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The Role of Sustained Attention in Early Cognitive and Language Development

A Longitudinal Study from 6 to 24 Months

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Introduction

In today's fast-paced, distraction-filled world, the ability to focus is more valuable than ever — yet it begins to take shape long before we enter a classroom or pick up a smartphone. Even in the first year of life, some infants fixate longer on objects, resist distractions more easily, and stay engaged with their environment in ways that others do not. These early differences in sustained attention may seem subtle, but growing evidence suggests they matter. Attention in infancy has been identified as a key predictor of developmental outcomes.

Research suggests that attention is not just about focus - it's a foundational mechanism that shapes how children think, learn and communicate. It plays a central role in how children process information, solve problems and manage distractions. How exactly does attention relate to later outcomes in cognition and language? By exploring how infants allocate their attention, we can begin to uncover the mechanisms that support early learning. In doing so, we gain insight into both the developing mind and the many pathways that lead to individual differences in development.

The present study explores how individual differences in sustained attention in infancy relate to emerging cognitive and language abilities. By examining behavioral measures of attention at multiple time points, we aim to better understand how attentional patterns support early developmental outcomes.

Theoretical Background

Sustained Attention and Its Development

Sustained attention, often referred to as the effortful maintenance of focused attention, is the ability to maintain concentration over extended periods. This form of attention is critical for cognitive development, as it supports learning, problem-solving, and memory formation by enabling individuals to remain engaged with a task or stimulus (Ruff & Rothbart, 2001; Fortenbaugh et al., 2017).

As children grow, sustained attention becomes more coherent and less tied to specific tasks or contexts. This developmental shift suggests that attention evolves into a more generalized cognitive ability (McQuillan, 2021). Attentional responses become stronger, and infants spend more time in focused attention, reflecting improvements in both quality and consistency of attentional control (Richards & Turner, 2001).

In early infancy (0–6 months), looking time tends to decrease with age, likely due to increased processing speed and improved ability to disengage from uninteresting stimuli (Colombo & Cheatham, 2006). Faster habituation also contributes to shorter look durations at this stage. However, from the latter half of the first year onward, longer looking is often interpreted as a marker of more mature attentional processes, particularly in response to complex stimuli. This suggests the emergence of intentional attention control and deeper stimulus processing (Colombo, 2001).

Endogenous attention refers to the voluntary allocation of attention based on internal goals and motivations. It enables individuals to maintain focus despite distractions and is a core component of cognitive control (Acar et al., 2018). Research demonstrates developmental increases in sustained attention across tasks, suggesting general improvement with age. Accordingly, look duration tends to increase from the end of the first year into early childhood (Wass et al., 2012).

Early attention is believed to be predominantly exogenous, driven by external features like novelty or visual salience. Over time, however, attention becomes increasingly governed by endogenous, voluntary, and top-down processes (Holmboe et al., 2018). While some propose that this shift occurs around 12 months, other research suggests it may begin as early as six months, continuing to develop thereafter (Kannass & Oakes, 2008). As endogenous control emerges, look duration increases, indicating more sophisticated attentional mechanisms.

The development of sustained attention is closely tied to emerging self-regulatory abilities, including inhibitory control—the ability to resist distractions and remain focused. Inhibitory control represents a higher-order attentional skill and is associated with sustained attention, with individual differences becoming apparent between 6 and 9 months of age (Kannass et al., 2006).

Longer looking has also been theorized to reflect the emergence of short-term goals. Infants who voluntarily sustain gaze on a stimulus may be demonstrating goal-directed behavior, focusing on something they wish to manipulate or learn about—an indicator of endogenous attention (Colombo & Cheatham, 2006).

Behaviorally, sustained attention in infancy manifests through prolonged gaze, reduced distractibility, and increased object engagement—all of which become more prominent with age (Wass et al., 2017). Ruff and Capozzoli (2003) found that distractibility decreases while focused attention increases during the first year, enabling infants to maintain attention despite competing stimuli. This supports the development of intentional behavior and volitional control of attention (Holmboe et al., 2018).

Older infants and children typically outperform younger ones in tasks requiring focused attention. They sustain engagement longer and resist distractions more effectively—a difference attributed to the development of endogenous attention. However, there is ongoing debate about exactly when this capacity emerges, with some suggesting a window between 8 and 12 months (Colombo & Cheatham, 2006).

Attention is also shaped by stimulus properties. Infants tend to look longer at dynamic stimuli (e.g., videos) than static stimuli (e.g., pictures), indicating that stimulus type influences attentional engagement (Shaddy & Colombo, 2004). Additionally, individual differences in preference for dynamic versus static stimuli suggest that endogenous factors contribute to variation in look duration (Wass et al., 2017).

Static stimuli are particularly susceptible to rapid habituation, especially as infants mature and become more efficient at visual processing. Improvements in processing speed and encoding strategies—such as quicker recognition of global features—may result in shorter looking times over time (Cuevas et al., 2014). Indeed, research shows that look duration to static stimuli declines between 3 and 6 months of age, supporting this developmental trend (Colombo & Cheatham, 2006).

Sustained attention and cognitive development

Research on attention during object exploration in infancy has revealed a strong association between longer durations of sustained attention and improved cognitive outcomes in later childhood. Specifically, infants who exhibit more prolonged and focused attention tend to demonstrate superior skills in problem solving, decision making, and symbolic play. (Kannass & Oakes, 2008). They are also more likely to achieve higher scores on standardized developmental assessments, suggesting that early attentional behaviors serve as early indicators of broader cognitive potential and learning efficiency (Choudhury & Gorman, 2000).

Sustained attention contributes to cognitive development by facilitating the allocation of mental resources to the in-depth processing of stimuli. When infants maintain focus on an object or task for extended periods, they engage more deeply with the information presented. This persistence reflects a volitional process, underscoring the infant's emerging capacity to intentionally regulate attention. Consequently, sustained attention is closely linked to inhibitory control, which enables infants to resist distraction and remain engaged with relevant stimuli (Choudhury & Gorman, 2001).

The development of inhibitory control is associated with the maturation of the anterior attention system, a neural network involved in regulating visual attention and suppressing irrelevant input. As this system matures, infants become increasingly adept at modulating their attentional focus—an essential foundation for higher-level cognitive processes. The growing ability to resist distractions and sustain attention on a chosen object thus reflects both behavioral and neurological progress in cognitive control (Posner & Rothbart, 2007).

Sustained attention is also closely related to selective attention and overall cognitive capacity (Sarter et al., 2001). Longer durations of attention are thought to support deeper learning and more effective engagement with stimuli. This relationship may be underpinned by developing self-regulatory mechanisms and more advanced cognitive skills, including improvements in working memory, cognitive flexibility, and information processing strategies (Fisher, 2019).

These cognitive developments occur alongside structural and functional changes in the brain, particularly in regions associated with executive functioning. The prefrontal cortex, which undergoes significant growth during infancy and early childhood, plays a central role in supporting sustained attention and related cognitive processes (Rosen et al., 2019). Within this region, the dorsolateral prefrontal cortex and the anterior cingulate cortex are especially important, as they are involved in goal-directed behavior, attentional regulation, and the manipulation of information—core components of the emerging executive function (EF) system (Reynolds & Romano, 2016). The development of these neural circuits supports children's increasing ability to manage cognitively demanding tasks requiring sustained focus and control.

Executive functions—comprising working memory, cognitive flexibility, and inhibitory control—are essential for reasoning, problem solving, and adaptive learning. These functions are closely tied to general cognitive abilities such as reasoning and processing speed (Salthouse, 2005; Del Missier et al., 2012; Brandes-Aitken et al., 2019). EF skills enable children to retain relevant information, shift attention flexibly between tasks, and suppress irrelevant or automatic responses, thereby facilitating goal-directed and adaptable behavior (Garon et al., 2008).

There is also evidence that early manifestations of sustained attention predict later executive functioning. For example, Johansson et al. (2015) found that sustained attention at 12 months of age was related to executive function at 24 months. This finding supports the idea that infants who are more capable of maintaining attention early on are more likely to develop robust EF skills later in childhood. Similarly, Colombo and Cheatham (2006) argue that voluntarily sustained attention in infancy may serve as a precursor to metacognitive skills and even broader cognitive outcomes, such as performance on IQ-related tasks.

The theoretical rationale for this relationship lies in the role of voluntary attention in selectively focusing on meaningful environmental features—particularly those aligned with an infant's goals or intentions. This focused engagement supports more efficient decision making and deeper information processing (Choudhury & Gorman, 2000). Conversely, infants who are easily distracted may struggle to process information effectively, which could hinder subsequent cognitive development (Colombo & Cheatham, 2006). Thus, individual differences in attentional control during infancy can have lasting implications for cognitive outcomes.

Further studies reinforce these findings, suggesting that sustained attention in infancy is associated with more adaptive behavior and enhanced executive function abilities in later childhood (Brandes-Aitken et al., 2019). This relationship highlights the foundational role of sustained attention in supporting learning and behavioral regulation. Children who exhibit stronger attentional control early in life are better equipped to adapt to new environments and manage increasing cognitive demands as they mature (Razza et al., 2010).

Finally, sustained attention has been linked to school readiness and academic learning. Children with effective attentional control are more capable of engaging in classroom tasks, following instructions, and absorbing new material. Studies by Wass et al. (2011) and Razza et al. (2010) show that attentional regulation in infancy can predict later educational outcomes and classroom behavior, underscoring the long-term developmental significance of early attention.

Sustained attention and language development

Sustained attention has been increasingly recognized as a critical contributor to early language acquisition, with research indicating that infants who maintain attention for longer periods tend to develop stronger receptive and expressive vocabulary skills (Kannass & Oakes, 2008; Yu et al., 2019). This relationship is thought to reflect the role of attentional control in enabling infants to focus on relevant linguistic input, thereby facilitating more effective learning. For example, the ability to remain engaged with a caregiver during naming episodes supports word learning by allowing infants to encode and associate auditory and visual information more efficiently (Yu et al., 2019).

This process aligns with what has been described as the "follow-in" pathway of word learning, where caregivers label objects that infants are already attending to, enhancing the likelihood that word-object associations are correctly formed. In this way, sustained attention helps create shared referential moments that are central to early language development (McQuillan, 2021).

Interestingly, evidence suggests that the relationship between attention and language outcomes can vary depending on task context. In tasks involving a single object, infants with shorter looking times—potentially reflecting faster processing—have been found to exhibit better vocabulary outcomes (Kannass & Oakes, 2008). This finding highlights that efficient disengagement from less informative stimuli may also support language learning, suggesting a nuanced role of attentional dynamics in early development.

Moreover, longitudinal research indicates that attentional focus in infancy is predictive of later vocabulary and broader language skills. For instance, studies have shown that infants who demonstrate higher levels of attentional control during object exploration are more likely to achieve advanced language milestones and exhibit greater school readiness (Razza et al., 2010; Wass et al., 2011).

Despite strong evidence supporting this link, some researchers propose a more reciprocal or co-constructive relationship between language and cognition. Deák (2014), for instance, argues that attentional and linguistic skills may develop interactively rather than through a unidirectional pathway. Similarly, Goldin-Meadow et al. (2014) suggest that language itself may serve as a scaffold for higher-order cognitive processes, emphasizing that language and cognition co-evolve through dynamic, experience-dependent mechanisms.

Collectively, these findings underscore that attentional control plays a foundational role not only in cognitive development more broadly, but also in shaping early linguistic outcomes. By enabling infants to remain focused on relevant input and resist distraction, sustained attention facilitates richer interactions with their environment—interactions that are essential for the acquisition of language and communication skills.

Study aims

The present study aims to investigate whether sustained attention in infancy—measured at 6 and 12 months of age—predicts later cognitive and language development. Additionally, this study seeks to explore whether sustained attention remains stable over time or changes between these two developmental time points. These objectives are grounded in existing theories on the maturation of endogenous attention and the proposed role of early attentional capacities in shaping later developmental outcomes.

To address these aims, we employed a longitudinal design with three measurement points. Sustained attention was assessed using a combination of eye-tracking and behavioral coding in response to a dynamic, non-social video stimulus. Cognitive and language development were measured using validated developmental tools, specifically the Bayley Scales of Infant and Toddler Development (Third Edition) and the ELFRA questionnaire.

While prior research has investigated the relationship between early attention and developmental outcomes, there is a lack of longitudinal studies that trace infants' attentional trajectories across multiple time points during the first year of life. Furthermore, previous work (e.g. Kannass & Oakes, 2008) has demonstrated that attentional behavior is highly dependent on task type and the nature of the stimuli. The current study expands upon this literature by focusing on infants' attention to dynamic, non-social stimuli, rather than interactive or problem-solving tasks.

In contrast to studies where attention was measured during performance-based tasks such as stacking cups, shape sorting, or engaging with social stimuli (e.g., Johansson et al. 2015; Ruff & Capozzoli, 2003), our study uses a controlled, video-based attention measure. This method minimizes external influences, offering a reproducible and relatively "raw" indicator of sustained attention that is less dependent on task-specific engagement or social interaction. Such an approach allows us to isolate attentional processes in a standardized context.

Moreover, the Bayley Scales have often been used in previous research primarily as exclusion criteria to identify developmental delays, rather than as direct outcome measures for cognitive development in typically developing populations. There is limited literature using the Bayley-III in this manner, particularly in relation to sustained attention (Choudhury & Gorman, 2001; Sun & Buys, 2012; Kaltsa et al., 2024; Ruff et al., 1992; Kopp & Vaughn, 1982). Our study thus offers a novel contribution by integrating this tool with attention data derived from a passive viewing task.

Finally, by including a relatively large sample in a longitudinal design, this study contributes robustly to the growing body of research on how early attentional capacities relate to later developmental outcomes. It also aims to refine our understanding of what attention to video stimuli reveals about the emerging cognitive and language abilities in infancy.

Research questions

H1: Sustained attention during the viewing of a nonsocial video at 6 and 12 months, as indicated by the total amount of looking and peak look duration predicts cognitive development as measured with the Bayley Scale at 24 months

H2: Sustained attention during the viewing of a nonsocial video at 6 and 12 months, as indicated by the total amount of looking and peak looks predicts language development as measured with the ELFRA questionnaire at 24 months

Explorative: On a group level, does sustained attention increase or decrease, or is stable from 6 to 12 months?

How are the two different attention measures related to each other?

Methods and Materials

Study design

The first measuring point is at 6 months, there are three tasks displayed on a computer screen in a fixed order. A baseline video, a gaze cue task and lastly a reward prediction task. The EEG-activity was measured as well as the eye-movements were recorded during those tasks, through a video-recording of the infant. For the research questions posed in this master-thesis only the data regarding the Baseline Video will be relevant. The Baseline video, shown in Figure 1, was previously used by Braithwaite et al. (2020) and consists of child-friendly 3D-animations, such as a plain flying. The video is 2min and 14sec long. (Link: https://bit.ly/3N5KGNW.)

Figure 1

Baseline Video

Note An exemplary screenshot of the non-social stimuli shown in the baseline video

The coding of the orientation latencies for the baseline video were done manually, the corresponding looking behavior was coded as: "looking" or "not looking". The coding was done with the interact software (Mangold International GmbH, 2020) The same applies for the second measuring point at 12 months.

The children were tested in a room with a playing mat to sit on and age-appropriate toys for a warming up phase. All distracting equipment was stored away until it was used. At the third measuring point at 24 months, there is a drumming task in which children had to imitate a video of a hand drumming at different paces. There is also a visual search task of different animals, where the child had to find the elephant amidst other distractor animals. The child was filmed with two cameras during those tasks. And lastly the Bayley scale of cognitive development is administered, as well as the ELFRA questionnaire, which measures the language development of the infant.

Parents were asked to sign an informed consent form for the study and for documenting in the form of photos and videos, which could be used inside the faculty or outside f.e. for social media purposes. The family was welcomed and offered refreshments and after that a phase of getting to know the child and just playing was done. After the administering of the different tasks, parents were thanked and compensated with a toy for the child, a tote-bag and either a voucher or a book, as well as 6 Euros for travel expenses.

140 participants were recruited through the Kinderstudien database, 76 female, 64 male. Of which 81 were monolingual and 36 were multilingual, for the rest we did not have the information available. The mean ages were 199 (min: 169, max: 217) days for the first measuring point, 377 (min: 304, max: 419) days for the second and 755 (min: 706, max: 825) for the third. Most of the participating parents have a university degree, only 35 had an AHS, BHS or Lehre degree at the highest. 22 of them had a household income under 45.000 Euro.

For the Bayley scale of infant and toddler development, which measures the development of infants 1 to 42 months. There are five domains in total: cognition, language, motor, social-emotional and adaptive behavior (Macha & Petermann, 2015) For this study the cognitive scales are used, which measure sensorimotor development, exploration and manipulation, object relatedness, concept formation and memory, simple problem solving or to sum it up cognitive development. It is about which developmental milestones are reached. It consists of 91 items. The items measure skills like counting, matching colors, different forms of play and others, as illustrated in Figure 2. They are increasing in difficulty the farther ahead the testing gets. For different ages there are different starting points, if a child is not able to complete five consecutive items, the testing ends. Items that are completed successfully are getting points and they are added up in the end. At 2 years you should for example observe symbolic play such as drinking from a cup, pretending to drink, representational play such as using a red block as a bar of soap to wash another toy and searching for hidden objects. (Bayley, 2006)

Figure 2

Bayley Scale case with items

Note. Source: Del Rosario et al. 2020

It is used to gather relevant normative and developmental age information and can aid in the diagnosis of developmental delay. (Del Rosario et al, 2020). The child is sat down at a table and the items are administered by two people, one presenting the task to the child and the other preparing next items and storing away already administered items. Since the administration takes up to 90 minutes, there is always the possibility of taking breaks, in case the child is having a hard time concentrating or if it gets overwhelmed. The coding followed the guidelines in the provided manual. (Bayley, 2006)

The ELFRA-questionnaire (Grimm & Doil, 2000) is used for recognizing children at risk for language development disorders. The ELFRA 2 for 24-month-old children focuses on productive vocabulary and the most important grammatical development steps as well as morphosyntax and simple sentence use. Parents fill out the form, checking off words, grammatical structures and sentences the child uses.

Sustained attention in infancy can be operationalized in multiple ways, each capturing different aspects of attentional engagement. In the present study, two commonly used measures were employed: peak look duration and total looking time.

Peak look duration refers to the longest continuous gaze an infant directs toward a stimulus, capturing the maximum duration of sustained engagement without interruption. This measure has frequently been used in the literature to assess sustained attention and is often interpreted as an indicator of attentional control and engagement with a given stimulus (Courage et al., 2006; Pérez-Edgar et al., 2010).

Total looking time, on the other hand, refers to the cumulative time an infant spends attending to the stimulus during a given trial. While used less frequently than peak look duration, it remains a valid and informative measure (Aslin, 2007; Kaltsa et al., 2024). Total looking time may reflect broader attentional tendencies, such as interest in or motivation to engage with the stimulus.

Using both measures provides a more nuanced view of sustained attention. For example, an infant may exhibit frequent but brief glances toward the stimulus, resulting in high total looking time but low peak look duration. Conversely, another infant may show fewer but longer looks, leading to higher peak look duration and potentially lower total looking time. Infants showing high values on both measures may be considered highly attentive, with long, sustained engagement and frequent returns to the stimulus.

The inclusion of both measures also acknowledges the complexity of attentional processes in infancy. Differences in these indices may reflect variability in processing efficiency, inhibitory control, or the infant's ability to regulate attention. For instance, numerous short glances—resulting in lower peak look duration—might not necessarily indicate inattention but could instead reflect self-regulatory mechanisms. Some studies suggest that more frequent shifts in attention can co-occur with higher cognitive engagement if such regulation supports sustained interest over time.

Overall, by integrating both peak look duration and total looking time, this study aims to capture a broader and more accurate representation of sustained attention. This dual-measure approach enhances our capacity to interpret the relationship between early attentional patterns and later cognitive and language development.

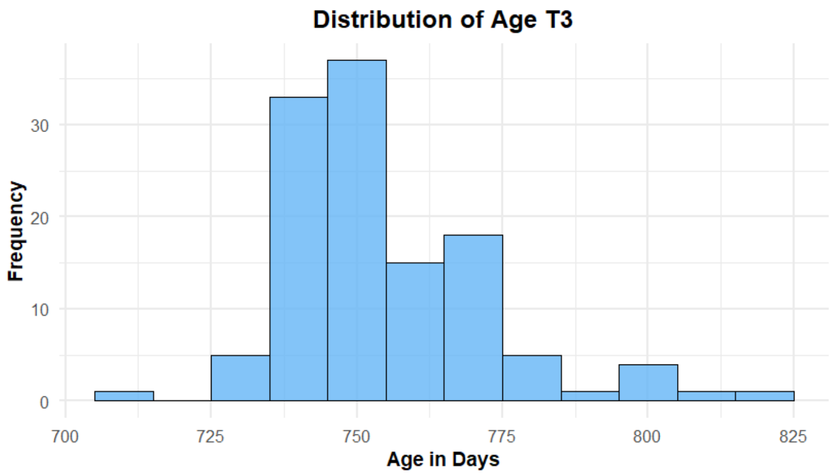
Results

Data analysis

For the main analysis, multiple regression models were conducted using RStudio. Given that age was included as a covariate in the analyses, since there was variability in the sample at the third timepoint, shown in Figure 3, raw scores from the cognitive development assessment were used rather than composite scores. Composite scores are age-normed and grouped according to standardized normative data, which would have introduced a form of age adjustment that is less precise. In contrast, by statistically controlling for age in days, this approach allows for a more fine-grained control of developmental variation, offering greater sensitivity to individual differences in cognitive development across the sample. This method provides a more accurate estimation of the relationship between early sustained attention and later developmental outcomes while accounting for age-related variability in a continuous manner.

Figure 3

Visual representation of the Age Distribution at the third timepoint



Cognitive Model

For the first hypothesis a multiple regression analysis was performed. The aim of this analysis was to examine whether the attention measures operationalized as number of segments watched in total and peak looks of the infants at 6 months (T1) and 12 months (T2) were predictive of cognitive performance, the outcome variable, measured by the Bayley scale. The most complex model contains six predictors, two for each of the attention measures and we are controlling for Bilinguality, and Age at the third time point, as shown in Table 1 below. 64 cases with all necessary data available were included.

Table 1

Multiple Regression Model of Cognitive Development

Predictor	Estimate	Std. Error	t-value	p-value
Intercept	61.65	25.13	2.45	0.017**
Number of segments T1	0.04	0.04	1.01	0.32
Number of segments T2	0.001	0.03	0.31	0.76
Peak looks T1	-0.05	0.03	-1.5	0.14
Peak looks T2	-0.02	0.02	-0.49	0.62
Bilinguality	-1,5	1.31	-1.41	0.26
Age T3	0.005	0.03	0.15	0.88

Note. The results with two asterisks are highly significant (**)

The results indicated that the model did not significantly predict cognitive performance (F= 0.64), p = 0.7) Indicating that the set of predictors did not reliably explain variance in the cognitive outcomes. With a multiple R^2 of 0.05, indicating that only 5% of the variance in cognitive performance was explained by the predictors. The adjusted R^2 was – 0.03. None of the predictors were significant. Because of the quite drastic difference in the adjusted R^2 we may have a problem with potential overfitting and lack of explanatory power.

None of the individual predictors reached statistical significance and the effect sizes are small or close to zero. Interestingly, attention measures at T2 (12 months), which were expected to be more predictive due to greater attentional maturation, also did not show significant associations. The poor model fit, combined with a negative adjusted R^2, suggests that the model may be over-specified — that is, it includes more predictors than can be justified by the sample size. With six predictors and only 64 cases, the model may lack the statistical power necessary to detect small to moderate effects. This could lead to an inflated standard error and unstable estimates.

Language Model

To test the second hypothesis — that sustained attention in infancy predicts later language development — a multiple linear regression analysis was performed. The language outcome variable was created by standardizing and combining scores from three ELFRA subscales: Productive Vocabulary, Syntax, and Morphology. This z-transformation was necessary to account for differences in scaling across the measures, allowing for a composite index of language ability at the third time point (T3). The model included attention measures at 6 months (T1) and 12 months (T2), as well as the control variables bilinguality and age at T3, as shown in Table 2. The analysis was based on 63 complete cases.

Table 2

Multiple Regression Model of Language Development

Predictor	Estimate	Std. Error	t-value	p-value
Intercept	-2.64	4.80	-0.55	0.58
Number of segments T1	-0.004	0.007	-0.63	0.53
Number of segments T2	0.002	0.004	0.46	0.64
Peak looks T1	-0.004	0.006	-0.70	0.48
Peak looks T2	0.001	0.005	0.38	0.70
Age T3	0.004	0.006	0.77	0.44
Bilinguality	-0.52	0.24	-2.11	0.04*

Note. The results with an asterisk are significant with $p < 0.05$ (*)

The regression model was not statistically significant overall, F=1.44, p=.21 with an R^2=.12, meaning that 12% of the variance in language outcomes was explained by the predictors. The adjusted R^2 =.04, indicating a relatively weak explanatory model when adjusted for the number of predictors.

Among all predictors, only bilinguality emerged as a significant variable (p = .04) The negative estimate suggests that bilingual children had lower scores on the German-language ELFRA questionnaire, which is expected given that the test assesses language proficiency in German only. This highlights a potential measurement bias, as the tool may underestimate language abilities in bilingual children, especially if German is not the dominant or first language at home.

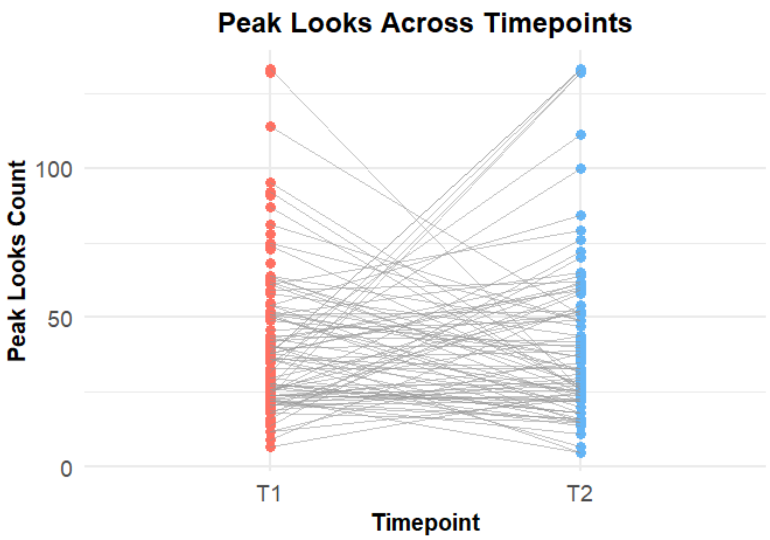
None of the attention variables — neither the number of segments watched nor peak looks at T1 or T2 — significantly predicted later language ability. The direction of effects was inconsistent, with some weakly positive and others weakly negative associations. This suggests that sustained attention in infancy, as measured in this study, may not directly predict language development at the age assessed, at least not through this specific operationalization.

Change in attention over time

To explore how sustained attention developed between 6 months (T1) and 12 months (T2), we examined two indicators: peak look duration and the total number of segments watched. Visual inspection of individual change scores for peak looks (Figure 4) did not reveal a consistent pattern across infants — some showed increases, while others showed decreases, suggesting variability in how attentional focus developed over this period.

Figure 4

Visual representation of the individual change in peak looks over time

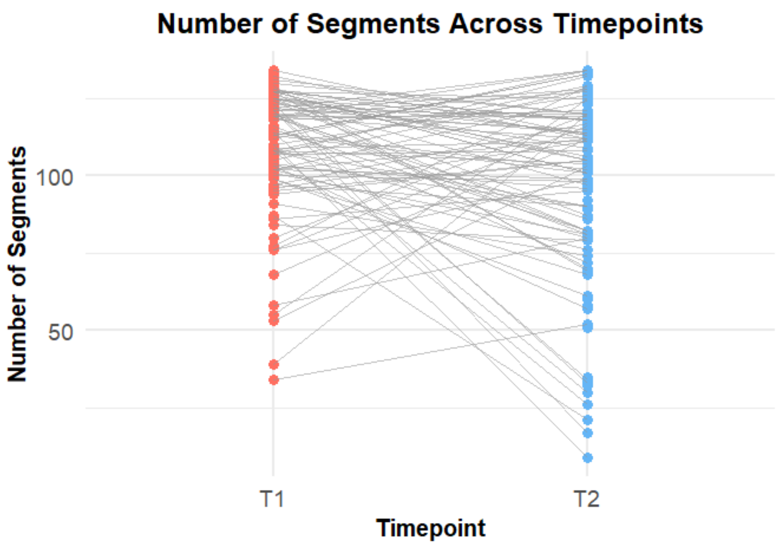


Note. The figure depicts the change of each individual peak looks count across the two measuring points

In contrast, the number of segments watched showed a more coherent trend, with a noticeable increase from T1 to T2 across participants, as seen in Figure 5. This suggests that, overall, infants became more engaged or attentive as they grew older.

Figure 5

Visual representation of the change in number of segments, that are watched, over time



Note. The figure depicts the change of each individual number of segments count across the two measuring points

To statistically assess whether these observed changes were significant, we conducted a paired sample t-test for both attention measures. The results are summarized below in Table 3.

Table 3

Paired sample t-test of both attention measures

Measure	t-value	p-value	Mean Dif.	95% CI (-)	95% CI (+)
Peak looks	-0.56	0.58	-2.32	-10,58	5.93
Number of segments	2.62	0.01**	9.82	2.37	17.26

Note. The t-test revealed highly significant results with $p < 0.01$ (**)

Only the change in number of segments watched was statistically significant (t=2.62, p=0.01), with participants watching nearly 10 more segments on average at 12 months compared to 6 months. This suggests a general increase in attentional engagement over time, possibly reflecting developmental improvements in sustained attention capacity.

The change in peak look duration, however, was not statistically significant (t=−0.56, p=0.58). This indicates that although infants watched more segments at T2, the intensity or duration of their focus on individual segments did not significantly change during this period.

Explorative Analysis

Correlation of attention measures

As part of our exploratory analysis, we examined the correlations among the different attention measures across both time points, shown in Table 4. This was done to gain a deeper understanding of how our attention variables relate to one another, and to explore potential underlying mechanisms that might explain the patterns observed in the primary models.

Table 4

Pearson Moment Correlation matrix of attention measures of attention measures

Measure	Number of segments T1	Number of segments T2	Peak looks T1	Peak looks T2
Number of segments T1	1.0	0.07	0.6	0.07
Number of segments T2	0.07	1.0	0.2	0.64
Peak looks T1	0.6	0.2	1.0	-0.03
Peak looks T2	0.07	0.64	-0.03	1.0

Note. 0.0- 0.1 are considered no to very weak correlations. 0.1-0.3 are considered weak correlations. 0.3-0.5 are considered moderate to strong correlations and 0.5-1.0 are considered strong correlations

There are strong within-time point associations. At both T1 and T2, there are moderate to strong correlations between the number of segments watched and peak look durations (r = 0.6; r = 0.64) This suggests that infants who watched more segments also tended to have longer individual looks at that time point, indicating a coherent attentional style or state. Surprisingly the cross-time associations are weak or negligible. These findings suggest that while attentional behavior is consistent within a given timepoint, it may not be stable over time. Infants between 6 and 12 months undergo rapid cognitive and neural changes, which could lead to shifts in attention strategies or capacities. The low cross-time correlations may reflect this developmental plasticity. Younger infants might rely more on attention driven by stimulus novelty or salience), whereas older infants may begin to show more goal-directed attention, reflecting emerging top-down control. This developmental progression could change how and when infants look at stimuli, dissociating early and later attention patterns.

Multicollinearity

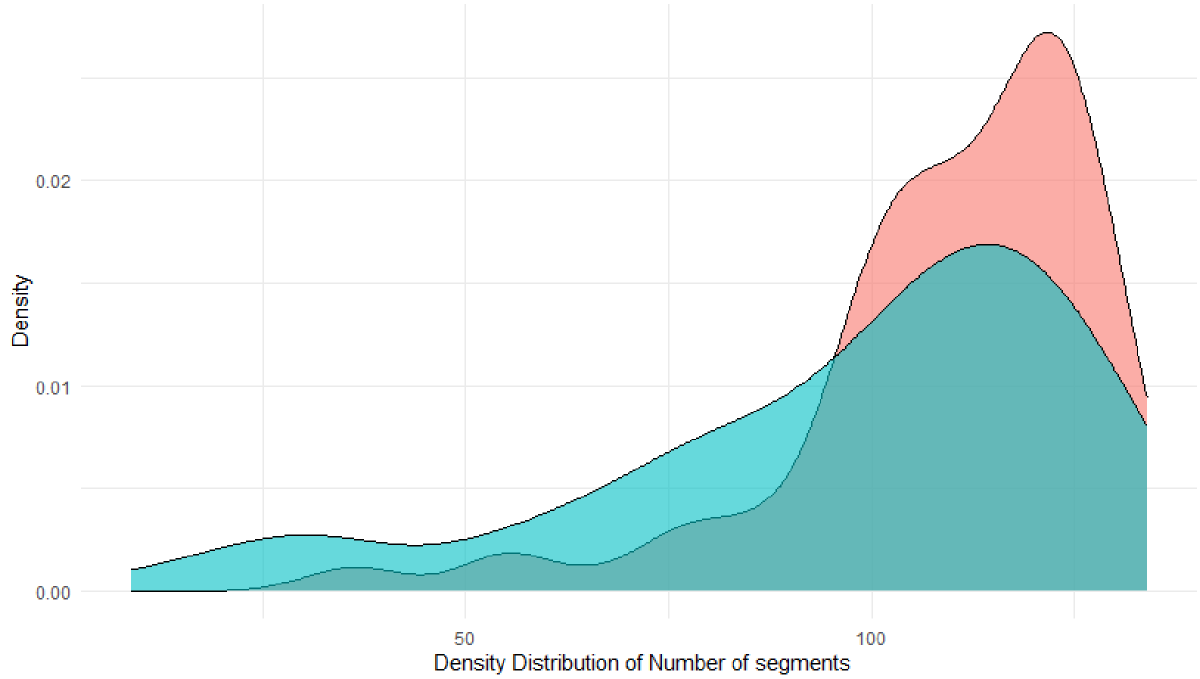
I did an analysis of the Variance inflation factor to check for Multicollinearity in the data. The values range from 1.1 to 2.0, indicating a low to moderate level, which should be no problem for our linear model.

Log Transformation (Skewness)

The distribution of the number of segments attended was left-skewed at both time points, as shown in Figure 6 indicating a clustering of data points toward higher values, with a peak and a long tail extending toward lower values. This suggests that most infants attended to many segments, while fewer infants attended for very short durations. Such a distribution may reflect a high level of interest or salience of the stimuli used, or potentially a sample with above-average attentional capabilities. Figure 7 illustrates in contrast, the distribution of peak look durations appeared to be right-skewed, suggesting that while most infants had relatively short peak looks, a smaller number of infants exhibited notably longer peak look durations. This illustrates an attention pattern where most infants have at least short episodes of inattention. Given that infants develop attentional control at differing rates, the presence of a few outliers with very long looks may reflect emerging attentional capacities that are not yet consistent across the broader sample.

Figure 6

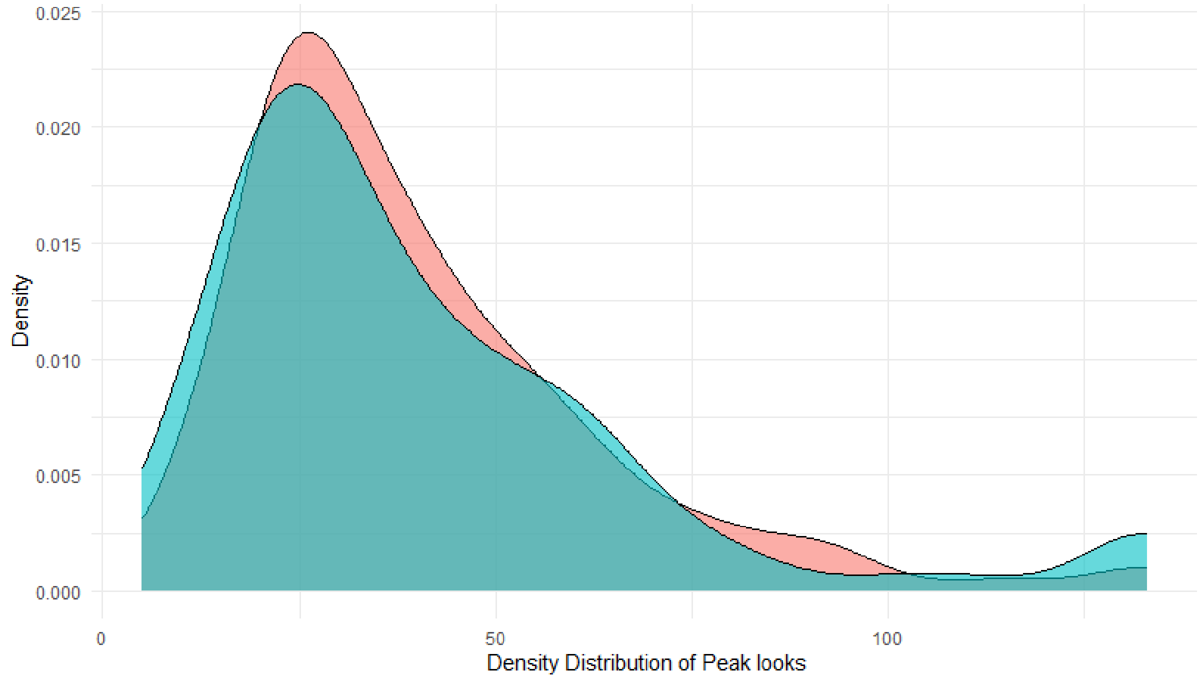
Visual representation of the density distribution of Number of segments watched at the 2 measuring points



Note. Red is representing the first measuring point (T1) and blue the second (T2)

Table 7

Visual representation of the density distribution of Peak looks at the 2 measuring points



Note. Red is representing the first measuring point (T1) and blue the second (T2)

To address this skewness, I applied a logarithmic transformation, which is a standard approach to normalize non-normal distributions and reduce the impact of extreme values. However, after log-transforming the skewed looking data and running the cognitive model again, the cognitive model showed no significant predictors and only a marginal change in explanatory power ($R^2 = 0.07$, adjusted $R^2 = -0.02$). Peak looks at T1 approached significance ($p = 0.08$), suggesting a possible weak association between early sustained attention and later cognitive performance — though this still falls short of conventional thresholds for statistical reliability. The language model remained nearly identical, with Bilinguality as the only significant predictor ($p = 0.04$). The log-transformation did not alter the model fit substantially ($R^2 = 0.12$; adjusted $R^2 = 0.04$), and none of the attention measures became more predictive. Meaning the data transformation did not meaningfully enhance the explanatory value of the models.

Model comparison using AIC

To explore whether simpler models would provide a better fit to the data, we compared models using the Akaike Information Criterion (AIC). Lower AIC values indicate better model fit, with differences greater than 2 generally suggesting meaningful improvement (Burnham & Anderson, 2002).

For the cognitive outcome models, the full model including both peak look durations and number of segments attended yielded an AIC of 430.48. A reduced model including only peak looks had an AIC of 428.94, and a model including only the number of segments attended had an AIC of 427.60. The differences between these AIC values are relatively small (< 3 points), suggesting that the more complex model does not substantially overfit relative to the simpler models. Given the theoretical rationale for including both attentional measures, we retained the full model for subsequent interpretation.

For the language outcome models, the full model including both predictors yielded an AIC of 198.90. Removing peak look durations resulted in an AIC of 196.16, while removing number of segments produced an AIC of 196.41. Although these AIC values are slightly lower than that of the full model, the differences are minor (≈2–3 points) and are directly on the commonly used threshold of greater than 2 points that would indicate strong support for a simpler model. Therefore, we retained the full model for consistency and theoretical completeness.

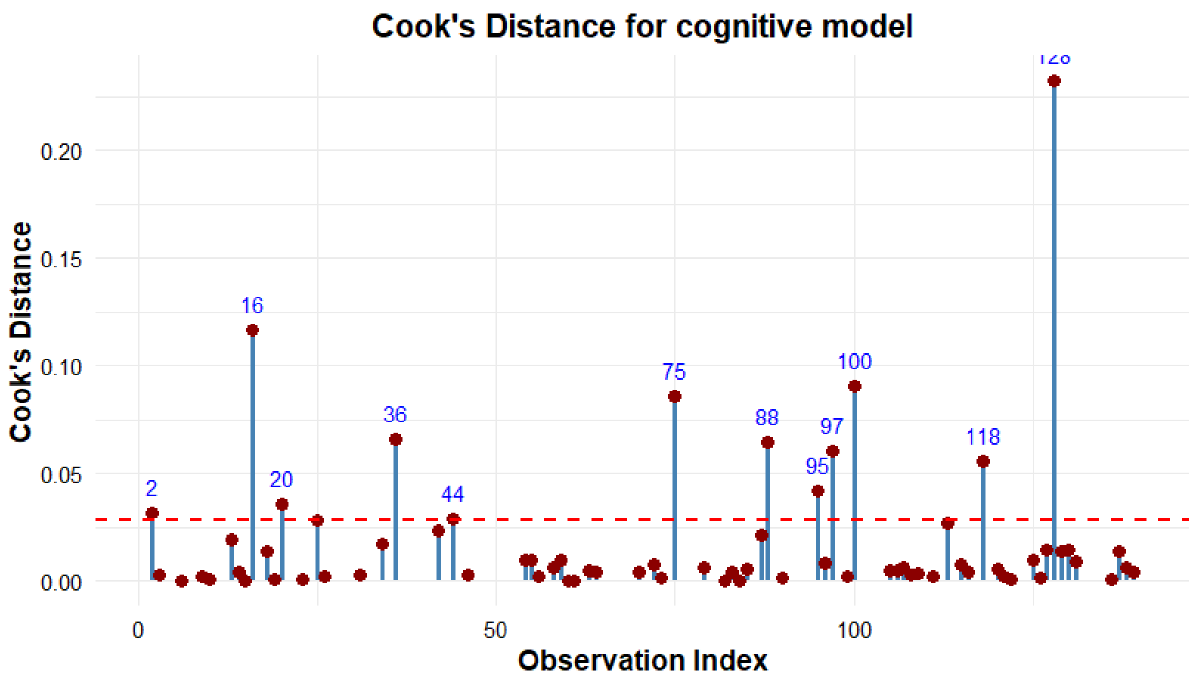
Overall, AIC comparisons suggest that while minor improvements in model fit could be achieved by simplifying the models, the differences are not substantial enough to warrant the removal of predictors. Retaining the full models allows for a more comprehensive assessment of the contributions of sustained attention measures to cognitive and language outcomes.

Outlier Analysis

To ensure the robustness of the regression models, an outlier analysis was conducted using Cook's Distance, as shown in Figure 8. A common threshold (4/n, where *n* is the sample size) was applied to identify potentially influential data points in the cognitive model. Several cases exceeded this threshold and were flagged for further inspection.

Figure 8

Cook's Distance Analysis of the cognitive model



Note. Cases over the red-dotted line are considered outliers and were further inspected for potential removal

After consulting the comments on how the testing for each of these influential cases went, there were a few cases for potential exclusion, because of behavior during the testing. For case DI002 the child was very shy and stopped participating at one point. For DI016 there were also items the child was not willing to do. For DI075 there seemed to be a general language barrier. DI095 did not complete the Bayley scale and DI128 was a difficult testing in general, the child could not concentrate and was not willing to complete a lot of the items. As shown in Table 5, after excluding those cases we ran the multiple regression analysis again.

Table 5

Multiple regression analysis of the cognitive model, after excluding outliers

Predictor	Estimate	Std.Error	t-value	p-value
Intercept	85.42	22.39	3.82	0.0003**
Number of segments T1	0.02	0.04	0.4	0.69
Number of segments T2	-0.03	0.03	-1.29	0.2
Peak looks T1	-0.03	0.03	-0.94	0.35
Peak looks T2	0.03	0.03	1.09	0.27
Age T3	-0.02	0.03	-0.57	0.57
Bilinguality	-2.56	1.21	-2.11	0.04*

Note. The results with an asterisk are significant with $p < 0.05$ (*) and highly significant with two asterisks with $p < 0.01$ (**)

The model is still not statistically significant ($F = 1.05$, $p = 0.4$) and has a multiple R^2 of 0.1, which means 10% of variance explained, but an adjusted R^2 of 0.004, suggesting limited explanatory power when adjusting for model complexity. We now have a significant predictor of the cognitive outcome, which is Bilinguality, indicating a potential influence on cognitive outcomes, which is not surprising, since the Bayley measure is instructed in german.

For the language model, exclusion of the influential cases did not meaningfully alter the pattern of results. The model remained statistically non-significant, but the fit improved slightly. The multiple R^2 increased to 0.215 and the adjusted R^2 to 0.12, suggesting that around 12% of variance in language outcomes was accounted for after adjusting for predictors. As before, Bilinguality remained the only significant predictor, consistent with the idea that the language measure used (ELFRA) is sensitive to German language proficiency

Residual Analysis

For the cognitive model, the residuals were approximately normally distributed and showed no significant skew, with a minimum of -12.05 and a maximum of 7.25. The residual standard error was 4.72 with 64 degrees of freedom, indicating a moderate level of unexplained variance.

In contrast, the language model exhibited a wider spread in residuals, ranging from -120.92 to 83.79, suggesting greater variability in model fit. The residual standard error was substantially higher at 52.02, reflecting a higher degree of unexplained variance compared to the cognitive model.

All analyses were conducted on a final sample of 69 observations, after excluding cases with missing data

Discussion

The results of the analyses did not support the hypotheses that sustained attention at 6 and 12 months predicts later cognitive or language development. Neither attention measure—peak look duration nor number of segments watched—was a significant predictor in either regression model, and both models explained only a small proportion of variance in the outcomes, with adjusted R^2 values below zero or close to zero, suggesting weak explanatory power. Notably, only bilingualism significantly predicted language scores, likely reflecting a measurement bias due to the German-language assessment. However, longitudinal analyses revealed that the number of segments watched significantly increased from 6 to 12 months, indicating a developmental rise in attentional engagement, while peak look duration remained stable. This suggests that while infants may attend to more content over time, the intensity of their focus does not necessarily increase during this period.

One potential factor contributing to the observed non-significant results of the multiple regression models, is that looking behavior does not necessarily equate to sustained attention or deep processing. Even infants who spent longer durations gazing at the stimuli may not have been thoroughly processing the information presented. In this context, longer looking times may not reflect better cognitive engagement. The stimulus material—dynamic video content—may have elicited bottom-up, exogenously driven attention, driven by perceptual salience, rather than endogenously controlled attention, which is more goal-directed and volitional (Wass et al., 2011). As such, looking time in this context may be capturing something different from other sustained attention paradigms, such as the Continuous Performance Task (CPT), which require active attentional control and have built in mechanisms to prove the participant is actively engaged with the task.

To better capture episodes of genuine sustained attention, additional behavioral indicators may be beneficial. These include motor quieting, facial expression, and behavioral stillness, which have been associated with deeper engagement and attentional control (Choudhury & Gorman, 2001). Merely watching a video may not be sufficiently demanding to discriminate between levels of sustained attention. More complex or challenging tasks might allow for clearer stratification based on attentional capacity. The attentional response is task-dependent, and passive viewing may have failed to adequately differentiate cognitive effort (Wass et al., 2011). It is possible that attention in a more cognitively demanding or ecologically valid context would have shown stronger associations with later outcomes, particularly with performance on standardized tests like the Bayley Scales.

Further, infant disengagement from the stimulus may reflect factors unrelated to cognitive maturity, such as emotional state, boredom, fatigue, or lack of interest in the video content. Similarly, performance on the Bayley-III may have been influenced by non-cognitive variables such as motivation, temperament, or environmental conditions during the assessment. Although the Bayley Scales are widely used, they were originally designed to detect developmental delays rather than to provide fine-grained measurement of abilities within a typical range. In fact, earlier studies primarily used the Bayley Scales to screen for developmental risk, not to track subtle variations in ability. It has also been criticized for being relatively blunt in its differentiation between domains, with reduced sensitivity to individual differences in children performing within the normal range (Del Rosario et al., 2023). Nonetheless, converging evidence supports its validity as a measure of general cognitive ability, with studies finding positive associations between Bayley cognitive scores and other standardized assessments of cognitive abilities, such as the WPPSI-III (Klein-Radukic & Zmyj, 2023). Still, the test's length and complexity may reduce attention and compliance, especially among toddlers, thereby affecting performance and increasing the likelihood of incomplete or lower-quality data.

Attrition may have also affected the results. Longitudinal research is particularly vulnerable to participant drop-out, especially over extended time spans. In our study, attrition was caused by relocation, illness, and changing family circumstances, which reduced the available sample and may have introduced bias. Additionally, the ELFRA-2 language questionnaire, though efficient and easy to administer, has its limitations. It is based on parental report, which is inherently subjective. The accuracy of such assessments depends on the parent's memory, observation skills, and potential biases, such as over- or underestimation of their child's abilities. Furthermore, the checklist format may fail to capture nuanced aspects of language use and is not ideal for differentiating language abilities within typically developing samples. Importantly, the ELFRA-2 is standardized on monolingual children, which may reduce its ecological validity for bilingual participants.

Another interpretive challenge lies in the rapidly changing nature of cognitive and attentional processes in infancy. During the first year of life, these functions develop in fits and starts, with considerable inter-individual variability. As a result, attention measured at 6 or 12 months may lack the stability and predictive validity required to forecast later developmental outcomes (Klein-Radukic & Zmyj, 2023). It is possible that the age points selected were too early to capture consistent attentional patterns that would correlate with downstream cognitive or language abilities.

Further complicating interpretation is the distinction between different types of attention. Research suggests that attention to dynamic stimuli is strongly influenced by exogenous visual salience (Wass & Smith, 2014). This may have inflated looking times across participants and limited variability. Indeed, salient stimuli often elicit prolonged looking even when cognitive processing is minimal (Pempek et al., 2010). In some cases, shorter looks or intermittent disengagement may even facilitate learning by promoting information segmentation or consolidation (Choudhury & Gorman, 2001). Therefore, longer looking durations do not necessarily equate to sustained, meaningful attention. This is reminiscent of the “sticky fixation” phenomenon, where longer looks may reflect difficulty in disengaging rather than deeper processing. (Colombo, 2001)

The ambiguity surrounding the construct of looking time is further supported by previous work. For example, one longitudinal study (Bornstein et al., 2006) found that fixation duration in infancy was not significantly associated with sustained attention measured by CPT in adolescence, suggesting that fixation may not reflect endogenous attentional control. Importantly, CPT scores were predictive of later intelligence, while early looking time was not. Additionally, that study found that family environment, specifically parental stimulation and vocalization, moderated the relationship between early attention and later cognitive outcomes. This aligns with other work showing that maternal responsiveness, joint attention episodes, and parent-child interaction quality are critical in shaping attention and cognitive trajectories (Razza et al., 2010). These variables were not controlled for in the present study and could have confounded associations.

A related possibility is that our task captured not sustained attention per se, but attentional inertia—a phenomenon in which attention to a stimulus becomes increasingly stable the longer it is sustained (Richards & Anderson, 2004). Attentional inertia is particularly relevant for dynamic stimuli like videos, where longer looking becomes self-sustaining and is associated with a decreasing likelihood of disengagement. This suggests a form of endogenous maintenance, albeit one driven by initial exogenous capture. In fact, Wass et al. (2017) reported that attentional inertia is more pronounced when infants attend to stimuli spontaneously rather than when externally directed, further highlighting the blurring between endogenous and exogenous influences in passive viewing paradigms.

Additional participant characteristics may also have influenced results. For instance, a non-representative sample, particularly one skewed toward higher socioeconomic status (SES), may display above-average performance due to enhanced access to cognitive stimulation, language exposure, and enriched home environments (Choudhury & Gorman, 2000; Goldin-Meadow et al., 2014).

Finally, the modest sample size (N = 63–64) after excluding missing data for the final analysis, limits statistical power, especially when testing models with multiple predictors. Smaller samples can lead to unstable parameter estimates and reduced ability to detect small-to-moderate effects. The discrepancy between R^2 and adjusted R^2 observed in our regression models suggests potential overfitting, likely due to the ratio of predictors to participants. This further emphasizes the need for larger samples in future research to reliably assess developmental pathways and interactions.

In summary, the present study underscores the complexity of assessing sustained attention in infancy and its relationship to later cognitive and language outcomes. The findings raise important questions about construct validity, measurement sensitivity, and contextual influences. Future work should incorporate multimodal attention measures, task variation, and broader environmental variables to better elucidate the developmental mechanisms underlying early attention and later outcomes.

Future directions

Given the complexities discussed, several avenues for future research are warranted. First, the Bayley Scales of Infant and Toddler Development were not administered at all assessment timepoints in the current study, which limits the ability to track developmental trajectories in parallel with attention measures. Incorporating repeated cognitive and language assessments would enable more nuanced modeling of developmental change and allow for examination of bidirectional associations between attention and cognitive growth over time.

Secondly, attention tasks should vary in complexity and ecological validity. Including both passive and active paradigms may better differentiate attentional control mechanisms and enhance predictive validity. Future research should account for family-level factors such as SES, parental education, home language environment, and parent-child interaction quality. These variables may moderate or mediate the link between early attention and developmental outcomes.

Finally, larger and more diverse samples are needed to improve statistical power and generalizability. This would allow for the testing of more complex models, including potential interaction effects and developmental subgroups, and help clarify individual differences in attentional and cognitive development.

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Appendix

Abstract (English)

This study investigates the longitudinal relationship between infant attention and later cognitive and language development. Attention was assessed at 6 and 12 months using a non-social, passive video watching paradigm, while cognitive and language outcomes at 24 months were measured using the Bayley Scales of Infant and Toddler Development (Bayley-III) and the ELFRA-2 parental questionnaire, respectively. A total of 140 infants (76 female) participated in the study. Contrary to expectations, the hypothesized predictive relationship between early attention and later cognitive and language outcomes was not supported. However, the number of segments that were watched significantly increased from 6 to 12 months, indicating a developmental rise in attentional engagement across time points, whereas peak look durations remained stable, indicating that attention episodes remained the same. These findings in contrast to existing literature highlight the complexity of assessing attention in infancy and its role in developmental outcomes. The results underscore the need for further research using a broader range of attention measures and task types—including both passive viewing and active engagement paradigms—and considering relevant covariates such as socioeconomic status (SES), home language environment, and everyday speaking habits within the household.

Keywords: Sustained Attention, Infancy, Cognitive Development, Language Development, Longitudinal Design

Abstract (German)

In dieser Studie wird die Längsschnittbeziehung zwischen der kindlichen Aufmerksamkeit und der späteren kognitiven und sprachlichen Entwicklung untersucht. Die Aufmerksamkeit wurde im Alter von 6 und 12 Monaten mit einem nicht-sozialen Video-Paradigma untersucht, während die kognitive und sprachliche Entwicklung im Alter von 24 Monaten mit den Bayley Scales of Infant and Toddler Development (Bayley-III) bzw. dem ELFRA-2-Elternfragebogen gemessen wurden. Insgesamt nahmen 140 Säuglinge (76 weiblich) an der Studie teil. Entgegen den Erwartungen konnte die angenommene prädiktive Beziehung zwischen früher Aufmerksamkeit und der späteren kognitiven und sprachlichen Entwicklung nicht bestätigt werden. Allerdings nahm die Anzahl der betrachteten Segmente des Videos zwischen 6 und

12 Monaten signifikant zu, was auf einen Anstieg des Aufmerksamkeitsengagements über die Zeitpunkte hinweg hindeutet, während die Dauer des längsten Blickes stabil blieb, was darauf hindeutet, dass die Aufmerksamkeitsepisoden gleich blieben. Diese Ergebnisse, die teilweise im Gegensatz zu bestehender Literatur stehen, verdeutlichen die Komplexität der Beziehung der Aufmerksamkeit im Säuglingsalter und zusammenhängender Entwicklungsergebnisse. Die Ergebnisse unterstreichen die Notwendigkeit weiterer Forschung unter Verwendung eines breiteren Spektrums von Aufmerksamkeitsmessungen und Aufgabentypen - einschließlich passiver Betrachtung und aktiver Beschäftigung mit Aufgaben- und unter Berücksichtigung relevanter Kovariaten wie sozioökonomischer Status (SES), häusliche Sprachumgebung und alltägliche Sprechgewohnheiten im Haushalt.

Schlüsselwörter: Anhaltende Aufmerksamkeit, Säuglingsalter, kognitive Entwicklung, Sprachentwicklung, Längsschnittdesign

Declaration of Independent Work

I hereby declare that I have written the present thesis independently and have not used any aids other than those indicated. All passages that are taken either literally or in substance from other works (including works from electronic databases or the internet) are clearly identified as such, with the source cited and in accordance with the rules of academic referencing. This declaration also applies to any images, tables, sketches, and diagrams used in the thesis.

For the preparation of this thesis, I have also used the following generative AI tools: ChatGPT (OpenAI, GPT-4.5, May 2025) for the purpose of paraphrasing. The tools used have been fully and truthfully disclosed, including product version and prompts.