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Social attention and gaze behavior in autism spectrum disorder

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1. Theoretical Background

Attending to another person as well as looking into their face and eyes are integral parts of human social interactions (Puce & Bertenthal, 2015). Through this, we can gather information on others' intentions, and emotional states or establish connections (Puce & Bertenthal, 2015). The innate attentional bias towards these stimuli, which are relevant for navigating social situations, is called social attention and has been widely studied in humans from birth on into adulthood (Puce & Bertenthal, 2015).

The face in general and the eyes in particular are special stimuli that capture our attention and appear to be processed in specialized neural systems (Haxby et al., 2000; Puce et al., 2015). Many studies have therefore focused on exploring behavioral and neural aspects of face processing, eye contact, and gaze behavior through measures like eye-tracking or neuroimaging.

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social communication and interaction, restricted, repetitive behaviors, and interests and/or sensory behaviors that begin early in life (American Psychiatric Association (APA), 2013). A more recent view of ASD sees the condition on a spectrum of *neurodiversity*, where deviations from what is considered to be typical human development are considered *neurodivergent*, and the range that constitutes typical development is *neurotypical* (NT) (Pellicano & den Houting, 2022).

Research on ASD has proposed that decreased social attention leads to such deficits in the social domain (Falck-Ytter et al., 2023). Studies comparing individuals with and without a diagnosis of ASD have indeed found evidence that autistic participants attend less to stimuli that are of social relevance (Chita-Tegmark, 2016; Guillon et al., 2014). A special focus lies hereby on the eye region as the eyes and the gaze of another person convey a lot of information, e.g. for processing emotional facial expressions or figuring out what another person attends to (Itier & Batty, 2009). However, various studies have found that the gaze of individuals with ASD does not linger as long or as often on this face region compared to the gaze of NT individuals (Guillon et al., 2014; Setien-Ramos et al., 2023). Theoretical frameworks propose that this is either due to these stimuli lacking the intrinsically rewarding qualities for individuals with ASD or that they tend to avoid the eyes as they represent aversive stimuli for them (Chevallier et al., 2012b; Stuart et al., 2023). At the same time as decreased attention to the eyes, increased gazing at the mouth in ASD has also been observed (Falck-Ytter & von Hofsten, 2011). Having said that, research on social attention and gaze behavior in ASD so far has yielded partially inconclusive results, and studies with paradigms that simulate real-life social interactions have not been widely conducted (Boraston & Blakemore, 2007; Falck-Ytter & von Hofsten, 2011).

The goal of this current study is to investigate gaze behavior in response to social stimuli encountered during a live interaction and to compare subjects with ASD to a NT control group. Eye-tracking technology will be used to measure gaze behavior and thus also social attention. Therefore, this thesis can contribute to the findings of studies examining social attention in ASD, especially by using an ecologically valid paradigm of social interaction. This might also bear relevance for the use of eye-tracking as a potential biomarker of ASD.

1.1. Visual Social Attention

Visual social attention can be defined as looking at and orienting towards other people, more specifically an inherent attentional bias towards social stimuli like faces or biological motion (Guillon et al., 2014). This attentional bias is shown from early infancy on and seems to serve an adaptive function that contributes to the development of social and communicative skills like for example language acquisition or face and emotion recognition (Chita-Tegmark, 2016). Observing another person's actions seems to evoke a cortical response in a similar way to when performing these actions oneself, a so-called 'mirror system' in the brain (Kilner et al., 2006). By paying attention to the behavior of a conversation partner, we can also anticipate their state of mind, like for example their intentions or desires (Bertenthal & Boyer, 2015).

During the first year of life, infants already display an inherent sensibility towards other humans (Puce & Bertenthal, 2015). In these early stages of development, the attention to social stimuli is more unintentional than intentional but still may provide the basis for later emerging facets of social cognition (Dawson et al., 2004; Rochat & Striano, 1999). The initial reflex to shift attention to social cues is driven by the encountered stimuli, which in turn during later stages of brain development allows for an individual to use their ability of selective and social attention (Puce & Bertenthal, 2015).

The face and eye area seem to be particularly salient stimuli relevant to social attention (Bertenthal & Boyer, 2015). Looking at these stimuli provides crucial information for social interactions (Falck-Ytter & von Hofsten, 2011). The intentions and emotions of the interaction partner are conveyed through facial gestures (Falck-Ytter & von Hofsten, 2011). Furthermore, their gaze direction as well as head and body orientation indicate where they divert and focus their attention (Falck-Ytter & von Hofsten, 2011; Langton et al., 2000). Attention can be guided through social interaction resulting either in eye contact, so-called mutual or direct gaze, as well as directing the attention to an object or event resulting in averted gaze (Bertenthal & Boyer, 2015). Additionally, looking at each other during a social exchange is a vital part of the interaction which helps to initiate, maintain, and regulate communication (Falck-Ytter & von Hofsten, 2011). When perceiving another individual's social attention on ourself by detecting their direct gaze, autonomic sympathetic arousal is increased (Helminen et al., 2011). This could be shown in a study by Helminen et al. (2011), where direct gaze elicited more elevated skin conductance responses, a marker for the autonomic nervous system, than averted or closed eyes irrespective of the duration of the eye contact.

Social attention on a behavioral level consists of the above-described behaviors, e.g. orienting towards faces, which are often assumed to be the result of specialized attention mechanisms in the brain (Falck-Ytter et al., 2023). While some of the evidence supports this hypothesis, an alternative view, which proposes that social attention is a result of domain-general attentional processes, namely bottom-up and top-down mechanisms of attention, is also discussed (Falck-Ytter et al., 2023). The development of social attention may also be the result of interrelated processes that are involved in selective attention: Exogenous orienting or stimulus-driven attention, and endogenous orienting or goal-directed attention (Corbetta & Shulman, 2002). Stimulus-driven attention starts with the stimulus and is considered to be done reflexively and automatically, with this mechanism being behind preferences that are shown from birth (Bertenthal & Boyer, 2015). In contrast, goal-directed attention requires the intentional allocation of attention based on an observer's goals or situation (Bertenthal & Boyer, 2015). When developing social attention and thereby an understanding of social interactions, a reciprocal relationship between where the attention of an individual is innately directed, which thus proposes a learning opportunity for social behavior, and the focus of attention based on what is acquired about others is likely (Bertenthal & Boyer, 2015).

While social attention is a complex process during development and in adulthood, that involves several elements, also for example head and body orientation or gestures (Langton et al., 2000), the focus in the following two subchapters will be mechanisms behind special attention to the face in general and to the eyes in particular.

1.1.1. Face Processing

Within the field of visual social attention, faces seem to be special stimuli for humans (Gliga & Csibra, 2007). Recognizing and processing them is a domain present from an early age and mastered by the time adulthood is reached (Gliga & Csibra, 2007). Functionally, the outstanding status of face perception is sensible for the recognition of others and therefore identifying friends or foes, recognizing relatives, and upkeep of social structures (Gliga & Csibra, 2007). Aside from other parts of the human body and other non-physical characteristics, like the voice, for example, we rely heavily on faces to identify one another (Gliga & Csibra, 2007). This seems to be the case because faces provide the most variable cues for recognizing another person and distinguishing them (Gliga & Csibra, 2007). As the main features of the face, namely eyes, mouth, and nose, and their arrangement are an integral feature of all humans, the perception of faces includes the identification of a person based on this innate structure as well as recognizing their emotional state by the changes of the shapes of facial features, like the mouth or the eyes, when we are expressing emotions (Hernandez et al., 2009). Not only is the recognition of identity a vital part deduced from the attention to faces but the information we can gain for social communication, especially from looking at the changeable parts of the face, is another aspect that plays a key role in face processing (Haxby et al., 2000).

As mentioned above, this interest in social stimuli in general and for faces in particular is present from infancy on. This early attentional bias towards faces permits forming the basis for developing social and emotional relationships by establishing reciprocity in social interactions (Hernandez et al., 2009). Basic orientation to face-like patterns has been examined in several studies with newborns and infants (Falck-Ytter et al., 2023). In their study, Johnson et al. (1991) could show that newborns more persistently track stimuli with schematic face-like features over ones with other patterns. One study also examined fetuses who exhibited preferential head turn behavior to face-like stimuli even before birth, although there has been criticism concerning the methods employed in this study (Reid et al., 2017; Scheel et al., 2018). Farroni et al. (2004) found that newborns aged two to five days looked longer at a schematic face with direct gaze. Substantial development in face perception is then shown from the age of two months on and gets more complex, as brain regions responsible for the mediation of face perception in adulthood begin to become functional (Bertenthal & Boyer, 2015; Johnson & Haan, 2010). Di Giorgio et al. (2012) found that in a visual display of heterogenous objects and a face, the attention directed towards the face in total was similar in six-month-old infants and adult participants, only differing in their first fixations. However, the face stimulus did not capture the attention of three-month-olds when presented in a complex visual display (Di Giorgio et al., 2012). Overall, the organization of cortical areas sensitive to faces as found in adult brains, only develops until after the age of ten years (Johnson et al., 2015).

In adults, the attentional bias towards faces and face-like patterns is still present and could be shown in multiple studies (Johnson et al., 2015). When upright faces were presented in the visual periphery, detection was faster than for objects of different categories (Hershler et al., 2010) and had an inhibition of return effect, which occurs after a reflexive attentional shift to a location and leads to a subsequent disengagement thereof (Theeuwes & Van der Stigchel, 2006). There may also be an influence on subcortical attentional processes, which could be shown by faces and face-like patterns overcoming interocular suppression, which suppresses cortical ways of face processing (Stein et al., 2011). Another study by Tomalski and colleagues (2009) showed faster orienting toward stimuli with face-like configuration and with normal contrast polarity, in comparison to faces with inverted layout or polarity.

The mechanisms behind this specialization for faces are still a subject of debate (Farroni et al., 2005). One view proposes that it might be the result of an interaction between the developing areas of the brain and the specific experiences infants gain with advancing development which then leads to increased specialization of brain areas in response to face-evoked activity (Bertenthal & Boyer, 2015; Morton & Johnson, 1991). In their theory, Morton and Johnson (1991) hypothesized that the development of face processing follows two processes. One system represents an innate disposition to orient toward faces, namely face detection, for which the authors used the term *Conspec* (Morton & Johnson, 1991). The other system acquires specialized processes for recognizing and processing faces and recruits cortical areas that receive input from subcortical regions responsible for the bias of *Conspec* (Morton & Johnson, 1991). Morton and Johnson (1991) call this system *Conlearn*. Additionally, more recent modulations of this theory propose that the subcortical route also plays a role in adulthood and the processing of eye contact (Johnson et al., 2015). This framework might also be relevant for a better understanding of non-typical development of social attention like it is the case with autism (Johnson et al., 2015), which will be explored in more detail in a subsequent section of this thesis.

Unlike other stimuli, when perceiving faces not only the individual features that make up the face are encoded but also their mutual distances, which is also called configural processing and is utilized to recognize larger configurations (Johnson et al., 2015). As for social attention in general, the question to which degree domain-specific or domain-general mechanisms are involved in face perception is a subject of debate (Kanwisher & Yovel, 2006). In their review, Kanwisher and Yovel (2006) conclude that evidence from studies supports the face-specificity hypothesis over domain-general approaches to face processing. The face-specificity hypothesis states that behind face perception lie specialized neural and cognitive mechanisms for this specific stimulus (Kanwisher & Yovel, 2006). On a neuropsychological level, there is evidence of a brain area specialized in the recognition of faces (Kanwisher et al., 1997). The fusiform gyrus of the temporal lobe shows a strong response when we perceive faces but not other objects and has therefore also been coined the *fusiform face area* (FFA) (Kanwisher et al., 1997). In a functional magnetic resonance imaging (fMRI) study Kanwisher et al. (1997) found that this area in the fusiform gyrus was significantly more activated during the passive viewing of faces compared to other objects and subsequent tests also showed a stronger activation in this region of interest for viewing of intact versus scrambles faces, full-front photos of faces versus of houses and thirdly, three-quarter-view photos of faces versus photos of human hands. Activation selective for faces was also found in other areas of the brain, namely the superior temporal sulcus (STS) and in a region called the *occipital face area* located in the occipital lobe, but the most consistent and strongest responses were located in the FFA (Kanwisher et al., 1997). This neural specialization for faces is also supported by evidence from the phenomenon of prosopagnosia when it is acquired after brain damage in the ventral occipitotemporal cortex occurs (Damasio et al., 1982; Kanwisher & Yovel, 2006). Prosopagnosia is the inability to recognize faces, while affected subjects are still able to identify another person based on other stimuli like their voice or a verbal description of them (Kanwisher & Yovel, 2006).

A more recent neural model of face perception suggests a distributed neural system (Haxby et al., 2000). This system can be divided into a core system of brain regions mediating the visual analysis of invariant and changeable aspects within a face and an extended system that can recruit other cognitive functions to analyze the meaning of signals perceived in faces relevant for inferring the mood, level of interest and intentions of another person (Haxby et al., 2000). The core system for analyzing the face visually comprises the inferior occipital gyri, which are associated with the early perception of facial features, the above-mentioned lateral fusiform gyrus associated with the recognition of the invariable features that make up each face's unique identity, and the STS which appears to be involved in the processing of the changeable aspects of the face, e.g. facial expression, lip movements, and the eye gaze (Haxby et al., 2000). Additionally, anatomical, and functional abnormalities in the STS as an important part of the social brain have been linked to ASD (Zilbovicius et al., 2006).

The core system of face processing supposedly interacts with an extended system of regions involved in other cognitive functions (Haxby et al., 2000). These interactions mediate the processing of visual stimuli from faces which are especially involved in social interactions like the focus of another person's attention, mouth movements that are speech-related, emotional facial expressions, or information on the identity of the other person (Haxby et al., 2000).

To recognize and reciprocate emotions we rely on facial expressions which is why in the extended system of face processing, brain regions involved in the processing of emotions like the amygdala, the insula, and the limbic system as a whole are also included (Haxby et al., 2000). A study by Baron-Cohen et al. (1999) found an activation in the amygdala when subjects were judging the state of mind based on the perception of the eye region in pictures of another person. Perceiving disgust in a face also seems to activate the anterior insula, whereas responses in the amygdala are evoked by disgusted as well as fearful faces (Phillips et al., 1998). In another fMRI study, the authors suggest that the amygdala is involved in the analysis of facial expressions for the purpose of learning an association concerning a possibly threatening but also rewarding stimulus by observing a stronger response of the amygdala during an association task with happy and fearful faces (Hooker et al., 2006).

In verbal social interactions, the perception of lip movements provides useful information for comprehending speech, therefore visual regions like the STS which is also associated with the visual processing of lip movements (Puce et al., 1998), and auditory regions in the superior temporal gyrus related to speech and phonemic content, are part of the wider neural system of face perception (Calvert et al., 1997; Haxby et al., 2000).

Studies have found that the anterior temporal regions of the brain are associated with retrieving the identity, name, and biographical information of a familiar person (Gorno-Tempini et al., 1998; Leveroni et al., 2000). These regions are thus also part of the wider network of processing faces as the perception of faces is closely linked to recognizing an interaction partner and their unique identity (Haxby et al., 2000).

For social attention, the direction of the eyes and the orientation of the head are important signals (Haxby et al., 2000). In an fMRI study Hoffman and Haxby (2000) found that when participants were attending to the direction of the eye gaze in a face, the intraparietal sulcus (IPS) showed an increased response, which the authors suggest signifies a recruitment of the system responsible for visual-spatial attention (Nobre et al., 1997). In a second experiment including faces with an averted gaze, a greater response in the IPS was elicited, possibly alluding to a shift of attention in the direction of the gaze (Hoffman & Haxby, 2000).

To summarize, there is a lot of information that can be gathered from looking at faces, and most of it is highly relevant to social situations. A special focus within the face lies on the perception of the eye area and the gaze, which will be explored further in the following paragraph.

1.1.2. Processing of the Eyes and the Gaze

Attention to and looking at socially relevant stimuli is a key aspect of social interactions as it contributes to gathering information about the interaction partner (Falck-Ytter & von Hofsten, 2011). More than other areas of the face, the eye area overall plays a vital role in conveying emotions, directing attention, and identity in social communication (Itier & Batty, 2009). During interactions with others, looking at their eyes informs us about the mental states of our counterparts (Frischen et al., 2007). At the same time, the eyes seem to serve a dual function: we can receive information about others from their eyes, but we can also establish communication with others through our eyes (Nasiopoulos et al., 2015). Not only are the eyes themselves considered a special stimulus for social attention, but also the movement of the eyes and where others gaze with their eyes (Falck-Ytter & von Hofsten, 2011). Following their gaze shows where they direct their attention, movements, and facial gestures, which emotions and intentions they convey, and we can establish and maintain communication with the counterpart in interaction through the gaze (Falck-Ytter & von Hofsten, 2011). Due to this plethora of information that can be gathered from the eye region, it is considered a special area within the face, with multiple studies examining various aspects like the processing of the eyes and the gaze in experimental tasks and social situations as well as the underlying neural systems behind these processes (Itier & Batty, 2009).

The focus of visual attention on the eyes can already be seen in infants and persists throughout adulthood as an important part of navigating social interactions (Frischen et al., 2007). By the age of four months, infants are able to distinguish between direct and averted gaze (Vecera & Johnson, 1995). In a naturalistic eye-tracking paradigm used to study face scanning and social interaction in infancy, six to twelve-month-old infants preferably looked at the eyes relative to the mouth (Keemink et al., 2019). Thus, eyes seem to trigger infants' attention, who show a preference for open eyes and direct gaze, which might in part be due to the salient morphology of the eyes (Gliga & Csibra, 2007).

The human eye has a unique complexion with a large region of the white sclera being visible and a rather small dark region consisting of the pupil and the iris (Frischen et al., 2007). When the pupil and the iris sit in the center of the sclera, we perceive this as eye contact or direct gaze, whereas when they are shifted to either side, we infer that another person is looking in the respective direction (Itier & Batty, 2009). This allows for easier detection of the gaze direction in humans either due to the physical appearance of the eyes having developed to be easily detected by our visual system or through specialized brain mechanisms for processing visual input from another person's eyes (Frischen et al., 2007; Langton et al., 2000). An interplay of these two hypotheses might also be at work with the eyes being special stimuli perceived by brain mechanisms developed to detect such information (Langton et al., 2000). Furthermore, the muscles in this region of the face controlling the mobility of the eyes as well as the arches of the brows enable a wide range of subtle facial expressions (Itier & Batty, 2009).

Studies on the attention to the eye region in the adult population found that internal facial features (eyes, nose, face) were viewed longer (Althoff & Cohen, 1999), and that of all facial features the eye region draws the most attention regardless of the focus of the task used, for example in a study by Itier et al. (2007) comparing the eyes and the gaze or in a study by Henderson et al. (2005) focusing on the learning of new faces (Itier & Batty, 2009). The ability to recognize faces is more impaired when the eye region is covered than compared to when the mouth or the nose is (McKelvie, 1976). A similar effect was found according to a study by Lewis and Edmonds (2003) that examined face detection and found disproportionate impairment when the eye region was masked in contrast to a masked nose, mouth, or forehead.

Beyond that, the eyes play a main role in conveying information essential for emotion recognition and are therefore also a key aspect in non-verbal communication (Itier & Batty, 2009). Many emotions involve specific expressions of the eyes and the region around the eyes (Itier & Batty, 2009). For example, fear and surprise are indicated by wide open eyes with the white of the sclera being more visible (Whalen et al., 2004), whereas squinted eyes signify disgust (Itier & Batty, 2009). In the "Reading the Mind in the Eyes" test by Baron-Cohen et al. (1997, 2001a), used to assess Theory of Mind (ToM) in ASD, pictures of isolated eye regions are perceived as sufficient to identify basic but also more complex emotions in a NT sample.

As mentioned above, attention to the eyes and the gaze also indicates the intentions of another person and can guide our attention. In a study with newborns, Farroni et al. (2004)

found that they could discriminate between direct and averted gaze in real faces and that they already showed a basic form of gaze following when an object in the periphery was cued by the pupil movement of a schematic face. This gaze cueing effect was also found in studies with adult participants (e.g. Bayliss & Tipper, 2005; Frischen & Tipper, 2004; Langton & Bruce, 1999). The gaze also provides a non-verbal communication tool to initiate joint attention (Falck-Ytter et al., 2023). This too can already be seen in infants, at about one year of age (Nyström et al., 2019), and at around eight to nine months alternating the gaze between an object of interest and another person in a so-called triadic interaction can be observed (Beuker et al., 2013). In an fMRI study examining joint attention in adult participants, the authors report that joint attention leads to an activation of brain regions associated with motivation and reward, such as the ventral striatum, with self-initiated joint attention eliciting a stronger response than when responding to others (Schilbach et al., 2010).

The underlying neural bases of the processing of the eyes and the gaze seem to function in a widespread network whose specific functional connections are still a subject of research, as studies employ tasks with different focuses or stimuli and yield partly contradictory findings (Itier & Batty, 2009). An area found to be associated with eye and gaze processing is the STS (Calder et al., 2002; Hoffman & Haxby, 2000). Studies have also found involvement of the medial prefrontal and orbitofrontal cortex to stimuli with direct gaze (Calder et al., 2002; Schilbach et al., 2006; Wicker et al., 2003). The activation of the fusiform gyrus, which is generally involved in face processing, was also found to increase in response to a face with direct gaze which might signify their social significance over faces with averted gaze (Calder et al., 2002; George et al., 2001; George & Conty, 2008). The amygdala also seems to be affected during eye/gaze processing, with the left amygdala responding especially to fearful eyes (Hardee et al., 2008). However, it is not entirely clear whether this is a direct effect of the perceived gaze or whether it is due to the emotional significance of the presented stimulus or respectively the eye region (Itier & Batty, 2009). Lastly, the IPS is specifically involved in the processing of eye movements, i.e. the shifting of the gaze, while it is also part of the neural network associated with spatial attention (Bristow et al., 2007; Corbetta et al., 1998; Haxby et al., 2000, 2002).

Not only does looking at another’s eyes tell us about their intentions and their mental states, but making eye contact also seems to modulate parts of our cognition and activates brain structures which are parts of a network involved in social communication and interactions (Senju & Johnson, 2009). In their review, Senju and Johnson (2009) explore what they call the ‘eye contact effect’, which they define as the effect perceived direct gaze has on the cognitive processing and/or behavioral response that follows immediately after or simultaneously with eye contact. One model of the eye contact effect they review focuses on the activation of arousal systems in the brain through eye contact which in turn leads to emotional arousal accompanied by visceral, autonomic, and endocrine reactions in the body (Senju & Johnson, 2009). Another model is based on the assumption that eye contact conveys intention and thus activates components associated with ToM, which overlap with regions that are relevant for the processing of eyes (Senju & Johnson, 2009). However, the authors found insufficient evidence from studies to account for the full explanation of the eye contact effect by these models and propose an alternative in the 'fast-track modulator model' (Senju & Johnson, 2009). They propose a subcortical pathway (superior colliculus, pulvinar, and amygdala) for the initial detection of eye contact which then projects to the above-described areas of the social brain involved in eye processing (Johnson, 2005; Senju & Johnson, 2009). Additional modulations based on the context and demands of the social situation take place in the dorsolateral prefrontal cortex, which also exerts top-down control over the social brain network and integrates information from the slower cortical route (Conty et al., 2007; George et al., 2001; Senju & Johnson, 2009).

1.2. Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder (ASD) is a heterogeneous condition that can manifest itself in impairments in social domains, repetitive behaviors, sensory abnormalities, and varying degrees of intellectual disabilities (Lord et al., 2020). In the International Classification of Diseases, 11th Revision (ICD-11) and the Diagnostic and Statistical Manual of Mental Disorder, Fifth Edition (DSM-5) ASD falls under the neurodevelopmental disorders and is used as an umbrella term that encompasses diagnostic categories by employing additional clinical specifiers and modifiers (Lord et al., 2020). Since the appearance of the symptoms can vary severely depending on the developmental stage, age, and severity of the impairment, the term spectrum is used to take these variations into account (APA, 2013). The term autism spectrum disorder therefore includes disorders previously referred to as early childhood autism, childhood autism, Kanner autism, high-functioning autism, atypical autism, unspecified pervasive developmental disorder, childhood disintegrative disorder, and Asperger syndrome (APA, 2013). ASD is prevalent in 1 in 132 people according to the Global Burden of Disease study conducted in 2010 (Baxter et al., 2015). Furthermore, it is found more commonly in males than in females with an estimated ratio of 4:1, or rather 3:1 when methodological quality and the method of determining diagnosed cases of ASD in the analyzed studies are taken into account (Loomes et al., 2017). However, it should be noted that there is a risk that girls will not be clinically diagnosed with ASD despite meeting the diagnostic criteria, resulting in a diagnostic gender bias (Loomes et al., 2017). It has also been suggested that female individuals with ASD are better at camouflaging their difficulties resulting in a later or absent diagnosis (Hull et al., 2017).

According to the DSM-5 (APA, 2013), the criteria for a diagnosis of ASD consist of five symptom clusters. In social communication and interaction (Criterion A), individuals with ASD show pervasive and sustained difficulties in the domains of social reciprocity, and non-verbal communication as well as in developing, maintaining, and understanding social relationships across different contexts (APA, 2013). Verbal and non-verbal deficits in this cluster can have different characteristics such as a lack of speech, language delays, comprehension problems, echoed speech, overly formal and literal language as well as intact verbal skills with impairments in the use of language for reciprocal social communication (APA, 2013). When it comes to engaging with others and sharing their thoughts and feelings, children with ASD show reduced initiation of social interactions, sharing of emotions, and imitation of the behavior of others (APA, 2013). Despite often developing compensation strategies, adults without intellectual disability and language impairments, have difficulties with processing and responding to social cues, and dealing with new and unsupported social situations, which are often accompanied by anxiety and effort for them (APA, 2013). Deficits in non-verbal communication first become apparent in a lack of joint attention during childhood and manifest themselves by a lack of, decreased or atypical use of eye contact, gestures, mimic, body orientation, and speech intonation (APA, 2013). Norms for age, gender, and culture should be applied to the deficits in developing, maintaining, and understanding relationships (APA, 2013). Social interest may be reduced, absent, or atypical with young children often not being interested in shared play or imagination or being intent on playing by very fixed rules (APA, 2013). Older individuals with ASD often struggle with determining appropriate behavior varying from situation to situation, with understanding irony, white lies, or other non-literal language (APA, 2013). There may be a preference for solitary activities or expectations of friendships which differ from the NT perspective (APA, 2013).

For a diagnosis of ASD according to DSM-5, there must be evidence of repetitive and restricted behaviors and interests (Criterion B) in two of the four following subdomains: stereotyped, repetitive behaviors, insisting on sameness, highly restricted and fixed interests, and hypersensitivity, hyposensitivity, or interest in sensory inputs (APA, 2013). These behaviors include motor stereotypies, using objects or language repetitively, adhering excessively to routines, or unchangeable and ritualized patterns of behavior (verbal or non-verbal) (APA, 2013). Abnormally intense and focused interests may also be present, which can also provide pleasure and open possibilities for education and occupation later in life (APA, 2013). These interests and routines can also be related to sensory input, e.g. reacting extremely to specific sounds or textures, excessively smelling, or touching objects, a fascination with lights or spinning objects, sometimes a seeming indifference to pain, heat, or cold, and reactions, rituals, or restrictions regarding certain food due to its taste, smell, texture, or appearance (APA, 2013).

The symptoms must be present in early development (Criterion C) and lead to a clinically significant impairment in social, occupational, and other important functioning (Criterion D), although it is possible that symptoms may not yet manifest fully from an early age on but develop later in life or that they may be masked by learned strategies with age (APA, 2013). For a differential diagnosis, an alternative explanation of the symptoms by an intellectual disability or a global developmental delay should be ruled out (Criterion E), although ASD and intellectual disability can also occur together, whereby social communication must be below the current developmental level for a comorbid diagnosis (APA, 2013).

The diagnosis of ASD is based on behavioral presentation evaluated by trained clinicians (Lord et al., 2020). Despite the heterogeneity in symptom presentation on the autism spectrum as well as during development, the aforementioned main diagnostic features can be detected on a reliable basis (Lord et al., 2020). Typically, the onset of symptoms is observed between the ages of 12 to 24 months with parents or caregivers reporting developmental delays or the lack of social or language skills (APA, 2013). During early childhood, behavioral characteristics like lack of social interest or unusual social interactions, strange play routines, repetitive behaviors, and unusual communication patterns become more apparent (APA, 2013). As ASD is not a degenerative disorder, progress in development in some areas can be seen in later childhood and adolescence (APA, 2013). Adults with ASD often use coping mechanisms and compensatory strategies to deal with difficulties arising from their symptoms (APA, 2013). These are especially successful in individuals with high intellectual and linguistic abilities, but can also be burdensome and strenuous (APA, 2013; Hull et al., 2017). Mainly, these strategies include masking symptoms to resemble the people around them and to compensate for their difficulties in social communication either with the goal of forming connections with others or due to external demands of certain situations (Hull et al., 2017).

Functionally, the symptoms of ASD can make learning through social interactions difficult during childhood, while aversion to changes and sensory hypersensitivity can lead to challenges during everyday life and later in school, even for individuals with above-average intellectual abilities (APA, 2013). In adulthood, independence and dealing with new situations, e.g. in the workplace, can be challenging, with many of those affected having a low level of psychosocial functioning which is characterized by an independent life and a gainful occupation (APA, 2013). In old age social isolation as well as problems with communication, like for example asking for help, are likely, but functional consequences of ASD in this age group are yet to be determined (APA, 2013).

In children, the diagnostic process includes a detailed report of the development usually given by the parents, as well as an observation of how the child interacts with the parents and an unknown adult during structured and unstructured situations (Lord et al., 2020). For adults the diagnostic instruments include interviews and questionnaires (also self-report), however, these often rely on extending the methodology of instruments used for children, i.e. on using reports on developmental data (Lord et al., 2020). Widely established and validated diagnostic instruments are the Autism Diagnostic Interview-Revised (ADI-R) and the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2) (Lord et al., 2020). The ADI-R is a structured interview, which includes 93 items on the development during early childhood, language development, communicative abilities, behavior during social interactions, stereotypical behaviors, and interests as well as comorbid symptoms (Rutter et al., 2003). It is usually conducted with a parent or another primary caregiver (Rutter et al., 2003). The ADOS-2 is a tool for the observation of behavior during social interaction and reciprocal communication with different modules for age groups from infancy to adulthood (Lord et al., 2012). A self-report questionnaire used with adults is the Autism Quotient (AQ) by Baron-Cohen et al. (2001b), which assesses autistic traits in the areas of *social skill, attention switching, attention to detail, communication,* and *imagination*. It has also been adapted for children and adolescents (Baron-Cohen et al., 2006).

Because of the transfer of diagnostic instruments for use in childhood to adulthood and the necessity of distinction of comorbid psychiatric disorders in, often undiagnosed, autistic adults, further developing and evaluating tools for the diagnosis of ASD in adults is crucial (Lord et al., 2020). Studies that employ methods such as MRI, fMRI, as well as electrophysiology, can contribute to a better understanding and diagnosis by exploring how the brain develops and functions aberrantly in ASD, although these types of studies have not yet yielded definitive results on these issues (Lord et al., 2020). Eye-tracking studies also offer valuable insights into the social phenotype of ASD, though most of their experimental paradigms still lack ecological validity (Klin et al., 2002a).

A variety of prenatal and perinatal environmental risk factors for ASD have been identified by studies and reviews, but these do have to be considered contributory, reactive, or even independent for ASD rather than causal (Lord et al., 2020). Additionally, genetic factors seem to contribute a considerable amount to the etiology of ASD, with a heritability ranging from 37% up to over 90%, although only a small proportion of the cases investigated can be traced back to a known genetic mutation, while in the others there may be multiple genetic factors at work (APA, 2013; Lord et al., 2020).

Comorbidities are common in ASD with as many as 70% of individuals with ASD possibly having one comorbid mental disorder and 40% having two or more (APA, 2013). Comorbid mental disorders often occurring with ASD include, among others, intellectual disabilities, speech impediments, developmental coordination disorder or specific learning disorders, attention deficit hyperactivity disorder, anxiety disorders, and affective disorders as well as problems with food intake or sleeping (APA, 2013; Lord et al., 2020).

As described above, in the conventional medical paradigm ASD is considered a neurodevelopmental disorder and is therefore characterized by deficits, deviating from an ideal 'state of health' (Pellicano & den Houting, 2022). More recently, an alternative paradigm has been proposed which sees autism as a variation within a diverse spectrum of minds, that have different strengths and weaknesses (Pellicano & den Houting, 2022; Robertson, 2010). This concept of *neurodiversity* explains a range of manifestations in human neurodevelopment and neurobiology (Pellicano & den Houting, 2022).

A *neurotypical* person in this context is someone whose neurodevelopment falls on the spectrum of what is assumed to be normal development (Pellicano & den Houting, 2022). Individuals who develop divergently from the typical range of neurodevelopment, like for example individuals on the autism spectrum, are referred to as neurodivergent in this paradigm (Pellicano & den Houting, 2022). The concept of *neurodiversity* also advocates for subjective well-being and quality of life for neurodiverse individuals and for accepting adaptive instead of typical functioning (Kapp et al., 2013; Robertson, 2010). In line with this falls also the perspective of self-advocacy which proposes to address the inequalities autistic people experience by accommodating their different views and needs, overall respect as well as inclusion and consultation of autistic voices in the research of autism (Lord et al., 2020).

1.2.1. Impairments of Social Attention in ASD

Deficits in the social domain are one of the core symptoms of ASD (APA, 2013). It is discussed whether reduced social attention in individuals with ASD could subsequently have effects that manifest themselves in these impaired social skills (Chita-Tegmark, 2016). Furthermore, in visual exploration and processing of socially relevant stimuli like faces especially individuals with ASD seem to use atypical strategies (Guillon et al., 2014). It is also discussed whether social attention and subsequent behaviors could potentially be a biomarker for ASD (Dawson et al., 2012; Murias et al., 2018). Murias and colleagues (2018) tested whether eye-tracking could serve as an outcome measure for social communicative abilities in a clinical trial with children with ASD in addition to caregiver report measures. They found that longer fixation times on an interaction partner were associated with higher social communication skills in the according parental report measures but not with other symptoms of ASD (Murias et al., 2018). Thus, they concluded that eye-tracking as a measure of social attention can also capture clinically relevant symptoms in the social domain of ASD and is promising to be an objective biomarker for future use in clinical trials (Murias et al., 2018). To study social attention, eye-tracking is a helpful technology used increasingly in social cognitive (neuro)science, as it serves as a non-invasive measure that is easily applicable across populations (from infants to adults) and can capture spontaneous viewing behavior like looking time and fixations spent on areas of interest (for example the eye or mouth area) (Boraston & Blakemore, 2007; Guillon et al., 2014).

In a review of eye-tracking studies conducted with individuals with ASD Chita-Tegmark (2016) suggests that social attention in ASD is affected on two levels: On the first level, attention to social stimuli that are encountered in an environment is reduced in comparison to non-social stimuli. Moreover, on a second level atypical strategies for processing and analyzing the encountered social stimuli (i.e. faces) are employed by individuals with ASD (Chita-Tegmark, 2016). Mechanisms behind this diverging processing of social stimuli could on the one hand be attentional abnormalities in early life that affect further development or on the other hand, persistent atypical attentional processes that occur at specific moments (Bush & Kennedy, 2015).

On a neurophysiological level, one meta-analysis of fMRI experiments found that during face processing individuals with ASD consistently activated the left fusiform gyrus (Ammons et al., 2021). They did not shift activation to object-centric regions of the fusiform gyrus, whereas NT individuals showed activation in the bilateral fusiform gyrus and other core regions as well as extended areas associated with face processing (Ammons et al., 2021).

In their fMRI study on face processing in ASD Kleinhans et al. (2011) also observed reduced activation in subcortical areas of face processing. Additionally, the STS which seems to be highly involved in social cognition was found to be anatomically and functionally impaired in individuals with ASD (Zilbovicius et al., 2006).

Like the preference for social stimuli in typically developing children, the lack thereof is present from early on in children with ASD. When examining early signs of social attention in three- to four-year-olds with ASD, a group of developmentally delayed children and a typically developing control group, Dawson and colleagues (2004) found that the ASD group performed significantly less well in tasks of social orienting, joint attention, and attending to another's distress. Another study on joint attention in infants at risk for developing ASD (due to them having a sibling with a diagnosis) and a follow-up diagnosis of ASD assessed that in a live eye-tracking paradigm they tended to initiate joint attention less than typically developing infants and a high-risk group without a subsequent diagnosis (Nyström et al., 2019). A further study conducted with infants with a high risk for ASD found no differences in the basic orienting towards faces in comparison to typically developing infants (Elsabbagh et al., 2013). Nevertheless, the autistic group showed sustained attention when looking at faces, which, according to the authors, could hint at difficulties processing such stimuli in infancy and in turn lead to the emergence of the more prominent first symptoms of ASD during childhood (Elsabbagh et al., 2013). When observing older children (7 to 15 years old) with and without ASD using a change blindness paradigm to measure attention to faces, Kikuchi et al. (2009) could show the lack of an attentional bias towards faces in autistic participants. This was also found in adult individuals with ASD in a study examining the allocation of attention to faces (Moore et al., 2012).

Another key aspect of social attention that seems to be affected in individuals with ASD is the processing of the eyes and the gaze (Itier & Batty, 2009). When gaze direction is used to predict a target stimulus, both participants with ASD and NT individuals orient their own gaze accordingly (Ristic et al., 2005). However, different processing strategies seem to be at play here: while the NT participants also responded to spatially non-predictive gaze cues, which might point to a bias through the social relevance of this cue for them, participants in the ASD group did not, from which the authors conclude that they are not sensitive to the social information conveyed through eye gaze (Ristic et al., 2005). In their study on the detection of direct gaze Senju and colleagues (2008) found that just as typically developing children, children with ASD detected realistic stimuli with direct gaze faster both isolated and in a face. When the stimuli were presented in inverted faces, the efficient search for a face with direct gaze was more affected by the inversion in the typically developing group, which suggests different processing strategies (Senju et al., 2008). Namely, this could mean that children with ASD did not rely on configural processing of the faces like the NT group, but were rather likely to use low-level perceptual information, e.g. the bilateral symmetry of the eyes (Senju et al., 2008). Griffin and Scherf (2020) tested whether the impaired processing of the gaze was due to decreased visual attention to faces in adolescents with ASD, but could not find support for a predictive relation between reduced fixations on the face and decreased performance in detecting gaze cues from it. Overall, there seem to be deficits in extracting socially relevant information from the eyes, which are crucial to social attention in NT individuals, in juxtaposition to intact non-social processing strategies of such usually social stimuli (Nation & Penny, 2008).

Various cognitive theories have been suggested to explain the symptoms of ASD in general and in the social domain especially (Lord et al., 2020). To assess the emergence and development of these differences and deficits in social attention, one focus lies on social motivation, which will be explored in more detail below.

1.2.2. Social Motivation Theory of Autism

As mentioned before, social stimuli take up priority in what humans pay attention to. Furthermore, social interactions also seem to be intrinsically rewarding which is why we seek them out (Chevallier et al., 2012b). The idea of social motivation and the effect of motivational aspects on the development of social skills and social cognition have recently moved more into the focus of autism research (Chevallier et al., 2012b). Chevallier et al. (2012b) propose the social motivation theory of autism which aims to explain the social impairments individuals with ASD experience and construes autism as an extreme case of decreased social motivation.

Prior approaches to the social deficits prevalent in ASD have focused on deficits in social cognition, in particular on the core idea of ToM (Chevallier et al., 2012b). ToM is defined as being able to attribute mental states like beliefs, knowledge, intentions, emotions, or desires, to oneself and others and therefore to predict and explain behavior (Baron-Cohen, 2000; Premack & Woodruff, 1978). According to Baron-Cohen et al. (1985), individuals with autism do not succeed in employing ToM and are therefore unable to represent others' mental states. This then leads to a disadvantage when trying to predict the behavior of other people and could explain the social deficits in ASD (Baron-Cohen et al., 1985). They tested their theory on children with ASD using a paradigm by Wimmer and Perner (1983), now known as the Sally-Anne-task or also false-belief-task, where the participants have to infer the wrong belief of another person despite their differing own knowledge (Baron-Cohen et al., 1985). Results of this study support the hypothesis of a failed employment of ToM in autistic children but also showed that a subgroup of them succeeded in this ToM task (Baron-Cohen et al., 1985). In contrast to this view, the social motivation theory of autism considers the impairments in social cognition as a consequence rather than a cause for the observed social deficits in ASD, which are therefore the results of impairments in social motivation (Chevallier et al., 2012b).

In typically developing humans, social motivation manifests itself on a behavioral level in three different ways: social orienting, seeking and liking social stimuli as well as social maintenance (Chevallier et al., 2012b). Social orienting is characterized as the innate attention toward social information which seems to be prioritized like other rewarding or beneficial stimuli (Chevallier et al., 2012b). As previously described, an attentional bias towards social stimuli has been found in several studies. An innate preference for faces as well as bodies is present in humans and shown from an early age (Farroni et al., 2005; Fletcher-Watson et al., 2008; Stein et al., 2011; Tomalski et al., 2009). Not only is attention captured by social stimuli but the social world is also found to be rewarding for humans, which in turn can also explain the prioritization of such information (Chevallier et al., 2012b). There are two components to reward, 'wanting' and 'liking', which also come into play when dealing with social signals (Berridge et al., 2009; Chevallier et al., 2012b). The hedonic value of a reward relates to the 'liking' component whereas 'wanting' includes its incentive salience meaning the motivational aspect which can lead to seeking to approach the reward and consuming it (Berridge et al., 2009; Chevallier et al., 2012b). There also seems to be an incentive value in social interactions which are found to be rewarding (Chevallier et al., 2012b). This is shown in studies on behavioral economics, e.g. where effort is applied also for social rewards (Hayden et al., 2007). Prosocial behaviors are often described as intrinsically rewarding, with an extrinsic reward even diminishing motivation, which was for example found for helping behavior in toddlers (Warneken & Tomasello, 2008). The third crucial aspect of social motivation is the maintenance of social relationships, namely the desire to engage with each other over extended time periods (Chevallier et al., 2012b). From an early age, people try to be perceived as likable by others and perform actions in order to maintain and enhance social relationships that they have formed, like flattering others or unconsciously mimicking their behavior to induce similarity and thus likeability (Chevallier et al., 2012b; Fu & Lee, 2007; Lakin & Chartrand, 2003).

The social motivation theory of autism proposes that in individuals with ASD the aforementioned behaviors of social orienting, seeking and liking of social stimuli as well as social maintaining are impaired and lead to the typical social deficits (Chevallier et al., 2012b). Through these impairments in social attention, which are present from an early age in ASD, valuable learning opportunities in the social domain are also not available and thus lead to further disruption in social cognitive development and in the acquiring of social skills (Chevallier et al., 2012b). In the domain of social orienting, diagnostic criteria and clinical descriptions of ASD as well as some eye-tracking studies, which will be discussed in more detail in a later part of this thesis, show for example less fixating on socially relevant stimuli like the face or reduced eye contact in support this theoretical framework (APA, 2013; Chevallier et al., 2012b). Deficits in social orienting are present from the point when the first symptoms of ASD manifest themselves in early childhood (Elsabbagh et al., 2013).

Diminished seeking and liking of social interactions shows itself in ASD through difficulties with social relationships, and also less engagement during cooperative activities (Chevallier et al., 2012b; Liebal et al., 2008). Children with ASD seem to have difficulties with verbal and non-verbal cues of another person who wants to initiate joint attention (Leekam & Ramsden, 2006). In one study adolescents with ASD reported finding social situations less pleasurable than a control group while the degree of social anhedonia was correlated with their symptom severity (Chevallier et al., 2012a). Another study comparing friendships and loneliness in children with ASD and NTchildren assessed that in the ASD group, the quality of friendships was reported lower and that autistic children, despite feeling lonely, associated this less with friendship (Bauminger & Kasari, 2000).

Furthermore, individuals with ASD also show fewer strategies to maintain social relationships, to preserve their reputation and their self-image when compared to typically developing individuals (Chevallier et al., 2012b). Here, results of studies on behaviors of social maintaining like social gestures of greeting and farewell (Hobson & Lee, 1998) or making decisions to achieve a certain reputation (Izuma et al., 2011) coincide with anecdotal reports of parents and caregivers who often notice individuals with ASD are not as concerned with presenting themselves in order to influence how people perceive them (Chevallier et al., 2012b).

On a biological level, a network of brain regions consisting of the amygdala, ventral striatum, as well as orbital and ventromedial regions of the prefrontal cortex seems to be involved in the different aspects of social motivation (Chevallier et al., 2012b). This same circuit has also been examined in individuals with ASD and does appear to function abnormally when compared to NT individuals (Bachevalier & Loveland, 2006). Different fMRI studies could show that on the one hand, participants with ASD exhibited a decreased neural response to social reward in these areas which are generally also associated with reward-processing (Scott-Van Zeeland et al., 2010). On the other hand, during the processing of faces, which are highly relevant social stimuli, the neural response differed from a NT control group, which might point to different processing strategies of social signals in ASD (Schultz et al., 2000). However, more research on this biological level of social motivation in ASD is needed to distinguish the potential atypical neural pathways of social rewards from reward in general and to determine whether 'wanting' and 'liking' are affected similarly (Chevallier et al., 2012b).

Despite providing a useful theoretical framework that has been corroborated by empirical evidence from different studies, the social motivation theory, just like theories of social cognition, for example, impaired ToM in ASD, is not without its shortcomings (Chevallier et al., 2012b). Both fail to explain other, non-social aspects of ASD like stereotyped repetitive behaviors and restricted interests or associations with intellectual disability or above-average abilities in the cognitive domain, e.g. savant skills (Chevallier et al., 2012b). These limitations can be addressed by taking a multiple-deficit approach to explain the symptoms of ASD and to consider social motivation as a promising perspective to account for the social impairments in ASD (Chevallier et al., 2012b). Since autism is a spectrum, it also remains to be determined whether a lack of social motivation is prevalent in all subtypes of ASD (Chevallier et al., 2012b). Another open question that still needs to be addressed is which role comorbidities, like anxiety, depression, or ADHD, which are common in people with ASD (Lord et al., 2020) play and how they influence social motivation and reward processing (Chevallier et al., 2012b).

1.2.3. Gaze Behavior in ASD

As discussed above, impaired social attention seems to be a prevalent feature in ASD. The social motivation theory of autism thereby offers a theoretical framework, to account for these social impairments through diminished social motivation (Chevallier et al., 2012b). Several studies have examined visual social attention, in particular the processing of the face and the eyes. Hereby eye-tracking offers an easily applicable method to measure and quantify gaze behavior, especially how it differs between individuals with ASD and NT individuals (Guillon et al., 2014). One prominent assumption regarding gaze behavior in research on ASD is the excess mouth and diminished eye gaze hypothesis, which proposes that within a face individuals with ASD look less at the eyes region and more at the mouth region (Falck-Ytter & von Hofsten, 2011). In addition to the social motivation theory, other theoretical models have been developed to explain specifically these differences in gaze behavior.

Klin et al., (2002b) found diminished eye gaze and excess mouth fixation in high-functioning adolescents with ASD compared to a NT control group when participants were watching video clips of people interacting, which were taken from a movie. The authors infer that individuals with ASD who have a higher verbal intelligence quotient (IQ) possibly use visual information from the mouth area that is speech-related to process social information (Klin et al., 2002b). The fixation of the mouth might also be due to physical contingencies, namely the audiovisual synchrony while seeing another person speaking (Falck-Ytter & von Hofsten, 2011). One study found that infants with ASD seem to not show a preference for biological motion compared to typically developing infants but rather to non-social physical contingencies (Klin et al., 2009).

A different approach suggests that children with ASD who differ in impairments in socio-emotional skills and non-verbal communication skills also differ in gaze behavior when viewing videos of other people’s faces, with more social than communicative impairments being predictive of excess mouth fixations (Falck-Ytter et al., 2010). Another contributing factor to differences that could thus be prevalent within the ASD group is the symptom severity and the type of impairment. In a study by Norbury et al. (2009) teenagers with ASD who have no language impairment showed less fixation time on the eyes, whereas ASD individuals with language impairments did not differ from the NT control group (Norbury et al., 2009).

Other theoretical frameworks have focused on reduced eye contact or looking at the eye region in individuals with ASD. Avoiding eye contact, which is among the core diagnostic features of ASD according to the APA (2013), has often been described as an early indicator of it, which then persists throughout the lifespan (Trevisan et al., 2017). One model suggests that eye contact leads to hyperarousal in the amygdala in ASD, which leads to avoidance of the eyes to regulate or avoid the subsequent arousal (Stuart et al., 2023). In a neuroimaging study, which also used eye-tracking to compare brain activation in subjects with ASD and NT subjects during gaze fixation, the authors suggest that fixations on the eye region were correlated with a hyperaroused response in the amygdala of ASD subjects, which could then lead to an avoidance of the eyes and the fixation on the mouth as a byproduct of this reaction (Dalton et al., 2005; Falck-Ytter & von Hofsten, 2011).

As the eye region also plays an important role in the processing of emotions, studies have also examined gaze behavior in ASD during the viewing of emotional faces (Itier & Batty, 2009; Setien-Ramos et al., 2023). Reisinger et al. (2020) assessed social attention and emotion recognition in participants from ages 3 to 25 and found less fixation time and amount toward the eyes in the ASD group regardless of the emotion of the presented face when compared to a group of NT individuals. When judging emotions individuals with ASD also seem to rely on different processing strategies of facial features, namely an increased use of information from the mouth area and decreased reliance on the eye region compared to a control group, as reported in a study by Spezio et al. (2007).

Some eye-tracking studies have examined social attention in ASD during live interaction conditions, although these interactions were only partly conducted in person with the help of a portable eye-tracker, and some were also carried out via computer screens. Children with ASD showed less and shorter fixations on the face of the experimenter during a dyadic interaction with them than the children in the NT control group (Noris et al., 2012). When using eye-tracking data obtained in a face-to-face interaction with an interviewer, Zhao et al. (2021) used a machine-learning approach to classify children with ASD and with typical development based on the length of the session and visual fixations, where the mouth as an area of interest (AOI) was found to be a pronounced feature in classification accuracy. Increased fixations on the mouth region as well as decreased ones on the eye region, when talking about people's emotions but not their actions, were observed by Hutchins and Brien (2016) when conducting an online interview with autistic children during eye-tracking. This gaze behavior in the ASD group was also correlated with higher symptom severity, more limited executive function, as well as poorer verbal and intellectual ability (Hutchins & Brien, 2016). In another study that used a dynamic social orientation paradigm where subjects would see an interaction partner on a screen, Kaliukhovich et al. (2022) found decreased attention to the face only in experimental conditions in which the actor on screen was occupied with another activity and in one in which joint attention was required. In a third experimental condition where the interaction partner on screen engaged in a viewer-directed speech, which resembles the paradigm of the current study, the differences in attention to the face were not significant (Kaliukhovich et al., 2022). The authors conclude that differences in visual social attention in individuals with ASD compared to a NT control group might be context-specific and that more studies examining specifically adults (as their paradigm was developed for younger children) in paradigms that resemble real-life social interactions are needed to establish eye-tracking as a biomarker for the allocation of visual social resources in ASD (Kaliukhovich et al., 2022).

During studies examining live social interactions with adult participants similar gaze behavior was observed. Reduced attention to the face of an interaction partner was assessed in autistic participants who focused more on the background than NT subjects during a conversation initiated by the experimenter in an eye-tracking study by Barzy et al. (2020). Hanley and colleagues (2015) compared spontaneous viewing behavior in a small sample of university students with and without a diagnosis of ASD and found that during a semi-structured interview, the ASD group fixated less on the eyes and more on the mouth. Using a similar paradigm Freeth and Bugembe (2019) observed that individuals with ASD fixated less on the experimenter’s face when their gaze was directed at the participant, as well as reduced eye contact compared to the NT group. However, when analyzing the phases of the interaction, more reduced eye fixations were shown by both groups when it was their turn to speak over when they were listening to the experimenter (Freeth & Bugembe, 2019). Likewise, another study observed similar gaze patterns to the eyes and the mouth in autistic and NT subjects during speaking and listening in an interaction with a confederate (Cañigueral et al., 2021). The authors hereby also consider that compensation strategies used by individuals with ASD might make the findings of such studies despite their real-life interaction harder to interpret (Cañigueral et al., 2021). In a study using eye-tracking during a live semi-structured interview through a screen, with the researcher at a remote location, and investigating the influence of oxytocin administration on social attention, the ASD group showed fewer fixations on and less looking time at eye region than the control group in the placebo condition, while no differences for mouth region and other areas of the face were found (Auyeung et al., 2015).

Eye-tracking studies have shown that when compared to NT individuals, individuals with ASD displayed differing gaze behavior when responding to social stimuli, especially diminished attention to the eyes and increased gazing at the mouth in ASD (Chita-Tegmark, 2016; Guillon et al., 2014). However, other studies failed to find differing gaze behavior between individuals with ASD and NT individuals. Speer and colleagues (2007) could only find decreased attention to the eyes in ASD compared to NT controls when they were viewing social dynamic stimuli (in this case video clips of people interacting taken from a film, which were the same as Klin et al. (2002b) used). However, they could not find differences in gaze behavior for images depicting social scenes (social-static condition) or an image (isolated-static condition) or video of a person speaking (isolated-dynamic condition) (Speer et al., 2007). In another study, both autistic and NT adult individuals showed a similar pattern of facial exploration, namely a preference for the eye region compared to other regions of the face (Hernandez et al., 2009). During fixations on the rest of the face, they also did not show a preference for the mouth (Hernandez et al., 2009). Regarding fixation duration however, the ASD group spent less time fixating on the eyes, which could hint at a lack of importance of this region of the face for them in contrast to the earlier described avoidance of the eyes (Hernandez et al., 2009). Bird et al. (2011) assessed that even though autistic participants spent less looking time on the face when calculating the ratio of the eye-to-mouth fixations within the face, they found that the ASD and the NT groups did not differ significantly. When examining children and adults with and without ASD regarding their fixation patterns while viewing video stimuli, Nakano et al. (2010) found that while adults with ASD showed preferred fixations on the mouth region in comparison to the NT group, in children the typically developing participants exhibited this increased mouth viewing behavior. During typical development, this preferred viewing of the mouth might be a necessary step for language learning (Nakano et al., 2010). A meta-analysis by Setien-Ramos and colleagues (2023), which focused only on eye-tracking studies conducted to measure social attention in adults with ASD, found that while decreased fixation number and duration on the eye region were consistent and the most discriminant marker in ASD, insights on attention to the mouth region are very heterogeneous.

Thus, the hypothesis of decreased fixations on the eyes and increased fixations on the mouth in ASD has only gained partial support by empirical evidence and in addition to that, remains to be reevaluated due to many contributing factors to gaze behavior only being considered to some extent in previous studies, which will be described below (Falck-Ytter et al., 2010; Guillon et al., 2014). Furthermore, different theories have been developed to account for the decreased attention to social stimuli in individuals with ASD, but there is no conclusive evidence that would weigh one of them clearly in favor of the others since empirical support for each has been gathered (Chevallier et al., 2012b; Stuart et al., 2023; Trevisan et al., 2017).

Eye-tracking studies comparing different aspects of social attention in ASD and NT groups use different paradigms with heterogeneous stimuli across different stages in development (infants, younger children, adolescents, and adults) (Guillon et al., 2014). Falck-Ytter and von Hofsten (2011) therefore conclude in their review that the results of those studies do not allow the generalization of the proposed gaze behavior to other contexts and across the lifespan. The stage of development of the participants, as well as the type and severity of the impairment in ASD, are also important to consider while examining social attention (Falck-Ytter et al., 2010; Nakano et al., 2010; Norbury et al., 2009). When comparing types of social stimuli used in eye-tracking studies, decreased social attention in the ASD compared to the control group was found for social dynamic stimuli (videos) where subjects' gazes focused more on the body than on the eyes in the social scenes that were shown (Speer et al., 2007). The ecological nature of the stimuli also seems to play a role in the elicited social responses with dynamic depictions of social interaction emerging as the preferred method to detect differences between an ASD and a NT group (Chevallier et al., 2015). A further important difference is what the paradigm intends to measure, namely if gaze strategies differ when completing a task or if differences in spontaneous viewing behavior of stimuli are captured (Boraston & Blakemore, 2007).

1.3. Research Question

So far, some studies on reduced social attention during eye-tracking tasks in ASD compared to NT controls have detected differences between these groups, whereas others could not find support in favor of this. Several age brackets, from early infancy to adulthood, have been examined regarding their gaze behavior with different paradigms to assess attention to social stimuli and/or gaze behavior (Guillon et al., 2014). In adults, the excess mouth and diminished eye gaze hypothesis has obtained only partial support - especially the decreased attention to the mouth - also because it seems to depend on the stimuli used and the complexity of the social interactions observed (Guillon et al., 2014). The stimulus types used in these studies therefore seem to play a role as well as the ecological relevance of stimuli (Chevallier et al., 2015). Social stimuli used in eye-tracking studies are mainly pictures or videos of social interactions or situations (Boraston & Blakemore, 2007). These stimuli can show gaze behavior while processing faces or while viewing social situations, but the results of the studies cannot be transferred to naturalistic social interactions as they happen in everyday life (Boraston & Blakemore, 2007). Chevallier and colleagues (2015) pointed out that presenting dynamic visual stimuli depicting social interactions in an ecologically valid paradigm seems to be ideal for distinguishing social attention in ASD from typical development.

The current study aims to contribute to research on gaze behavior and thus visual social attention in adults with ASD by employing an eye-tracking paradigm that measures fixations on relevant social stimuli, namely the face, eyes, and mouth, in a situation where participants interact with another person. By comparing social attention and gaze behavior in individuals on the autism spectrum and NT individuals, the thesis will help to learn more about the extent to which social stimuli are processed atypically by autistic people. A portable eye-tracking methodology and the social stimuli that will be encountered in a social interview situation that resembles real-life interactions constitute a paradigm with higher ecological validity. Eye-tracking hereby offers an easily applicable, non-invasive measure of social attention in this situation. By using a more naturalistic paradigm, these findings could also provide more insight into actual gaze behavior in social interactions (Boraston & Blakemore, 2007). As only inconsistent support for a diminished eye and excess mouth gaze, while processing faces in subjects with ASD has been found in studies so far, the thesis aims to add to the research in this field by exploring whether there is a difference in gaze behavior between adults with ASD and NT adults in social interaction. More precisely the following hypotheses will be analyzed:

> H1: During a face-to-face interview, adult individuals with ASD show different gaze behavior compared to the NT control group.
>
> > H1a: Individuals with ASD show more fixations on the background, i.e. non-social regions, than the individuals in the control group.
> >
> > H1b: When fixating on areas of the face, in the ASD group individuals' gaze focuses less on the eyes of the interviewer compared to the NT control group.
> >
> > H1c: When fixating on areas of the face, in the ASD group individuals' gaze focuses more on the mouth of the interviewer compared to the control group.

The hypotheses are derived from the two levels on which social attention is attenuated in ASD according to Chita-Tegmark (2016), to address a more global level of decreased attention to the face as a social stimulus in H1a and to go into further detail about these fixations of socially relevant areas within the face of a social interaction partner in H1b and H1c.

2. Methods

The hypotheses examined in this thesis were investigated as part of the OXY project of the Clinical Social Neuroscience Unit led by Giorgia Silani and colleagues at the University of Vienna. This overall study, headed by Raimund Bühler, investigated the effects of oxytocin and the opioid system as well as possible interactive effects on social attention and social motivation in NT participants and participants with ASD. By administering

Oxytocin and Naltrexone separately and combined, possible influences were investigated in an eye-tracking paradigm as well as in a reinforcement task using social and non-social rewards as feedback. My master thesis focuses on one aspect of the study comparing social attention and gaze behavior in the group with ASD with the NT control (CTRL) group. In the course of testing, every participant experienced each of four pharmacological conditions on four different testing days, usually two weeks apart: Naltrexone-Oxytocin, Naltrexone-placebo, Oxytocin-placebo, and placebo-placebo. The study hereby used a double-blind design. After administration of both drugs or placebos participants completed the three tasks in a randomized order each session. A reinforcement association learning task was implemented, where participants chose one of two symbols (cues) and received either social or non-social feedback following their choice. They were expected to learn from the feedback and increasingly choose cues with high probability.

Furthermore, subjects took part in a task that explored their curiosity for new music. In the eye-tracking task, which my research focuses on, the experimenter conducted an interview with the participants while they were wearing a mobile eye-tracking set-up to measure the fixation frequency on socially relevant regions during the interaction. In addition to these three tasks, participants were asked to fill out questionnaires regarding their guess whether they received the medication or a placebo each session, regarding their rating of the attractiveness of the investigator as well as the following questionnaires: the Interpersonal Reactivity Index (Davis, 1980), the Social Interaction Anxiety Scale (Mattick & Clarke, 1989), the State-Trait Anxiety Inventory (trait version; Spielberger, et al., 1983), the Autism Spectrum Quotient (Baron-Cohen et al., 2001), the Barcelona Music Reward Questionnaire (Mas-Herrero et al., 2013), questions on music in general, the Perceptual Curiosity Scale (Collins et al., 2004), and the subscale of the Becks Depression Inventory (Beck et al., 1996).

2.1. Sample

From the overall sample of subjects (n = 79) who participated in the overarching study, only those who had completed all four sessions, including the placebo condition, or who had completed this condition before dropping out could be included. One had to be excluded due to missing eye-tracking data from the according session. Thus, data from 17 participants had to be excluded. Consequently, a total of 62 participants (age range = 18 – 70, mean age = 31.02, *SD* = 11.74; 31 female = 50%, 31 male = 50%,) were analyzed for this thesis, of these 29 belonged to the ASD group and 33 to the control. In the ASD group 17 participants identified as female (58.6%), 12 (41.4%) as male, and in the control group 14

(42.4%) as female and 19 (57.6%) as male. Values for age and IQ can be seen in Table 1 and the results of the t-test for independent samples conducted for age and IQ to ensure that the two groups were matched, i.e. did not differ significantly. One participant (age: 70) in the control group exceeded the age level set at 65 for the study but was not excluded from the analysis as several participants who had dropped out had already been excluded from the current thesis resulting in a loss of testing power.

Table 1.

Sample characteristics divided by group as well as comparison of age and IQ between groups

Variable	CTRL group (n = 33)			ASD group (n = 29)			Group differences[a]	
	M	*SD*	*Range*	*M*	*SD*	*Range*	*t*	*p*
Age	29.15	10.45	19-70	33.14	12.91	18-65	-1.34	.18
IQ	106.79	10.00	81-124	113.14	18.06	85-145	-1.68[b]	.10[b]

Notes. [a] Calculated using t-tests for independent samples.
[b] Adjusted for heterogenous variances.

NT subjects were recruited through the Study Participant Platform of the Cognitive Science Hub at the University of Vienna. Subjects with ASD were recruited using a database available to Giorgia Silani of ASD individuals participating in previous studies, through contact with institutions and treatment centers in Vienna with clients on the autism spectrum as well as recruitment through social media platforms targeted at users and groups dealing with topics surrounding ASD.

All participants were assessed in advance about the following inclusion/exclusion criteria by an online screening questionnaire sent prior to participation: subjects in the control group should be between 18 and 65 years old, fluent in German, and have no knowledge of Japanese Symbols (Kanji) due to their use in the reinforcement learning task, which is part of the overarching project. They could be excluded beforehand due to visual impairment, pregnancy, a psychiatric or neurological disorder, taking psychiatric medication, or regular drug or alcohol use or dependency. The ASD group was screened for: fluency in German, knowledge of Japanese Symbols (Kanji), and regular drug or alcohol use or dependency. Due to the high prevalence of comorbid diagnoses and psychiatric medication being taken in the ASD population, ASD subjects were not excluded based on these criteria so as not to limit the sample. However, data on medication type and comorbid disorders were collected in the screening questionnaire. All participants who participated in the ASD group also provided an official diagnosis administered by a psychiatrist or psychologist.

2.2. Study Design

As mentioned beforehand, subjects participated in four sessions so that they would experience different combinations of Naltrexone (in pill form), Oxytocin (inhaled nasally), and placebo (Mannitol pill, nasal inhalation of saline solution) respectively. The study has a double-blind design, in addition to the order of the pharmacological conditions as well as the order of the three tasks (eye-tracking, reinforcement learning task, and music curiosity task) in each session being randomized. For the research question of the current thesis, the relevant condition is the placebo-placebo combination, as the focus lies on the between-subject comparison of the ASD and the NT control group. Hence the current study employs a between-subject design to examine group differences in gaze behavior between a group of autistic and a control group of NT participants. Using eye-tracking methodology, attention to areas of the face relevant during social interactions can be measured. Using the recordings of the eye-tracking task, four areas of interest were defined: non-face, face, eyes, and mouth. The AOI are mutually exclusive. Fixations on each AOI were then counted and standardized for the duration of the interview (relative number of fixations/length of interview in seconds). As a dependent variable serves as the mean fixation rate in Hertz, namely fixations per second throughout the whole interview. This fixation rate was computed for each of the four AOIs. As these are measured per participant, a within-subject comparison of the fixations between the AOIs will also be made.

2.3. Study Procedure

While the overall procedure of a session in the OXY project involved more steps, described here are only those that are relevant to the research interest of this thesis. The study was conducted in testing rooms at the Institute for Clinical and Health Psychology at the University of Vienna. At the beginning of each testing session participants filled out a written informed consent form. After that, they were asked to rate their current mood and emotions in the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). To get global intelligence levels to match the ASD and the NT sample, participants also had to complete the Mehrfachwahl-Wortschatz-Intelligenztest (MWT-B; Lehrl, 2005), a paper and pencil test which allows the measurement of global intelligence in an easy and quick manner.

For the eye-tracking task, the participant and experimenter were seated at a table across from each other. A mobile eye-tracking set-up was used which participants could wear like a pair of glasses. They were asked to put on the eye-tracking glasses prior to the beginning of the task so that the experimenter could adjust the cameras directed at the eyes to ensure ideal confidence of the measurements (≥ 0.9). After adjusting the equipment, the calibration of the eye-tracker was carried out. Participants were asked to fixate the calibration marker (provided by Pupil Labs) which was positioned at the face area of the experimenter as the desired region of interest and to move their head in a slow spiraling movement for about 30-60 seconds. The calibration is used to understand the interrelation between the position of the pupils and their corresponding gaze position within the coordinate system captured by the world camera which is positioned on the forehead of the participant (Pupil Labs, n.d.). By fixation on the target within the view of the world camera the Pupil Core software collects the reference location of the calibration marker and the pupil data (Pupil Labs, n.d.). It then correlates these in time and computes a mapping function that serves to estimate the gaze for prospective pupil data (Pupil Labs, n.d.). Once the calibration process was completed, the experimenter started the recording in the Pupil Core software and gave the participant the instructions for the upcoming interview task. They were asked to keep their head as still as possible during the eye-tracking and were informed that the following task would consist of a series of questions designed to mimic a conversation. Participants visited the lab four times due to the design of the overarching project, but the overall session and the interview were always conducted by the same experimenter for each subject. The interview (in German) was supposed to resemble a realistic and natural conversation and should last about eight to ten minutes. To ensure comparability between subjects and between investigators, it was semi-structured with an interview guide consisting of 13 questions about the everyday life of the participant. These questions could also be extended through further inquiries to ensure the interview would reach the supposed length to collect sufficient data. Structured questions, in the beginning, could be answered with ‘Yes’ or ‘No’, whereas later questions would become more open (for instance ‘Did you sleep well last night?’ or ‘What did you do last weekend?’; for the full list of questions see Appendix). To enable an exchange, participants also had the possibility to ask the investigator questions at the end of the task. After completing all the tasks required per session, participants were also asked to rate the attractiveness and likeability of the interviewer in a short online questionnaire. Finally, a debriefing took place and subjects filled out a compensation form, receiving 40€ per session plus winnings from an experimental task.

2.4. Devices

The present study examined the gaze behavior in a naturalistic interview situation with a researcher. For this purpose, a Pupil Core head-mounted binocular eye-tracker was used. This device records with one world camera on the forehead and infrared spectrum eye cameras for detecting the dark pupil (Kassner et al., 2014). It can be connected to a laptop via USB-C, from which the camera streams are read by the software Pupil Capture for real-time pupil detection, gaze mapping, and recording (Kassner et al., 2014). The world camera captures the user's vertical field of vision and can be adjusted along a transverse axis with a range of 90° (Kassner et al., 2014). The eye cameras can be fitted to the variations in the participant's face and eyes moving them along an adjustable arm or rotating the ball joints on which they are attached (Kassner et al., 2014). Before conducting the interview, the experimenter had to set the eye-tracker so that the upper camera represented the participant's field of vision with the interviewer in view and the participant's eyes were sufficiently captured by the eye cameras. The eye-tracker then locates the dark pupil in the infrared-illuminated image of the eye through a pupil detection algorithm, which is in most cases robust against reflection in the pupil areas and does not depend on corneal reflection (Kassner et al., 2014). From eye to the world space pupil positions are mapped to represent the gaze (Kassner et al., 2014). For this, a transfer function consisting of two bivariate polynomials of adjustable degree is used whose specific parameters are obtained by running the above-described calibration routine (Kassner et al., 2014). The software Pupil Capture can record videos from the world and eye cameras as well as detect pupil and gaze data, which can then be analyzed further (Kassner et al., 2014).

The online questionnaire participants filled out via SoSci Survey in every session to rate the attractiveness and likeability of the interviewer contained the following questions, which were rated on a 7-point Likert-Scale ranging from 'not at all' ('überhaupt nicht') to 'very' ('sehr'):

- Did you find the person interesting? ('Fandest du die Person interessant?')
- Does the person seem like a good person? ('Scheint die Person ein guter Mensch zu sein?')
- Does the person seem like a nice person? ('Scheint die Person ein netter Mensch zu sein?')
- Does the person seem open-minded? (‚Scheint die Person aufgeschlossen zu sein?')

2.5. Data Analysis

For the current study, fixations with a duration of 80 to 220ms and a maximal dispersion of a 1.5° visual angle were detected by the eye-tracking setup. These were filtered by confidence level, with confidences lower than 0.8 being removed, which also includes automatically detected blinks of the participants. The gaze data gathered from the recordings of the interviews was subsequently exported with the software Pupil Player for further analysis. Moving areas of interest were later defined in the recordings of the eye-tracking by using a face detection method called multi-task convolutional neural network (MTCNN) through analysis using a Python script, also inspired by David Sandberg's TensorFlow implementation of the FaceNet facial recognition model (for the code see: https://github.com/raimund-buehler/face_detection_small) (Ge et al., 2021; Sandberg, n.d.). This method employs a face detection algorithm which then yields the position of the face of the interviewer and the position of regions within the face like the eyes and mouth (Ge et al., 2021; Sandberg, n.d.). Around the social areas of interest (face, eyes, mouth) mutually exclusive ellipses were drawn. Relevant fixations were tested regarding their position in one of these ellipses and counted for each region. Fixation counts were normalized for the duration of the respective interview, resulting in the fixations per second on each AOI.

Statistical analyses were performed using SPSS Statistics 29 for MacOS (IBM, 2022). The extracted fixation rate was corrected for positive skewness by using a square root transformation. The transformed variable approximated normal distribution and was therefore suitable for the following analysis. A mixed analysis of variance (ANOVA) with the between-subject-factor group (ASD, CTRL) and the inner-subject factor AOI (Eyes, Mouth, Face, Non-Face) was conducted, corrected by the Huynh-Feldt adjustment.

To account for other possible influences on social attention and gaze behavior during the interview, the ratings of attractivity and likeability of the interviewer as well as familiarity with them, operationalized through the position of the placebo-placebo condition within the four testing conditions (first, second, third or fourth session) of the overarching study, were also considered in the analysis. The former was compared between the groups by using a t-test for independent samples, while the latter was included as an additional factor in the initial mixed ANOVA.

3. Results

3.1. Assumption Checks

With the adjusted fixation rate, the performed ANOVA has a metric dependent variable. The between-subject factor (group) is categorical and contains independent groups, for which dependent measures of the AOIs are conducted.

Homoscedasticity was assessed by Levene's tests within the levels of the factor AOI. Variances were equal within the AOIs Eyes (F (1, 60) = 0.001, p = .98), Mouth (F (1, 60) = 0.24, p = .63), and Face (F (1, 60) = 0.05, p = .82). However, within the AOI Non-face, the Levene's test was significant (F (1, 60) = 5.58, p = .02) meaning equal variances cannot be assumed here.

Sphericity was assessed by the Mauchley-test, which was significant (χ^2 = 43.21, p < .001), resulting in a violation of this assumption. Therefore, the results were corrected by using the Huynh-Feldt correction.

Through histograms, normal distribution of the fixation rate for each group within each of the four AOIs was first assessed visually and predicted a normal distribution of the data. Shapiro-Wilk tests also yielded no significant results, as can be seen in Table 2, which means normally distributed data can be assumed.

Table 2.

Shapiro-Wilk test of normal distribution

Shapiro-Wilk				
	Group	Statistic	*df*	*p*
Fixation rate *Eyes*	CTRL	0.98	33	.84
Fixation rate *Eyes*	ASD	0.95	29	.23
Fixation rate *Mouth*	CTRL	0.95	33	.10
Fixation rate *Mouth*	ASD	0.93	29	.06
Fixation rate *Face*	CTRL	0.98	33	.85
Fixation rate *Face*	ASD	0.96	29	.40
Fixation rate *Non-face*	CTRL	0.97	33	.39
Fixation rate *Non-face*	ASD	0.94	29	.10

Overall, because of the robustness of the general linear models like the ANOVA against individual violations of assumptions, the results of the following analysis should still be interpretable.

3.2. Main Analysis

To test whether gaze behavior differed between the ASD and the CTRL group in general and within the regions of interest (Eyes, Mouth, Face, and Non-Face), a two-way mixed ANOVA was performed. Because the assumption of sphericity was violated as indicated in the Mauchley-test, the Huynh-Feldt correction was applied. For the main effect of AOI, the Huynh-Feldt estimate of the departure from sphericity was $\varepsilon = 0.81$. A significant main effect for AOI was found (F (2.44) = 25.47, $p < .001$, $\eta_p^2 = 0.3$). For the between-subject factor Group, the main effect was not significant (F (1) = 0.48, $p = .49$, $\eta_p^2 = 0.01$). The interaction between Group and AOI was also not significant (F (2.44) = 2.09, $p = .12$, $\eta_p^2 = 0.03$). In Figure 1 the profile plot shows the normalized fixation rate for each group in the four AOIs.

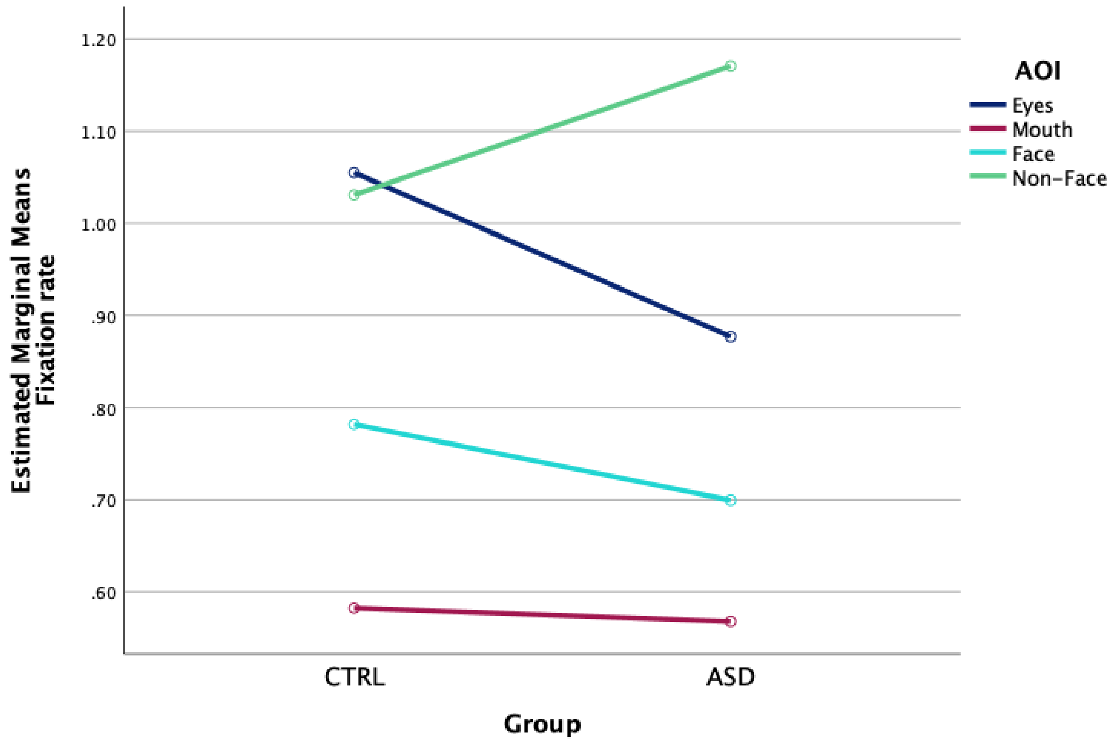

Figure 1. Profile plot of the mean fixation rate on the four AOIs by Group

Post hoc testing using Bonferroni-adjusted pairwise comparisons revealed significant differences in the fixation rate for all the AOI except when comparing eyes and non-face in the CTRL group. For this group, the fixation rate on the eyes was higher than on the mouth and the rest of the face, and fewer fixations per second on the mouth in comparison to the face and the non-face region were observed. The CTRL group also showed fewer fixations on the face than the non-face region. In the ASD group, significant differences were found in the comparisons of eyes and mouth with an increased fixation rate on the eyes over the mouth, as well as lower fixation rates on the mouth versus the non-face region, and on the face versus the non-face region. Results of the pairwise comparisons are displayed in Table 3.

Table 3.

Pairwise comparisons of the AOI in each Group based on estimated marginal means

Group	(I) AOI	(J) AOI	Mean difference (I-J)	p^b	*95% CI*
CTRL	Eyes	Mouth	0.47*	< .001	[0.20, 0.74]
		Face	0.27*	.003	[0.07, 0.47]
		Non-Face	0.02	1.00	[-0.28, 0.33]
	Mouth	Face	- 0.20*	.008	[-0.36, -0.04]
		Non-Face	- 0.45*	< .001	[-0.72, -0.17]
	Face	Non-Face	- 0.25*	.02	[-0.47, -0.03]
ASD	Eyes	Mouth	0.31*	.03	[0.02, 0.60]
		Face	0.18	.16	[-0.04, 0.39]
		Non-Face	- 0.29	.10	[-0.62, 0.03]
	Mouth	Face	- 0.13	.25	[-0.30; 0.04]
		Non-Face	- 0.60*	< .001	[-0.90, -0.31]
	Face	Non-Face	- 0.47*	< .001	[-0.71, -0.23]

Notes. * The mean difference is significant at the .05 level.

[b] Adjustment for multiple comparisons: Bonferroni

3.3. Control Variables

From the brief questionnaire on attractiveness and likeability of the interviewer, sum scores were calculated and their means were compared between the NT (M = 23.55, SD = 3.62) and autistic participants (M = 23.59, SD = 3.56) using a t-test for independent samples. The two groups did not differ significantly in their ratings of attractiveness and likeability of the interviewer (t (60) = - 0.05, p = .97). Therefore, these ratings were not included as a control variable in the statistical model of the main analysis.

To control for a possible influence of familiarity with the interviewer during the four testing sessions, a mixed ANOVA with the between-subject factors Group (ASD, CTRL) and position of the placebo condition (Session 1, 2, 3, 4), and the within-subject factor AOI was conducted in addition to the main analysis. Here too the assumption of sphericity was violated as indicated in the Mauchley-test, so the Huynh-Feldt correction was applied. For the main effect of AOI, the Huynh-Feldt estimate of the departure from sphericity was $\varepsilon = 0.92$. A significant main effect for AOI was still present ($F\ (2.75) = 24.24$, $p < .001$, $\eta_p^2 = 0.31$). The interaction between Group and AOI was also not significant ($F\ (2.75) = 1.58$, $p = .20$, $\eta_p^2 = 0.03$) as was the interaction between the position of the session and AOI ($F\ (8.26) = 0.93$, $p = .50$, $\eta_p^2 = 0.05$). The three-way interaction between Group, AOI, and session position did not yield significant results ($F\ (8.26) = 1.26$, $p = .27$, $\eta_p^2 = 0.07$). Furthermore, when looking at the between-subject factors, no significant main effects were found for Group ($F\ (1) = 0.17$, $p = .68$, $\eta_p^2 = 0.003$) and the position of the session ($F\ (3) = 1.94$, $p = .13$, $\eta_p^2 = 0.10$). However, the interaction between the group and session position did reach significance ($F\ (3) = 3.07$, $p = .04$, $\eta_p^2 = 0.15$). This was explored further with a simple effects analysis. This analysis revealed significant differences between the two groups for the AOIs Eyes, Mouth, and Face only when the placebo condition was the second out of the four sessions. For the eye region, the CTRL group showed a higher mean fixation rate than the ASD group (mean difference = 0.46, *SE* = 0.19, 95% *CI* [0.07, 0.84], $p = .02$). This was also the case for the mouth region (mean difference = 0.40, *SE* = 0.18, 95% *CI* [0.04, 0.77], $p = .03$), as well as the rest of the face (mean difference = 0.33, *SE* = 0.12, 95% *CI* [0.09, 0.57], $p = .007$). Of the 62 participants, 18 completed the placebo condition in session 1 or 2, 11 in session 3, and 15 in session 4. The distribution of autistic and NT subjects in the session positions is displayed in Figure 2, revealing that group size was only equal for session 2.

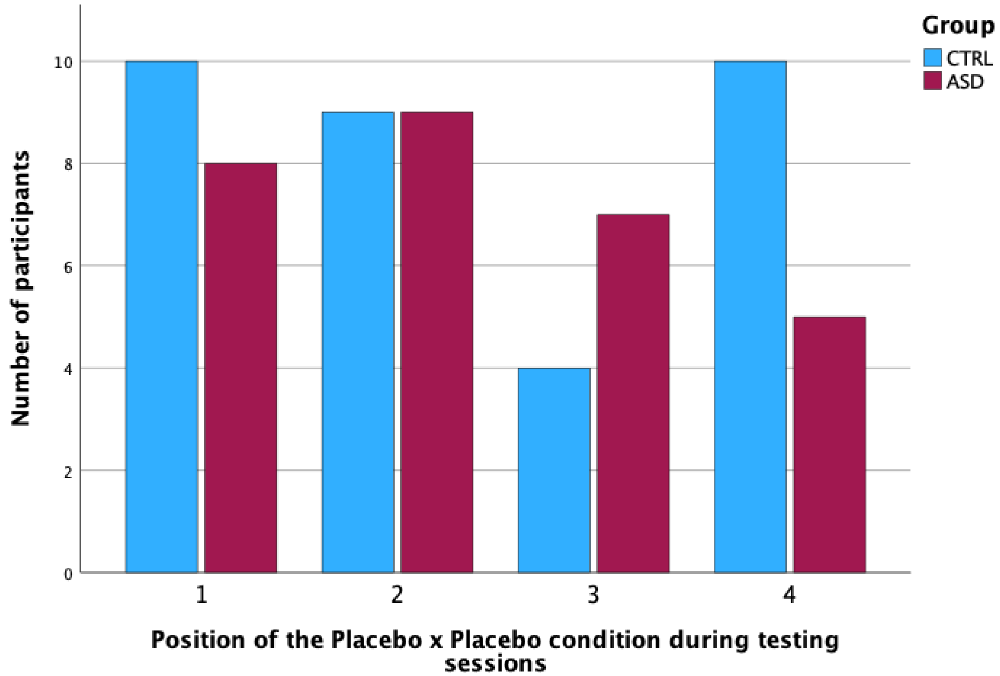

Figure 2. Number of participants in each group for each position of the placebo condition

3.4. Exploratory Analysis

In this section, I present the results of an exploratory analysis aimed at examining potential group differences in the fixation rate through further investigation of the data. It is important to note that these analyses are exploratory in nature and are based on trends visible in the main analysis.

As the interaction of AOI*Group approached significance and trends in the visualization of the data were visible for the AOIs Eyes, Face, and Non-Face, as can be seen in Figure 3, a simple effects analysis was conducted for further exploration of the data despite the interaction not having reached significance.

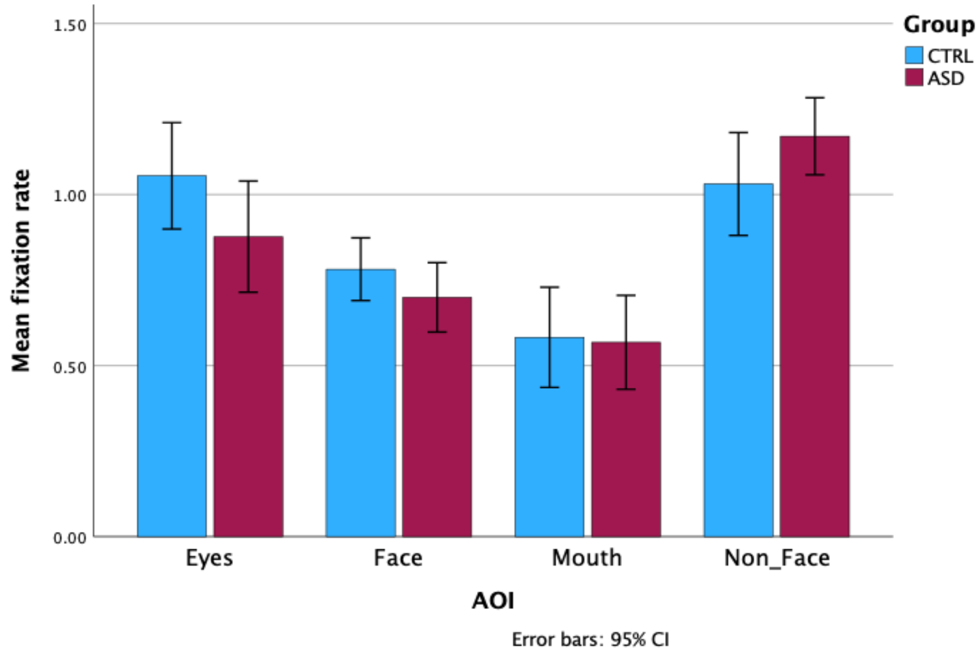

Figure 3. Number of fixations per second for each of the four AOIs by group

The mean difference between the groups for fixations on the eyes was 0.18 (*SE* = 0.11, 95% *CI* [-0.43, 0.4]), with the CTRL group (*M* = 1.06, *SE* = 0.08) scoring higher than the ASD group (*M* = 0.88, *SE* = 0.8). However, this difference failed to reach significance (*p* = .11). No significant mean differences were observed between the groups (CTRL vs. ASD) for the mouth (mean difference = 0.02, *SE* = 0.10, 95% *CI* [-0.18, 0.21], *p* = .88), the face (mean difference = 0.08, *SE* = 0.07, 95% *CI* [-0.05, 0.22], *p* = .22), and the AOI Non-face (mean difference = -0.14, *SE* = 0.09, 95% *CI* [-0.05, 0.33], *p* = .14).

As group differences for the eye region approached significance and given the importance of this region for the current study, an independent exploration of the fixation rate on this AOI was additionally conducted. A t-test for independent samples was performed between the CTRL and ASD groups. The difference approached but did not reach significance, with a p-value of .056 (*t* (60) = 1.61, Cohen's *d* = 0.41). While the difference in mean fixation rates on the eye region between the two groups was not statistically significant, Cohen's d (*d* = 0.41), suggests a small-to-medium-sized effect (Cohen, 1988).

Boxplots (see Figure 3) were used to visually represent the distribution of the fixation rate on the AOI Eyes across the CTRL and the AOI groups. The central line within each boxplot represents the median, while the box itself spans the interquartile range and contains the middle 50% of the data. Whiskers indicate the minimum and maximum values within 1.5

times the interquartile range. The boxplots also show a trend towards fewer fixations on the eyes in the group of autistic participants when compared to the NT control group.

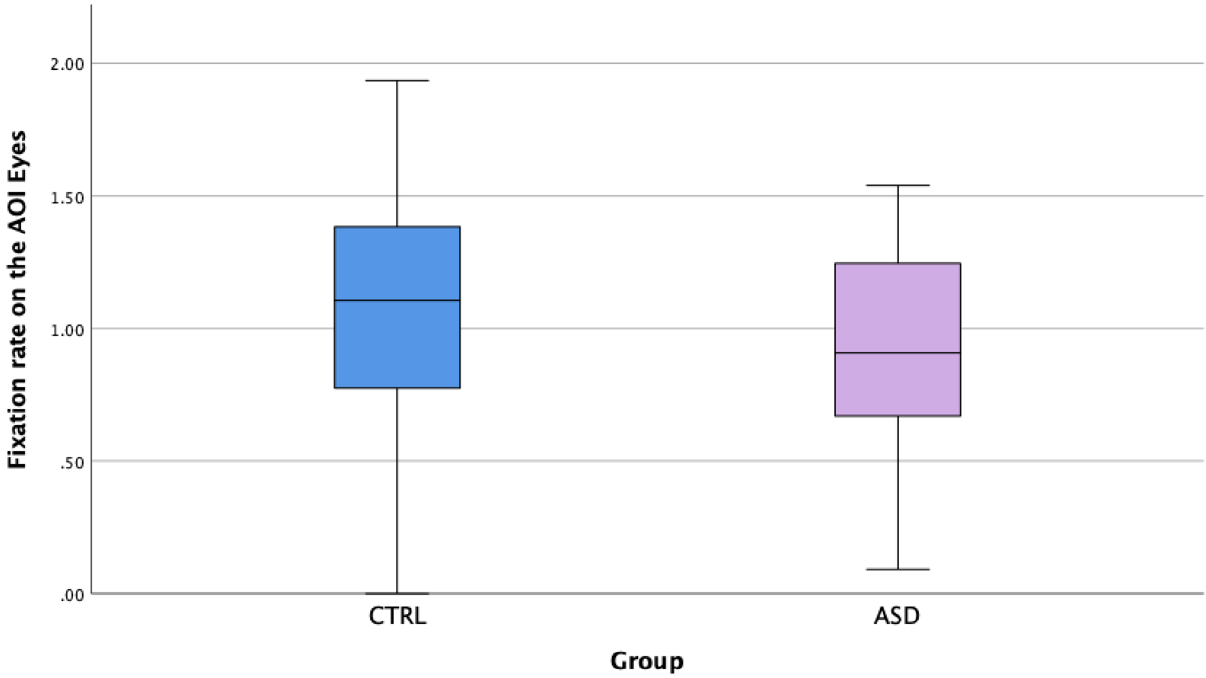

Figure 4. Boxplots of fixations per second for the AOI Eyes by group

4. Discussion

4.1. Main Insights

The present thesis aimed to examine differences in gaze behavior during a social interaction and thus differences in social attention between individuals with ASD and NT individuals. For this purpose, the subjects participated in a live one-on-one interview with an experimenter, all while wearing mobile head-mounted eye-tracker to measure fixations of the participants on AOIs within the face of the interviewer (eyes, mouth, and the rest of the face) and in the background (non-face). As other studies on gaze behavior in ASD have mainly used social stimuli such as pictures or videos, the methodology of the current study addresses the issue of ecological validity of the results by using a naturalistic interaction with another person as the target stimuli and therefore contributes to the growing body of research that examines the social impairments of ASD in real-life social situations.

The hypotheses were derived from a review by Chita-Tegmark (2016) that proposes that social attention in ASD is impaired on two levels: On a more general level, it is hypothesized that the attentional bias towards social stimuli that is present in NT individuals is impaired in autistic individuals (Chita-Tegmark, 2016). Secondly, when processing social stimuli like the face, different processing strategies are employed by individuals with ASD (Chita-Tegmark, 2016). On this second level, studies have found evidence for diminished gaze to the eyes and increased fixations on the mouth in individuals with ASD (Falck-Ytter & von Hofsten, 2011).

Thus, differences between autistic and NT subjects were expected to show less attention on the face and more on the background in the ASD group. Within the face, participants in the ASD group were anticipated to exhibit fewer fixations on the eyes and more fixations on the mouth than in the CTRL group. Gaze behavior was operationalized by the number of fixations per second on the respective AOI. The AOIs were defined to be mutually exclusive, making up four areas: Eyes, Mouth, Face, and Non-face. To allow for a comparison between individuals with ASD and NT individuals, data from 29 participants for the ASD group and 33 for the CTRL group were analyzed (total $N = 62$).

In the analysis, a significant main effect was found for the AOI, indicating differences between the fixation rate on the eyes, the mouth, the rest of the face, and the non-face part in the participant's field of vision across both groups. Post hoc comparisons showed that in the CTRL group, the fixation rate on the eyes was higher than on the mouth and the rest of the face. NT participants also fixated more often on other areas of the face compared to the mouth area. When looking at the fixations on the background (AOI Non-face), the NT group showed a higher fixation rate on this area than on the mouth or other regions of the face. In the ASD group, partially similar patterns of gaze behavior were observed. A higher fixation rate on the eyes, when compared to the mouth region, as well as a higher rate of fixations on the non-face AOI compared to the mouth or the rest of the face. A similar pattern was observed in a study by Hernandez et al. (2009), in which the autistic as well as the control group showed increased fixation times on the eye region when scanning neutral and emotional faces. For NT individuals, this result is to be expected as the eye region is an important area within the face that carries highly relevant information for social interactions (Itier & Batty, 2009). For the ASD group, these findings contrast previous studies that report preferential looking at the mouth area and decreased fixations on the eyes (Klin et al., 2002b). Hernandez and colleagues (2009) argue that while an initial preference for the eye region was present in the participants with ASD in their study, their interest in this AOI declined while it stayed the same for NT subjects. A more detailed analysis of the data of this thesis also revealed that for the eye region, although not significant, a trend suggested a group difference. While gaze patterns seemed similar within the two groups, the viewing time allocated to the relevant AOIs, especially the eye region and the non-face area in this case, might differ. Increased fixations on the non-face region might be due to the nature of the interaction during the interview. As the experimenter usually only spoke when asking the interview or follow-up questions, the participants would probably have had the main proportion of speaking time. In a study on gaze behavior during an interaction with an active speaker and a listener, it was found that the speakers tended to look less at the listener, except for a brief window where they were seeking a response from the listener (Bavelas et al., 2002). Similarly, Ho et al. (2015) used eye-tracking to show that gaze also signals turn-taking during conversations with the speaker starting to speak with an averted gaze and conveying the end of their turn by looking at the listener.

Contrary to expectations, no significant interaction was observed between the group affiliation and the AOIs. A further exploration of the data revealed some notable trends. A group difference in the fixation rate on the eyes approached significance, both in an exploratory simple effects analysis and t-test for independent samples with the CTRL group showing more fixations on the eyes than the autistic group. With Cohen's d at 0.41 for the t-test, suggesting a small-to-medium-sized effect (Cohen, 1998), this difference warrants further investigation in a study specified for the current research question and appropriately powered for it. The group difference in fixation rate on the background also suggests that participants with ASD show a higher fixation rate on the non-face AOI than the CTRL group. However, this did not reach conventional levels of significance ($p = .05$).

While these trends did not reach significance, some appear to at least point in the direction assumed in the a priori hypotheses. It must be noted that these trends still need to be investigated further. Autistic individuals were expected to look less at the eye region than the CTRL group and more at the background than at socially relevant regions in the face of the experimenter, as attention to socially relevant stimuli generally seems to be reduced in ASD (Chita-Tegmark, 2016; Guillon et al., 2014). While no significant effects were found for such a difference, trends in the data show that the fixation rate on the non-face AOI was indeed higher for the ASD group compared to the CTRL group. In line with the social motivation theory of ASD, this could hint at the impairment of the basic process of social orienting towards faces in autistic individuals as for them these lack the rewarding qualities they have for NT individuals (Chevallier et al., 2012b). However, as mentioned above, within both groups the non-face region was gazed at more often than the mouth and the rest of the face, which could possibly be attributed to the nature of the interaction.

Further exploration of the data could also show that, compared to the NT group, autistic participants gazed less at the eye region. However, this also fell short of significance. Reduced eye contact in individuals with ASD is among the diagnostic indicators (APA, 2013) and has garnered evidence from several studies (Hanley et al., 2015; Klin et al., 2002b; Reisinger et al., 2020). It is still debated what underlying cause can explain this decreased attention to the eyes. Theoretical frameworks have different approaches to explain this behavior and are each partly supported by empirical evidence. The hyperarousal model suggests that looking into another's eyes elicits an aversive response in autistic individuals and thus leads to gaze aversion (Trevisan et al., 2017). On the other hand, the social motivation theory hypothesizes that social information does not carry the intrinsic reward that it has for NT individuals, thus the attentional bias towards these stimuli is missing in ASD (Chevallier et al., 2012b). The mindblindness framework of ASD is based on the assumption that ASD comes from impairments in ToM and therefore difficulties in inferring the mental states of others, which typically developing individuals often do by gathering information from the eyes and the gaze among others (Trevisan et al., 2017). Data from eye-tracking cannot give insights into which cause can explain aberrant gaze behavior, therefore it might be interesting to pair it with neuroimaging measures to observe reward circuitry or potential hyperarousal in the amygdala or to pair it with qualitative methods to get impressions of how autistic individuals experience eye contact like it was done by Trevisan et al. (2017).

It might also be difficult to interpret differences in social attention due to individuals with ASD camouflaging their social deficits in certain situations. In a study by Hull and colleagues (2017) a compensatory mechanism reported by autistic participants was to force and maintain eye contact.

Evidence for increased fixations on the mouth region when comparing autistic to NT subjects was not found. Contrary to previous evidence (e.g. Hanley et al., 2015; Hutchins & Brien, 2016; Klin et al., 2002b), this hypothesis was not supported in the current study. Although there are some studies supporting the excess mouth gaze in ASD hypothesis, overall the findings for the mouth area are not as consistent and are more heterogeneous than evidence for the eyes (Setien-Ramos et al., 2023). In their meta-analysis, Setien-Ramos and colleagues (2023) identified the eye and non-social areas as the most sensitive to distinguish adults with ASD from NT adults.

4.2. Limitations

The current study is subject to several limitations. Firstly, although the interview task was designed to closely resemble a naturalistic social interaction, it still is different from social situations in real life in many ways. Questions were asked by the interviewer, and although the participants could ask them questions in the end, if they wanted to, the reciprocal nature of a conversation could not sufficiently be achieved in this format. Especially, as some participants were reluctant to ask further questions. Additionally, to ensure ideal measurements participants were asked to sit as still as possible and not to move their heads around too much during the interview task. This might have contributed to a more artificial nature of the situation and could possibly create tension, as non-verbal gestures and head movements are part of social interactions. In the ASD group in particular, wearing the eye-tracker might have felt distracting to some, as hypersensitivity to sensory input can be a symptom present in individuals with ASD.

As the thesis was part of a bigger research project, the structure of the testing sessions might also not have been ideal for this research interest. Although the data used here was from the placebo sessions only, participants still had to go through the procedure of the medication intake. This might have provoked some anxiety or anticipation of possible side effects, which could have in turn influenced their behavior during the interview task. Due to the waiting time after taking the medication/placebo and the other two tasks performed in every session, it cannot be ruled out that participants felt fatigued and no longer concentrated fully on the current interview.

Possible influences of the attractiveness and likeability of the interviewer in the eyes of the participants were addressed through an according questionnaire, in which the ASD and the CTRL group did not differ significantly in their ratings. However, despite a corresponding note to answer truthfully, these answers might have been prone to social desirability, which makes the actual effects of perceived attractiveness and likeability difficult to measure and control for.

Overall, the ASD sample in this study consisted of individuals with average to above-average IQ with most of them having been diagnosed with Asperger syndrome. Consequently, this makes the results only applicable to this subgroup on the autism spectrum. However, as ASD is a diverse condition it might be valuable to also explore the gaze behavior of other subgroups and possibly differences within the autism spectrum. Evidence for within-group differences in ASD has also been examined in other studies, for example, by Norbury and colleagues (2009), who found differences in gaze patterns between autistic participants with and without language impairments.

4.3. Implications and Future Research

The present study makes a relevant contribution to the research of social attention in ASD, especially by employing ecologically valid stimuli. Still, more research is needed that focuses on natural social interactions and how they are processed by autistic individuals. These interactions could possibly also be explored in the field with mobile eye-tracking setups, which further enhances ecological validity. This field of research also has implications for the use of eye-tracking technology as a potential biomarker for autism in diagnostics and clinical research. Impaired social attention and gaze behavior typical for ASD could thus be used to identify symptoms of ASD and how they change in response to interventions that address the social domain. This could, in turn, be grounds for the development and enhancement of therapeutical interventions. For example, the overarching project of which this study is part of as well as the study by Auyeung et al. (2015) were looking into the effects of pharmaceutical interventions on social impairments in ASD and hereby used eye-tracking as a marker for changes in social attention. To further support the development of such treatment options, more research to sustain them is needed.

As eye-tracking studies can show gaze behavior and how it differs from NT individuals, they cannot show why this is the case. Future research should address the underlying cause of these differences, whether they are based on a lack of social motivation in ASD or on avoidance of arousal, in order to make interventions more targeted and concise.

As mentioned beforehand, future eye-tracking studies on social attention in ASD should also address within-group differences of individuals on the autism spectrum. Several age groups have been examined regarding their gaze behavior when encountering social stimuli. However, these cross-sectional studies make it difficult to distinguish which effects are typical for specific development stages or if they apply in general. A promising approach might also be a longitudinal examination of the development of gaze behavior in autism to better distinguish gaze behavior in age groups and how it develops typically and atypically.

Lastly, it would be interesting to explore if there are other influences on social attention in ASD. The symptom severity of social impairments might be an important factor to consider for an association with atypical social attention as well as comorbid conditions like social anxiety disorder, ADHD, or depression, which each influence social behaviors in their own way. Examining these potential contributing factors may lead to a more comprehensive understanding of the underlying drivers of atypical social attention in ASD.

4.4. Conclusion

This thesis aimed to find differences in gaze behavior between autistic and NT individuals during a social interaction. However, no significant results were obtained in support of the research question and the a priori hypotheses. Within both groups fixation rates on the eyes were significantly higher, as were those on the non-face AOI. A notable trend and effect size was observed for differences in fixations on the eyes, with the CTRL showing more fixations in this area than the ASD group. For the mouth region, no excess fixation rate was found for autistic participants. Thus, the excess mouth/diminished eye gaze hypothesis proposed in the literature on social attention in ASD is not supported by the results of the current study. Furthermore, when comparing fixations on the non-social AOI, another trend was observed indicating an increased fixation rate on the non-face AOI for the ASD group when compared to the NT group.

To conclude, the thesis could show that while the initial hypotheses were not supported by the data, promising trends were visible in further exploration of the data, which warrant further investigation. Moving forward, future research should seek to replicate and extend these findings.

Overall, the study improves the understanding of aberrant social attention in ASD and how it translates into gaze behavior by using an ecologically valid testing paradigm for social interactions. The results may be a prompt for further research in this field, which can later contribute to the enhancement of eye-tracking as a biomarker for ASD and possibly to the development of therapeutical interventions whose efficacy could be measured with eye-tracking methodology.

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List of Abbreviations

ADI-R = Autism Diagnostic Interview-Revised

ADOS-2 = Autism Diagnostic Observation Schedule, 2nd Edition

AOI = Area of interest

ANOVA = Analysis of variance

APA = American Psychiatric Association

AQ = Autism quotient

ASD = Autism spectrum disorder

CTRL = Control

DSM-5 = Diagnostic and Statistical Manual of Mental Disorder, Fifth Edition

FFA = Fusiform face area

fMRI = Functional magnetic resonance imaging

ICD-11 = International Classification of Diseases, 11th Revision

IPS = Intraparietal sulcus

IQ = Intelligence quotient

MTCNN = Multi-task convolutional neural network

NT = Neurotypical

STS = Superior temporal sulcus

ToM = Theory of mind

Appendix

Abstract (English)

Autism spectrum disorder (ASD) is a heterogeneous neurodevelopmental condition that is characterized, among other symptoms, by deficits in the social domain which manifest themselves in social interactions and communication. In contrast to neurotypical individuals, the innate attentional bias towards socially relevant stimuli like faces or eyes seems to be impaired in individuals with ASD. Studies using eye-tracking methodology have found that autistic participants show a different gaze behavior than their neurotypical peers, namely a decreased attention to the face in general and the eyes specifically, as well as increased fixations on the mouth area. To investigate these assumptions concerning gaze behavior in ASD, 29 autistic and 33 neurotypical subjects (total $N = 62$) participated in an eye-tracking task that mimicked a real-life social interaction. Fixations per second on four areas of interest (eyes, mouth, face, and background) were compared within and between the two groups. Gaze behavior within the groups showed similar significant differences between fixations on the eyes and the non-face regions when compared to the other areas of interest. However, when comparing the ASD and the control group, no significant differences were found. A further exploratory analysis revealed notable trends, that seem to go in the direction of the a priori expectations but need to be investigated further. These trends, possible explanations for the findings above, as well as implications for future research, are discussed. As part of a bigger project, the current thesis was probably susceptible to confounding variables due to the study design of the former.

Keywords: Autism Spectrum Disorder, Eye-Tracking, Social Attention, Gaze Behavior, Eye Contact

Abstract (German)

Autismus-Spektrum-Störungen (ASS) sind heterogene neurologische Entwicklungsstörungen, die neben anderen Symptomen durch Defizite im Sozialleben gekennzeichnet sind, die sich in sozialen Interaktionen und in der Kommunikation manifestieren. Im Gegensatz zu neurotypischen Personen scheint der Aufmerksamkeitsbias für sozial relevante Reize wie Gesichter oder Augen bei Personen mit ASS beeinträchtigt zu sein. Studien, die Eye-Tracking verwenden, haben ergeben, dass autistische Teilnehmer:innen ein anderes Blickverhalten zeigen als ihre neurotypischen Mitmenschen, nämlich eine verringerte Aufmerksamkeit auf das Gesicht im Allgemeinen und die Augen im Speziellen sowie eine erhöhte Fixierung auf den Mundbereich. Um diese Annahmen bezüglich des Blickverhaltens bei ASS zu untersuchen, nahmen 29 autistische und 33 neurotypische Proband:innen (Gesamt $N = 62$) an einer Eye-Tracking-Studie teil, die eine realistische soziale Interaktion simulierte. Die Fixationen pro Sekunde auf vier Bereiche (Augen, Mund, Gesicht und der Hintergrund) wurden innerhalb und zwischen den beiden Gruppen verglichen. Das Blickverhalten innerhalb der Gruppen zeigte ähnliche signifikante Unterschiede zwischen den Fixationen auf die Augen und die nicht-sozialen Regionen im Vergleich zu den anderen Regionen. Beim Vergleich zwischen der ASS- und der Kontrollgruppe wurden jedoch keine signifikanten Unterschiede gefunden. Eine weitere explorative Analyse ergab nennenswerte Trends, die in die erwartete Richtung zu gehen scheinen, aber noch weiter untersucht werden müssen. Diese Trends, mögliche Erklärungen für die obigen Ergebnisse sowie Implikationen für die weitere Forschung werden diskutiert. Als Teil eines größeren Projekts war die vorliegende Arbeit aufgrund des Studiendesigns möglicherweise anfällig für Störvariablen.

Schlüsselwörter: Autismus-Spektrum-Störung, Eye-Tracking, Soziale Aufmerksamkeit, Blickverhalten, Augenkontakt

Interview Questions

Wir werden nun ein Gespräch führen. (Ich würde dabei die Du-Form benutzen, ist das in Ordnung? Gut.) Setz dich gemütlich hin und versuch bitte, dich und deinen Kopf nicht mehr allzu sehr zu bewegen. Ich werde dir jetzt ein paar Fragen stellen und wenn du möchtest, kannst du mir am Ende auch einige Fragen stellen. Die Idee ist es, ein möglichst entspanntes und natürliches Gespräch zu führen. Wenn du bereit bist, starten wir.

- Hast du letzte Nacht gut geschlafen?
- Hast du letzte Nacht von etwas geträumt?
- Hast du in der letzten Woche in einem Restaurant gegessen?
- Warst du letzte Woche draußen in der Natur?
- Hast du in der letzten Woche ein Buch gelesen?
- Welchen Film oder welche Fernsehsendung hast du zuletzt gesehen? Hat er dir gefallen? Worum ging es darin?
- Was hast du am letzten Wochenende unternommen?
- Könntest du mir bitte erzählen, was du am nächsten Wochenende vorhast?
- Was war das interessanteste Ereignis, das du in der letzten Woche erlebt hast?
- Als du heute Morgen aufgewacht bist, hast du dich darauf gefreut, an dieser Untersuchung teilzunehmen oder war es für dich eher eine Verpflichtung?
- Könntest du mir bitte von deinem Weg zum Labor erzählen? Wie bist du hergekommen? Hast du lange gebraucht? Ist auf dem Weg etwas Interessantes passiert?
- Wie hast du dich nach der Verabreichung der Medikamente gefühlt?
- Hast du noch irgendwelche Fragen, die du mir stellen möchtest?

English Translation:

We are now going to have a conversation. (I would use the "you" form, is that okay? Good.) Sit down comfortably and please try not to move yourself and your head too much. I'm going to ask you a few questions now and if you like, you can ask me a few questions at the end. The idea is to have as relaxed and natural a conversation as possible. When you're ready, we'll get started.

- Did you sleep well last night?
- Did you dream about something last night?
- Did you eat in a restaurant last week?

- Did you go outside in nature last week?
- Did you read a book last week?
- What was the last movie or TV show you watched? Did you like it? What was it about?
- What did you do last weekend?
- Could you please tell me what you are planning to do next weekend?
- What was the most interesting event you experienced last week?
- When you woke up this morning, were you looking forward to taking part in this study or was it more of an obligation for you?
- Could you please tell me about your route to the lab? How did you get here? Did it take you long? Did anything interesting happen on the way?
- How did you feel after you received the medication?
- Do you have any questions you would like to ask me?

Attractiveness Questionnaire

Während des Experiments wurden Ihnen einige Fragen gestellt. Bitte geben Sie an, wie attraktiv Sie die Person empfanden, die Ihnen die Fragen gestellt hat. Ihre Angaben können nicht mit Ihnen in Verbindung gebracht werden, antworten Sie also bitte wahrheitsgetreu.

Frage	1 (überhaupt nicht)	2	3	4	5	6	7 (sehr)
1. Fandest du die Person interessant?							
2. Scheint die Person ein guter Mensch zu sein?							
3. Scheint die Person ein netter Mensch zu sein?							
4. Scheint die Person aufgeschlossen zu sein?							

English Translation:

During the experiment, you were asked some questions. Please indicate how attractive you found the person who asked you these questions. Your answers cannot be linked to you, so please answer truthfully.

Question	1 (not at all)	2	3	4	5	6	7 (very)
1. Did you find the person interesting?							
2. Does the person seem like a good person?							
3. Does the person seem like a nice person?							
4. Does the person seem open-minded?							