting, I prepared an updated summary of my former master thesis concept, and I sent Prof. Ratcliffe the latest version of the document. During the meeting, we discussed the ideas of my former master thesis concept.

Expertise in Autism Spectrum Disorder

Prof. Ratcliffe informed me of his basic understanding of Autism Spectrum Disorder. In his book "Rethinking commonsense psychology", he covered Theory of Mind (cf. Section 7.1 Theory of Mind) and the seminal study carried out by Baron-Cohen and his colleagues on the mentalizing abilities of children on the autism spectrum (Baron-Cohen et al., 1985).

3. Log of the Meeting with Philosopher in Computer Science Christopher Frauenberger

Overall Communication

I and Christopher Frauenberger had a meeting on May 19, 2017, to discuss my initial master thesis concept. Previous to the meeting, I prepared a short introduction into my professional background, a summary of my interests and of my former master thesis concept, and a short list of questions about his research projects. In the allocated time, we discussed mostly my former master thesis project and briefly about a project with children on the autism spectrum he was working on. We discussed in a clear manner. Christopher Frauenberger did not understand the logic of the underlying assumptions of my former master thesis project, pinpointed limitations of my former conceptual framework, and clearly told me I had to rework my concept.

Expertise in Autism Spectrum Disorder

Christopher Frauenberger carried out previous research projects about the experience of children on the autism spectrum with technologies developed for and with them.

4. Log of the Meeting with Electrical and Computer Engineer Nima Taheri-Nejad

Overall Communication

I, Nima Taheri-Nejad, and my supervisor Paolo Petta had an introductory meeting in March 2017, and I and Nima Taheri-Nejad met separately on two further occasions (April 7, 2017 and October 4, 2017) to discuss about our research interests and projects and aspects of my former master thesis concept. Prior to the meetings, I prepared an introduction into my professional and educational background and a summary of the scope and the aims of my former and current master thesis concepts. During the dyadic conversations, I observed mismatches of collaboration intentions and difficulties in communicating aspects on the same topic. Nima Taheri-Nejad was interested in obtaining my advice on the design of the robot he intended to build for children on the autism spectrum and on testing the already developed technologies for children on the autism spectrum. I was interested in discussing the process of building a robot for children on the autism spectrum and in characteristics of the child-robot interaction in comparison to the human-human interaction.

We discussed design guidelines and potential roles of a robot interacting with a person on the autism spectrum. Nima Taheri-Nejad briefly explained the definition of a robot and presented a few examples of social robots (e.g., Paro, the seal robot). I presented a summary of the guidelines of the Applied Behavioral Analysis therapy (cf. Section 14.2 Behavior Therapy), and I advised Nima Taheri-Nejad about the types of basic emotions the Kiwi robot he planned to build should display in the interaction with persons on the autism spectrum.

Expertise in Autism Spectrum Disorder

Nima Taheri-Nejad had a basic understanding of the symptomatology of Autism Spectrum Disorder, and he had conducted a study involving a child on the autism spectrum.

Appendix B My Former Master Thesis Concept

The primary aim of the master thesis is to study the constitutional features of social interaction of autistic children from the perspectives of phenomenology and human-robot interaction. Taking the phenomenological viewpoint, the ambition is to identify, detail and interpret a social fundament autistic children might possess and/or a particular style of interaction. In the HRI approach, the focus is on describing and understanding the ASD child-robot interaction and on analyzing the variables leading to an efficient outcome of the therapy. The final goal is to conclude implications for therapy of ASD children from the obtained research findings, building on my own professional background and practical experience. An additional goal might be to apply the obtained conclusions to an understanding of the social mind of healthy subjects. The central phenomenon to be studied is the role of inner motivation of ASD children in their interaction with humans and robots in a physical shared environment.

The phenomenological view on the topic of social interaction states/postulates/suggests an impairment of ASD children of primary and secondary intersubjectivity. Our study will refer to social motivation as a key factor of autistic children's manner and style of bodily/intersubjective interaction. We will attempt to identify and describe basic social skills of autistic children during their bodily interaction with their caregiver and to differentiate it from the style of interacting of persons with typical development.

The literature on HRI often reports and even highlights a high inner motivation of ASD children while interacting with robots, as well as the presence of social skills and positive emotions. We will describe and compare the nature of the interactions of ASD children with robots versus with their caregivers. We will carry out a meta-analysis of the literature regarding the elements of an efficient robo-therapy, such as the role of the robot, therapy setting, and procedural teaching of skills to inform future robo-therapy approaches.

My earlier work in the master study pointed to the communication gap between therapy and research in the study of ASD. Also against our own professional background, we will address this gap explicitly by proposing practical suggestions for ABA therapy and robot therapy from the obtained scientific results.

Given the variety of theories explaining social cognition/social interaction of humans, we will give arguments for taking a phenomenological stance when explaining the phenomenon. Moreover, the implications of taking the phenomenological stance for the understanding of the social healthy mind will be presented.

The general question of my research is how autistic children interact with their animate and inanimate environment and what obstacles they encounter in their attempt to "interact". The methodological problem of specifying a restricted environmental social context and identifying the fundamental elements of social interaction will be addressed first.

The particular phenomenology-related questions refer to whether ASD children present an intersubjectivity basis for the interaction with other humans or/and how their style of interaction is particularized. The obvious issue with these questions consists in (having to) defining and enumerating the constituents of the notion of a basis of social interaction. Additional questions inquire whether ASD children perceive humans differently from objects and whether they assume a bodily/pre-reflective agency of others. These identified obstacles are of methodological nature; therefore I will address them at a theoretical level.

The questions related to the HRI field are: how do ASD children interact with robots and what are the relevant elements of an efficient robot-therapy? No problems have been identified for this part.

Appendix C Glossary of Terms of the Enactivist Paradigm

De Jaegher (2006) and De Jaegher et al. (2010) explain basic terms of the enactivist theory.

1) *Autonomy* is the property of organisms—as systems of constitutive elements—to self-generate and self-maintain their unique identity under precarious condition. The unique identity of the organism bases on *operational closure*—internal processes of the organism are conditioned on other internal/external processes. Under precarious conditions—given the same external conditions, single elements of a system cannot function normally—, the organism is able to function.

2) *Coordination* is the non-accidental *correlation* (e.g., similarity, complementarity, repetition) of behaviors. It is "the juxtaposition of two behaviors at the same time that have the same purpose" (De Jaegher, 2006, p. 76). The same purpose can be "one or more common or connecting factors" (idem). Accidentally correlated behaviors are characterized by a coherence, but share no common goal.

3) Gallagher (2005) argues mental processes to be *embodied*, meaning that the mind is expressed and perceived through the bodily interaction. To be more specific, Gallagher (2005) argues we know the mind of the other on account of our innate social abilities and our behavior is "known" on account of the expressive and intentional nature of behavior.

4) *Emergence* is the outcome of different levels of analysis (e.g., behavioral, neural etc.). Emergence appears at any structural level of the organism.

5) *Experience* is viewed as an integral aspect of the embodied engagement with the world. The concept guides the interplay between science and phenomenology in their quest to explain a phenomenon. Experience is given by the ability of the organism to make sense of the world around them.

6) *Functional coordination* defines the role coordination has in facilitating and maintaining interaction. Example of coordinated actions is sending e-mails to organize the physical location of a meeting support interaction (De Jaegher, 2006).

7) *Interaction* is defined as a temporally extended process that describes the bi-directional interdependence of behaviors or the temporarily phase of non-interdependence of at least two agents (De Jaegher & Di Paolo, 2007). During the event of interaction, agents' actions are guiding and influencing each other.

8) *Interactional coordination* refers to the influence of the interaction on enabling and maintaining coordination between two social agents. De Jaegher (2006) gives here an example of two women saying goodbye with a kiss and the dynamics of the interaction (e.g., mimics, gestures, the flow of the interaction) guide coordination in interaction.

9) *Sense-making* is an active process of interacting with the world, which results in "generation and transformation of meaning"(De Jaegher, 2006, p. 65). The organism creates individual intrinsically-relevant meaning in the interaction with the environment that would not be available outside this interaction with the environment. Moreover, the meaning-making occurs in the situated context and within the embodied organism. Because of this aspect the organism does not have to actively ignore the irrelevant aspects of the environment and choose the relevant ones. Deciding between relevant and irrelevant aspects in the situated context happens automatically. In this way, a normative perspective of the organism is established, which is "grounded in the self-production of the living system" (De Jaegher, 2006, p. 52). As explained before, generation of meaning or understanding is an activity situated in the world. As an activity, it makes use of movements and purposeful behaviors. Therefore, actions and behaviors are both tools and methods of expression of the sense-making.

10) Being *situated* is the property of the organism to be in a "frame" that is meaningful according to its needs, characteristics, history of interactions, couplings with the environment and its situation (De Jaegher, 2006).

Appendix D Supplementary Information about the Studies Analyzed in Chapter 8‘Autistic’ Embodiment

To help the reader gain a quick overview of and basic information about the reviewed publications in Chapter 8‘Autistic’ Embodiment, I have created these tables. In Table 1 are presented basic information about the selected publications that discuss motor processes in persons on the autism spectrum; in Table 2 are presented the validity and fidelity characteristics of the battery tests applied in the selected publications discussing motor processes in persons on the autism spectrum; and in Table 3 are presented basic information about the selected publications that discuss visual perception in persons on the autism spectrum.

Reference	Kaur et al. (2018)	Ament et al. (2015)	Amaral et al. (2017)	Esposito & Pasca (2013)
Aim	To assess motor functions of participants on the autism spectrum	To evaluate motor impairments in participants on the autism spectrum and participants with ADHD (Attention Deficit Hyperactivity Disorder)	To research hysteresis in participants on the autism spectrum Hysteresis – adaptive change of the organism to the changing environment	To argue that motor dysfunction in participants on the autism spectrum plays a crucial role
Participants	24 ASD (Autism Spectrum Disorder) participants (2 f.; 12 HASD (persons on the autism spectrum with IQ>70); 12 LASD (persons on the autism spectrum with IQ<70); 12 TD p. (3 f); randomized sampling; 5-12 y; ADOS-2 diagnosis;	56 ASD (8 f); 63 ADHD (9 f); 81 TD (typically developed) (12 f); 8-13 y; convenience sampling; DSM-IV diagnosis; most ASD and ADHD took psychoactive medication; 40 ASD had co-morbid ADHD and other disorders	41 ASD (6 f) 42 TD (11 f): m age 6-11 y; no information on sampling method; ADOS-2 diagnosis; clinician evaluation;	

Method	Standardized assessments (BOT-2 (Bruininks-Oseretsky test of motor proficiency-2nd edition) and SIPT-BMC (Sensory Integration and Praxis Test – Bilateral Motor Coordination Subscale)) Motor coordination paradigm (evaluation of simple and complex coordination of action in solo and social context)	Standardized assessment (MABC-2 (Movement Assessment Battery for Children -2nd edition) -Subscales: Manual Dexterity, Balance, Ball Skills)	Grasping-Placing Task: 19 white foam cubes, 1cm increase/decrease in size; hysteresis: transition point – average of smallest cube picked with 2 hands and biggest cube picked with 1 hand; Experiment 1 – placing cube on table; Experiment 2 – placing cube in hands of investigator	Synthesis of scientific evidence; Argumentation
Results	BOT-2: both LASD and HASD participants scored lower than TD participants SIPT-BMC: LASD participants scored lower than HASD participants in mirroring and total errors and time for completion task. Paradigm: significant group effect for most actions.	Every 1 point decrease on the MABC subscales associated with increase in the likelihood for a developmental diagnosis; Manual Dexterity item associated with ADHD; Balance item associated with ASD	Exp. 1: Both ASD and TD p. demonstrated hysteresis Exp. 2: TD demonstrated hysteresis; ASD demonstrated atypical hysteresis	
Discussion	Motor impairments (gross and fine motor skills, praxis, body coordination) are universal in ASD	ASD present greater motor impairments than ADHD and TD. Deficient catching and balance skills are strongest predictors of ASD.	Children demonstrated in Exp. 1 adaptive behavior at critical points. In Exp. 2, the social context influenced ASD's adaptive abilities.	Motor abnormalities manifest early in ASD; have a life-long impact; motor and social processes have common etiology; may have predictive value

Table 1 – Overview of Publications Investigating Movement Processes in Autism Spectrum Disorder

Reference	Battery Test	Aim	Validity[3] and Reliability[4]	Strengths and Limitations
Ament et al. (2015)	MABC-2 (Movement Assessment Battery for Children -2nd edition) (Henderson et al., 2007)	To identify and describe impairments in motor skills of 3-16 year old	**Discriminative validity**: evaluation at 4 years is predictive of motor improvements at 8 years (Griffiths et al., 2017; Wuang, Su, & Su, 2012) **Internal Consistency**[5]: 0.82-0.90; and **Test-Retest Reliability**[6]: 0.97 (Wuang et al., 2012)	+ simple test administration - lack of specificity (wide range of the age of the targeted population)
Kaur et al. (2018)	SIPT-BMC (Sensory Integration and Praxis Test – Bilateral Motor Coordination Subscale) (Ayres, 1989)	To evaluate sensory integration processes of learning and behavior in 4-8 years old	**Discriminative validity**[7]: capable between participants with and no learning disability (Cermak & Murray, 1991) **Construct validity**[8]: yes (Ayres, 1989) **Inter-rater Reliability**[9]: moderate agreement (Asher & Knox, 2008) **Test-retest Reliability**: from 0.48 to 0.93 (Ayres, 1989)	+ wide range of sensory and praxis integration domains - supplementary clinical observations and case history required (Asher & Knox, 2008) - additional professional knowledge is required for interpretation (Ayres, 1989)
Kaur et al. (2018)	BOT-2 (Bruininks-Oseretsky test of motor proficiency-2nd edition) (Bruininks & Bruininks, 2005)	To assess gross and fine motor skills in 4-21 y	**Content Validity**[10]: Yes **Discriminative Validity**: capable to discriminate between clinical and non-clinical groups **Inter-rater Reliability**: >.90 **Test-Retest Reliability**: Short Form >.80; Fine Manual Control/Body Coordination <.80 (Bruininks & Bruininks, 2005) **Ecological Validity**[11]: Bilateral Coordination and Balance not linked to riding bicycle; Upper-Limb Coord. linked to gross, not fine motor (Vinçon, Green, Blank, & Jenetzky, 2017)	+ the administration via photos for participants (minimal language demands) - weak test-retest reliability for some subtests - time-consuming scoring process (prone to error) (Deitz, Kartin, & Kopp, 2007)

Table 2 - Reliability and Validity of Battery Tests Applied in the Publications Investigating Motor Processes in Persons on the Autism Spectrum

[3] Validity of an assessment is the degree to which the evaluation measures what it is supposed to measure.
[4] An assessment is reliable when it produces similar results under similar experimental conditions.
[5] Internal Consistency is a characteristic of an assessment that shows that several items (from different assessments, usually questionnaires) that are known to measure similar constructs produce similar results.
[6] Test-Retest Reliability is a characteristic of an assessment that shows that an assessment of the same construct done successively under the same experimental conditions produces similar results.
[7] The assessment for discriminative validity shows that concepts or measurements that are not expected to be related are actually unrelated.
[8] Construct validity of an assessment is the degree to which the assessment measures the construct it is expected to measure.
[9] Inter-rater Reliability is the degree of agreement of the results of assessments among raters.
[10] Content Validity is the degree to which an assessment measures all facets of the measured construct.
[11] Ecological Validity is the degree to which the methods, materials and setting of the study depict the aspect of the real-world that is investigated.

Reference	Nayar et al. (2017)	Guy et al. (2016)	Perreault et al. (2015)	Schauder et al. (2017)
Key Terms	global processing – attention to the center, automatic; local processing – attention to details;	global processing – overall, gestalt processing; local processing – detailed processing	Low-level characteristics- elementary (e.g., spatial frequency); Mid-level characteristics – intermediate between low- and high-level: global (2,3,5 RFP) and local (10 RFP)	Visual processing of motion
Aim	to asses local and global processing patterns in ASD	To assess global and local visual perception in ASD p. in relation to age	To assess whether low-level characteristics (i.e., luminance and texture) influence discrimination of a visual pattern	To assess the integrity of the mechanisms *response gain control* impairment (atypical increased stimulation at high-contrast stimuli) and *increased receptive field size* ("atypical large population receptive fields in extrastriate visual areas" (p. 829)) in ASD participants.
Participants	28 ASD (11 f) 22 TD (0 f) DSM-IV-RT – 6 did not meet DSM-5 criteria; 7-13 y; convenience sampling; ASD participants had other co-morbidities and took medication	39 ASD and 40 TD; normal vision; 6-16 y; DSM-IV-TR; sampling of convenience	29 ASD p. (2 f) 30 TD p. (5 f) 19 y; DSM-IV-TR; Convenience sampling; participants have corrected or normal vision	20 ASD (1 female); 20 TD (0 females); 10-17 years; 10 ASD p. took psychoactive medication; visual acuity confirmed; no information on sampling procedure
Experimental Design	Kanizsa Illusory Contours (KIC); forced choice match to sample; 2 conditions: basic KIC and KIC with noise; eye-tracking; Measures of accuracy, reaction time, touching and looking behaviors	Navon Task; 4 conditions: global, local, global-to-local, and local-to-global; measures of accuracy and reaction time (RT);	Individual task construction; Forced choice paradigm; target – circle, distractor- radial frequency patterns (RFP) 8 conditions – 2,3,5,10 RFP/luminance and texture	Individual task construction; 3 conditions: a. mixed contrast/small stimulus size, b. mixed size/high-contrast, c. mixed-size/low-contrast; p. had to detect the motion direction of stimuli; task difficulty given by duration of presentation of stimuli.

Results	ASD p. made more errors and were slower during KIC + noise condition than TD. ASD p. looked less than TD at the center of the stimuli; no significant differences for local stimuli.	RT improved with age in TD group and decreased with age in ASD group. Global and local RT follow similar developmental trajectories within ASD and TD group. Local-to-global interference was significant in ASD group.	*Luminance Condition* ASD p. had higher threshold for 3 and 2 RFP. ASD p. had lower performance than TD p. *Texture Condition* ASD p. had lower discrimination performances than TD p. ASD p. performed worse with increase of RFP.	a. Both groups showed increased sensitivity at low and mid- contrast, but constant sensitivity at high contrast. ASD p. performed worse than TD group. b. Both groups performed worse with increasing stimulus size. c. Both groups improved their performance with increasing stimulus size.
Discussion	TD p. focused their attention more at the center of the stimuli. ASD p. present a slight global processing impairment—measured in looking behaviors and accuracy responses. Results are taken to contradict WCC (Weak Central Coherence) (Happé, 1996) and EPF (Happé & Booth, 2008)	In the absence of task-interference, ASD adolescents may be slower to process global information. Given interference, they may present a stronger local influence on global processing. The results are interpreted within the EPF model.	ASD mid-level pattern perception is given by the efficacy with which local elements (luminance and texture) are integrated. Global processing in ASD is dependent on luminance characteristics of the contour of the stimuli. Results are interpreted within the EPF (Enhanced Perceptual Functioning) model.	Impairments of ASD visual processing of motion (specific for small stimulus sizes) can be explained by the increased receptive field size theory. Interpretation of results is connected to theories of detailed processing of persons on the autism spectrum.

Table 3 - Overview of Publications Investigating Visual Perception Processes in Autism Spectrum Disorder

Appendix E Analyses of the Communication Gap between the Fields of Therapy, Research, and Theory Investigating Autism Spectrum Disorder

Given the documented research-to-practice gap between the fields of Therapy and Research investigating Autism Spectrum Disorder (Guldberg, 2017) (discussed in Chapter 15 The Communication Challenge), I set out to evaluate whether the publications selected in this master thesis as basis for argumentation connect their findings to all fields of Therapy, Research, and Theory. The hypothesis (H4)) that there is a collaboration gap between theory, practice, and research investigating Autism Spectrum Disorder is partially confirmed. Following are the tables with the Research, Therapy, and Theory papers organized alphabetically that show whether and what information individual papers provide to the fields of study and practice.

Reference	Aim	Theory	Research	Therapy
Tyler (2015)	To summarize and analyze the work on ToM	**Theoretical Paper** Analyzing characteristics of ToM	Psychological research presenting the evidence that lead to the formulation of ToM and its implications for autism spectrum disorder	Unnamed interventions that address ToM deficits of persons on the autism spectrum
Bottema-Beutel (2017)	review of the corpus of interactional research on ASD	**Theoretical Paper** Presenting limitations of the cognitivist approach; Promoting the advantages of the enactivist theory	Analysis of research promoting an interactionist perspective on social interaction	Unnamed interventions that focus on the live and direct social interaction unit between social agents
De Jaegher (2013)	Aim: Proposing an enactive account on autism	**Theoretical Paper** Enactivist Framework	Research on the Embodiment, Sense-making, and Social Interaction of persons on the autism spectrum	Relationship Development Intervention; Intensive Interaction
Shultz et al. (2018)	To review publications discussing infant-caregiver social interaction development	**Theoretical Paper**	Neuroscience and psychological evidence discussing "Social Adaptive Action and Brain Specialization in Autism Spectrum Disorder"	-
Bolis & Schilbach (2017)	Aim: evaluating the interplay of sensory-motor processes in relation to social processes in autism spectrum disorder	**Theoretical Paper** The predictive coding framework; Enactive Theory on social Interaction	Neuroscientific and Psychological research on sensori-motor and social processes	-

Casartelli et al. (2016)	Aim: to investigate the relationship between motor characteristics and social processes in autism spectrum disorder	**Theoretical Paper** Presenting characteristics of Motor cognition theory	Neuroscientific and Psychological research on motor and social processes	Promotes the need for a stronger link between research and therapy in designing interventions for people in the autism spectrum; no clear pointers to characteristics of therapy
Donnellan et al. (2013)	Aim: to assess the implications of motor and sensory characteristics for autism spectrum disorder	**Theoretical Paper** Presenting a dynamical systems perspective	Neurological evidence on sensory and motor characteristics of persons on the autism spectrum	Promoting therapies for persons on the autism spectrum that focus on the relationship and interaction between the client and the interventionist; analyzing traditional therapies
Esposito & Pasca (2013)	Aim: Assessing Motor Abnormalities in persons on the autism spectrum	**Theoretical Paper**	Motor Characteristics of Persons on the Autism Spectrum	
Moseley & Pulvermüller (2017)	Aim: investigating the role of sensorimotor processes within cognitive processes	**Theoretical Paper** Supporting the enactive theory	Psychological and neurological findings on the sensorimotor processes of persons on the autism spectrum	-
Thye et al. (2017)	Aim: to evaluate the impact of sensory processes on social impairments in autism spectrum disorder	**Theoretical Paper** Supporting Atypical hierarchical information processing Theory; No mentioning of a general theory	Neurological and Psychological Studies	Importance of sensorial sensitivity evaluation before designing therapies

Table 4 -Analysis of the Communication Gap between **Theory**, Therapy, and Research about Autism Spectrum Disorder

Reference	Aim	Theory	Research	Therapy
Amaral et al. (2017)	Assessing Hysteresis in A Grasping Task in Persons on the Autism Spectrum	Dynamics of System Coordination	**Research Paper**	Robot Interventions
Ament et al. (2015)	Assessing Motor Impairments in Catching and Balance in Children with Autism	-	**Research Paper**	-
Brezis et al. (2017)	To investigate synchronization between persons on the autism spectrum and persons with a typical development	**-**	**Research Paper**	Mentioning that interventions targeting improving synchronization should integrate the findings of the study
Curioni et al. (2017)	To investigate interpersonal motor coordination in persons on the autism spectrum	-	**Research Paper**	-
Fitzpatrick et al. (2017a)	To investigate Social Motor Synchronization and Motor Skill in persons on the autism spectrum	**-**	**Research Paper**	Difficulties synchronizing and implicit learning should be targeted in interventions
Guy et al. (2016)	To investigate global and local visual processing in autism spectrum disorder	Integrating visual perception findings within bottom-up theories	**Research Paper**	-
Kaur et al. (2018)	To compare praxis, motor performance, coordination, and interpersonal synchrony between children with and without Autism Spectrum Disorder	-	**Research Paper**	Movement-based interventions
Kostrubiec et al. (2018)	To investigate the relationship between socio-adaptability and motor coordination in persons on the autism spectrum	Integration of results within embodied social cognition	**Research Paper**	-
Nayar et al. (2017)	To investigate global and local visual processing in autism spectrum disorder	Integration of research within visual perception theories	**Research Paper**	-
Perreault et al. (2015)	To investigate visual perception in persons on the autism spectrum Research Paper	-	**Research Paper**	-

Romero et al. (2018)	To investigate the whole-body movements between children with autism spectrum and a clinician	**-**	**Research Paper** Demonstrate the connection between ToM deficits and embodied social interaction in children on the autism spectrum	-
Schauder et al. (2017)	To investigate motion perception in persons on the autism spectrum	Integrating results within visual motion perception theories	**Research Paper**	-
Stevenson et al. (2017)	To investigate the influence of multisensory processing on speech perception in autism	Interpretation of findings within both top-down and bottom-up perception theories	**Research Paper**	Treatments should include perceptual learning strategies

Table 5 - Analysis of the Communication Gap between **Research**, Therapy, and Theory about Autism Spectrum Disorder

Reference	Aim	Theory	Research	Therapy
BabyRobot Project	Aim: to evaluate effectiveness of robot-therapy for children on the autism spectrum	-	Psychological evidence on social impairments of persons on the autism spectrum	**Therapy Paper**
DREAM Project	Aim: to evaluate effectiveness of robot- and human-therapy for children on the autism spectrum	Promoting ToM	Psychological research on deficits of skills of persons on the autism spectrum	**Therapy Paper**
Koch et al. (2015)	Aim: to evaluate the feasibility of dance therapy for persons on the autism spectrum	Promoting an embodied theory on autism and an interaction account	Psychological evidence on the deficits in social interaction presented by persons on the autism spectrum	**Therapy Paper**
MacDonald et al. (2014)	Aim: to evaluate the effectiveness of EIBI for persons on the autism spectrum	-	Psychological evidence on the deficits in social interaction presented by persons on the autism spectrum	**Therapy Paper**

Table 6 - Analysis of the Communication Gap between **Therapy**, Research, and Theory about Autism Spectrum Disorder

Appendix F Glossary of Terms of the Applied Behavioral Analysis Intervention

1) *Discrete Trial Teaching* (DTT) is a teaching technique based on the basic triad of: *contingency* (antecedent-behavior-consequence), an additional *motivating operation (MO)* term, and an optional step of *prompting* (R. Leaf, McEachin, & Harsh, 1999). J. Leaf et al. (2016) state that DTT should be applied in a flexible yet structured manner in a naturalistic context, with the interventionist applying various strategies of the intervention (e.g., different instructions and prompts) that is based upon the learner's response during instruction. A *discriminative stimulus* (i.e., the antecedent; can be an instruction) should inform the client that a response is expected from them; the verbal format of the instruction should be varied on a trial-by-trial basis (e.g., depending on language level, history with task, and successful attending to task.). MO is an environmental variable that alters (increases or decreases) the reinforcing or punishing effectiveness of some stimulus and alters (increases or decreases) the frequency of all behavior that has been reinforced or punished by that stimulus (Cooper et al., 2014). The *prompt* is an aid offered during therapy that should increase the likelihood for the person to display the targeted behavior (Wolery, Ault, & Munson, 1992).

2) *Functional Behavior Assessment (FBA)* is a core procedure of ABA that consists in formulating hypotheses about the relation between specific environmental events and behaviors (Cooper et al., 2014). By applying FBA, it is possible to understand the function (purpose) of the targeted behavior (Roane et al., 2016) and to change it. It is stated that this function can be one of the two: "to get something" or "to get out of something" (Cooper et al., 2014). The interventionist targets a behavior (an adaptive one (e.g., saying *Hello*) with the aim to increase the frequency of its appearance or a disruptive one (e.g., pulling hair) with the aim to decrease the frequency of its appearance), identifies the reinforcement that increases the likelihood of the targeted behavior by assessing the consequence of the behavior across multiple instances, and finally hypothesizes the function of the behavior by analyzing both the antecedent and the consequence of the behavior (Cooper et al., 2014). FBA is usually applied in the therapy for persons on the autism spectrum to understand the function of challenging behaviors (e.g., screaming, biting etc.) and to diminish its frequency. This can be done by applying antecedent-based techniques and by teaching behavioral alternatives (J. Leaf et al., 2016).

3) *Pivotal Response Training* (PRT) is and alternative method to ABA, but still consists of ABA principles. PRT focuses on the motivation to interact with others, self-initiation and management, generalization of skills to multiple cues (Roane et al., 2016), and direct natural consequences (Williams, Koegel, & Egel, 1981) that are known to improve responsiveness, rate of responding to instructions, and positive affect (Mohammadzaheri, Koegel, Rezaee, & Rafiee, 2014).

4) *Reinforcement* is one core principle of ABA-based procedures that is applied to increase and maintain desired behaviors (Cooper, Heron, & Heward, 2007). Reinforcement is any stimulus that has been observed to increase the frequency of behavior (J. Leaf et al., 2016). Stimuli that are only *preferred* by persons, but do not lead to an increase in the appearance of times of a targeted behavior, do not qualify as reinforcement.

5) According to Cooper et al. (2014), the *three term contingency* or the *A-B-C paradigm* refers to the link between the Antecedent (A), the Behavior (B), and the Consequence (C) that is manipulated during ABA therapy to modify the frequency of appearance of behaviors. The antecedent is the specific environmental condition or a stimulus change existing or occurring prior to the targeted behavior. Here, behavior refers to the targeted behavior. And the consequence refers to the stimulus change that follows the targeted behavior. The consequence can increase the frequency of the targeted behavior (reinforcement), or it can decrease the frequency of the targeted behavior (punishment).

Appendix G Proposal for a Single-case Study of a Pre-scholar on the Autism Spectrum

Within the context of the master thesis, I and my supervisor Paolo Petta submitted a proposal for a single-case study of a pre-scholar on the autism spectrum to the Ethical Committee at the University of Vienna that was accepted on 03 April 2018. The general aim of the study was to gather qualitative and quantitative data about the sensori-motor patterns and the social interaction rhythm of a child on the autism spectrum, in an attempt to add relevant evidence to the validation of the research question RQ1 of the Master Thesis (i.e., What are descriptive general and individual characteristics of the style of interaction of persons on the autism spectrum?) and its hypothesis H1) (i.e., The 'autistic' embodiment is exclusively connected to the way persons on the autism spectrum make-sense of and socially interact in the world.). Attached are the submitted and accepted documents.

Antragsformular zur Beurteilung einer geplanten wissenschaftlichen Studie durch die Ethikkommission der Universität Wien

Version 15 (Oktober 2017)

Die beantragte Studie ist als Beilage anzuhängen. Es kann **zusätzlich** (!) zur kurzen Beantwortung der Fragen (max. 150 Wörter) auf den sich beziehenden Teil im Antragsformular verwiesen werden.

Nicht zutreffende Punkte bitte mit t.n.z. (trifft nicht zu) beantworten.

1. Allgemeines

1.1. Bei der vorgelegten Studie handelt es sich um:

☐ ein drittmittelfinanziertes Projekt

Fördergeber/Universitätsinterne Projektnummer/Kostenstelle (falls bereits vorhanden):

☒ ein universitätsinternes Projekt

☐ eine Dissertation (PhD-Arbeit)

Name des Betreuers/der Betreuerin:

Die/der BetreuerIn wurde über die Einreichung informiert

☐Ja ☐Nein

☒ eine Masterarbeit/eine Diplomarbeit

Name der Betreuerin/des Betreuers:

Univ.-Lektor, Dipl.-Ing., Dr., Paolo Petta

Einreichung wurde beantragt von:

☒Betreuerin/Betreuer ☒Studienrechtliches Organ

1.2. Warum bzw. wofür wird ein Votum der Ethikkommission benötigt?

☒ Die Untersuchung könnte die physische oder psychische Integrität, das Recht auf Privatsphäre oder sonstige subjektive Rechte oder überwiegende Interessen von Versuchspersonen beeinträchtigen.

☐ Das Votum wird von einem Publikationsorgan verlangt.

☐ Das Votum wird von einem Fördergeber verlangt.

☒ Sonstige Gründe, nämlich:

Verifikation der Einhaltung der ethischen Grundsätze an der Univ. Wien

1.3. Wurde für die Studie bereits ein Begutachtungsverfahren durch eine Ethikkommission durchgeführt?

☐Ja ☒Nein Wenn Ja, Gutachten beilegen!

2. Kurzinformationen zur geplanten Studie

2.1. Titel der Studie

Sensori-Motor Patterns and Interaction Rhythm of a Child on the Autism Spectrum

2.2. Handelt es sich um eine Teilstudie innerhalb eines größeren Forschungsvorhabens? Wenn ja: bitte den Titel dieses größeren Projekts angeben!

The proposed study is a key part of my Master Thesis (referred to as in the following also as "P.I." of the present study) in the context of the MEi:CogSci Master Programme at the University of Vienna (https://ssc-phil.univie.ac.at/studien/master-cognitive-science/) under the supervision of Univ.-Lektor Dipl.-Ing. Dr. Paolo Petta. The title of the Master Thesis is "Theoretical and Therapeutical Aspects of the Social Interaction Phenomenon of Children on the Autism Spectrum Disorder". The main scientific contribution of the Master Thesis is to argue for an enactive account of Autism Spectrum Disorder (cf. 2.6 for an explanation of the term "enactive") and to compare interactions of caregiver-child on the autism spectrum and robot-child on the autism spectrum interactions to understand how each type of interaction can and does address the nature of the disorder.

2.3. Fachdisziplin

Cognitive Science, Psychologie, Artificial Intelligence

2.4. Kurzbeschreibung der geplanten Studie (max. 500 Wörter)

The planned research is an observational study case of a 6 year old child on the autism spectrum, during which the social interaction between the child and I (experimenter and interventionist) will be filmed for analysis purposes. The general aim of the study is to collect data on the sensori-motor patterns of a child on the autism spectrum (stimuli sensitivities and necessities (e.g. hypersensitivity to light, need of strong physical input, hyposensitivity to outside vibrations) and posture, gross and fine-motor movements (e.g. playing with toys in a horizontal position, tip-toeing, difficulties with putting objects on a string)) and to interpret the behaviors in context, in a first validation of the hypothesis that persons on the autism are 'differently embodied' (in terms of specific sensorimotor, affective, neurophysiological, and biological structures). A further aim is to study the child's interaction rhythm, analyzing time responses to turn-taking in cooperation games (e.g. building a Lego tower) and to compare it to documented reaction times of neurotypical children. The motivation for the intended study includes: acquiring first-hand experience in conducting this kind of study and understanding what annotations are conducive to answering these research questions (these skills will be key for scaled-up further experimentation in planned Ph.D. work), providing researchers and theoreticians with empirical research material, in addition to and beyond contributing to the specific validation of research hypotheses of the Master Thesis.

The acquired video data will be stored in anonymised and safe form on storage facilities of the University of Vienna (related technical matters have been clarified with the Univ. of Vienna technical staff), analyzed in ELAN (an annotation program for audio and video data), and reaction times and sensori-motor behaviors of the child will be annotated. P.I. will install 2 cameras in the playroom of the participant's house to film interaction sessions lasting 30 min (related technical tests have been successfully completed). During the interaction, the participant will be encouraged to play adequately with age-appropriate toys (e.g. ball, cars, trains and tracks), to complete mastered tasks (e.g. building a Lego tower, assembling a puzzle) in cooperation with P.I., and to play independently with toys of the participant's choice. After each session, the participant will have a 30 min break. During playing, P.I. will implement principles of Applied Behavioral Analysis to assure a successful communication and interaction with the participant to the study.

P.I. (BS in Psychology) is a cognitive science master student, and acquired proficiency in the processing of video data corpora in a completed video annotation project co-supervised by Paolo Petta and Stephanie Schreiter (OFAI). In addition, she has been interacting as a interventionist with the study participant children candidates (see 3.5), and is working towards the Registered Behavioral Technician (RBT, https://www.bacb.com/rbt/) Credential under the supervision of X BCBA (Board Certified Behavior Analyst).

2.5. Zielsetzung der Studie (Fragestellungen, Hypothesen etc.)

The principal objective of this pilot study is to gather first video indications (or evidence) of any sensori-motor particularities of a child on the autism spectrum and to interpret the observed acts in their context, so as to ascertain whether these could point to a distinct embodiment (i.e. sensing and moving) of children on the autism spectrum. Another objective is to identify particularities of social interactions between a neurotypical and a child on the autism spectrum (e.g., regarding interaction rhythm).

Research Questions:
1. Do children on the autism spectrum present specific sensori-motor patterns when interacting in/with the environment?
2. Do children on the autism spectrum interact differently than neurotypicals?

Hypotheses:
1. The child on the autism spectrum presents hypo- and hyper-sensitivities to stimuli in the environment (e.g. tactile, visual etc.).
2. The child on the autism spectrum seeks particular types of sensorial stimulation.
3. The child on the autism spectrum presents distinct particularities of the gross and fine motor skills and the posture of the body.
4. The child on the autism spectrum responds later in turn-taking games than the neurotypical child.

2.6. Wissenschaftliche und gesellschaftliche Relevanz der Studie

This pilot study may provide evidence in support of the enactive account on autism spectrum disorder and will inform planning of scaled-up follow-up research. The enactive account hypothesizes that persons on the autism spectrum make sense of the world and interact with the environment and agents in a different manner than neurotypicals. The enactive account aims at bridging together different phenomena of the autistic life: social interaction, experience, embodiment—that are usually studied in isolation—into a coherent framework. Such a foundation would allow us to improve our understanding of how persons on the autism spectrum feel in a non-autistic context, which environments would suit persons on the autism spectrum, and to improve quality of life prospects.
Independently of the specific scientific outcome, the study furthermore will produce a piece of timely and topical research data for further analysis. It is also an important exemplar helping to bridge the gap between practitioners in the field of autistic children care and therapy and researchers and scientists, a core concern in the MEi:CogSci study of P.I., who has established working relationships to related associations and interest groups to whom the experiences gained in the study will be disseminated.

2.7. Beschreibung des Untersuchungsdesigns (z. B. Erhebungszeitpunkte, Kontrollgruppen, Anzahl der Gruppen, Fallzahlschätzung, Stichprobengewinnung u. dgl.)

Pilot study case: a single child on the autism spectrum, embedded in routine home-care therapy sessions.
Data acquisition: multiple (three) half-hour sessions on a single day, up to 6 days (spread over a period of up to 3 weeks).

2.8. Beschreibung der Methode der Datenerhebung, der Stichprobe (StudienteilnehmerInnen), der Studienmaterialien (z. B. verwendete Instrumente) u. dgl.

Study materials: 2 digital cameras (a digital camera Sony Model-DSCW830 and a smartphone camera (Smartphone Huawei P9 Lite 2017), 2 tripods, an alarm timer (on the smartphone), toys and materials present in the private room of the child, a laptop, USB cables for data transfer from the cameras to the laptop.

The interaction between P.I. and the child on the autism spectrum will be filmed by 2 cameras placed at suitable (relevant field of view, stable and safe, etc.) locations (e.g., on top of a wardrobe) in the playroom in the house of the participant (the technical viability of the setup has been verified). The cameras will film independently during the 30 min interaction sessions. P.I. will verify the status of the cameras 2-3 times per session, and will explain to the participant that they are recording. After 30 mins of interaction, an alarm (that the child has been acquainted with before the study) will ring to mark the end of the session. During the following 30 min break (and at the end of the final recording session), the recorded material will be transferred from the cameras to the laptop of the principal investigator where it will be stored in a password-secured fashion.

Safe long-term storage of cleaned and anonymised data has been arranged with the University of Vienna central storage facilities.

Target population typology: Children with a diagnosis on the autism spectrum in the age range from 3 to 11-12, who acquired or present the following skills: staying in a room for a period of 30 min, ability to imitate simple movements, ability to follow simple instructions (formed of 3-4 words), ability to play appropriately with toys (cars and trains, imaginative play- use spoon to feed a baby, assembly of puzzles, building Lego towers).

The employed diagnosis of autism spectrum follows the The Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM–5; American Psychiatric Association, 2013): persistent deficits in social communication and social interaction across multiple contexts and restricted, repetitive patterns of behavior, interests, or activities (https://images.pearsonclinical.com/images/assets/basc-3/basc3resources/DSM5_DiagnosticCriteria_AutismSpectrumDisorder.pdf, visited 2017-12-17).

2.9. Geplanter Beginn und voraussichtliche Gesamtdauer der Studie
Hinweis: Bereits begonnene oder abgeschlossene Projekte werden von der Ethikkommission nicht begutachtet.

The planned study is scheduled to take place in early 2018 (and only after receipt of clearance by this ethics commission) and will comprise on the order of 3 days of data acquisition, depending on the availability of the legal caregivers and on the physical and emotional condition of the child.

3. StudienteilnehmerInnen

3a Rekrutierung der Teilnehmenden sowie Ein- und Ausschlusskriterien für die Studienteilnahme

3.1. Geplante Anzahl der Teilnehmenden

1 (a single participant, reflecting the the pilot nature of the study)

3.2. Voraussichtliche Zeitdauer der Studienteilnahme für die Teilnehmenden

Total interaction time will be 3 hours, accrued over individual sessions of no more than 30 mins, with at least 30 min breaks between sessions. The sessions will take place across multiple days, with no more than three sessions per day, for a nominal total of three recording days.

The total targeted amount of 3h of interaction time reflects estimates of the amount of the recording material likely needed in order to capture multiple instances of the targeted behavior as required for a more representative analysis and interpretation in a single subject study design.

3.3. Charakterisierung der Teilnehmenden

- Mindestalter: 3 Höchstalter: 12
- Geschlecht: ☒ männlich ☒ weiblich
- Sind nicht persönlich Einwilligungsfähige einschließbar? ☒ Ja ☐ Nein
- Handelt es sich bei den Teilnehmenden um Kinder, Besachwaltete oder andere vulnerable Gruppen?

Yes, the study deals with a minor child on the autism spectrum.

3.4. Beschreiben Sie das geplante Rekrutierungsverfahren (bitte alle zur Verwendung bestimmten Materialien, z. B. Inserate, beilegen):

Given the pilot study nature of the present research undertaking and its embedding in the bounded contexts of a MS thesis work, the technical and methodological risks are to be minimised, by drawing on the established professional relationships of the study conductor P.I. with children on the autistic spectrum that she has been interacting with. Please see 3.5, below for furth details.

3.5. Legen Sie kurz die Auswahl der Teilnehmenden sowie die Ein- und Ausschlusskriterien dar (wenn zutreffend: explizite Begründung für den Einschluss von Personen aus geschützten Gruppen, z. B. Minderjährigen, temporär oder permanent nicht einwilligungsfähigen Personen)

P.I. has been interacting with two children on the autism spectrum of different families as an interventionist for around a year in Vienna, under the supervision of X BCBA. Over this time, she has been complying with and applying principles of Behavioral Analysis to stimulate acquisition and maintenance of skills and to decrease the probability of appearance of problem behaviors. Out of these two candidates, the actual participant in the study is to be selected after the obtainment of ethical clearance, so as to maximize the likelihood of efficient acquisition of relevant data.
The participant to the study must have a diagnosis on the autism spectrum and must have the required basic levels of imitation skills, receptive instruction skills and playing skills.
The participant to the study must not present any medical condition immediately before and during the participation to the study.
The legal caregivers will be asked for a written confirmation that their child has a diagnosis on the autism spectrum and does not present any medical condition prior to the study.
X BCBA will be asked for a written confirmation that the child presented at the last evaluation basic skills of imitation, receptive instruction and playing. X assesses the progress of the child monthly. Last evaluation was made in December. Next evaluation will be in January, but the exact date is not yet set.

3.6. Wird die Zustimmung der Teilnehmenden oder deren gesetzlicher Vertretung eingeholt?

☒ Ja (Informationsblätter und Einwilligungserklärung beilegen)

☐ Nein Wenn nein, warum nicht:

3.7. Welche (persönlichen, sozialen, institutionellen) Beziehungen bestehen zwischen den Teilnehmenden und den Studiendurchführenden (z. B. Studierende-Lehrkraft, Dienstnehmer/in-Dienstgeber/in etc.)? Ist die Freiwilligkeit der Studienteilnahme gewährleistet?

There is a personal relationship between the principal investigator (playmate/psychologist applying ABA principles) and the potential participant children (playmate/learner) that has been developed over 1 year of playing and interaction. There is a social relationship between the principal investigator and the legal caregivers of the potential participants (acquittance/acquittance).
Voluntary participation will be ensured through informed consent and information forms, in which it is explicitly stated that participation in the study is voluntary and retraction of the consent from the study can be made at any point without any negative repercussions. Before and during the study, there will be discussions with the legal caregivers, to explain and remind them of the voluntary aspect of the participation in the study.

3b Datenschutz

3.8. Welche personenbezogenen Daten werden erhoben?

Videos of the interaction between P.I. and the participant will be collected.

3.9. Wie wird die Anonymität der Teilnehmenden gewährleistet?

The code names "A" and "B" will be used instead of the name of the participants in every reference to the participants (i.e. in the analysis and interpretation of the data, in the naming of the videos and the folders, in discussions with the supervisor and other scientific peers, in publications, etc.). The informed consent and information letters will be kept in separate folders from the videos, and the association between the name of the participants and the code names will not be possible.
Video meta-data will be cleaned of participant-related information (including e.g., geo-location)
The video files will be named using the following format: "V" + number of the session + code name "A" (e.g., "V1A", "V2A", etc.).

3.10. Wenn eine vollständige Anonymisierung personenbezogener Daten nicht möglich ist: Wie wird die Privatsphäre der Teilnehmenden geschützt?

t.n.z.

3.11. Werden Stimmen, Bilder oder Videos aufgenommen?

☒ Ja ☐ Nein

Wenn Ja: Wird die Einwilligung der Teilnehmenden zur Aufnahme eingeholt?

Yes, the informed consent of the legal caregivers of the participant as well as the participant to the study will be obtained prior to any recording .

3.12. Wie wird gewährleistet, dass die Teilnehmenden jederzeit die laufende Mitwirkung an der Studie abbrechen können?

The legal caregivers will be informed through the information material and informed consent sheets that they can retract from the study at any time without experiencing negative repercussions. At the end of each day of filming sessions, a summary of the interactions, reports on the physical and emotional condition of the child and the encountered issues, and a reminder of the voluntary aspect of the participation to the study will be provided to them. Further explicit reminders will be made after completion of the data acquisition, and at the time of the completion of the study (along with information about the key study outcomes). The legal caregivers will be informed immediately of any changes in the contact information provided to them.

3.13. Wie erfolgt die Verarbeitung und Auswertung der Studiendaten?

☐ personenbezogen, Begründung:

☒ indirekt personenbezogen Wie erfolgt die Anonymisierung?

Acquired video files will be cleaned of relevant meta-data (e.g., automatic geolocation tagging), and all material will be stored and handled in anonymised fashion (see also 3.9, above). The video files will be permanently stored in password-protected safe storage space provided by the central facilities of the University of Vienna. The video data will be opened and processed in the program ELAN, and specific behaviors and time responses of the child will be annotated according to the research questions of the study. Frequency numbers of the annotated behaviors, reaction times of the participant to the study, comparisons of reaction times from current planned study with results documented in the literature, as well as specific key behaviors will be analyzed and interpreted. Throughout all analysis, interpretation, and publication of data, code names will be used to refer to participants.
Further sharing of video material for non-profit research purposes will be made dependent on binding compliance to preservation of the anonymity of the recorded participants and abstaining from any activity that could endanger such anonymity.

3.14. Wie wird mit den Studiendaten nach Abschluss der Studie umgegangen? (Aufbewahrung: wie, wo, für wen zugänglich, wie lange?)

After completion of the study, the anonymized (cf. in particular 3.9) cleaned and consolidated video data sets and related documents will be kept on the safe storage facility offered by the University of Vienna as valuable scientific data assets for as long as the quality of service can be guaranteed (The University of Vienna ZID has confirmed that this storage is fit for this purpose) and any necessary hand-over from one responsible person to the next can be implemented and cleanly documented. Each granted access to the data will be always password-protected and requires binding compliance with preservation of data protection (cf. 3.13). Availability of data will be terminated as soon as any of these conditions (i.e., consideration of the data assets to be of value to the scientific community by the person in charge; guaranteed quality of service by the University of Vienna technical management; retirement of the responsible person in charge without appointment of a successor) should become violated. But for exceptional circumstances preventing the implementation of the following procedure, before such termination of service all parties with working access grants will be informed with a grace period of at least two weeks.

3.15. Wie wird den Teilnehmenden die Einsicht in ihre persönlichen Studiendaten ermöglicht?

The legal caregivers can request access to the video data of their child and a copy of the analysis and interpretation of the data. The legal caregivers will be granted access to their video data stored at the University of Vienna repository through a dedicated set of credentials that will be provided to them upon their committing to compliant handling of all information and that will give them access to pertinent material only. The legal caregivers will receive at request an accessible and simplified version of the analysis and interpretation of the data.

3.16. Können sich Teilnehmende über die Forschungsergebnisse informieren?

☒ Ja ☐ Nein Wenn nein, Begründung:

3.17. Auf welche Weise und wie lange können die Teilnehmenden die Löschung ihrer Studiendaten verlangen?

The legal caregivers can retract their informed consent and request deletion of the acquired study data in authenticated written form only. Such request should be sent to the P.I. or the academic supervisor, and confirmation of receipt should be obtained. Legitimated requests are to be followed up immediately. In compliance with established European best practice (cf. e.g., the published Opinions of the Article 29 Data Protection Working Party of the European Commission), any withdrawal is not retroactive but prevents any further processing of the interested individual's data.

3c Folgen der Studienteilnahme für die Teilnehmenden

3.18. Ist die Teilnahme an der Studie für die Teilnehmenden mit absehbaren Risiken oder anderen anzunehmenden problematischen Begleiterscheinungen verbunden (z.B.: Schmerzen, Unannehmlichkeiten oder Verletzungen der persönlichen Integrität)? Welche Maßnahmen werden zur Vermeidung und/oder Versorgung von unvorhergesehenen/unerwünschten Ereignissen getroffen?

Risks:

Health and Safety

1. The participant to the study may sustain physical injury.

Handling Procedure: In case of a minor physical injury, legal caregivers will be informed immediately about the incident. In case of a major physical injury, local authorities (Police-133 and Ambulance-144) and legal caregivers will be immediately called/summoned, and the participant child's injuries will be temporarily dealt with by applying first aid measures.

Risk Probability: Physical injuries have a low probability of occurring, as the participant child is not exposed to harm and danger during the study to a greater extent than in regular daily interaction.

Impact: The impact of these events onto the health of the participant can range from small to great depending on the severity of the injury.

Minimizing Risks: To minimize this risk, the interaction between P.I. and the participant will be restricted to the playroom in the house, and it will not include intensive activities (e.g. climbing, running, jumping on inappropriate surfaces).

The child will be monitored during the session for any kind of medical sign or condition that could influence the outcome of the study or that could indicate deterioration of the well-being of the participant. In case of an observed relevant medical sign or condition prior or during an interaction session, the study will be immediately suspended until renewed explicit clearance by the legal caregivers.

Emotional well-being

1. The participant might show ostensive aggressive behaviors towards the cameras in the room.

2. The participant might display behaviors associated with shame or feelings of distress for being filmed.

Handling Procedure: In either case, a special protocol will be implemented according to the regulations provided by BCBA X and according to the professional and ethical guidelines of the Registered Behavior Technician (RBT). The child will be immediately removed from the environment and handed over to

temporary care of the caregiver present in the house. Then, all video recordings will be terminated, and the cameras will be stored in a safe and hidden storage space outside the room. The continuation of the study and the handling of the acquired material will be made pending on obtaining a renewed clearance from the participant's legal caregivers, the therapy supervisor, and the master thesis supervisor.
Risk Probability: Both classes of risks have a low probability of occurring, because the candidate children (cf. 3.4 and 3.5) have been filmed before by the legal caretakers and by P.I. at the legal caregiver's request, and no alarming behaviors have been recorded.
Minimizing risks: To minimize the risk of emotional distress, both cameras will be placed on high surfaces in the room (i.e. on the wardrobe), and they will not intervene directly in the interaction between the principal investigator and the child.
Impact: The impact of this risk can range from small to large, depending on factors such as: mood of the child, personality of the child, etc.
3. The participant may undergo meltdowns due to increased sensory stimulation or tantrums during the interaction sessions. Sensory stimulation and tantrums are states experienced on a regular basis by persons on the autism spectrum.
Handling Procedure: In case of a meltdown, the principal investigator will try to immediately identify the source of the sensory overloadt, the child will be prompted to make a stop gesture, and the child or the identified disturbing sensorial source will be immediately removed from the environment. In case of a tantrum, the function of the behavior will be identified, and specific measures will be implemented according to the recommendations made by BCBA X and according to the guidelines of the RBT code.
Risk Probability and Minimizing Risks: The probability of these risks is medium, because there are a variety of factors that can influence the appearance of a meltdown or a tantrum, but as P.I. interacted with the potential participants for a year, she has personal experience in handling and minimizing the risk of tantrums and meltdowns.
Impact: The impact of the associated behaviors can range from small to medium, depending on the history of tantrums and sensorial states of the participant.

Participation in the study
1. The child participant might not want to spend time in the study room.
Handling Procedure: The participant child is free to leave the study room at any point during the 30 min interaction session. In the case of the child leaving the room, 2-3 minutes will be spent outside the room before prompting the child to return to the room. If the child should refuse, a 30 min break will be granted. If after the break the child should still refuse to return to the room, the continuation of the study will depend on the outcomes of discussions with the interaction and master thesis supervisors, as well as renewed written consent from the legal caregivers.
Risk Probability and Minimizing Risks: The likelihood of this risk is low because P.I. has bonded with each of the potential participant children over one year of continued interaction, and P.I. will aim to make the social interaction fun and engaging. To further reduce this risk, a short evaluation of the child's physical well-being and mood will be made within the first 5 minutes of interaction sessions. In case of detected fatigue or other conflicting health states, the continuation of the study will be paused until the child is feeling better.
Impact: The impact of this behavior is estimated to be low, as the participant child is familiar with their private play room serving as study room, and they know they can leave this room at any point.

Invasion of Privacy
1. The participant child may not understand that a study is taking place and/or the implications and the procedure of the study (i.e., that the participant is being filmed).

Risk Probability: The likelihood of occurrence of this risk is medium, depending on how much the child understands the explanations received from the principal investigator about the planned study.
Minimizing risks: To minimize the risk, P.I. will show the participant child the cameras before the beginning of the study and before each interaction session, and will explain in plain terms and gestures that the participant will be filmed for a period of time. During the sessions, the principal investigator will also point from time to time to the place of the cameras in the room and will make a short comment about the cameras filming.
Handling Procedure: In case of the appearance of behaviors that threaten the dignity of the participant child, the child will be gently guided to other activities, and the storage of the specific video will be pending on consent from the legal caregivers.
Impact: The impact of recording indecent behaviors can range from low to medium, depending on the participant child's understanding of the purpose, of the interaction and the presence and role of the camera in the study room.

Management of Research Data
Potential breaches of anonymity, confidentiality, and invasion of privacy due to hacking/infestation with viruses can occur. Probability of this event happening is low. The principal investigator will make sure to have installed antivirus programs and the latest operating system updates, but these issues cannot be fully avoided. In the case of this event happening, the legal caregivers and the local authorities will be informed about the situation. Accurate and complete trails of the data and processes will be kept (including access logs to the central data repository at the University of Vienna) to allow detection and assessment of the extent of any data corruption and breaches, and the initiation of related handling and recovery procedures.

Other Effects
Participation in the study requires spending time in a room for a continuous period of time of 30 min. At the end of the session, the participant might avoid interacting with other persons and might want to spend time alone.
During the interaction, the child will spend their time in an appropriate and adequate manner. The sessions will engage the child in meaningful interactions during which the child will play appropriately with toys and will complete activities.

3.19. Welche Verfahren werden eingesetzt, um unerwünschte Effekte einer Studienteilnahme zu identifizieren, diese zu dokumentieren und zu berichten? Beschreiben Sie, wann, durch wen und wie dies erfolgt, z. B. freies Befragen und/oder an Hand von Fragelisten.

Unwanted study participation effects are identified in particular by observing the participants' avoidance behaviors of the location of the playing room and of particular interactions, and by monitoring aggressive and shamed behaviors (e.g., due to being filmed). In case of observing any such behaviors, the continuation of the study will be paused immediately, and further actions will be carried out according to established protocols (cf. 3.18).
The legal caregivers will be asked at the end of each data acquisition day whether they developed any concerns and/or questions regarding the study and its continuation.

3.20. Wird eine Teilnahmevergütung bzw. eine Aufwandsentschädigung (Ausgleich von Fahrtspesen und Einkommensentgang) an die Teilnehmenden bezahlt?

There is no participation fee, and no monetary incentive will be given to the participant to the study or to the legal caregivers. With their informed consent, the legal caregivers will grant the P.I. free access to the the household facilities as required for the described implementation of the research study and will in particular grant free access to electrical power required for the machinery (i.e., the two digital cameras and the laptop). The principal investigator will not receive any monetary sum for her interaction with the participant in the study. Insurance for both participants of the interaction will be covered by Wiener Gebietskrankenkasse (WGKK).

3.21. Welche voraussichtlichen Vorteile bzw. welcher mögliche Nutzen sind für die Teilnehmenden mit der Studie verbunden?

The interaction sessions will engage the participant in the study through fun play, encouraging completion of attainable (easy) tasks, and by providing opportunities to engage in one-on-one social interaction with another person.

The legal caregivers should gain possibly novel information about characteristics of the way their child moves and senses their environment, through inspection of the recorded interactions and by reading a compendium of the analysis and interpretation of the results of the study.

The study should point to relevant aspects of the embodiment and interaction rhythm of one child on the autism spectrum for practitioners and researchers to direct and allocate resources in their research.

The study will contribute to the content of the master thesis work of P.I.—aiming at comparing the human-child on the autism spectrum interaction to the robot-child on the autism spectrum interaction—and will significantly extend her qualifications and knowledge for future research contributions to the field.

The study will extend the expertise of the involved supervisor, contributing to bridging well-known gaps between academic research and communities of practice.

The study will serve as exemplar within the MEi:CogSci curriculum, helping to streamline the key process of ensuring compliance with ethical regulations, and to making efficient collaboration with the Ethics Committee a sustainable and sustained reality.

3d Weitere ethische Aspekte

3.22. Werden die Teilnehmenden in vollem Umfang über Art, Ziel und Inhalt der Studie informiert?

☒ Ja ☐ Nein, Begründung:

Werden die Teilnehmenden getäuscht?

☐ Ja ☒ Nein

Wenn ja: Beschreibung und Begründung der Notwendigkeit der Täuschung:

3.23. Welche weiteren möglicherweise auftretenden Probleme bzgl. Studienteilnahme und Studiendurchführung gibt es aus Ihrer Sicht?

Other possible issues that might occur during the implementation of the study are related to all technical procedures, ranging from the handling of equipment to the handling of electronic data and workflows. These aspects are being addressed through involvement of related sources of expertise, and continuous proactive verification of the P.I.'s qualifications.

3.24. In welchem Verhältnis stehen potenzielle Risiken der Studie zum erwarteten wissenschaftlichen und gesellschaftlichen Nutzen?

Intrusion of privacy is a delicate ethical aspect in research, especially if it involves vulnerable participants. In the case of the current study, the investigation of the participant's sensori-motor interaction patterns and reaction times in turn-taking games will allow consideration in a complete manner than possible in the context of online interaction and direct observation. Also, the interpretation of the observed behaviors will be made in context. Given the absolute paucity of available material of this kind, the results of this contained and carefully prepared pilot study can be expected to provide highly valuable information to all parties involved: to the parents of the child—on how their child interacts with the environment (sensori-motor patterns and interaction rhythm)—, to researchers and practitioners in the field—for their studying and interacting with children on the autism spectrum—, and for the society at large—to gain an improved understanding on the nature and manifestations of autism spectrum disorder and how it can help create adapted environments.

3.25. Unter welchen Bedingungen ist eine Unterbrechung der Studie vorgesehen? Unter welchen Umständen wird die Studie gänzlich abgebrochen?

The study will be paused immediately in the case of the observation of early signs of alarming behaviors of the participant, such as: refusal to spend time in the playing room, aggression towards the camera and distress for being filmed, any kind of medical condition, behaviors that put the dignity of the participant at risk, in case of physical injury or emotional distress, and if during the P.I.'s regular debriefings and discussions with her supervisor X, the master thesis supervisor Paolo Petta, or the legal caregivers of the participant any issues should be identified.
The study will then not be resumed unless a consensual solution has been identified and clearly documented.
The study will be terminated at the request of the legal caregivers at any point during the study, without any need to specify a reason and without experiencing unfavorable consequences to the well-being of either the child or the caregivers, or whenever the interaction supervisor, the master thesis supervisor and the experimenter should reach consensus that the continuation of the study be no longer beneficial.
If the study should be terminated prematurely, all acquired data will be deleted immediately.
Any such termination is to be clearly documented and acknowledged in written form by all these parties.

4. Sonstige Anmerkungen

5. Studiendurchführende

Geben Sie alle an der Studie Mitarbeitenden an:

Bitte berücksichtigen Sie dabei ggf. die Abgrenzung der Funktionen Projektleitung (Leitung des Gesamtprojekts), Studienleitung (Leitung einer Teilstudie) und Versuchsleitung (Durchführung einer Studie). Diese unterschiedlichen Funktionen bzw. Zuständigkeiten sollen auch in der TeilnehmerInneninformation und Einverständniserklärung entsprechend abgebildet werden.

Name	Institution	Funktion*	Qualifikation**

* z. B. Studienleitung, Projektleitung, Versuchsleitung, Planung, Auswertung, Datenerhebung

** z. B. Senior Researcher, Dissertant/in, Postdoc usw.

Gibt es Interessenskonflikte zwischen den beteiligten Forscher(inne)n?

☐ Ja ☒ Nein

Wenn Ja: Beiblatt Interessenskonflikt ausfüllen und beilegen.

6. Name und Unterschrift der antragstellenden Person

Name:
Institution/Firma:
Position:

Unterschrift der antragstellenden Person: Hiermit bestätige ich, dass die in diesem Antrag gemachten Angaben zur geplanten Studie korrekt sind und die Studie gemäß dieser Angaben und in Übereinstimmung mit den Prinzipien guten wissenschaftlichen Arbeitens durchgeführt wird.

Ich versichere, den empirischen Projektteil der eingereichten Studie (Rekrutierung, Datenerhebung) nicht vor dem Votum der Ethikkommission zu beginnen.

Unterschrift der Antragstellerin/des Antragstellers, Datum

6.1. Zustellungsbevollmächtigte/r falls nicht antragstellende Person

Legal Guardian's Information and Legal Guardian Consent Sheet for the Participation of a Child under Their Custody in the Study, *Sensory-Motor Patterns and Interaction Rhythm of a Child on the Autism Spectrum*

Dear Legal Guardian,

a child under your custody is invited to participate in the study, "Sensori-Motor Patterns and Interaction Rhythm of a Child on the Autism Spectrum", which is to be carried out by P.I., in the context of her master thesis work at the University of Vienna (Supervisor: Dr. Paolo Petta).

As the legal guardian of this minor child, you are authorized to give your consent for the voluntary participation of your child in this study. You can refuse to allow your child to participate in the study, and you can retract your consent at any time during the study, without having to provide explanations and without incurring any negative consequences.

The planned study is necessary to gain valuable scientific knowledge about the play behavior of your child on the autism spectrum. The child's participation in the study is only possible with both, the child's and the legal guardian's consent. Please study the following text carefully and do not hesitate to contact the principal investigator of the study, P.I., with any questions you may have.

Please sign the consent form *only* if:

- you have fully understood the aim, purpose, and scope of the planned study,
- you are ready to allow your child to participate in the study
- you are clear about your rights as a legal guardian participant and the rights of your participant child in the study

1. What are the Aim and Purpose of the Study?

*This study is aimed at contributing to the verification of the practical applicability and helpfulness of a novel way of looking at and understanding the behavior of children on the autism spectrum. According to this view, their behavior is not due to some "*disease*" to be "cured", but rather reflects an altogether different reality in which they live, perceiving their environment and responding to social interaction in ways uncommon to us "*neurotypicals*". If corroborated, this perspective should inform new ways to develop and establish working relationships between the worlds of persons on the autism spectrum and neurotypicals, to foster improved mutual understanding, and to establish environments suited to all.*
This work is part of P.I.'s master thesis work, in which she compares interactions between children on the autism spectrum and human caregivers *to those of children on the autism spectrum and* robots, *typifying the observed realities and trying to characterize the fuller potential of either setting, so as to develop promising ways of employing and combining the two options.*
*Beyond these scientific aims, learning how to carry out successful studies, gaining in methodological and practical experience about the "*dos and don'ts*" is a key stepping stone towards larger diffusion and larger-scale research on this topic, thereby also closing the gap and improving the exchange between the communities of academic researchers and applied practitioners, who share the aim to improve the quality of life of persons on the autism spectrum, of the people close to them, and of our society as a whole.*

2. How is the Study Implemented?

*In order to be able to study with due care what actually happens between the caregiver and the child, and what behavior the child actually engages in, the Principle Investigator (P.I.) P.I. will set out with acquiring video footage — over six sessions, lasting no more than half an hour each — from two different camera angles. In these sessions, she will try to engage the child in specific kinds of activities (social interactions, as well as individual problem solving and other tasks), that are expected to be particularly informative. Against the background of the personal experience of different situations that developed in the recorded sessions, she will then analyze the collected video material with the help of software that allows to jointly inspect and annotate the two video streams: Through these annotations, and considering the contexts within and across which the observed behavior unfolded, we expect to identify and relate indications, references, symptoms, and pieces of the child's activity and subjective experience in a way that matches the predictions of the novel "*situated, embodied, embedded*" model of human behavior. This should help the development of a novel, markedly better, more comprehensive, more informative, and more successful way to understand, manage, and participate in the social life worlds of autistics* and *neurotypicals in particular, and more generally the development of a better grasp on human social reality.*
This proposed study is a pilot case: an important and comparatively small-scale observation of the behavior of a single established dyad (i.e., the individual behaviors and interactions of two people who have already bonded) consisting of a single child on the autism spectrum and a single human caregiver.
At the end of each filming day, P.I. will provide you with a summary of the filmed interaction sessions, reports on the physical and emotional condition of the child, the highlights of the day and any issues encountered. You will then always have the opportunity to ask any questions you may have. As active contribution to data protection, you will also be reminded of your voluntary participation in the study and the option to revoke your consent.
As already mentioned, we aim to collect a total of three hours of video material, across sessions of 30 minutes duration. This target reflects estimates of the amount of recorded material likely needed in order to capture multiple instances of the targeted behavior, as required for a more representative analysis and interpretation in a single-subject study design. In-between interaction sessions, the participant child will be granted breaks of at least 30 minutes, and we do not plan to record more than three sessions per day, i.e.: up to 1.5 hrs of recorded video acquired per day over 2.5 hrs (set-up and wrap-up times not considered). The video-acquisition part of the study thus should take place over 2 to 3 (probably not consecutive) non-working days (i.e., rest days).
Before each interaction session, P.I. will show the child the cameras and explain in simplest terms and with the use of gestures that the interaction will be filmed. During each session, she will verify the cameras are in working order and remind the child of the presence of the cameras and that the cameras are filming them. In case of the child presenting any negative, e.g. aggressive, behaviors towards the cameras, a protocol will be implemented (cf. item 7 on identified risks and issues, below). Within the first minutes of each recording, P.I. will carry out a short evaluation of the child's mood and physical well-being: In case of identified physical or mental distress, a special protocol will be implemented (cf. item 7 on identified risks and issues, below).
P.I. will apply principles of Applied Behavioral Analysis (ABA) to interact with the participant child in the study in a fun manner, and will try to engage the child to play properly with toys and to bring activities to completion (e.g. puzzles). She will not force the child into unwanted activities, but will apply 2-3 physical prompts in case the child should not initiate response to a proposed task itself. In case of any unexpected events in the interaction (cf. item 7 on identified risks and issues), ABA principles will be applied to deal with the situation at hand.
The setting-up of the recording equipment and all filming will take place in the participant's room, inside the familiar setting of the child's home. P.I. will set up and check the filming equipment, collect the data of the interaction session, move and process the video data on her personal laptop, and finally transfer the material to safe online storage at the University of Vienna. She will analyze and interpret the data under qualified methodological and scientific supervision; and will draw final conclusions based on these empirical findings and a review of published related work.

3. Context of the Study

This study is part of P.I.'s master thesis work at the University of Vienna that is aimed at explicating the roles of theory, research, and therapy and the relationships between these fields involved in the study of Autism Spectrum Disorder. In her master thesis, P.I. intends to advocate an enactive account of the disorder: This view highlights how also persons on the autism spectrum's style of social interaction are largely dependent on their particular perceptions and engaged in making sense of this experienced environment. A key role of this study within the master thesis work is to investigate implications of the enactive account of the disorder that are of practical *importance. Another aim is to compare the interactions of ASD individuals with "neurotypical" humans (as characterized in the results of this observational study and the enactive account of social interaction) to their interactions with robots employed in therapeutical settings — as described by international high-quality research projects in Europe (such as DREAM, https:// dream2020.eu/*, last visited 2018-03-26*) and the US (cf. e.g. Brian Scassellati's research group at Yale University, https://scazlab.yale.edu/ , last visited 2018-03-26) — to understand how each kind of interaction relates to the nature of the ASD and the Sensory-motor needs of the ASD person: What are lowlights of each interaction type, and how can they be minimized? And what are highlights, and how can they be best exploited?*

4. Requirements for Participation and the Role of the Participant Child in the Study

To qualify for the study, the participant child must have a diagnosis on the autism spectrum and must have the basic levels of imitation, receptive instruction, and playing skills. These qualifications will be ascertained by X, BCBA (Board Certified Behavioral Analyst).
The participant child in the study will engage in social interaction in their private room for 30 min with P.I.. The participant child can leave the room at any time (cf. item 7 on identified risks and issues, below). The participant child will be encouraged to play properly with toys through well-known activities, will participate in play activities that are appropriate for their age, and will be spending a small period of time on independent play. In-between each of the at most three daily sessions, your child will be granted 30 min breaks.

5. Credentials and Roles of the Project Staff

P.I., *B.S. in Psychology, is a cognitive science master student at the Department of Philosophy at the University of Vienna (supervisor: Univ.-Lektor Dipl.-Ing. Dr. Paolo Petta), and is pursuing the RBT Credential (https://www.bacb.com/rbt/ - last visited 2018-03-26) under the supervision of M.S. X, BCBA.*
P.I. carried out voluntary work for six months at AITA (Association for Therapeutic Intervention in Autism Disorders, Bucharest, Romania-2014-2015), assisted a child on the autism spectrum in completing activities in kindergarten for four months (Bucharest, Romania - 2014), assisted in-home ABA therapy for five months for a child on the autism spectrum (Bucharest, Romania - 2015), and most recently has applied behavioral principles in teaching skills and ensuring a successful communication in her interaction with two children on the autism spectrum under the supervision of X, BCBA, for a year (Vienna, Austria – 2016-2017). She has acquired the working knowledge and skills required to get to know the personality of ASD children: their sensorial needs and challenges, and their responses to specific environmental stimuli; and has learned to address ASD children's tantrums and meltdowns.

P.I. is affiliated with the University of Vienna, Department of Philosophy.
The tasks of P.I. as **principal investigator** *in this study include: to serve as main point of contact in the interactions of the legal guardians of the participant child with the scientific peers; responsibility for the installation and care of the technical equipment for recording and for the temporary storing for the processing of the video data; protecting the confidentiality of the recorded data, the information about the study participant, and about the legal guardians; responsibility for the interaction with the participant child, minimizing risks and implementing procedures for handling of side effects of the interaction— cf. item 7 on identified risks and issues, below).*

Paolo Petta, *Univ.-Lektor Dipl.-Ing. Dr.rer.tech, is qualified for supervision in the field of cognitive science in general and in the field of cognitive robotics in interventional social settings in particular, given his topical research activities, such as in the EU projects SAFIRA (Supporting Affective Interactions in Real-Time Applications), HUMAINE (Human-Machine Interaction Network of Excellence on Emotions), and SERA (Social Engagement for Robots and Agents), next to ongoing teaching and supervising in the Middle European interdisciplinary master's program in Cognitive Science (MEi:CogSci) at the University of Vienna, Department of Philosophy and the Medical University of Vienna, Institute of Artificial Intelligence and Decision Support.*

For the present purposes, Paolo Petta is affiliated with the University of Vienna, Department of Philosophy. His main tasks as **project supervisor** *include: supervision of the activities of the principal investigator; contact person for the legal guardians and the scientific peers; maintenance of the online platform for the sharing of the recorded data with legal guardians, scientific peers, and X; handling the technical and policy issues associated with the permanent storing of the participant's data at the University of Vienna.*

X, *M.A., is a Board Certified Behavioral Analyst (BCBA - Certification Number: 1-07-3952; Original Certification Date: 2007-11-30). She has been P.I.'s supervisor in her professional interaction in Vienna with two children on the autism spectrum for approximately 1 year, between 2016 and 2017. X evaluates the performance of the acquired skills of your child and the efficacy of the implemented Applied Behavioral Analysis Programs at least once a month.*

The main tasks of X as **Board Certified Behavioral Analyst** *include: providing the project lead with a written signed consent form confirming that the participant child presented at the last evaluation the basic skills of imitation, receptive instruction, and playing necessary to qualify for the study; supervising all ABA-related activities of P.I. (i.e., compliance with ABA principles in the interaction with children); and being a contact person for P.I. and the legal guardians of the participant child during the implementation of the study sessions. X, BCBA, has the right to abort the study in light of relevant and alarming issues that might endanger the well-being of the participant child and/or of the legal guardians.*

6. What is Gained by Participating in the Study?

The interaction sessions will engage the participant child in fun play and encouraged completion of feasible tasks, and will provide opportunities for them to engage in one-on-one social interaction with a known and trusted other person.
By participating in the Study, you become entitled to be informed about the identified characteristics of the way the participant child moves and senses the environment, as documented in recorded interaction behavior and explained in a compendium of the results of the study to be provided to you. You have the right to access all recorded video material, upon providing written confirmation of your understanding of assumed data protection responsibilities. At your request, you will be provided with an electronic copy of P.I.'s completed master thesis in PDF format, and you may ask for clarifications regarding its content. All information provided about this study is to be considered confidential and must not be shared without the explicit consent of the researchers involved.
For researchers and practitioners in the field, the study is expected to explicate relevant aspects of the embodiment and interaction rhythm of children on the autism spectrum, informing and contributing to shaping further research in the area.
For P.I., the study will not only form an important part of her master thesis effort, but also allow her to exercise and further develop her knowledge and skills in carrying out applied research in the field, equipping her for her planned Ph.D. studies and further improving her abilities to bridge the gap between the work realities of academic research and applied therapeutical practice.

7. Are There Any Identified Risks in the Implementation of the Study, and Are There Any Issues or Other Side Effects to Reckon With?

The participant child must not present any medical symptoms before and during the recording of the interaction sessions. Identified health issues with the participant child (e.g., as indicated by explicit complaints and other symptoms) prior and during the study must be reported and can lead to the exclusion of the participant child from the study.

Risks:

Health and Safety

1. The participant child in the study may sustain physical injury.

*Handling Procedure: In case of a minor physical injury, the legal caregivers will be informed immediately about the incident. In case of a major physical injury, local authorities (European emergency number: 112; Austrian Police: 133, Austrian Ambulance: 144) and legal caregivers will be immediately called/*summoned*, and the participant child's injuries will be temporarily dealt with by applying first aid measures.*

Risk Probability: Physical injuries have a low probability of occurring, as the participant child is not exposed to harm and danger during the study to a greater extent than in regular daily interaction.

Impact: The impact of these events on the health of the participant child can range from minor to severe, depending on the nature of the injury.

Minimizing risks: To minimize this risk, the interactions between P.I. and the participant will be restricted to the playroom in the house, and will not include intense activities (such as climbing, running, or jumping on inappropriate surfaces).

The participant child will be monitored during the sessions for any kind of medical sign or condition that could affect the outcome of the study or that could indicate deterioration of the well-being of the participant. In case of an observed relevant medical sign or condition prior or during an interaction session, the study will be immediately suspended until renewed explicit clearance by the legal caregivers.

Emotional well-being

1. The participant might show ostensive aggressive behaviors towards the cameras in the room.

2. The participant might display behaviors associated with shame or feelings of distress for being filmed.

Handling Procedure: In either case, a special protocol will be implemented, according to the regulations provided by X, BCBA, and the professional and ethical guidelines of the Registered Behavior Technician (RBT). The child will be immediately removed from the stressful environment and handed over for temporary care to the caregiver present in the home. Then, all video recordings will be terminated, and the cameras will be stored in a safe and hidden storage space outside the room. The continuation of the study and the processing of the acquired material will be made pending on obtaining renewed clearance from the participant's legal caregivers, the therapy supervisor, and the master thesis supervisor.

Risk Probability: Both classes of risks have a low probability of occurring, because all candidate participant children have been filmed before by the legal caretakers and by P.I. at the legal caregiver's request, and no alarming behaviors were recorded.

Minimizing risks: To minimize the risk of emotional distress, both cameras employed will be placed on high surfaces in the room (i.e., on a wardrobe), and they will not intervene directly in the interaction between the principal investigator and the child.

Impact: The impact of this risk can range from small to large, depending on factors such as the personality and mood of the child, as well as past and recent experiences.

3. The study participant may undergo meltdowns due to increased sensory stimulation or tantrums during the interaction sessions. Meltdowns and tantrums are states experienced on a regular basis by persons on the autism spectrum.

Handling Procedure: In case of a meltdown, the principal investigator will try to immediately identify the source of the sensory overload, the child will be prompted to make a stop gesture, and the identified disturbing sensorial source or the child will be removed from the environment. In case of a tantrum, the function of the behavior will be identified, and specific measures will be implemented, according to the recommendations made by X, BCBA, and the guidelines of the RBT code.

Risk Probability and Minimizing Risks: The probability of these risks is medium, because there are a variety of factors that can influence the occurrence of a meltdown or a tantrum, but as P.I. interacted with the potential participants for a year, she has personal experience in handling and minimizing the risk of tantrums and meltdowns.

Impact: The impact of the associated behaviors can range from small to medium, depending on the history of tantrums and sensorial states of the participant.

Participation in the Study

1. The participant child might not want to spend time in the study room.

Handling Procedure: The participant child is free to leave the study room at any point during the 30 min interaction session. In the case of the child leaving the room, 2-3 minutes will be spent outside the room before prompting the child to return to the room. If the child should refuse, a 30 min break will be granted. If after the break the child should still refuse to return to the room, the continuation of the study will depend on the outcomes of discussions with the interaction and master thesis supervisors, as well as renewed written consent from the legal caregivers.

Risk Probability and Minimizing Risks: The likelihood of this risk is low, because P.I. has bonded with each of the potential participant children over one year of continued interaction, and she will aim to make the social interaction fun and engaging. To further reduce this risk, a short evaluation of the child's physical well-being and mood will be made in the first 5 minutes of each interaction session. In case of detected fatigue or other conflicting health states, the continuation of the study will be paused until the child is feeling better.

Impact: The impact of this behavior is estimated to be low, as the participant child is familiar with their private play room serving as study room, and they know they can leave this room at any point.

Invasion of Privacy

1. The participant child may not understand that a study is taking place and/or the implications and the procedure of the study (i.e., that the participant is being filmed).

Risk Probability: The likelihood of occurrence of this risk is medium, depending on how well the child understands the explanations received from the principal investigator about the planned study.

Minimizing Risks: To minimize the risk, P.I. will show the participant child the cameras before the beginning of the study and before each interaction session, and she will explain in plain terms and gestures that the participant is to be filmed for a period of time. During the sessions, she will also point from time to time at the cameras in the room and make short comments about the cameras filming.

Handling Procedure: In case of the appearance of behaviors that threaten the dignity of the participant, the participant child will be gently guided to other activities, and persisting and processing of the specific video will be pending on consent from the legal caregivers.

Impact: The impact of recording indecent behaviors can range from low to medium, depending on the participant child's understanding of the purpose of the interaction and of the presence and role of the camera in the study room.

Management of Research Data

Acquired video files will be cleaned of any identifying meta-data (e.g., automatic geo-location tagging; with the exception of identifiers required for anonymous access), all material will be stored and handled in anonymized fashion. The video files will be permanently stored in password-protected safe storage *space provided by the central facilities of the University of Vienna. The video data will be processed with the professional annotation tool ELAN (https://tla.mpi.nl/tools/tla-tools/elan/, visited 2018-03-26), and specific behaviors and time responses of the participant child will be annotated according to the research questions of the study. Frequencies of the annotated behaviors, reaction times of the participant child, comparisons of identified reaction times with results documented in the literature, as well as specific key behaviors will be analyzed and interpreted. Throughout all analysis, interpretation, and publication of data, code names will be used to refer to the participant.*

After completion of the study, the anonymized video data and related documents will be stored on the password-protected online storage space at the University of Vienna. The University of Vienna ZID (Zentraler Informatikdienst) has confirmed that this storage is fit for this purpose. The data will be accessible only to P.I. - principal investigator, Paolo Petta - master thesis supervisor, and — upon request — to the members of the defensio jury; X, BCBA- consulting therapy supervisor; and the legal caregivers of the participant to the study. Each granted access will be password-protected and requires binding compliance with preservation of data protection.

Further sharing of video material in case of publication of the research results in a scientific journal will be made dependent on binding compliance with preservation of the anonymity of the recorded participant and abstaining from any activity that could endanger such anonymity (e.g. blurring the face of the participant child).

During and beyond the completed study, accurate and complete trails of the data and related processes will be kept (including access logs to the central data repository at the University of Vienna), also so as to allow detection and assessment of the extent of any data corruption and breaches, and the initiation of related handling and recovery procedures.

The cleaned and consolidated data sets will be kept on the safe storage facility offered by the University of Vienna as valuable scientific data assets for as long as the quality of service can be guaranteed and any necessary hand-over from one responsible person to the next can be implemented and cleanly documented. Availability of data will be terminated as soon any of these conditions (i.e., consideration of the data assets to be of value to the scientific community by the person in charge; guaranteed quality of service by the University of Vienna technical management; retirement of the responsible person in charge without appointment of a successor) should become violated. But for exceptional circumstances preventing the implementation of the ensuing procedure, before such termination of service all parties with working access grants will be informed with a grace period of at least two weeks.

Other Effects

Participation in the study requires spending time in a room for a continuous period of time of 30 min. At the end of the session, the participant child might avoid interacting with other persons and might want to spend time alone.

During the interaction, the participant child will spend their time in an appropriate and adequate manner. The sessions will engage the child in meaningful interactions during which the child will play appropriately with toys and will complete activities.

8. Does Participation in the Study Imply any Further Effects on the Way of Life and What are the Resulting Commitments?

Participation in the study will involve spending time in a room for a continuous period of time of 30 min. At the end of each such session, the child might avoid interacting with other persons and might want to spend time alone.

During the sessions, your child will spend his time in an appropriate and adequate manner. The sessions will engage the child in a meaningful interaction during which the child will play appropriately with toys and will complete activities.

9. What is to be Done Upon Occurrence of Symptoms of Discomfort, Unwanted Side Effects and/or Injuries?

Any symptoms of discomfort, side effects, and injuries that should occur will be immediately reported to the legal caregivers, the supervisor of the study, and the BCBA supervisor. These include e.g. the participant child's refusal to spend time in the playing room, aggression towards the camera and distress for being filmed, any kind of medical condition, behaviors that put the dignity of the participant at risk, physical injury or emotional distress. The study will then not be resumed unless a consensual solution has been identified and clearly documented. After any such potential risk should materialize, legal caregivers will be asked for renewed written consent to continue in the participation to the study. In case of occurrence of any of the mentioned side effects, a specific and immediate protocol will be implemented, as described in the 'Handling Procedure' section of item 7, 'Are there any Identified Risks in the Implementation…', above. In case of occurrence of unforeseen side effects, the continuation of the study will be paused until discussions and further consent from legal guardians and project supervisor will be obtained.

10. When Will the Study be Aborted?

The study can be prematurely terminated by the legal caregivers of the client at any time, without having to specify any reason for doing so and without incurring negative consequences. The study will also be aborted if the principal investigator, the supervisor of the project, and the BCBA should reach consensus that participation to the study is not warranted.
If the study should be terminated prematurely, all acquired data will be deleted immediately.
Any such termination is to be clearly documented and acknowledged in written form by all these parties.

11. In Which Ways will the Data Collected in the Context of this Study be Used?

Setup of Equipment
In the study room, two cameras will be filming: a smartphone camera and a small digital camera. Both cameras will be positioned at a high location, i.e., on top of a wardrobe. Before and during each recording session, P.I. will verify the equipment is in working condition. She will likewise take care of cleaning up the technical installation at the end of each recording day.

Procedure and Data Collection
Both cameras will operate independently over each 30 min recording session. P.I. will check the cameras a few times per session to make sure they are in working condition (including verifying the field of view, etc.). After 30 min, an alarm (that the child has been acquainted with before the study) will ring, to announce the end of the session.

Data Handling
All filmed data is immediately transferred to safe online storage space technically managed by the University of Vienna ZID (Zentraler Informatikdienst), and it will be used for scientific research purposes only. The data will have been cleaned of all identifying meta-data (such as geolocation data, with the exception of identifiers allowing for anonymous access). All data will be handled in a secure and confidential manner during and after the study. In more detail, at the end of each recording session, P.I. will transfer all filmed data to her password-protected personal laptop, with filenames complying with an anonymization scheme. All data on the phone and the digital camera will be deleted immediately after this transfer to the laptop. The video data and the informed consent data of the study will be kept separate (i.e. in different locations), so that the names of the participants cannot be associated with the videos. P.I. will then immediately transfer the consolidated cleaned video files from her laptop onto a safe storage space provided by the University of Vienna (deleting the files from her personal laptop).

Data Storing
All recorded data will be stored in an anonymized form in a password-protected electronic storage space at the University of Vienna. P.I. was assured by the ZID (Zentraler Informatikdienst) at the University of Vienna that the storage space is fit for storing such confidential study data. Please see item 7 for planned data handling beyond

the lifetime of the study. In case you should wish to retract your consent from the study, all related data will be deleted immediately upon receipt of written authoritative request (cf. "Confidentiality", below, in case of publication).

Confidentiality
All recorded data will be stored and processed in anonymized form. If considered scientifically relevant, the gender and the diagnosis on the autism spectrum of the participant might be disclosed.
During the study, the following persons will have access to the collected data: P.I., Paolo Petta, qualified scientific peers of P.I. (e.g. members of the Defensio jury) upon written request, and X, the BCBA consulting therapy supervisor. Each mentioned person will pledge in written to comply with the rules of confidentiality and data protection. Any permission to visualize the video files will be granted through dedicated person-specific credentials, and all access will be recorded in a data trail.
As a relationship has already been established between P.I. and you and your child, we herewith confirm explicitly that no information acquired prior to the participation to this study has been or will be made public without your knowledge and without your explicit and written consent.
You can retract your informed consent and thereby request the deletion of all acquired study data in authenticated written form only. Such request should be sent to the P.I. or the academic supervisor Paolo Petta, and confirmation of delivery should be obtained. Legitimated requests are to be followed up immediately. In compliance with established European best practice (cf. e.g., the published Opinions of the Article 29 Data Protection Working Party of the European Commission), any withdrawal is not retroactive but prevents any further processing of the interested individual's data.

12. Do any Costs Result from Participation in the Study? Is there any Compensation or Reimbursement?

With your consent you grant us permission to use your household rooms for the described study purposes and in particular to draw on your household electrical facilities to power our machinery (i.e., including the two digital cameras and P.I.'s laptop). Any additional use of facilities or commodities will be explicitly requested and is up to negotiation. Your participation in the study is free of charge and you will not receive any monetary compensation. The P.I. will not receive any monetary sum for her interaction with the participant child in the study. Insurance for both participants in the interaction will be covered by the Wiener Gebietskrankenkasse (WGKK).

13. Opportunity to Discuss any Further Questions

For any further questions, please contact the P.I., Study guidance, as well as information about the rights of the participant will be readily offered. Further information will be provided through consultation with the advisors.

Principal Investigator, Study Lead	Name: P.I.
Experiment and Master Thesis Supervisor	Name: Paolo Petta
Other relevant persons	

14. Declaration of Informed Consent by the Legal Guardian

Name of the legal guardian in capital letters: ....

Name of the participant child under their custody in capital letters: ……………………..…………………………….

Date of birth of the participant child under their custody: ....

I agree to have the identified child under my custody participate in the study, "Sensory-Motor Patterns and Interaction Rhythm of a Child on the Autism Spectrum".

I have been informed in detail and explicitly by P.I. about the aims, importance and scope of the study and the resulting demands on me for the participation of my child in the study. In addition, I have read the text of this Legal Guardian Information Sheet and Consent Form, in particular section 7, *Are There Any Identified Risks in the Implementation of the Study, and Are There Any Issues or Other Side Effects to Reckon With?* All questions that occurred to me have been answered comprehensibly and sufficiently by the study lead. I had sufficient time to decide whether I would like the child in my custody to participate in the study. I have no further questions at the moment.
I will comply with the guidelines as required for the implementation of the study, but I do reserve the right to terminate my voluntary participation at any time, without incurring any drawbacks. In case I should want to drop out of the study, I can request the necessary steps to be initiated at any time, in writing or orally, with "P.I. (email:)".

At the same time, I agree that the behavior of the identified child under my custody be video recorded and analyzed in the study.
I agree that the recorded data will be permanently stored electronically in anonymized form. The data is to be stored in a form accessible only to the project management (P.I. and Paolo Petta), secured according to current standards.

Should I wish to have my data deleted at a later date, I can request the necessary steps to be initiated without having to specify any reason, in writing,
with "P.I. (email:)"
or the academic supervisor, "Paolo Petta (email:)".

I have read and understood the section with the explanations. During the informed consent discussion, I was able to ask all questions of my interest. These have been answered completely and comprehensibly.

I have received a copy of this participant information and consent form.
The original remains with the study lead.

(Date and signature of the legal guardian)

....

(Date, name and signature of the study lead)

....

"*Hello A!*

Today we will play together with toys, with the car, with the Lego blocks.

And look, we have these here also: a phone with a camera and another camera.
I would like to film us, how we play/ the cameras will watch and record us.
I would like to record us to get to know you better and how we play. need to film us to know more about you.
Would you like that? Is this OK with you?"

I will give A the phone and the camera to inspect the video camera to understand what they are.

"*I will put the cameras here [on top of the wardrobe], and the cameras will be filming/will be watching us. Is this OK with you? Do you want that?*"

These questions are not aimed at obtaining a response to the specific question asked, but rather serve as probes for any adverse reaction to the cameras, and for an acknowledgment of the presence of the cameras, such as a gesture or an eye gaze at the camera.

„*Hallo A!*

Heute werden wir zusammen mit Spielzeugen (mit dem Auto, mit den Legosteinen) spielen.

Und schau, wir haben auch diese hier: ein Telefon mit einer Kamera und eine zweite Kamera. Ich möchte uns filmen, wie wir spielen / die Kameras werden uns sehen. Ich möchte uns filmen, um mehr über Dich zu erfahren. Würde Dir das gefallen? Ist das OK für Dich?

Ich werde die Kameras hier [oben auf den Schrank] aufstellen, und die Kameras werden uns filmen / uns beobachten. Ist das OK für Dich? Willst du das?"

One candidate child is non-verbal and understands English, the other candidate child is verbal (can pronounce just a few words) and understands German. But the level of understanding of the children is low and they can understand only words (e.g. "banana"," crackers", "water") or short instructions ("Do this", "Give me", "Come here", "Sit down", "Stand up"). Also for this reason, the actual purpose of questions asked is as explained above.

A-play session example

P.I. will arrive to the playroom 20 min before the beginning of the first of each day's recording sessions. She will install the equipment and verify it is functioning. She will also verify availability and ready all required toys and other materials in the room of the participant.

1. Informed Consent: The child enters the playroom. P.I. will pick up each of the cameras and explain to the child that their interaction will be filmed. She will also make the child familiar with the sound of the alarm that will ring at the end of each recording session. If the child does not present any aggressive behaviors towards the cameras or the sound of the alarm, she will set up the alarm and will proceed with the next step.
2. Assessing the condition of the child: P.I. will put the cameras back to their nominal recording location and will verify their functioning. She will then engage with the child in physical play for around 5 min (tickling, massaging, jumping on the trampoline, dancing, carrying out any other preferred activities, etc.). During this period, she will evaluate the physical and emotional condition of the child. She will take notes on the condition of the child, and if the child should seem tired or distressed, the interaction will be postponed for up to a few hours or downright to the next agreed day of recording. If the child should seem to be in a fit condition, then she will proceed with the next step.
3. Cooperation phase: P.I. will interact with the child for 10 min by encouraging cooperative play with mastered toys and activities: playing with car, building a Lego tower, assembling a puzzle, singing a song. During this phase, the interaction will consist in playing one cooperative game after the other (maximum 10 activities) and in a 15s playing with a preferred toy after each completed game In case the child should not respond in cooperative tasks, P.I. will provide the child with up to 3 gentle physical prompts. In case the child should still not respond to the interaction, P.I. will change the activity. After 10 min, P.I. will move to the next step.
4. Independent play: P.I. will put out preferred toys of the child and some further activities, and will leave the child to play independently. During this phase, the child is expected to interact with selected objects or to occupy their time with routine activities. This phase will last around 5 min. After the allocated time, P.I. will move to the next step.
5. Sensorial phase: P.I. will encourage completion of tasks that require fine motricity coordination (e.g. buttons in a box, putting pieces on a string), and gross motricity coordination (e.g. following an obstacle course: going over a stick, going through a tunnel, jumping on the trampoline). The sensorial phase will last around 10 min. During this phase, P.I. will present the child with one activity after the other, and the child is expected to complete them independently. In case of delayed response to the completion of the game, P.I. will provide up to 3 physical prompts. In case the child still does not interact appropriately with the activity, P.I. will present the next game. After each task, the child will receive a preferred toy to play with for 15-20s. At the end of the allocated time, P.I. will move on to the next phase.
6. Independent play: P.I. will leave the child to play independently with objects of choice. This phase will last around 3 min, during which the child is expected to interact with the displayed objects or to interact with the environment in a regular way. At the end of this phase, P.I. will praise the child for their interaction, will inform the child that the session is over and will hand in the child to the present caregiver in the house.

7. Free time: After completion of each interaction session (i.e. at the latest upon the ringing of the alarm), the child will have a 30 min break. In case the participant to the study will not want to take a break, P.I. will put preferred toys and activities in the room in the house which is supervised by the caregiver.

During the interaction, P.I. will check the cameras a few (typically: 2-3) times and at these occasions will remind the child that the cameras are filming.