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Visual Orienting in Infancy as a Predictor of Cognitive Development

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1. Theoretical Background

Since the middle of the 20th century, research in the field of visual attention, particularly in infants, has aroused increasing interest. In the process, researchers explored the complexity of looking behaviour and attentional processes. However, despite decades of investigation, numerous questions about the complex components and mechanisms underlying visual attention and its interaction and connection with cognitive and motor domains remain. Visual development begins early in infancy and involves complex processes that allow infants to engage with and explore their environment (Atkinson, 1984; Atkinson & Braddick, 2012; Braddick & Atkinson, 2011; Brito et al., 2019; Kiesel & Koch, 2018; Szpiro & Carrasco, 2015). In this thesis, the possible correlation between visual orienting and cognitive development in infants is examined in more detail in order to identify possible links and gain more precise insights into the development of infants. The following chapter provides a brief overview of existing literature on visual attention, orienting processes, and their effects on and interactions with the cognitive development.

1.1. Defining Visual Attention and Orienting

Visual attention is present from an early age on and refers to our ability to process visual information. It is a very important part of cognition and perception and helps us to find our way around our environment (Petersen & Posner, 2012). As described by Carrasco (2011):

> Attention (…) is the mechanism that turns looking into seeing. In perception, ignoring irrelevant information is what makes it possible for us to attend to and interpret the important parts of what we see. Attention allows us to selectively process the vast amount of information with which we are confronted, prioritizing some aspects of information while ignoring others by focusing on a certain location or aspect of the visual scene. (Carrasco, 2011, p. 1484)

Attention therefore is the cognitive mechanism that enables us to select visual stimuli, focus on relevant details and filter out distractions at the same time, in other words, the mechanism that allows us to perceive meaningfully (Carrasco, 2011). A further important aspect of attention is visual orienting. Visual orienting requires directing attention to a particular stimulus or location, enabling the orienting process. Depending on the definition used, visual attention and visual orienting are often used interchangeably or as distinct but interconnected functions. In this thesis, I use the definition of Posner (1980), in which the term attention is used as umbrella term referring to the general state of awareness and focus on a specific stimulus. Orienting, on the other hand, refers to the specific process of focusing attention on a particular sensory input, e.g. a stimulus, or an internal semantic structure in memory (Posner, 1980). In attentional orienting, visual stimuli can be prioritized on the basis of their spatial location or their temporal occurrence. The spatial orienting of attention is the ability to direct attentional resources to a specific location, while the temporal orienting of attention is the ability to focus on a specific time to optimise behaviour (Coull et al., 2000; Coull & Nobre, 1998; Petersen & Posner, 2012; Posner, 1980). Furthermore, orienting can be either overt by moving the eyes (looking behaviour) and head to a stimulus, or covert, without moving and just by the central mechanism (Posner, 1980).

There are two main modes in attention, the endogenous and exogenous attention. In *endogenous* attention, or voluntary and goal-directed attention, attention is focused based on internal goals and expectations. As a top-down process, it is consciously controlled. (Corbetta & Shulman, 2002; Henderson, 2003; Müller & Rabbitt, 1989; Posner, 1980; Wang et al., 2019). It is also referred to as 'sustained' attention, which indicates the temporal nature of this type of attention (Colombo, 2001; Fuller & Carrasco, 2006; Porges et al., 1973). Endogenous attention is supported by the frontal and parietal cortex (Petersen & Posner, 2012).

In contrast, *exogenous* attention, or involuntary stimulus-driven attention, is based on an external stimulus and is a bottom-up process. Exogenous attention is characterised by a rapid onset and short duration in time and is therefore also referred to as 'transient' attention (Carrasco, 2011; Henderson, 2003; Moyano et al., 2022). The orienting response is triggered almost reflexively to conspicuous or unexpected environmental stimuli, such as sudden movements or bright colours and lights (Carrasco, 2011; Coull et al., 2000; Müller & Rabbitt, 1989; Posner, 1980; Wang et al., 2019). Exogenous attention enables even young infants to orient to new stimuli and get to know their environment better (Szpiro & Carrasco, 2015)

1.2. Early Development of Visual Orienting

Visual orienting emerges early in development, facilitating exploration of the environment, as it is crucial for becoming familiar with new stimuli (Atkinson, 1984; Johnson et al., 1991; Kiesel & Koch, 2018; Posner, 2016). Already in the *first months of life*, infants develop basic visual skills such as visual acuity, oculomotor control, and accommodation which are important for the integration of visual information (Atkinson, 1984; Braddick & Atkinson, 2011; Kiesel & Koch, 2018; Piaget & Inhelder, 1969; Pinquart et al., 2019; Schwarzer & Jovanovic, 2015).

Visual Short-Term Memory (VSTM) helps with information integration as it enables infants to form stable representations despite interruptions such as saccades (Irwin, 1991; Ross-Sheehy et al., 2003). Studies on the development of visual attention show that infants direct their fixation from a central target to a peripheral target already in the first months of life, as long as both targets are not visible at the same time but one after the other (Aslin & Salapatek, 1975; Atkinson & Braddick, 2012; Tronick, 1972). In the *first six months of life*, new skills such as averting gaze from a stimulus and anticipating different types of visual outcomes are also developing (Johnson et al., 1991).

Infants at around *4 months of age* are not only able to track moving objects smoothly, but their eye movements are able to predict the movement or appearance of the stimulus (Aslin, 1981). Studies have also shown that the VSTM capacity of infants *aged 6 months* is limited, especially when the stimuli involve multiple objects. In contrast, older infants, *from 7 months on*, are able to recognise changes in the arrangement of multiple objects and link information about the identity and location of the objects (Aslin, 1981, 2017; Haith et al., 1988; Johnson et al., 1991; Oakes et al., 2009; Oakes et al., 2006; Ross-Sheehy et al., 2003).

Starting at around *3 to 6 months*, infants are slowly developing endogenous attention in addition to exogenous attention (Colombo, 2001; Johnson et al., 1991; McConnell & Bryson, 2005). The emerging endogenous attention aligns with suggestions that *7- to 8-month-old* infants usually focus more on stimuli that are more likely to teach them about their environment (Kidd et al., 2012). Those two types of attention, endogenous and exogenous, interact, but also interfere with each other to initiate the appropriate behaviour in specific situations. While the endogenous attention works voluntarily and goal-oriented, the exogenous attention must also be active to be able to intervene reflexively and involuntarily. For example, an infant who is looking for a toy might hear background noises from other infants. While he continues to search for the toy (endogenous attention), he also perceives the background noises and may react to them reflexively (exogenous attention). (Colombo, 2001; McConnell & Bryson, 2005; Pfister et al., 2012; Richards & Casey, 1992; Schwarzer & Jovanovic, 2015).

Towards the *end of the first year* of life, abilities such as depth perception and pattern and object recognition also develop (Pinquart et al., 2019). Starting at the age of *2 to 3 years*, children can already form more complex visual expectations of their environment, such as the ability to predict contextual associations in eye-movement tasks. This ability is related to the executive attention system, which is important in coping with conflicting responses, as in spatial conflict tasks. The cognitive skills used in this may also be related to the ability to apply rules developing at 3 years of age (Rothbart et al., 2003; Zelazo & Jacques). In summary, the development of visual attention and orientation starts from a very early age and is important for visual exploration and information processing. The mechanisms and processes in visual exogenous orientation are discussed in more detail in the following chapter.

1.3. Gaze Movement in Overt Exogenous Orienting

In attention and also visual exogenous orienting, several networks work together, whereas Posner (2008) describes three networks of attention. The *alerting network* generates and maintains alertness during reaction tasks affecting attention and performance. The *executive network* is involved in complex processes for problem solving like the intentional coordination of attentional actions (Fan et al., 2002; Fan & Posner, 2004; Kiesel & Koch, 2018; Posner, 2008; Posner & Raichle, 1996; Schmenk, 2003) Finally, in the *orienting network*, the spatial orienting of the focus is supported by the selection of information. This network also includes exogenous orienting. To make visual orienting possible, it is assumed that the executive network must also be activated as it is also responsible for object perception (Kiesel & Koch, 2018; Posner & Raichle, 1996).

During the process of overt visual orienting, the eye actively directs its gaze to the important information, as it sees most clearly at the point of fixation (Henderson, 2003). However, even during the fixation of stimuli, eyes never remain completely steady, as there are slight shifts in the fixation points (Schmidt & Birbaumert, 2006). In overt exogenous orienting, the gaze movement occurs through saccades, during which there is usually no visual processing (Joos et al., 2003; Poole & Ball, 2006). Visual processing only occurs again when the point of interest has been reached with the direction of gaze (Henderson, 2003; Kiesel & Koch, 2018). A saccade usually lasts between 15 ms and 100 ms, whereby the orienting process itself takes longer (Schmidt & Birbaumert, 2006). In overt visual orienting, a scan path is created, consisting of the saccades and fixations, while three sub-processes are distinguished. The first one is *disengagement*, in which attention is disengaged from the first stimulus, while the second one, *shifting*, refers to the shifting of attention. The last sub-process is *engagement*, in which attention is directed to a new stimulus. In order to perform overt orienting, the focus of attention must first be shifted to the target stimulus (Casteau & Smith, 2019; Schmenk, 2003). The ability to move the eyes quickly and precisely may influence how efficiently we can process visual information, make adequate action plans and react to relevant stimuli (Casteau & Smith, 2019).

1.4. Visual Attention and Orienting as a Predictor of Later Developmental Outcomes

The visual attention of infants has been investigated in several studies including its relation to cognitive development. Alongside information integration and memory processes, analysing visual attention, particularly looking behaviour, provides insights into brain processing speed and development (Colombo, 2001; Colombo & Cheatham, 2006; Johnson & Vecera, 1996; Messinger et al., 2017; Posner & Rothbart, 2007; Rose et al., 2002). The findings from studies by Pejovic et al. (2021), Rose et al. (2005), and Ross-Sheehy et al. (2017) suggest a correlation between increased visual attention and orienting in infants and advanced later cognitive abilities. Research has shown that individual differences of cognitive abilities in adults, such as working memory capacity, can influence the looking behaviour (Hitzert et al., 2014; Weaver et al., 2017).

Also learning, another key part of cognitive development, is associated with visual orienting. The study of Szpiro and Carrasco (2015) showed that exogenous attention plays a significant role in learning acquisition in adults by enhancing the encoding of stimuli. By using task-irrelevant cues to manipulate attention during training, it was observed that the training of exogenous attention can lead to improved learning acquisition. This suggests that exogenous attention can promote perceptual learning by enhancing the processing of stimuli ultimately leading to improved learning outcomes.

Furthermore some studies indicate that infants who have better visual attention skills, such as visual scanning or joint attention, have more positive results in language acquisition and recognition memory (Morales et al., 1998; Rose et al., 2001; Rose et al., 2003). In Rose et al. (2003), the relationship between visual attention and visual recognition memory in infants (5, 7 and 12 month-old) was examined. Two looking behaviour tasks were used to measure visual attention and visual recognition memory. The visual paired-comparison (VCP) task and continuous familiarization task assessed the two types of visual attention, look duration and the frequency of shifting gaze between targets, as well as visual recognition memory and processing speed. The results showed that better visual attention and processing speed in infants lead to better recognition memory. In this regard, shorter looks and more shifts in looking behaviour correlated with a better visual recognition memory. The recognition memory is a good indicator of later cognitive abilities such as IQ and language development (Rose et al., 2003, 2004). In the study of Pejovic et al. (2021) visual orienting and audiovisual speech processing abilities in infants with down syndrome and typically developing infants between 5-7 months of age are compared by using the Visual Expectation Paradigm (VExP). This method involves displaying visual stimuli at different spatial positions following a fixed sequence while recording the gaze of the participants (Dougherty & Haith, 1997; Haith et al., 1988; Moyano et al., 2022; Rothbart et al., 2003). The authors measured the looking latency to visual stimuli with flashing lights by placing the infants in a testing booth making them look at a central positioned green light. Two red lights were positioned laterally of the infant. The looking behaviour was recorded on camera, and afterwards coded by the researchers. The central flashing green light was given at the beginning and as soon as the infant oriented to it, it was coded, switched off and one of the lateral red lights started to flash. As soon as the infant oriented its gaze to the red light, it was coded again, and so the overtly orienting latency time was measured. The study revealed that typically developing infants exhibit faster visual attention than infants with down syndrome. Additionally, infants with down syndrome showed less focus on the eyes compared to the background, indicating difficulties in processing linguistically relevant cues, highlighting the link between visual attention and other cognitive abilities (Pejovic et al., 2021).

Especially in research with infants who are not typically developing, differences between visual attention and cognitive development become visible. Studies focusing on prematurity, autism spectrum disorder and neurodevelopmental conditions suggest that visual attention is related to cognitive abilities or both are often affected simultaneously (Dakin & Frith, 2005; Elsabbagh et al., 2013; Evers et al., 2018; Rose et al., 2005; Ross-Sheehy et al., 2017).

Prematurity often leads to cognitive deficits in infants, such as having a below average IQ, language delays, and learning disabilities (Aylward, 2002; Rose et al., 2005). The study by Ross-Sheehy et al. (2017) investigated attention processes in premature and full-term infants. The infants participated in the Infant Orienting with Attention (IOWA) task. It is an attentional cueing task that assesses visual attention overt orienting behaviour in infants by measuring eye movements from a central to a peripheral target (Dougherty & Haith, 1997; Moyano et al., 2022; Pejovic et al., 2021; Ross-Sheehy et al., 2017). 5-month-old full-term infants exhibit faster reaction times compared to pre-term infants. While this could indicate delays in the processing of peripheral stimuli or eye orientation of pre-term infants, by 10 months of age they have made up for most deficits. However, a reduced perception of cues and increased interference of cues in pre-term infants was still observed at 10 months. This in turn may indicate deficits in covert attention and exogenous orienting (Ross-Sheehy et al., 2017). The data collected can provide information on attention, orienting latencies, saccade plans, visual competition, and the effects of spatial cues. Studies like this underscore the importance of considering early attentional processes in neurocognitive development (Dougherty & Haith, 1997; Moyano et al., 2022; Pejovic et al., 2021; Ross-Sheehy et al., 2017).

Elsabbagh et al. (2013) conducted a study investigating the disengagement of visual attention in infancy and its relationship to the autism spectrum disorder likelihood. The study involved infants, some of whom were at high risk of autism and others at low risk. They were tested at 6 to 10 months and again at 12 to 15 months by presenting them attention tasks. In the tasks the infants first looked at a central animation on a monitor followed by a peripheral stimulus either to the right or to the left of the central one. In the overlap condition, the central stimulus remained displayed so that both stimuli overlapped and throughout the testing the looking behaviour was recorded and later analysed. They found that infants with average attention shifting skills who effectively shifted their gaze from a central to peripheral stimuli were less likely to show early autism traits. In contrast, infants who had difficulty with this task were more likely to show early autism traits. The correlation between the disengagement of attention and ASD risk, along with difficulties in attentional flexibility and shifting, suggests that the visual attention development could potentially serve as an early marker for ASD risk (Anderson et al., 2006; Dakin & Frith, 2005; Elsabbagh et al., 2013; Evers et al., 2018).

2. Present Study

Previous findings suggest that the role of visual attention and orienting is important for the overall cognitive development of infants. It is a fundamental mechanism for learning about novel stimuli, facilitating perceptual learning, and it is contributing to a good overall development (Atkinson, 1984; Casteau & Smith, 2019; Johnson et al., 1991; Kiesel & Koch, 2018; Posner, 2016; Szpiro & Carrasco, 2015). The ability to selectively focus on relevant stimuli while filtering out distractions is vital for optimal learning outcomes. Visual attention is a subset of cognitive functions in which different networks interact with each other. It is therefore assumed that it is also linked to other cognitive abilities, also depending on the conceptual proximity to the different areas. Deficiencies in visual attention can significantly impact cognitive and developmental performance, potentially leading to delays in cognitive skills (Anderson et al., 2006; Morales et al., 1998; Rose et al., 2005; Ross-Sheehy et al., 2017).

Conditions like cerebral palsy and various developmental disorders such as autism spectrum disorder have been associated with issues in visual attention, as demonstrated by studies conducted by Ego et al. (2015), Elsabbagh et al. (2013), Dakin and Frith (2005) and Philip and

Dutton (2014). Given the implications for infant development, scientific research in this domain becomes crucial. Such research can unravel the mechanisms underlying visual attention and orienting and uncover correlations with developmental risks. Understanding the impact of developmental risks is also necessary for the implementation of targeted interventions that support optimal infant development.

In this thesis, the focus lies on overt exogenous orienting, as assessed with infants' looking behaviour, and its possible relationship to later cognitive abilities. The study conducted should provide valuable insights for both theoretical understanding and practical interventions. In conclusion, the current thesis will further investigate the following main hypotheses:

H1.a: Longer latencies in overt exogenous orienting at 6 months will negatively correlate with later cognitive development outcomes at 24 months.

H1.b: Longer latencies in overt exogenous orienting at 12 months will negatively correlate with later cognitive development outcomes at 24 months.

H2: A significant improvement in visual exogenous orienting is expected in infants from 6 months to 12 months.

H3: The negative correlation between visual orienting at 12 months and cognitive development at 24 months is expected to be stronger for items on the cognitive scale emphasizing visual attention compared to other items.

3. Methods

This research was conducted as a part of the longitudinal project of the ‘Wiener Kinderstudien’ (Vienna Children Studies) within the Department of Developmental and Educational Psychology at the University of Vienna. Supervision for the study was provided by Univ.-Prof.in Dipl.-Psych.in Dr.in Stefanie Höhl and Mag. Alicja Brzozowska, Ph.D. Parts of the specific subproject of the Wiener Kinderstudien, known as ‘Selective neural entrainment and dynamic attention in infants’, were the focus of this thesis.

A two-method approach is used for the study, on the one hand to investigate the overt exogenous orienting in more detail, and on the other hand to find out the level of cognitive development in infants. The first method used is a visual orienting task which is based on the approaches of tasks like the VExP (Moyano et al., 2022; Rothbart et al., 2003) and IOWA task (Ross-Sheehy et al., 2015) to examine gaze orienting towards peripheral stimuli. The second method used to assess the level of cognitive development is the Bayley Scales-III of Infant and Toddler Development, German Version (Bayley-III) (Reuner & Rosenkranz, 2014). The subsequent sections outline the methods and procedures employed in the study.

3.1. Participants

The participants for this study were recruited via a university-associated databank, whereby parents could register if they were interested in taking part in a study with their infant at the Institute of Developmental Psychology at the University of Vienna. At the time of recruitment, the participants lived in close surroundings in and around Vienna. Parents were contacted via telephone or email by members of the research team, who provided information about the study and a short version of its overall procedure. A follow-up email containing all the information for the parents and a reminder message shortly before the appointment were sent.

Being a full-term infant (i.e., infants born in the 37th week or later; > 2,500 g) and starting with the age of around 6 months at Time Point 1 and no known visual impairments were the inclusion criteria.

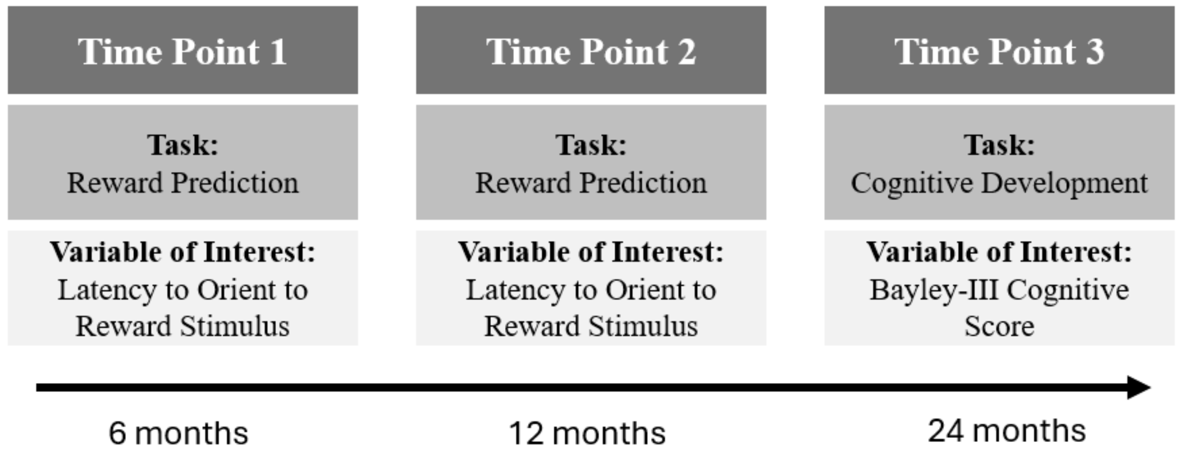
The parents of the participants received €6 for travel expenses. At Time Point 3, they additionally received either a €15 drugstore voucher or a book on infant education and research. The infants got a toy, even if the testing was discontinued. Parents were also provided with a participation certificate featuring a photo of their child, which was taken during the testing.

3.2. Research Design, Procedure and Processing

The data collection for Testing Time Point 1 (6-month-old infants) already started in April 2022 and the Testing for Time Point 3 (24-month-old infants) will continue till around July 2024. The study sample for T1 consisted of N = 140 infants (76 female; 64 male), 133 of whom also attended T2. The data analysis for T2 and the data collection for the last T3 are still in progress. Depending on the time point, two main tasks were used in this study. At time point T1 (6 months) and time point T2 (12 months), the visual exogenous orienting task was used in which the latency times for orienting to a reward stimulus were examined. At time point T3 (24 months) cognitive development was assessed with the Bayley-III focussing on the cognitive scale (see Figure 1).

Given that the study ‘Selective neural entrainment and dynamic attention in infants’ is extending beyond the duration allocated for the master's thesis part, a temporal boundary of mid-March (15.03.2024) has been imposed on the used data of the data collection. Accordingly, all data gathered up to this deadline from Time Point 3 will undergo further analysis.

Figure 1: Research Design Including Time Points, Tasks and Variables of Interest



In the following subchapters the particular methodology behind the tasks, the procedure and the data processing are described in more detail.

3.3. Visual Attention Task

The infants were presented with a screen showing various stimuli and their visual attention was monitored using video footage. Three parts were conducted sequentially, whereby the study described in this thesis only focuses on the third part, the *Reward Prediction Task*.

3.3.1. Visual Attention Task Experimental Set Up

The testing of Time Points 1 and 2 had already been completed before the start of this master's thesis and just needed to be evaluated. The procedures for these time points involved EEG and looking behaviour data. The caregiver (mostly the mother of the infant) and infant were welcomed into the laboratory of the Wiener Kinderstudien at the University of Vienna, and the parents were once again informed about the study procedure. As long as there were no interruptions, the testing itself took about 12 minutes on average and there were two researchers present during the testing. First the head circumference of the infant was measured so that the EEG cap could be placed on it. The infant was usually sitting on the parent's lap in the testing booth during the whole testing. Before the testing started, the parents were told to have as little interaction with the infant as possible while testing so that there were fewer interruptions and distractions. In order to minimise other distractions, the test area was separated by curtains from the rest of the laboratory. In front of the infant at a distance of around 80 cm an iiyama G-MASTER GB2560HSU computer screen with a refresh rate of 144Hz was set up displaying the task. There were two synchronised cameras, with one capturing the infant's face and the other recording the computer screen.

3.3.2. Reward Prediction Task

As already mentioned, the Reward Prediction Task is based on approaches such as the VExP (Moyano et al., 2022; Rothbart et al., 2003) and IOWA task (Ross-Sheehy et al., 2015). In this task, a fixation cue was presented for 500 to 750 ms, followed by an image of a female face with a direct gaze displayed centrally. Simultaneously two identical non-social objects were presented peripherally, flickering at different frequencies (3.43 Hz and 4.5 Hz, 5.54 Hz and 6.55 Hz, or 4.5 Hz and 6.55 Hz depending on the trial). The frequency at which the flickering non-social objects blinked also predicted the infant on which side the reward stimuli would appear. However, as the focus of this thesis is on the overt exogenous orienting, the prediction aspect of this task is not investigated further in this thesis.

After two seconds, the face and the flickering objects disappeared, and a reward stimulus in the form of a cartoon character appeared for 1000 ms on one of the two sides of the peripheral stimulus (see Figure 2 for illustration). The reward stimulus rotated while appearing on the screen for a more interesting experience and as a form of reward. In total, the prediction task consisted of 48 trials.

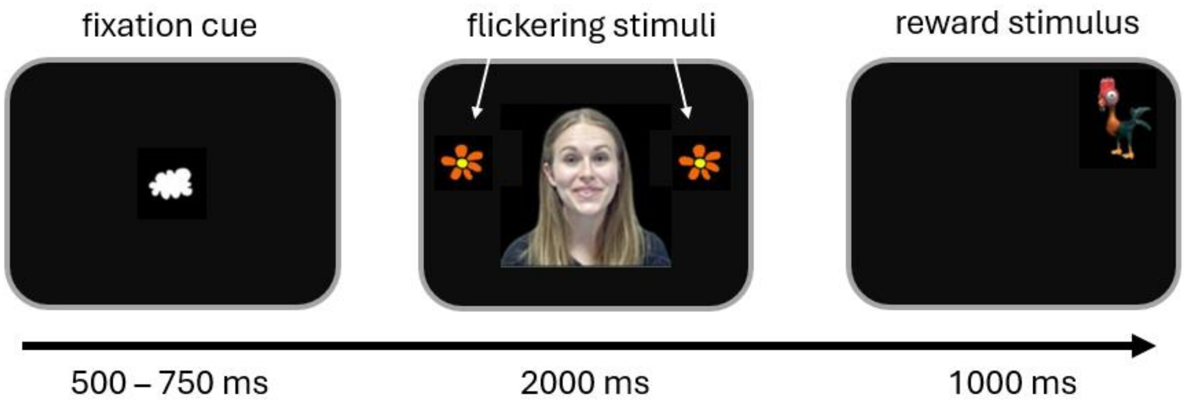


Figure 2: Prediction Task Visual Exogenous Orienting Set-Up

3.3.3. Visual Attention Task Data Processing

The latencies at Time Points 1 and 2 were measured with the help of video coding of visual overt orienting of the 6- and 12-month-old infants. Whereby the data collected at time point 1 was already analysed, the one of time point 2 had to be analysed for this thesis. The collected EEG data was not relevant for this study, but video recordings of the infants were analysed and coded. The recordings using the software VideoSyncPro (version 2.5.7.5) from both synchronized cameras, Camera 1 and Camera 2, were opened using the Mangold Interact software (Mangold International GmbH, 2020), and the triggers were transferred. Ensuring that both videos ran synchronously allowing reliable coding was a key aspect. Afterwards, key shortcuts were used to indicate whether the infant was looking to the left, to the right, at the centre of the screen, away from the screen, was distracted or whether the gaze was not codable in the videos.

The latency of exogenous eye orienting was measured from the moment the face disappeared in the centre and the reward stimulus appeared on the right or left side. In cases where the infant was not looking at the centre of the screen before the disappearance of the face cue or neglected to orient its gaze towards the reward stimulus, the trials were considered as invalid. Additionally, infants' trials were excluded from latency analyses if their response times were less than 100 ms (Matsuzawa & Shimojo, 1997), as this is too short for a saccade for orienting to the stimulus.

Following this, the coding of the videos was documented in a Microsoft Excel (Microsoft Corporation, 2021) sheet, including comments whether the run was good or bad in terms of distraction and crying.

After all the files had been coded, the average latency times of the infants were processed via Python in Visual Studio Code (Version 1.81.1, Visual Studio Code, 2021) using the script already created by Matteo Mattersberger (2023) also stated in his thesis (Mattersberger, 2024). To do so, the raw data of Mangold Interact (Mangold International GmbH, 2020) had to be converted into a csv (format for tabular data) file. The triggers and the start of the respective tasks were already defined in the script. By inserting the source folder with all the csv files from T2, individual Excel documents were created for each infant, but also a document including all participants and their average latency times for the reward prediction task. To calculate the average latency for each infant proportionally, it was specified in the Python code that the sum of the latencies of the valid trials was divided by the number of the valid trials. These values allowed to assess how long the visual orienting by the infants took, indicating their responsiveness to the reward stimulus and their ability to orient to new stimuli.

3.4. Bayley Scales-III

The Bayley Scales-III of Infant and Toddler Development is an updated form of the Infant and Toddler Developmental Assessment Instrument. The US version includes five different scales measuring cognitive, language, motor, social-emotional and adaptive behaviour skills in infants between the age of 1 and 42 months, while the German version only includes the cognitive, language and motor subscales. The material, consisting of toys such as pegboards, dolls, balls, and puzzles, is stored in a trolley case and includes an implementation manual with test standards (See Figure 3). The technical manual documents the theoretical background of the properties and quality criteria (Macha & Petermann, 2015).

The cognitive scale assesses sensorimotor manipulation, problem solving and concept formation. The language scale is divided into receptive and expressive communication and the motor scale is divided into gross and fine motor skills.

Figure 3: Bayley-III Parts of Testing Kit German Version

The infant must pass the first three following items in the subtests for the test to continue. If one of the three items is not passed, the next lower age section is skipped back to and started again. This allows the starting point of the infant to be adjusted more precisely to the infants' stage of development. The test ends as soon as five items in a row are failed. (Albers & Grieve, 2007; Lennon et al., 2008; Piñon, 2010; Reuner & Rosenkranz, 2014). The reliability (based on German norm sample N = 1009) of the Bayley-III shows a medium to high internal consistency of 0.77 (SprR) and 0.89 (MotG) for the total sample. The retest reliability (N = 54 premature infants) shows a moderate correlation between subtest values (t1 and t2) of 0.20 (SprE) and 0.46 (MotG). The construct validity is supported by examining the sub- and scale intercorrelations, whereby the correlations are in the low to medium range. The highest correlation is between SprE and SprR (0.41) at subtest level and the highest scale intercorrelation is between cognition and motor skills (0.43). The correlation between the scales and their constituent subtests is consistently between 0.66 and 0.69 (Macha & Petermann, 2015).

3.4.1. Bayley-III Cognitive Scale

The Bayley-III cognitive scale is a tool designed to assess various aspects of cognitive development in infants and young children. It encompasses a range of behaviours and abilities, including different kinds of play, information processing, problem-solving skills, attention, memory, and numerical reasoning. Through observation and structured tasks, the scale aims to provide insights into the cognitive abilities and developmental progress of infants (*Bayley-III Clinical Use and Interpretation*, 2010; Häusler, 2015; Reuner & Rosenkranz, 2014).

As play contributes to cognitive development, the Bayley-III cognitive scale attempts to analyse and assess behaviours such as functional play, pretend play, and symbolic play. When playing, six-month-old infants normally favour single objects for playing, but just a few months later they associate several different objects with each other and play with different things at the same time (Bruner, 1973; Piaget & Cook, 1998, 1952; Reuner & Rosenkranz, 2014; Singer et al., 2010). At 12 months, infants usually already show increased symbolic play.

In the cognitive Bayley-III, the items focus on *information processing*, such as the habituation process, attention to novelty, memory and problem solving (Bornstein & Sigman, 1986; Hayne et al., 1987; Piaget & Cook, 1998, 1952; Piaget & Inhelder, 1969; Reuner & Rosenkranz, 2014; Rovee-Collier & Barr, 2010). These areas are linked to later cognitive performance whereby Frick et al. (1999) found a correlation between cognitive performance at the age of one year and later on in life. To assess *habituation and memory processing*, novel stimuli are used to see if the infant becomes habituated to the stimuli. Several studies suggest that preference for new stimuli indicates that the infant orientates itself to new things in the environment and adapts its mental processes to them, as in accommodation (Bornstein & Sigman, 1986; Hayne et al., 1987; Piaget & Cook, 1998, 1952; Piaget & Inhelder, 1969; Reuner & Rosenkranz, 2014; Rovee-Collier & Barr, 2010). As an infant develops it acquires increasingly advanced *problem-solving skills*. One example of this is the typical hiding of objects and the infants' different reactions to this depending on their age. While a six-month-old child grasps a partially hidden object, a nine-month-old infant searches for an object that has been completely removed from its field of vision. At 24 months, the child is already able to find an object that has been removed and hidden elsewhere (Dunst et al., 1982; Piaget & Cook, 1998, 1952; Piaget & Inhelder, 1969; Reuner & Rosenkranz, 2014). In the area of problem solving on the cognitive scale, Bayley III involves, for example, hiding a bracelet under one of two flannels, which are then swapped. The child must then lift the correct flannel to find the bracelet (Reuner & Rosenkranz, 2014). In addition to problem solving, attention and object permanence are also tested.

Numerical reasoning is also part of the cognitive scale and includes tests on one-to-one matching, counting and cardinality. During early infanthood, infants successively acquire the ability to match one-to-one, the stable number sequence and finally also the understanding of the number of objects in a set. The ability to correctly name the number of objects in a set, cardinality, usually develops from around the age of three (Piaget & Inhelder, 1969; Reuner & Rosenkranz, 2014; Wynn, 1990).

All in all, the cognitive scale contains a total of 91 items, with infants aged between 1 and 41 months being the target group of the test. The cognitive abilities, tested at the third time point (T3) with 24 months, start in the Bayley-III with the letter M, as this is for the age group 22 months and 16 days to 25 months and 15 days. If the infant is unable to solve one of the first three items starting with the letter M, the researcher jumps back to the point of the previous entry age, e.g. L for 19 months and 16 days to 22 months and 15 days, and starts again from this point. (*Bayley-III Clinical Use and Interpretation*, 2010; Häusler, 2015; Reuner & Rosenkranz, 2014). Overall, the Bayley Scales-III cognitive scale helps to playfully determine the current level of development in the areas of habituation, attention, memory, and problem solving.

3.4.2. Bayley-III Experimental Procedure

Before using the Bayley-III, the researchers underwent diagnostic training at the General Hospital of Vienna (AKH) to ensure accurate and consistent results. The training took place in July 2023, providing a theoretical introduction to the diagnostic tool. The research members then had the opportunity to take part in Bayley-III testing with patients at the University Clinic for Pediatrics and Adolescent Medicine at the AKH and practiced later on in the laboratory in teams of two using the instrument for improving their skills in assessing correctly.

The data collection started in October 2023. The procedure was as follows: the caregiver and infant were welcomed at the Department of Developmental Psychology in Vienna. In the designated testing room, a brief overview of the procedure was explained. Prior to the Bayley-III testing at the same appointment, two further short tests were carried out with the infant regarding sensorimotor synchronisation and visual search. These tests are not relevant to this work and will not be detailed further. Recognising that infants are often shy and reserved in the beginning, there was a period of playing time and getting to know each other with the infant before the actual testing, allowing them to get used to the environment. At the same time of the testing, the parent completed all relevant questionnaires.

The Bayley-III assessment took place within the same room and lasted for around 1.5 hours, depending on the infants' level of focus and desire to collaborate. The assessment was conducted by two research members from the institute. One person presented the tasks, interacting directly with the infant, while the other person assisted with the tasks, including measuring the time, ensuring the proper storage of items from the Bayley-III kit after each task, and noting additional behavioural observations.

If infants were unable to solve five items in a row, or voluntarily discontinued, the particular scale or the entire assessment was stopped. In the end, only the cognitive and the gross motor scale were tested. As many infants soon became unfocused and distracted due to the exciting situation, the need to maintain concentration and the length of the two tasks before the Bayley-III testing, the gross motor scale was usually started after the cognitive scale so that the infants had the opportunity to move around after the cognitive scale.

Parents were instructed not to provide any hints during the testing process and to interact with their child as little as possible, unless actively requested. They were usually in a position at a distance from the infant, rather than sitting directly with them, whereby some infants only wanted to cooperate when their parents were sitting next to them. Scheduled breaks interrupted the assessments, allowing the infant brief periods of rest and the opportunity to eat and drink. Immediately after the test, the two testers discussed any uncertainties that arose during the test and, if necessary, discussed individual items and brought together their opinion as to whether the item counted as fulfilled or not fulfilled, so that there was better inter-rater reliability, and the observation and evaluation did not depend on just one person.

3.4.3. Bayley-III Data Processing

After the testing, the data of the cognitive scales was analysed and prepared for an adequate comparison. In order to analyse the Bayley-III data for hypothesis testing, the infants' points of the cognitive scale first had to be added together. As the starting point of the test depends on how old the infants are, we started with the letter M for 24 months. However, as already mentioned it was

sometimes necessary to go back one letter and start at a younger age if one of the first three items was not fulfilled. In most cases, it was therefore assumed that the infant had achieved all points up to M. The points achieved from M onward were then totalled and added to the points before M (if completed 44 points before M). In exceptional cases, only the points up to J or K were assumed as complete and the subsequent points were added up again depending on the level of achievement. This made it possible to calculate a score of the cognitive scale for each infant.
For hypothesis 3, special scales were calculated and only the points from J onwards (as no infant had to start earlier than J) were counted and divided into *scale 1* with all passed items from J onwards and *scale 2* with the items from J onwards considered to be related to visual attention.
In order to obtain a classification of the 'visual items' of the cognitive scale of the Bayley-III for hypothesis H.3, the work of Häusler (2015) was used. In this thesis the items of the cognitive scale of the Bayley-III were subcategorised into the six categories concept formation/classification, part-whole relationship, representative thinking, imitation, problem solving and remembering using a content-based item analysis. In H3 it is assumed that due to the conceptual proximity of visual orienting (T2) and the cognitive items (T3), which are associated with visual attention skills, there is a stronger negative correlation than with all the cognitive items combined. The areas of imitation, problem solving and remembering were most likely to be attributed to visual attention and were therefore analysed as 'visual items' for the third hypothesis.

3.5 Statistical Methods

The statistical methods used for the analysis varied depending on the hypothesis. For the purpose of applying the statistical methods the software IBM SPSS Statistics (IBM Corp., 2021) was used.

H1.a: For the hypothesis 'Longer latencies in overt exogenous orienting at 6 months will negatively correlate with later cognitive development outcomes at 24 months.', a linear regression was used as the statistical method. This allows the linear relationship between a *predictor*, which in this case is the orienting latencies at T1, and an *outcome*, the results of the cognitive Bayley-III score at T3, to be investigated in more detail.

H1.b: As the hypothesis 'Longer latencies in overt exogenous orienting at 12 months will negatively correlate with later cognitive development outcomes at 24 months.' is almost the same hypothesis as H1.a, whereby the T2 data was used instead of the T1 data, a linear regression was also used to analyse the data. The linear relationship between the predictor (orienting latency at T2) and the outcome (cognitive Bayley Scales-III Score at T3) is therefore analysed in more detail.

H.2: For the hypothesis ‘A significant improvement in visual exogenous orienting is expected in infants from 6 months to 12 months.’ a paired t-test is used for the statistical analysis. The variables used are the orienting latencies at T1 and T2. The requirements such as normal distribution and homogeneity were also carried out in SPSS (IBM Corp., 2021) before the main analysis.

H.3: For the last hypothesis 'The negative correlation between visual orienting at 12 months and cognitive development at 24 months is expected to be stronger for items on the cognitive scale emphasizing visual attention compared to other items', a correlation analysis was carried out. Using SPSS (IBM Corp., 2021), *correlation 1*, consisting of the visual orienting latencies at T2 and the cognitive Bayley-III results at T3, and *correlation 2*, consisting of the visual orienting latencies at T2 and the cognitive Bayley-III results of the items associated with visual attention and orienting, were analysed. Subsequently a Fisher-Z-test, in which the two correlation results could be compared, was carried out.

4. Results

4.1. Descriptive Statistics

There was a total of 27 data sets that included all three time points T1, T2 and T3. At time point T1 (6 months visual orienting) 109 (31 missing) data sets were included, at time point T2 (12 months visual orienting) 82 (58 missing) data sets were included and at time point T3 (24 months cognitive scale of the Bayley-III) 59 (81 missing) data sets were collected and processed for the statistical analysis so far. See *Table 1* for a more detailed distribution of the sample, the average latencies and scores achieved on the Bayley-III cognitive scale. Reasons for the missing data sets were the lack of enough valid trials (at least three valid trials), technical issues in the data analysis, the not yet completed data collection, and the discontinuation of participation in the study. As this is a longitudinal study and the hypotheses also relate to at least two points in time, only the data of infants who were present at a minimum of two time points during testing could be used.

When analysing the overlapping data for the three points in time, the number of valid samples from T1 to T2 was $n = 67$ (33 female; 34 male), from T1 to T3 was $n = 43$ (23 female; 20 male) and from T2 to T3 $n = 35$ (15 female; 20 male). For more detailed information on the distribution and normal distribution at time points T1, T2 and T3, see *Appendix Figures 8-10.*

Table 1: Descriptive Statistic for All Three Time Points

	N	Minimum	Maximum	Mean	Std. D.
T1 **Visual Orienting Latencies**	109 (63 female; 46 male)	168.76 ms	667.73 ms	404.84 ms	1 15.81 ms
T2 **Visual Orienting Latencies**	82 (39 female; 43 male)	120 ms	796.67 ms	436.95 ms	130.71 ms
T3 **Bayley-III Cognitive Scale**	59 (28 female; 31 male)	56 points	76 points	67.41 points	4.82 points

4.2. Statistical Analysis of Hypotheses

Following the descriptive evaluation, the hypotheses H1.a, H1.b, H2 and H3 are now statistically analysed and presented again with the help of plots.

4.2.1. Hypotheses 1.a

In H1.a, linear regression (n = 43) was chosen as the statistical method to investigate the influence of longer latencies in exogenous orienting to reward stimuli at 6 months (T1) on cognitive developmental outcomes at 24 months (T3). The hypothesis states that longer latencies in orienting to reward stimuli at 6 months will show negative correlations with later cognitive developmental outcomes at 24 months, which means faster exogenous visual orienting will display higher cognitive developmental scores of the Bayley-III 12 months later.

The results of the linear regression analysis examining the relationship between T1 and T3 indicated $t = -0.765$ with $p = 0.449$. Therefore, the correlation is non-significant ($p > 0.05$). The R^2 value calculated was 0.014. For an illustration of the distribution of T1 and T3 data *see Figure 4*. Overall, the statistical results indicate that the hypothesis that longer latencies in orienting to reward stimuli at 6 months would show negative correlations with later cognitive developmental outcomes at 24 months is not significantly supported and can therefore not be accepted.

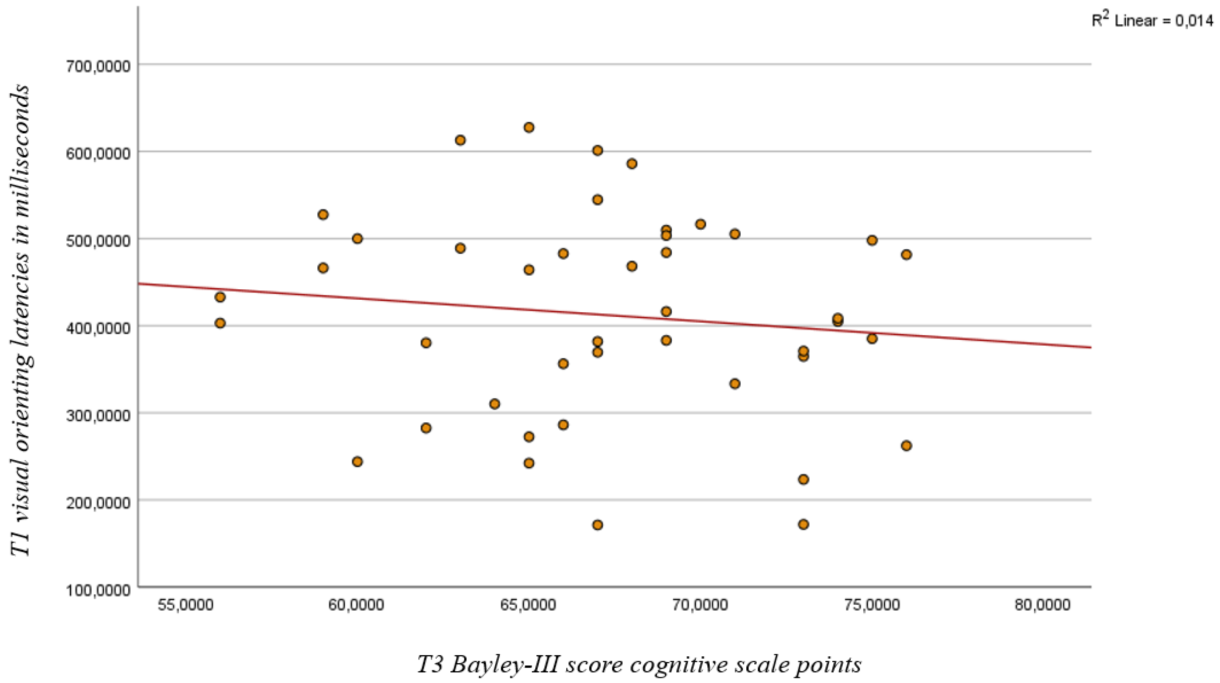


Figure 4: Scatterplot of Mean Orienting Latencies (in ms) at T1 Against Mean Bayley-III Score of the Cognitive Scale at T3 with Regression Line

4.2.2. Hypotheses 1.b

The hypothesis H1.b investigating the relationship between latencies to orient reward stimuli at 12 months (T2) and cognitive developmental outcomes at 24 months (T3) stated that longer latencies would show negative correlations with later cognitive developmental traits. For the statistical hypothesis testing a linear regression ($n = 35$) was calculated with the help of IBM SPSS (IBM Corp., 2021).

The linear regression between the latency of the independent variable T2 and the Bayley-III score of the dependent variable T3 resulted in $t = -0.0651$ and $p = 0.520$ (*see Figure 5* for distribution of the data and regression line). The calculated R^2 value was at 0.013. The correlation between the data of T2 and T3 was therefore not significant ($p > 0.05$).

Overall, the statistical results do not support the hypothesis, as no significant was found, which therefore suggests that longer latencies in orienting to reward stimuli at 12 months may not be associated with later cognitive developmental outcomes at 24 months.

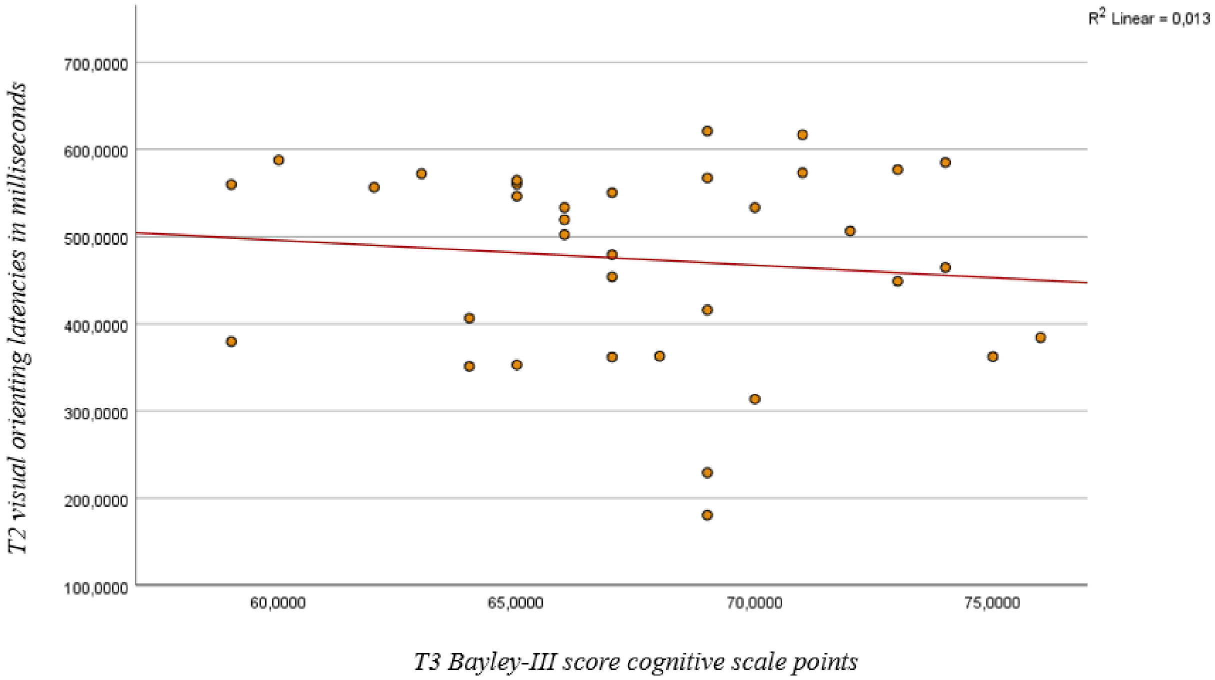


Figure 5: Scatterplot of Mean Orienting Latencies (in ms) at T2 Against Mean Bayley-III Score of the Cognitive Scale at T3 with Regression Line

4.2.3. Hypotheses 2.0

For the present hypothesis, it was expected that there would be a significant improvement in visual exogenous orienting in infants aged 6 to 12 months. The results were analysed using SPSS, whereby the descriptive statistics showed that the mean orienting latencies (including all T1 data) were at 404.84 ms (SD = 115.81 ms; n = 109), while at the later time point (including all T2 data) they were at 436.95 ms (SD = 130.71 ms; n = 82). Only the data of the participants we had from time points T1 *and* T2 could be included (n = 67). As a result, the statistics changed again slightly, with the mean of T1 being 406.50 (SD = 109.57) and of T2 being 424.9 (SD = 15.59). *See Figure 6* for the distribution of the latencies between T1 and T2.

Performing the paired t-test results showed a mean difference between the T1 and T2 data of -18.39 ms (SD = 186.52 ms), with a t-value of 0,807 and df = 66. The one-sided significance was at p = 0.789 while the two-sided significance was at p = 0.422. Furthermore, at T2 the variance appears to be higher (13410.84) than at time point T1 (17084.545). The results show that the average reaction times between the two time points (T1 and T2) did not show a significant difference in this study. It can therefore be concluded that the hypothesis of a significant improvement or change at all in visual exogenous orienting in infants from T1 at 6 months to T2 at 12 months cannot be confirmed based on the available statistical analyses. For an understanding of the individual paired data results of T1 and T2 as well as the distribution and variance of the data, *see Figure 7*.

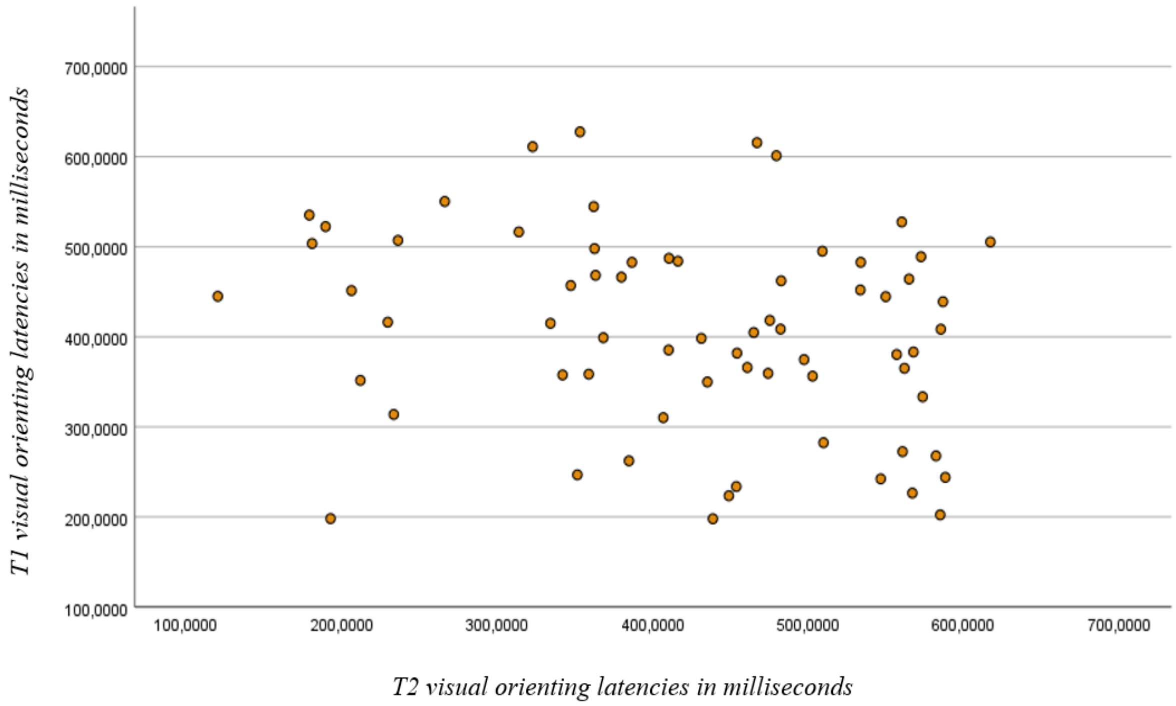


Figure 6: Scatterplot of Mean Orienting Latencies (in ms) at T1 Against T2

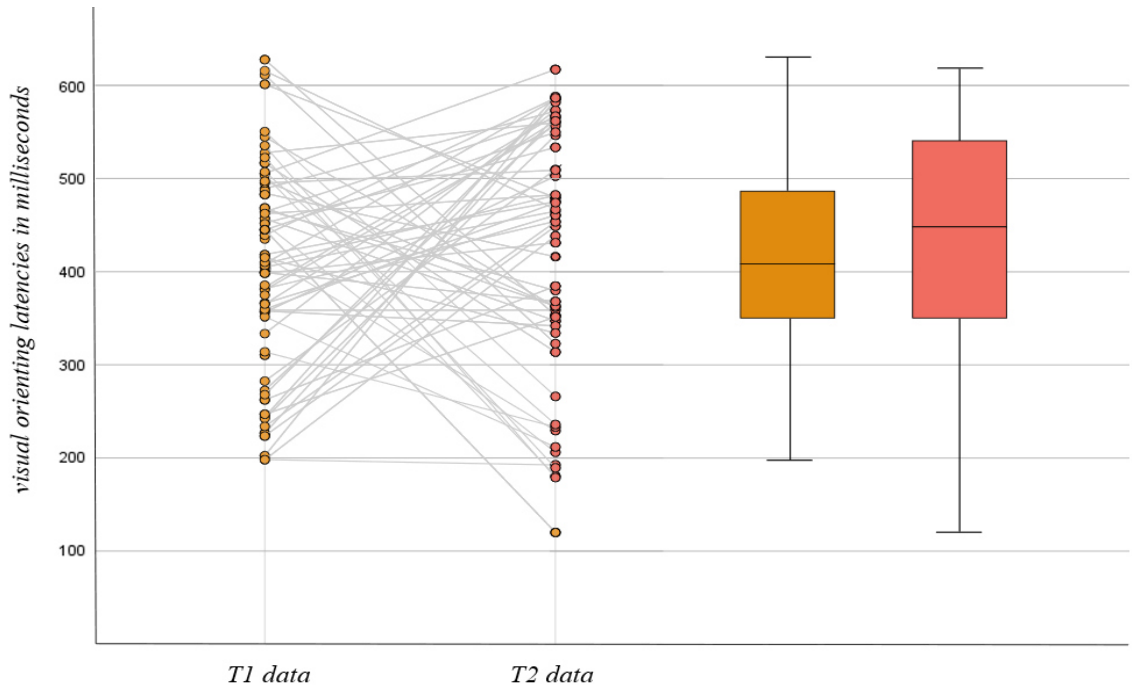


Figure 7: Pairwise Comparison of the Individual Latency Times of T1 and T2 with Boxplot

4.2.4. Hypotheses 3.0

The correlation between the visual orienting latencies at T2 and the Bayley-III cognitive scale at T3 is expected to be stronger for items on the cognitive scale that emphasise visual attention compared to all cognitive items (starting at J in the cognitive scale) together.

The first correlation (Correlation 1) between the data from the 12-month test (T2 data) and the results of the Bayley-III test for as visual categorised cognitive items (T3 visual) had a Pearson correlation coefficient r1 = 0.082. The one-sided significance of this correlation coefficient was with p = 0.320 not significant (n = 35). The second correlation (Correlation 2) between T2 and the results of the cognitive Bayley-III from the start of testing (usually from letter M = 24 months of age, sometimes from the letter J or K) showed a Pearson correlation coefficient r2 = -0.008. Here, the one-sided significance was also not given at p = 0.481 (n = 35).

The Fisher-z test for comparing the correlations should then be carried out. However, as no significant results were obtained for the correlations 1 and 2, it was not appropriate to carry out a Fisher-z test.

Based on these results, hypothesis H3 with the assumption that the negative correlation between visual orienting at 12 months (T2) and cognitive development at 24 months (T3) has a stronger correlation for items classified as visual on the Bayley-III Cognitive Scale compared to the correlation between T2 and all items from J onwards at T3, cannot be accepted due to a lack of significance in the correlations between T2 data and T3 visual data (Correlation 1), as well as T2 data and T3 data (Correlation 2).

5. Discussion

The present study investigates the relationship between visual exogenous orienting in early infancy and later cognitive development. This study utilizes the non-invasive method of the visual attention task, alongside video coding of overt visual orienting in infants, and the Bayley Scales of Infant and Toddler Development, Third Edition German Version (Reuner & Rosenkranz, 2014). The aim is to provide valuable insights for both theoretical understanding of the relationship between overt visual orienting and cognitive development, and practical interventions in those areas.

As already in the theoretical background stated, research suggests that exogenous attention enables perceptual learning, while eye movement in the attention process of visual orienting may be influenced by cognitive functions such as working memory capacity and attentional control (Hitzert et al., 2014; Szpiro & Carrasco, 2015; Weaver et al., 2017).

The present study did not find significant correlations between the latencies of visual exogenous orienting to reward stimuli and cognitive developmental outcomes. Thus, not only hypothesis H1.a, referring to the time points T1 at 6 months and T3 at 24 months, but also hypothesis H1.b, referring to the time points T2 at 12 months and T3 at 24 months, were rejected. The hypotheses which state that there is a correlation between the visual orienting latencies at 6 as well as 12 months, and the cognitive development at 24 months are therefore not accepted. Although this contradicts the assumptions, it is possible that poor orientation values (long latency periods) at T1 are again at an average level just a few months later. This, in turn, aligns with the already mentioned study of Ross-Sheehy et al. (2017), which used similar methods and also observed a rapid catch-up on deficits. This ability could influence the correlation between the values at the two time points T1 and T3. Nevertheless, the results suggest that factors other than visual exogenous orienting may play a greater role in predicting later cognitive developmental outcomes.

Furthermore, there was no significant difference in the visual exogenous orienting of infants at the age of 6 months to the age of 12 months observed. However, the development of endogenous attention could have an influence on the lack of significant differences between the latencies of the two time points. Endogenous attention may already have a stronger influence at the age of 12 months than at the age of 6 months, as already explained in the theoretical background (Johnson et al., 1991; McConnell & Bryson, 2005; Schwarzer & Jovanovic, 2015). This type of attention is not as well developed at the age of 6 months as it is at the age of 12 months and could possibly interfere with exogenous attention. It is therefore possible that despite the overall better developed exogenous attention at the age of 12 months compared to 6 months, exogenous attention is influenced by already planned actions or expectations of endogenous attention (Pfister et al., 2012). In our experiment, it would therefore be possible that the infant already has higher goal-driven attention at the second time point (12 months) and that the latency period is disrupted or extended by other conscious goals. This could, for example, be a stronger interest in the facial cue. The variance in latency times at T2 also appears to be higher than at T1. The more heterogeneous gaze behaviour at T2 could be due to infants having different endogenous orienting goals, and individual differences in the development of endogenous attention.

Moreover, the hypothesis stating that the negative correlation between visual orienting at the age of 12 months (T2) and cognitive development at the age of 24 months (T3) is stronger for visual items on the cognitive scale than for all items on the cognitive scale from the appropriate age group onwards could not be supported. The correlation analyses showed no significant differences between the different items on the cognitive scale, suggesting that the visual cognitive items do not have a stronger relationship with orientation latencies than the cognitive items in general. This could also be due to the low number of visual items (a maximum of 10 items were obtained), so statistical statements should be treated with caution.

These results suggest that the visual exogenous orienting of infants alone may not be enough to accurately predict later cognitive developmental outcomes, or it may not be particularly related to the cognitive abilities tested with the Bayley-III specifically. Other factors such as the environment but also character traits, daily condition, and different developmental leaps, as well as social influences, could also have a great impact on the results of the cognitive Bayley-III score.

5.1. Limitations and Implications for Future Research

Despite the strengths of the longitudinal study's design allowing observations of developmental changes over time, there were limitations in our study.

During the three data collection points T1, T2 and T3, not all unsystematic influencing factors could be excluded. In addition to noises and a new, exciting environment, it was not possible to identify the exact state of health, tiredness, and shyness. After T3, the parents received a questionnaire regarding temperament, which they were then asked to complete. This will be included and analysed in other sub-studies.

Moreover, during the testing of T3, it was noticed that there were individual differences in behaviour between the interaction of the infants and the researchers. While some infants were open, proactive, and willing to make contact and play with the researchers, others acted shy, reserved, anxious and needed a longer warm-up phase. Even after this phase, it cannot be expected that infants who are shyer in personality will perform the same way as those who have no fear of contact. This difference can influence the cognitive performance results. Of course, it is difficult to identify or even eliminate all disruptive factors, but in addition to the Bayley Scales-III cognitive test, it could be considered whether there are also procedures in which the parents are more involved, and the researchers are only in the observation situation and not in the interaction situation. The infants' sleepiness or sleep behaviour could be examined more closely in future studies with the help of brief documentation by the caregivers over a few days or weeks before testing. This would allow to calculate the condition of the infants on the day of testing more accurately.

The study covers three points in time and a total of 18 months of the infant's age, which means that changes over time could be examined more closely. Nevertheless, it must be mentioned that developmental leaps can occur in the first few years of life, which can make it difficult to predict behaviour and developmental stages individually. One example is language development, where infants with developmental delays can be on a same level as typically developing infants after a few weeks due to a sudden developmental leap (Bever, 1982; Sadurní & Rostan, 2002; van Dijk & van Geert, 2007). This means that longer intervals between the test points or more testing points, for example the time at which infants start elementary school, would be interesting in order to investigate the relationship between visual orienting or attention in general and cognitive development. These observations underscore the importance of considering the dynamic nature of developmental processes, as discussed in the theoretical background section. The complex interplay between visual attention and cognitive development, as outlined in the theoretical background by studies like Atkinson (1984), Johnson et al. (1991) and Schwarzer and Jovanovic (2015), highlights the need for further exploration of individual differences in developmental paths in future research.

Regarding the evaluation of time point T2, the design could be strengthened by an interrater reliability test. Such tests have already been conducted for T1, but not for T2. As the video coding of the infants' looking behaviour is carried out manually, different evaluators may arrive to different results. Especially in the millisecond range, errors can occur having an impact on the hypotheses.

Another limitation is not using other data included in the study such as the flickering frequencies predicting the reward stimulus. As already mentioned, the flickering stimuli each had different frequencies at which they blinked. Detailed analyses concerning the potential predictive effects of the flickering stimuli on orienting latencies to reward stimuli could have been included. This inclusion might have led to significant relationships between gaze behaviour and later cognitive development.

Furthermore, the sample composition of our study could be more diverse, as the recruitment took place in the university environment. This could limit the external validity and the results cannot be fully transferred to the population. For future studies, more diverse recruitment through different media and from different locations may be helpful. Regarding the sample size, it was not possible to include the entire sample size of the project, as there were time constraints for this work. With more participants, more meaningful results could be acquired.

Lastly, due to the non-significant results of the hypotheses, it should be considered whether the investigation of exogenous visual orienting should perhaps also be extended to other areas of visual attention, as different aspects of the visual area are closely related and are often difficult to separate. When evaluating the H3, it is also difficult to categorise cognitive items according to their association to the visual attention area, as they are often composed of visual attention, problem solving, and memory and these areas cannot be strictly separated. Cognitive designed items that can be more strictly separated into visual and non-visual items would be important for future research.

5.2. Conclusions

Overall, this study explored a unique approach that combines methods in a novel manner, which hasn't been previously employed. It aimed to explore the relationship between visual exogenous orienting at 6 and 12 months and cognitive development with the Bayley Scales-III at 24 months, but in the statistical hypothesis testing I did not find evidence supporting this relationship.

Therefore, the hypotheses suggesting a negative relationship between the visual exogenous orienting latencies of the test points at 6 and 12 months and at 24 months concerning the cognitive development, as well as regarding the improvement of latency times of visual exogenous orienting from 6 to 12 months, have not been accepted by now. In sum, the study highlights the complexity of the developmental processes relating to visual orienting and cognitive development in infants. Although the results of this study were not significant, further attention should be given to the research area of visual orienting and cognitive development. This could be achieved by implementing the in the limitations discussed measures such as testing and accounting for fatigue, health status and temperament, using more testing time points for more accurate longitudinal data, and applying inter-rater reliability. Research in this area has the potential to enhance our understanding of developmental processes, thus offering better support for infant's development.

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6. Appendix

6.1. Figures

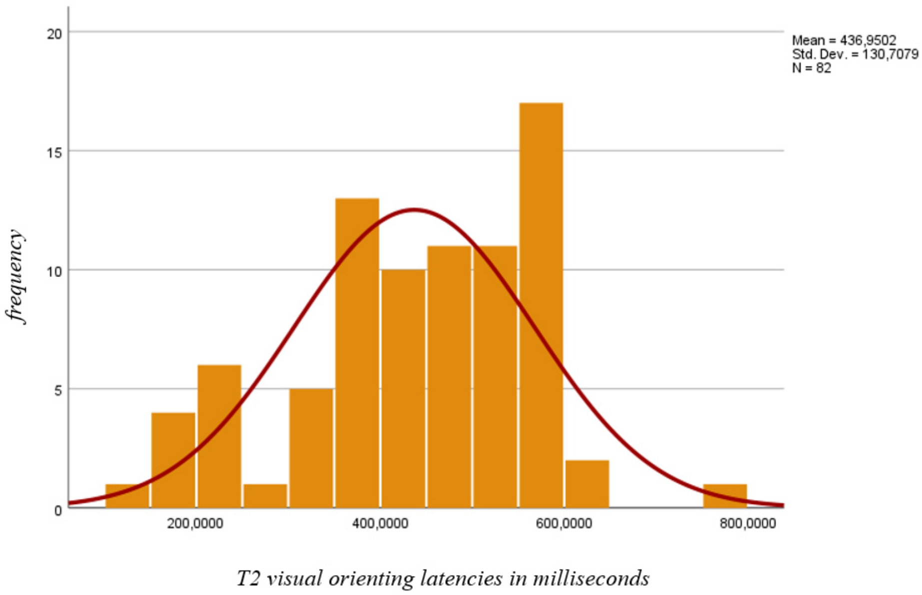

Figure 8: Distribution of Latency Times in ms at T2 with Normal Distribution Curve

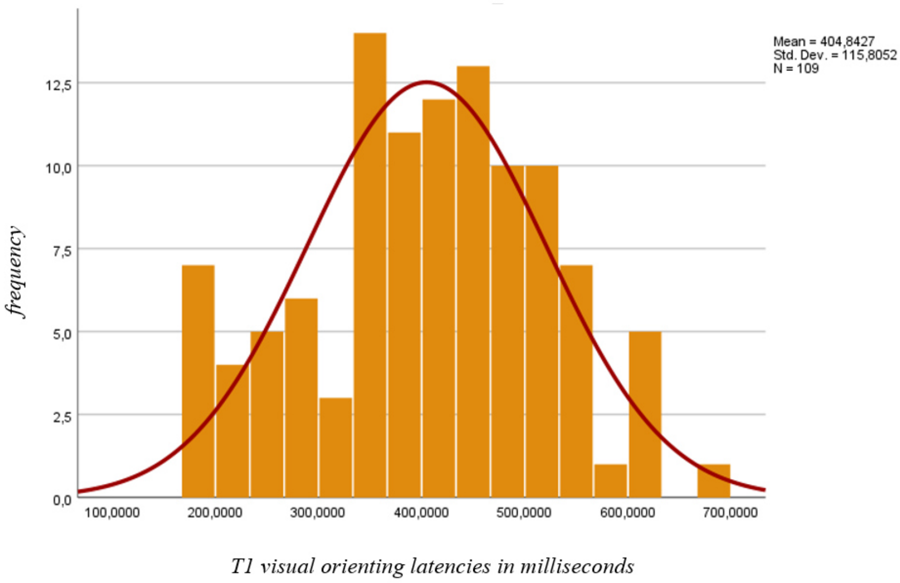

Figure 9: Distribution of Latency Times in ms at T1 with Normal Distribution Curve

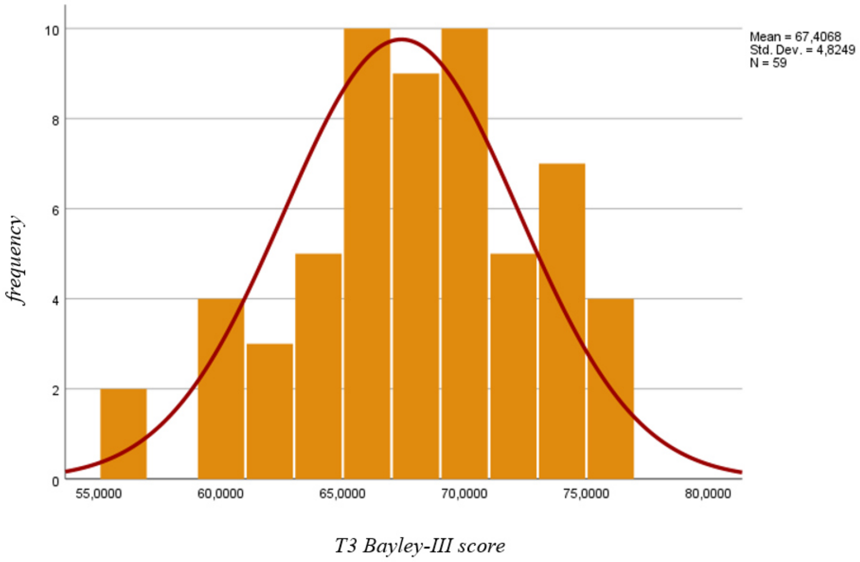

Figure 10: Distribution of Bayley-III cognitive scale scores at T3 with Normal Distribution Curve

7. Abstract (English)

The present study investigates the relationship between overt exogenous orienting and later cognitive development. In a longitudinal design, the exogenous attention orienting with a looking behaviour-based task at 6 and 12 months, and cognitive development with the German version of the Bayley Scales-III at 24 months was investigated. The study was conducted as part of a Wiener Kinderstudien project at the University of Vienna. It was expected that latencies in overt exogenous orientation would be negatively correlated with later cognitive development, and that there would be a significant improvement (i.e. decrease) of latencies between 6 months and 12 months. Furthermore, it was hypothesised that the items of the cognitive Bayley-III identified as 'visual' would show a stronger negative correlation with the latencies of T2 than all cognitive items. I did not find evidence to support these hypotheses. The results suggest that factors other than overt exogenous orientation may play a greater role in predicting later cognitive development, or that other methods may be better suited to investigate these effects. Overall, the study emphasises the complexity of infant visual behaviour development, and points to the need for a more comprehensive understanding of the factors that shape infant cognition.

8. Abstract (Deutsch)

In der vorliegenden Studie wird der Zusammenhang zwischen offener exogener Orientierung und der späteren kognitiven Entwicklung untersucht. In einem Längsschnittdesign wurden die exogene Aufmerksamkeitsorientierung im Alter von 6 und 12 Monaten mit einer auf Blickverhalten basierenden Aufgabe, und die kognitive Entwicklung mit der deutschen Version der Bayley Scales-III im Alter von 24 Monaten, untersucht. Die Studie wurde im Rahmen eines Projekts der Wiener Kinderstudien an der Universität Wien durchgeführt. Es wurde erwartet, dass die Latenzzeiten in der offenen exogenen Orientierung negativ mit der späteren kognitiven Entwicklung korrelieren würden und, dass es eine signifikante Verbesserung (d.h. Verringerung) der Latenzzeiten von 6 auf 12 Monate geben würde. Darüber hinaus wurde angenommen, dass die als "visuell" identifizierten Items des kognitiven Bayley-III eine stärkere negative Korrelation mit den Latenzzeiten von T2 aufweisen würden als alle kognitiven Items zusammen. Es wurden keine Belege für diese Hypothesen gefunden. Die Ergebnisse deuten darauf hin, dass andere Faktoren als die offene exogene Orientierung eine größere Rolle bei der Vorhersage der späteren kognitiven Entwicklung spielen könnten oder dass andere Methoden besser geeignet sind, diese Effekte zu untersuchen. Insgesamt unterstreicht die Studie die Komplexität der Entwicklung des Sehverhaltens von Kleinkindern und weist auf die Notwendigkeit eines umfassenderen Verständnisses der Faktoren hin, die die kindliche Kognition beeinflussen.