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Exploring Auditory Working Memory in Turkish Infants through the ADAM Game Experiment

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ABSTRACT

The present study aims to explore the association between sleep patterns and working memory in infants. The study comprised a sample of 28 participants ranging in age from 6 to 25 months. A sub-sample of 22 participants completed the entire battery. To measure these variables, two instruments were employed: 1) a Sleep Diary, and 2) the ADAM experiment, which assessed phonological working memory. The Sleep Diary was distributed to the families of the infants, who were instructed to record their sleep patterns for three consecutive days and nights leading up to the test day. The ADAM experiment was administered twice, with the second session taking place approximately two weeks following the initial assessment.

Our findings demonstrated a computed mean phonological memory span of 2.44, suggesting an approximate memory capacity of two items. Furthermore, our analyses approached statistical significance solely in the context of the correlation between sleep efficiency and processing speed. Conversely, the examination of the relationship between working memory and total sleep time/ sleep duration/ daytime naps/ age did not yield statistically significant outcomes. Given the exploratory nature of this study and the constraints of a relatively small sample size, there is a need for future investigations to build upon and extend the findings of this research.

INTRODUCTION

Phonological memory is the ability to remember and manipulate the sounds of language. It is an important aspect of language development and is often studied in the context of reading and spelling skills. There is evidence that infants are able to remember and distinguish between different speech sounds from a very young age, and that this ability is related to later language development. Hence, this initial study aims to explore the progression of auditory working memory development in a group of 22 Turkish infants, ranging from 6 to 25 months old.

One of the reasons that phonological memory is so important is that it helps children to segment words into their individual sounds, or phonemes. This is a crucial step in learning to read, as it allows children to match written letters with the sounds they represent. Children with strong phonological memory are better able to break words down into their individual phonemes, which makes it easier for them to sound out new words and build their vocabulary. For example, Swoboda et al. (1978) found that normal and at-risk infants' ability to discriminate between vowel sounds was influenced by their memory for the sounds. Similarly, Werker (1991) argued that infants' ability to discriminate between speech sounds is based on their ability to form phonological categories, which are shaped by their linguistic experience.

Moreover, phonological memory helps children to learn new words more easily. When children hear a new word, they are able to store it in their phonological memory and then use this memory to retrieve the word when they need it. This is especially important for vocabulary development, as it allows children to learn and use new words in their speech and writing.

Overall, research on phonological memory in infants and young children is important because it helps us to understand the underlying cognitive processes that support language and literacy development. By studying phonological memory, researchers can identify the factors that contribute to early reading and language skills, and develop interventions and strategies to support children who may be at risk for developmental delays.

Sleep is important for many aspects of cognitive development in infants, including phonological memory. Research has shown that sleep plays an important role in the consolidation of phonological memory in infants (Belia et al., 2022). During sleep, the brain is able to process and consolidate new information that has been learned during the day. This means that when infants get enough sleep, they are more likely to retain new words and sounds that they have heard and to use this information to improve their language skills. Thus, more nighttime sleep leads to better phonological memory, and both nighttime sleep and daytime naps may be important for the development of phonological memory in infants (Belia et al., 2022). Belia et al. suggest that "less interrupted nighttime over daytime sleep leads to subsequent vocabulary growth, with children with longer daytime sleep also being more likely to develop language delays in later years"(2022).

CHAPTER 1

Literature Review

1.1. Working Memory: Concept and Theoretical Framework

What is auditory working memory?

First of all, it is important to understand what working memory is. Working memory refers to the capacity to keep in mind and mentally work with information that is not currently present in the physical environment. Specifically, when it comes to auditory stimuli, working memory refers to the capability to retain and manipulate sounds in the mind (Kaiser, 2015).

On the other hand, working memory is important for language comprehension, learning, and reasoning. Research has found that short-term phonological memory, which is a part of working memory, is particularly important for acquiring new vocabulary. Specifically, the capacity to repeat nonwords, which relies on short-term phonological storage, has been found to be the most accurate predictor of success in language acquisition (Service, 1992). Therefore, working memory is crucial for processing and retaining linguistic information, which is necessary for language comprehension and learning.

1.1.1. Central Models for Understanding Auditory Working Memory

Baddeley's Model of Working Memory

Baddeley's model of working memory (1992) provides a theoretical framework to explain how we hold and manipulate information in our minds. This model consists of three main components: the phonological loop, the visuospatial sketchpad, and the central executive.

The phonological loop is responsible for temporarily storing and manipulating auditory information like spoken words or sounds. It consists of two parts: the phonological store that holds the auditory information for a short duration, and the articulatory rehearsal process that allows us to refresh and maintain this information by mentally rehearsing it silently.

In contrast, the visuospatial sketchpad handles visual and spatial information. It allows us to mentally represent and manipulate images, objects, and spatial relationships. For instance, when you mentally visualize the layout of a room or imagine rotating an object in your mind, you're using the visuospatial sketchpad.

Lastly, the central executive acts as the control center of working memory. It allocates attention and resources to the phonological loop and visuospatial sketchpad, while interacting with long-term memory and other cognitive processes. The central executive plays a crucial role in coordinating and integrating information from different sources, making decisions, and solving problems (Baddeley & Hitch, 1989).

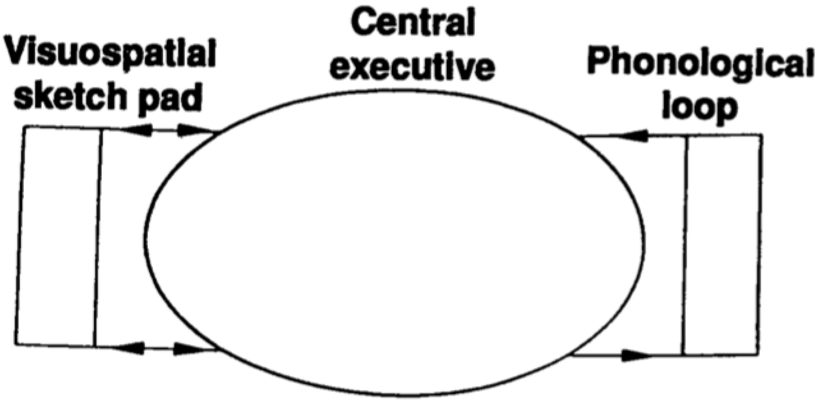

Figure 1. Baddeley's Model of Working Memory, 1992

The Episodic Buffer

The episodic buffer is a component added to the working memory model, originally presented as a three-component model in 1974 by Baddeley and Hitch. Acting as a limited-capacity temporary storage system, the episodic buffer has the ability to combine information from various sources, including subsidiary systems and long-term memory. It is overseen by the central executive, which accesses stored information in conscious awareness, reflects upon it, and manipulates it.

Contrasted with the original model, the episodic buffer introduces a temporary storage function for information held in a multimodal code, consolidating information from subsidiary systems and long-term memory into a unified episodic representation. This buffer is thought to be essential in both inputting information into and retrieving information from episodic long-term memory. In contrast, the original model lacked the episodic buffer and instead proposed a phonological loop and a visuospatial sketchpad as the two subsidiary systems controlled by the central executive (Baddeley, 2000).

Multi-Store Memory Model (Atkinson-Shiffrin)

Atkinson and Shiffrin proposed the multi-store model as an explanation of memory. According to this model, there are three distinct memory stores: sensory memory, short-term memory (STM), and long-term memory (LTM).

The model assumes that information is transferred between these stores in a linear sequence. Each memory store has its own unique characteristics in terms of how information is processed (encoding), capacity for storing information, and duration of storage. The transfer of information between stores follows a linear progression, resembling an information processing system like a computer, with input, process, and output stages. When information is detected by the sense organs, it first enters sensory memory, which holds a brief impression of sensory stimuli. If the information is attended to, it then moves into STM. If the information is given meaning through elaborative rehearsal, it is subsequently passed on to LTM.

However, the model is too simplistic, especially when it implies that short-term and long-term memory function in the same way without any differentiation (Mcleod, 2023).

Moreover, the idea that rehearsal alone is sufficient to explain the transfer of information from short-term memory (STM) to long-term memory (LTM) is considered too simplistic. The model fails to consider other factors like motivation, emotional impact, and learning strategies such as mnemonics, which play a significant role in the process of learning.

Additionally, rehearsal is not always necessary for information to be stored in LTM. For instance, we are able to recall information that we haven't actively rehearsed, like swimming skills, while sometimes finding it difficult to recall information that we did rehearse, like reading notes during revision (Mecleod, 2023).

As a result, the significance of rehearsal in transferring information from STM to LTM is much less important than what was claimed by Atkinson and Shiffrin in their 1968 model (Mcleod, 2023).

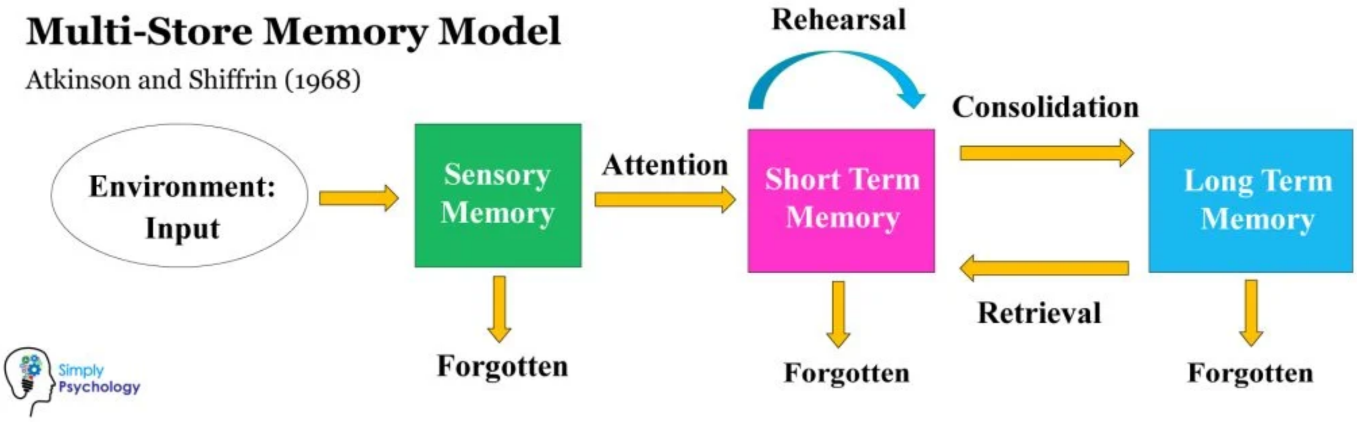

Figure 2. Multi-Store Memory Model (Mcleod, 2023)

1.1.2. Neural Correlates of Auditory Working Memory

The auditory working memory involves both sensory and cognitive mechanisms because it requires the brain to process and store auditory information in a way that can be accessed and used later. Sensory mechanisms are involved in the initial processing of auditory information, such as the detection of sound waves by the ear and the processing of these signals by the auditory cortex in the brain. However, to remember this information, the brain must also use cognitive mechanisms, such as attention, rehearsal, and retrieval processes. For example, the phonological loop is a cognitive mechanism that allows the brain to rehearse and repeat auditory information in order to keep it in working memory. The connection between the auditory cortex and the frontal motor areas is another cognitive mechanism that allows the brain to hold onto auditory information for longer periods of time (Kaiser & Brosch, 2016). Overall, the combination of sensory and cognitive mechanisms is necessary for the brain to process, store, and retrieve auditory information in working memory. Therefore, this section's scope covers the neurological aspects of the auditory working.

Several brain regions are involved in auditory working memory, including the auditory cortex, the prefrontal cortex, and the parietal cortex. The auditory cortex is responsible for processing auditory information, while the prefrontal cortex is involved in executive functions such as attention, planning, and decision-making. The parietal cortex is involved in spatial processing and working memory (Kaiser & Brosch, 2016).

Persistent neuronal activity during the retention period, match suppression, and match enhancement are involved in auditory working memory. Persistent neuronal activity refers to the continued firing of neurons in the brain during the retention period, which allows the brain to hold onto auditory information for longer periods of time. Match suppression and match enhancement refer to the ways in which the brain filters and prioritizes auditory information based on its relevance to the task at hand (Kaiser & Brosch, 2016).

The neural processes responsible for auditory working memory include long-lasting neural activity within the auditory cortex. A recent study has revealed that auditory information is temporarily stored in the auditory cortex through persistent changes in the firing rates of neurons and the modulation of slow electrical potentials (Huang et al., 2016). These changes manifest as either amplification or suppression of neural activity, positive or negative fluctuations in local field potentials (LFPs), and strengthened regional sources during the delay period compared to the baseline. Similar to other brain regions like the visual, somatosensory, and prefrontal cortex, the auditory cortex is recruited and undergoes persistent changes in neural activity to support auditory working memory(Huang et al., 2016).

Auditory working memory encompasses the intricate interplay of sensory and neurological foundations of auditory working memory, involving various brain regions such as the auditory cortex for processing, the prefrontal cortex for executive functions, and the parietal cortex for spatial processing and working memory. The underlying neural processes underscore the significance of persistent neuronal activity within the auditory cortex, indicating that auditory information is temporarily stored through the modulation of neural activity, particularly involving slow electrical potentials, amplification or suppression of neural activity, and fluctuations in local field potentials. These findings highlight the dynamic neural basis of auditory working memory, akin to other brain regions, emphasizing the intricate orchestration of sensory and cognitive functions in this vital cognitive process (Huang et al., 2016).

1.1.3. Developmental Aspects of Auditory Working Memory

Auditory working memory is a fundamental cognitive process that plays a crucial role in our ability to process and retain auditory information for short periods of time. It refers to the temporary storage and manipulation of auditory stimuli in our memory system. The developmental aspects of auditory working memory encompass the changes and progressions that occur in this cognitive function across different stages of human development, from infancy through childhood and into adulthood. Understanding how auditory working memory develops can shed light on the underlying mechanisms involved in language acquisition, reading comprehension, and other cognitive abilities that rely heavily on auditory information processing. This section aims to explore the developmental aspects of auditory working memory and its implications for cognitive development.

Research investigating the impact of experimental variables on children's immediate memory has revealed notable changes in the functioning of the phonological loop as children mature. Even very young children possess a phonological store component in their memory; however, the capacity for mental rehearsal does not develop until approximately the age of 7 (Cockcroft, 2015). When memory items are presented audibly and do not require mental rehearsal, children between the ages of 3 and 5 demonstrate sensitivity to phonological similarity and word length. Conversely, when memory items are presented visually, children in this age range perform inconsistently, indicating that the phonological loop is not involved in processing nonverbal material (Gathercole et al., 1998). Adams & Gathercole (1996) emphasize that the development of phonological short-term memory predominantly relies on improvements in rehearsal speed and retrieval from memory. Moreover, the emergence of mental rehearsal as a strategy for incorporating non-auditory material into the phonological loop and actively maintaining the contents of the phonological store greatly influences this development.

Additionally, a pioneering study by Benavides-Varela & Reoyo-Serrano (2021) proposes that infants may possess a more precise representation of linguistic sounds compared to non-linguistic sounds when dealing with a limited range of numerical quantities.

This finding holds potential implications for our comprehension of auditory perception and memory development in infants. It suggests that infants show a heightened sensitivity to the sounds of their native language from an early age, which can facilitate language acquisition and overall development. Furthermore, it implies that infants may more effectively utilize their auditory memory and attentional resources when processing linguistic sounds, with potential implications for the broader development of auditory memory and attentional capabilities. Nonetheless, further research is necessary to fully explore these potential implications.

1.1.4. Cognitive Factors Influencing Auditory Working Memory: Attention

Various cognitive functions are intricately linked to auditory abilities, particularly sustained auditory attention (Nieto et al., 2022). Attention, as a foundational cognitive process, plays a crucial role in shaping the brain's information processing across multiple sensory modalities, including auditory perception (Noyce et al., 2021).

Noyce et al. (2021) further elucidate that the intricate workings of attention span at various stages of our cognitive processes, employing forward and backward connections between different brain regions to focus on what deserves attention while filtering out distractions. Concentrating on specific auditory information, an aspect of focused attention, enhances sound perception and is influenced by the relevance of auditory stimuli in a given task. In essence, auditory perception relies on three core attentional processes: top-down attention, driven by intentions and objectives; object-based attention, which enables the seamless tracking of sound sources; and bottom-up attention, an involuntary mechanism prioritizing critical or unexpected auditory cues (Noyce et al., 2021).

Furthermore, according to a study conducted by Best et al. (2008) sustained attention to a specific sound in a noisy environment enhances the brain's ability to recognize and isolate that sound over time. However, shifting attention to a new sound requires an adjustment period for the brain to become attuned to the new auditory input. Consequently, transitioning between sounds can be a challenging process, potentially impeding information processing speed. Moreover, the study revealed that continuous sounds emanating from a fixed location facilitate attention as they demand less cognitive effort for recognition, allowing the brain to allocate more resources to sound retention (Best et al., 2008).

Together, these processes enable the filtration of irrelevant data, the concentration on essential elements, and swift responses to environmental stimuli. In conclusion, the interplay between cognitive functions and auditory abilities underscores the intricate processes guiding our perception of auditory stimuli, enriching our understanding of human cognition.

1.2. The Role of Sleep in Working Memory and Cognitive Functioning

This section delves into the intricate relationship between sleep and working memory, a core cognitive function that enables the temporary storage and manipulation of information. Understanding the role of sleep in working memory is crucial, as it can shed light on how sleep patterns impact our ability to process, retain, and utilize information effectively. This exploration will illuminate the interconnectedness of sleep quality, duration, and their implications for cognitive performance, offering insights into the significance of sleep.

According to a study conducted by Paavonen et al. (2010), insufficient sleep duration and poor sleep quality have demonstrated connections with lower processing speed in cognitive tests. Furthermore, an association between poor sleep quality and compromised attention and reaction time, particularly was found to be evident in a symbol digit substitution task. Interestingly, these findings suggest that the cumulative effects of inadequate sleep may manifest as deficits in executive functioning and working memory in some children. Notably, children experiencing poor sleep quality or insufficient sleep duration exhibited a higher incidence of errors in tasks like the Continuous Performance Test (CPT), symbol digit substitution, and one-back or two-back working memory exercises. Additionally, research suggests that there is a correlation between poor sleep quality and reduced processing speed and verbal aptitude (Paavonen et al., 2010).

Sleep has a vital role in promoting the consolidation and reconsolidation of memories. When we sleep, our brains experience various molecular, cellular, and systems-level adaptations that transform initial, unstable memory representations into more enduring ones. These adaptations improve the effectiveness and usefulness of stored memories as time progresses. Scientists have discovered specific types of memory that exhibit significant activation during sleep, and they have observed that different stages of sleep, such as REM (rapid eye movement) and NREM (non-rapid eye movement), may contribute differently to the consolidation of memories (Stickgold & Walker, 2013).

Research revealed that infants with a higher proportion of nighttime sleep, indicating better sleep consolidation, exhibited enhanced performance in tasks demanding intricate executive functions, including abstract reasoning, concept formation, and problem-solving abilities at the preschool stage (Bernier et al., 2016). Bernier et al. (2016) found that the relationship between sleep consolidation and cognitive proficiency remained statistically significant even after accounting for initial cognitive levels. Nevertheless, no substantial correlation was observed between the overall duration of sleep and cognitive performance.

Moreover, the findings from the study conducted by Bernier and colleagues (2016) underscore that executive functioning's association with total or nighttime sleep duration, coupled with the well-documented decline in sleep duration during the first year of life, supports the notion that cognitive advantages of sleep in infancy and early childhood are more likely attributable to factors such as its maturation, quality, or organization rather than simply the quantity of sleep.

On the other hand, sleep deprivation can have a negative impact on memory retention and recall. Studies have shown that sleep plays a crucial role in supporting memory consolidation and reconsolidation processes. During sleep, our brains undergo a series of adjustments that convert initial, labile memory representations into more permanent ones, which enhances the efficiency and utility of stored memories over time. Sleep deprivation can interfere with these processes, leading to impaired memory retention and recall. For example, one study found that subjects who were deprived of sleep after learning a motor task showed no enhancement of either performance or brain activity at retest, indicating that sleep deprivation had interfered with a latent process of plasticity and consolidation. Overall, the evidence suggests that sleep is critical for optimal memory consolidation and that sleep deprivation can have a negative impact on memory retention and recall (Stickgold&Walker, 2013).

Research implies a predictive association between diverse sleep metrics (e.g., number of awakenings, duration of the longest sleep interval, sleep efficiency, total sleep duration, nighttime sleep duration) and cognitive development, based on prior investigations. Furthermore, they highlighted that insufficient nocturnal sleep duration in early childhood was linked to lower cognitive abilities upon entering school, whereas well-regulated circadian sleep patterns at 19 months of age exhibited a positive correlation with cognitive performance (Horvath & Plunkett, 2015).

Study by Horvath & Plunkett found a longitudinal relationship between sleep patterns and early vocabulary development in infants and toddlers (2016). Specifically, the number of daytime naps was positively associated with both predicted expressive and receptive vocabulary growth, whereas the length of night-time sleep was negatively associated with the rate of predicted expressive vocabulary growth. Sleep efficiency was also positively associated with both predicted receptive and expressive vocabulary growth. These results suggest that daytime naps and sleep efficiency are important predictors of language development in young children (2016). Vocabulary learning is closely related to cognitive functioning, as it involves various cognitive processes. When individuals learn new words, they engage their memory, attention, and processing speed. Memory helps retain and recall the new vocabulary, attention is required to focus on the words and their meanings, and processing speed influences how quickly one can grasp and use new words.

Additionally, the study conducted by Morales-Muñoz et al. (2021) provides valuable insights into the relationship between sleep patterns in infancy and the development of executive functions in toddlers. The findings suggest that sleep disruption in early childhood can have a negative impact on inhibitory control and working memory in toddlers. The study also highlights the importance of healthy sleep patterns in early childhood, as various sleep difficulties at 12 months were found to distinctively affect WM and IC in toddlers, possibly in a nonlinear manner. The inverted U-shaped association between proportion of daytime sleep at 12 months and IC at 30 months is particularly noteworthy, as it indicates that average proportions of daytime sleep were longitudinally associated with better IC performance.

Moreover, research by Nieto et al. (2022) endeavored to explore the connection between the duration of nighttime sleep and executive functioning within a group of Spanish preschoolers, aged 3 to 6 years. Their results revealed noteworthy associations between nighttime sleep duration and working memory, indicating that preschoolers with shorter nighttime sleep duration tended to exhibit inferior performance in this domain.

In conclusion, research underscores the crucial role of sleep in memory consolidation and reconsolidation processes, emphasizing its significance in enhancing the efficiency and utility of stored memories over time. Studies have revealed distinct patterns of memory activation during different sleep stages, with both REM and NREM sleep contributing to memory consolidation (Stickgold & Walker, 2013). Conversely, sleep deprivation can hinder these processes, leading to impaired memory retention and recall, as evidenced by studies showing the negative impact of sleep deprivation on motor task performance and brain activity (Stickgold&Walker, 2013). Furthermore, the longitudinal relationship between sleep patterns and early vocabulary development in infants and toddlers, highlight the importance of daytime naps, night-time sleep length, and sleep efficiency in predicting language development. Findings on nighttime sleep duration also help to enrich our knowledge on its effects on working memory in preschool children as sleep disruptions negatively impact working memory (Nieto et al., 2022).

Overall, these findings underscores the intricate connection between sleep, memory, and cognitive functioning, with implications for understanding memory processes in various contexts.

1.3. Cultural Factors in Sleeping Habits: Turkey vs Italy

The influence of cultural factors on sleeping habits can be observed in varying patterns and practices across different regions and societies, and one such intriguing comparison lies between Turkey and Italy.

A study explored Turkish mothers' perspectives on their children's sleep issues and how they put their children to sleep, focusing on infants up to 2 years old. The research aimed to identify appropriate and inappropriate practices for settling children to sleep in this age range and assess the prevalence of sleep problems. It employed a descriptive questionnaire and involved mothers with infants aged up to 2 years from pediatric clinics at a university hospital and a state hospital in a Turkish province (Karacam&Ancel, 2016). The findings reveal that Turkish mothers employ various approaches such as breastfeeding, gentle rocking motions, lullabies, and co-sleeping to facilitate their children's sleep. Co-sleeping, in particular, is viewed as a means to strengthen the emotional bond between mother and child, although it is important to note the potential risks associated with this practice, such as an increased risk of sudden infant death syndrome (SIDS). Contrarily, another study found that in Turkey, the rate of bed sharing with parents among three-month-old infants was reported to be lower compared to European countries. Istanbul was the sample for Turkey, and the rate of bed sharing with parents was detected as 2% at the 3rd month (Gursoy et al., 2019).

It is crucial to educate parents about the potential risks and benefits of co-sleeping and provide guidelines on safe sleep practices. The investigation also highlights that sleep-related difficulties in Turkish infants can have a profound impact on the well-being of both the mother and the child. Maternal depression, anxiety, and fatigue are often observed in mothers of infants with sleep problems, emphasizing the importance of addressing such issues to promote the overall health and well-being of both mother and child.

Additionally, research on Italian infants' sleep patterns indicates that they sleep less than infants from other countries, with their sleep duration decreasing as they age (Ferri et al. 2016). Normative data on Italian infants' sleep patterns during the first year of life can not only reassure parents about their child's sleep but also help identify incorrect parental behaviors and provide appropriate interventions to prevent the development of sleep disorders. The prevalence of co-sleeping in Italy is also high, with a significant number of infants sharing a bed with their parents. However, studies have shown that bed-sharing infants tend to have more awakenings compared to those who sleep alone.

Another study investigating the sleeping habits of Italian preschoolers found a high incidence of parental involvement at bedtime associated with longer sleep latency, a higher incidence of night wakings, and a reduction of nighttime sleep in preschoolers. Additionally, the childrearing practice of allowing preschoolers to fall asleep in the parents' bed and then moving them to their own bed later in the night is common in Italy (Giannotti et al., 2005).

These findings suggest that parental practices play a significant role in the sleep habits of Italian preschoolers. The high incidence of parental involvement at bedtime and the childrearing practice of co-sleeping may contribute to the development of sleep problems in Italian preschoolers.

The comparison of sleeping habits between Turkey and Italy highlights cultural variations. These insights underscore the profound influence of culture on sleep practices, emphasizing the importance of understanding and addressing these differences for the well-being of children and parents. Specifically, it has been observed in both cultures that co-sleeping is associated with a higher number of nighttime awakenings that may be considered more problematic by parents if they co-sleep with their child.

1.4. Summary

In summary, the initial section delves into phonological memory, which pertains to the capability of remembering and manipulating language sounds. It underscores the significance of phonological memory in various facets of language development, including reading, spelling, and vocabulary acquisition. The ability to break down words into individual sounds facilitates children in pronouncing unfamiliar words and expanding their vocabulary. Furthermore, phonological memory aids children in storing and recalling new words effortlessly, thereby bolstering their language and literacy development.

Shifting to the subsequent part, the discussion centers around the impact of sleep on auditory working memory. It elucidates the pivotal role of sleep in consolidating and augmenting phonological memory in infants. Adequate sleep supports infants in retaining new words and sounds, thereby fostering improved language skills. The section underscores the importance for parents to ensure their babies obtain sufficient sleep to fortify healthy cognitive development, as well as lay a strong foundation for future learning and language abilities.

In summary, this text explores the significance of phonological memory in language development and how sleep influences auditory working memory in infants.

CHAPTER 2

Current Research

2.1 Background and Significance

In recent years, the field of developmental psychology has witnessed a growing interest in understanding the intricate interplay between sleep patterns and cognitive development in infants. Among the various facets of cognition, auditory working memory stands out as a critical cognitive function that plays a fundamental role in language acquisition and overall cognitive development. While both sleep and auditory working memory have individually garnered substantial attention in developmental research, there remains a compelling need to investigate the potential nexus between these two domains. Sleep, as an essential component of early life, is known to exert a profound influence on cognitive processes. Exploring the relationship between sleep and auditory working memory in infants between 6 to 25 month old holds the promise of shedding light on the underlying mechanisms that contribute to auditory working memory during this formative period of life.

Thus, this study is a part of one of the pioneer studies in this specific topic as it explores the relationship between sleep and auditory working memory in 5 to 24 months old infants from Turkey. By understanding how working memory functions in such young age, we can gain insights into early cognitive abilities and potential developmental trajectories. Moreover, sleep is known to be essential for consolidating memories and facilitating learning processes. Investigating the relationship between sleep and auditory working memory in infants can help us unravel the intricate interplay between sleep patterns and cognitive development. Ultimately, this research can contribute to the optimization of early interventions and educational strategies targeted at enhancing cognitive abilities in infancy and beyond.

It is important to note that every culture has its unique linguistic features, including sounds, phonetics, and intonation patterns. By studying infants from a particular culture, researchers can gain insights into how these distinct linguistic elements influence cognitive processes, such as auditory working memory. Understanding how infants from different cultures process and remember auditory information can shed light on the universal or culture-specific aspects of cognitive development. Additionally, this research can aid in identifying potential variations in language acquisition milestones across cultures, helping to develop more effective interventions and support systems for children from diverse linguistic backgrounds. Ultimately, by studying a specific culture in infant auditory working memory, researchers can contribute to a more comprehensive understanding of human cognition and promote inclusivity in developmental studies.

The ADAM experiment and sleep diary were utilized to measure sleep and phonological working memory. Participants were asked to complete the ADAM test, an auditory working memory task that involved remembering and recalling a series of sounds. The ADAM test measured the participants' ability to process and retain auditory information over a specific period. Alongside this task, families were also required to maintain a sleep diary, where they recorded their baby's' sleep duration, quality, and any disruptions or other factors that may have affected their rest. Combining these two methods allowed this research to examine the relationship between sleep patterns and the participants' performance in auditory working memory tasks. This approach provided valuable insights into the potential impact of sleep on cognitive abilities, particularly in the domain of auditory working memory, highlighting the importance of sufficient and quality sleep for optimal cognitive functioning.

2.2. Research Objectives and Questions

Understanding the cognitive development of infants is a complex area of research that often requires investigating multiple factors involved. One key aspect of cognitive development is auditory working memory, which plays a crucial role in language acquisition and verbal communication. Furthermore, sleep has been identified as a significant contributor to cognitive functions, particularly in early childhood. This study aims to explore the relationship between auditory working memory and sleep patterns in Turkish infants for this specific group of participants, taking into account the potential influence of cultural factors.

The research objectives of this study aim to comprehensively investigate the association between auditory working memory and sleep quality in Turkish infants. Specifically, the study seeks to explore potential variations in auditory working memory performance and sleep patterns among Turkish infants. An examination of cultural factors, such as bedtime routines and environmental factors will be conducted to determine their impact on infant auditory working memory and sleep patterns.

In order to achieve these objectives, several research questions will be addressed. Firstly, the study aims to determine the correlation between auditory working memory performance and sleep quality among Turkish infants. Secondly, the study aims to pave the way for further research investigating cultural factors on the development of auditory working memory and sleep patterns by conducting this research with Turkish infants. By addressing these research objectives and questions, this study aims to provide valuable insights into the relationship between auditory working memory and sleep quality in Turkish infants, shedding light on the potential impact of cultural factors.

CHAPTER 3

Methodology

3.1. Research Design

In this study, there are two key assessment tools used: an online experimental task called ADAM (ADAptive Memory), and a Sleep Diary. ADAM focuses on measuring auditory working memory capacity, while the Sleep Diary collects data on various aspects of participants' sleep, such as total sleep time, sleep duration, sleep efficiency, nap time, and the number of naps taken over three days before the day of the test.

3.2. Participants

This study involved a cohort of 22 participants falling within the age range of 6 to 25 months who diligently completed the prescribed procedures. Notably, all participants were of Turkish nationality. However, within the encompassing cohort of 22 participants, some of them resided outside the borders of Turkey, specifically in the United States and Germany. Consequently, these infants were exposed to a language distinct from Turkish; 6 of them experienced exposure to German while 5 were exposed to English. Conversely, the remaining participants lived in Turkey and exclusively encountered Turkish in their everyday lives.

Participant recruitment was executed via the snowball sampling technique, leveraging online platforms such as Facebook and WhatsApp groups. In order to disseminate detailed information and facilitate enrollment, research brochures were indiscriminately distributed among prospective individuals. Subsequently, those showing interest made direct contact with the researcher, and participating families further contributed to the recruitment process by referring other parents. Commencing with an initial outreach to 44 parents, it is worth noting that 16 individuals ceased communication following the primary interaction. Moreover, 6 of the participants' data were excluded as they were not adequate for analysis. Consequently, the study successfully yielded a final participant count of 22, after accounting for attrition, who diligently completed the comprehensive procedure, therefore providing a wealth of invaluable data for subsequent analysis.

3.3. Data Collection

The research was conducted within a comfortable residential setting and it comprised two sessions that were scheduled 15 days apart. Parents of the participants were given instructions to utilize a personal computer with a display size of at least 13 inches and to select a well-lit and silent room for the sessions. Infants were positioned on their parents' laps at a specific distance from the monitor, preferably facing a window to receive enough light.

The Labvanced platform was employed to present the stimuli and a calibration process was executed to ensure accurate visual and audio presentation. Prior to each session, parents were requested to complete a sleep diary for the three days leading up to the test day.

Throughout the study, all participants commenced at Level 3, irrespective of their age, based on the findings from prior investigations (Koksal, 2023). In the second session, infants were adaptively assigned either Level 2 or Level 4 contingent upon their performance in the initial session.

3.4. Measures and Instruments

Data collection is a critical component of research studies, particularly when assessing sleep patterns in infants. Sleep diaries have proven to be valuable instruments for gathering information about an individual's sleep habits (Horvath & Plunkett, 2016). In this section, we will discuss the process and significance of collecting sleep diaries before conducting an infant sleep assessment.

3.4.1. Sleep Diary

For the purpose of this study, parents were actively involved in the data collection process. Prior to each assessment session, they were requested to complete a sleep diary for the three days leading up to the test day. This timeframe was chosen to capture a representative sample of the infant's sleep patterns.

The sleep diary used was retrieved from previous research from the field and provided to the families of the infants being assessed (Horvath & Plunkett, 2016). Parents were given thorough instructions on how to accurately fill out the diary. The diary required information related to both daytime and nighttime sleep, including the timing and duration of sleep periods. Parents were encouraged to record any significant events that could impact the infant's sleep, such as waking up during the night or any factors that may have influenced sleep quality.

By involving parents in the data collection process, we aimed to ensure the accuracy and reliability of the sleep diary entries. Parents, being the primary caregivers, have firsthand knowledge of their infant's sleep patterns and could offer valuable insights.

Collecting data for three days and nights leading up to the assessment session was necessary to capture a comprehensive snapshot of the infant's sleep patterns. By extending the data collection period to multiple days, we aimed to reduce the likelihood of obtaining misleading or atypical sleep data that can occur on a single night. This approach allows for a more accurate representation of the infant's sleep habits and provides a broader understanding of sleep patterns over time.

To ensure the integrity and quality of the data collected, instructions were provided in a clear and concise manner. Parents were encouraged to record data promptly and accurately, avoiding any retrospective estimations. Researchers were available to address any questions or concerns that parents may have had during the data collection period. Additionally, measures were in place to monitor and identify any inconsistencies or missing data within the sleep diaries.

3.4.2. The ADAM Game Experiment

The ADAM game was designed based on previous literature (Benavides-Varela & Reoyo-Serrano, 2021). The syllables were synthesized with the female voice of the MBROLA Italian database using eSpeak NG IT4 (Dutoit et al., 1996). The study included a total of three blocks with two distinct phases: a familiarization phase comprising 6 trials and a subsequent test phase consisting of 2 trials (as depicted in Figure 3). During the familiarization phase, the trial initiation involved an animated visual attractor at the center of the screen, along with two white squares placed on either side. As the infant fixated on the central attractor, a set of syllables would play. After the syllables ended, the central attractor vanished, leaving only the two white squares visible for a duration of 1 second.

Following this, a looming puppet would materialize on one of the two white squares for a duration of 2 seconds. The pairings of sequences with puppet locations were counterbalanced across all participants .

To prevent monotony, the presentation syllable sequences alternated in a pseudo-random order, ensuring that no sequence was repeated more than three times consecutively. The coupling of sounds with puppets was randomized. Different syllables were utilized across trials to avoid infants forming semantic associations between puppet appearance and specific sounds.

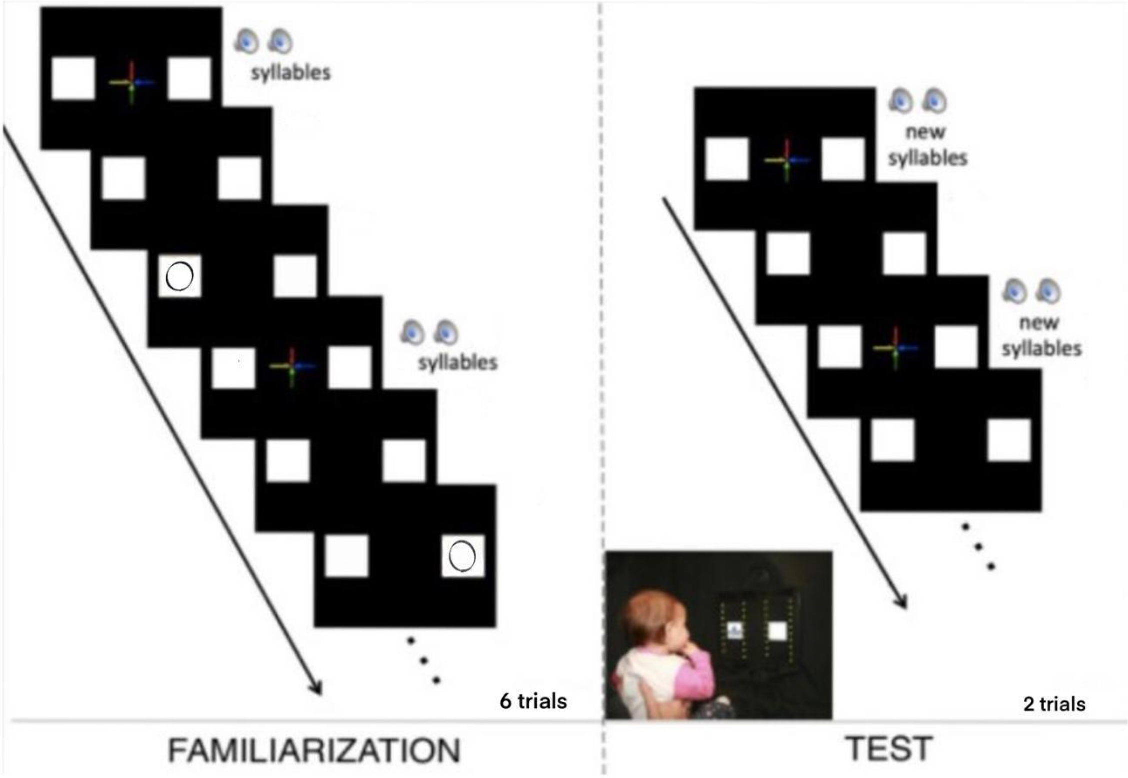

Figure 3. Familiarization and Test Trials

The study commenced with all infants starting at ADAM Level 3, where they were introduced to 3-syllable sequences specifically designed to be devoid of any Turkish meaning. While developing the experiment, extensive examination was conducted on all levels to ensure that the sounds used did not carry any significance in Turkish. If an infant does not recall the 3-syllable sequences, they will proceed to Level 2, where they will be exposed to 2-syllable words. On the other hand, if an infant effectively holds onto the 3-syllable sequences, they will advance to Level 4, where they will encounter 4-syllable sequences in the last session. More details on the coding and scoring procedure follows.

3.5. Coding Procedure

The process of analyzing the data involved multiple steps. Initially, the focus was on coding the infant's gaze in the ADAM experiment, which was recorded via the families' webcams throughout the sessions. Following the first session, the researcher downloaded the recorded videos from Labvanced and the videos were then divided into three different categories: examination, expectation, and play, each lasting for 2, 1, and 1 second respectively, while recording the attention of the babies.

To begin the analysis, all the videos were down-sampled to 25 frames per second using the Smart Converter application (Apple, n.d.). Subsequently, the converted videos were meticulously assessed frame by frame at intervals of 40 milliseconds using the ELAN app (Max Planck Institute for Psycholinguistics, 2000). By slowing down the videos, it became possible to track the eye movements of the infants and determine the precise moments when their gaze was directed towards the stimuli.

3.5.1. Dependent Variables

During the coding process, the primary factors considered were the initial direction of the child's gaze (referred to as "first look"), the overall duration of the child's gaze towards the left or right ("total look"), and the time it took for the child to redirect their gaze away from the center ("latency time"). Following the completion of the first ADAM game at Level 3, the scores for each child in terms of both "first look" and "total look" were calculated based on the accuracy and inaccuracy of their responses to the target and distractor stimuli. Furthermore, the difference score was computed by taking into account the quantity of accurate and erroneous responses in both target and distractor trials. It involves calculating the discrepancy between the number of correct responses and incorrect responses, which is then divided by the total number of responses.

In addition to tracking ADAM game scores, the sleep diary analysis focuses on various aspects of sleep patterns, encompassing total sleep duration, sleep time, awakening duration, nap occurrences, number of naps, and overall sleep quality.

To determine the total sleep time, the hours of sleep per night, excluding waking periods, are tallied. This calculation is performed for three consecutive nights (or two, depending on the number of days the parents recorded). Subsequently, the results from each night are combined and divided by the total number of recorded nights (minimum two nights). Furthermore, sleep duration is computed by summing the hours of sleep from when the infant goes to bed until their final awakening in the morning, including any periods of wakefulness during the night. A similar calculation method is used to determine the total duration of awakenings during the night, which is then averaged over the recorded nights.

Similarly, to the calculation of total sleep time, nap durations are determined. The number of naps is derived from the average number of times the infants slept throughout the recorded days. Lastly, sleep efficiency is calculated by dividing the total sleep time by the sleep duration.

Aspect of Sleep Pattern	**Calculation**
Total Duration of Sleep	Average of uninterrupted sleep hours across the recorded nights
Duration of Awakening	Total duration of awakenings / number of awakenings averaged across the recorded nights
Total Duration of Naps	Average of individual nap durations across the recorded days
Number of Naps	Average number of recorded nap times across the days
Sleep Efficiency	Total sleep time / Duration of sleep averaged across the recorded nights

Figure 4. Description of the Sleep Data and its Computation

3.6. Description of Statistical Analyses

The statistical analysis involved various methods to explore the data. Initially, a Spearman correlation analysis assessed the relationship between working memory and the age of participants. Additionally, a regression analysis, considering sleep efficiency and age, did not find significant contributions to working memory. Lastly, a Pearson's correlation analysis explored the relationship between processing speed and sleep efficiency, which showed an approach to statistical significance within the group.

3.7. Ethical Considerations

In conducting this research, we acknowledged the importance of ensuring the well-being, safety, and rights of the participating infants. The following ethical considerations have been taken into account:

Informed Consent: As infants are unable to provide informed consent themselves, the consent of their legal guardians was obtained prior to their participation in this study. Detailed information about the purpose, procedures, potential risks, benefits, and confidentiality measures was provided to the parents. They had the right to refuse their infant's participation or withdraw consent at any time without penalty.

Voluntary Participation: Participation in this study was entirely voluntary for both infants and their parents. No individual or social pressure will be exerted to coerce participation. The decision to participate did not affect the infants' access to care or services.

Minimizing Harm and Discomfort: All research procedures will be designed to minimize any potential harm or discomfort to the participating infants. Researchers will follow established guidelines and standards in research involving infants to ensure their well-being throughout the study.

Confidentiality and Privacy: Any data collected during the study will be kept confidential and stored securely. Personal information will be anonymized, and participants will be given unique identifiers to protect their privacy. Data will only be accessible to the research team and will be used solely for the purpose of this study.

Monitoring and Oversight: This research study has obtained ethical approval from the relevant institutional review board (Comitato Etico della Scuola di Psicologia -University of Padova). The study will be conducted in adherence to all applicable laws, regulations, and professional ethical standards. A qualified researcher will oversee the entire research process, ensuring compliance with established ethical guidelines.

Reporting of Findings: The results of this study will be reported in a manner that protects the anonymity and confidentiality of the participants. Findings will contribute to the scientific knowledge base on infant development and may be shared with relevant stakeholders, such as healthcare professionals, educators, or parents.

By addressing these ethical considerations, we aim to protect the rights and well-being of all participants involved in this research study.

CHAPTER 4

4.1. Descriptive Analysis of Participants

An initial investigation into the study's participants involved a descriptive analysis encompassing demographic characteristics, parental educational backgrounds, and the language development of the infants under study. The primary objective was to gain comprehensive insights into the typical profiles of infants across various age ranges. The study cohort consisted of 21 Turkish infants aged between 6 to 25 months. Notably, 78.57% of the mothers had completed their university education, while 21.43% had earned a Master's degree. Among the fathers, 64.29% held university degrees, 35.71% had completed a Master's program, and one father had obtained a high school diploma. The parents reported no instances of sight or hearing impairments, linguistic difficulties, or developmental issues among the infants, with the exception of one participant who mentioned a family history of hearing-related problems.

4.2. ADAM Game Results: Analysis of Auditory Working Memory

The study initially focused on evaluating the auditory working memory of the sample. To analyze this preliminary research, the researchers considered the difference in total looking time on the ADAM test. All participants needed to finish a minimum of four out of the eight total trials during the test phase to ensure the data was suitable for analysis. Hence, regardless of their age, all of them successfully completed level three in the ADAM experiment.

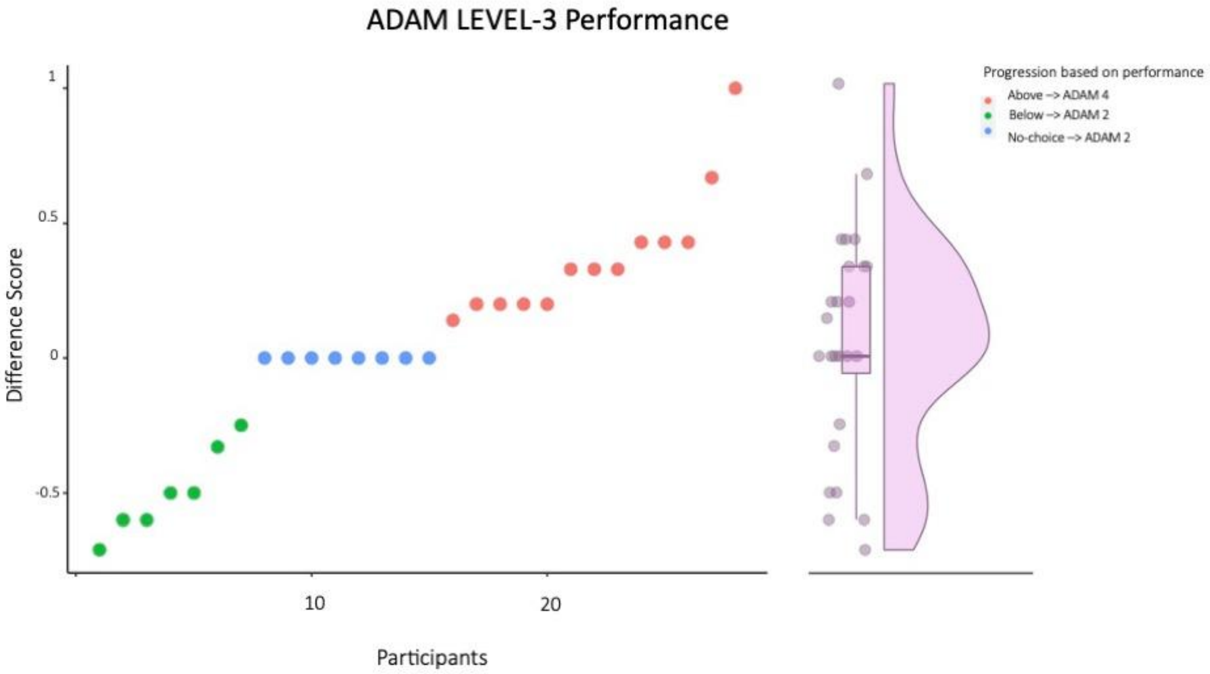

Figure 5. ADAM Game Level 3 Performance Analysis of All Participants

Figure 5 presents the data illustrating the disparities in total gaze duration scores obtained during the ADAM 3 assessment. These results underscore the notable variability in the responses of the study participants. Within the cohort of 28 infants, 13 effectively achieved a favorable score, facilitating their progression to level 4 in the subsequent experimental phase. Conversely, 7 children encountered challenges in passing the test, resulting in the attainment of negative scores. Furthermore, 8 infants manifested distinctive patterns of behavior, ultimately attaining a score of zero in their performance on ADAM 3. In addition, it is evident that a large portion of the data falls between the 1st and the 3rd quartiles.

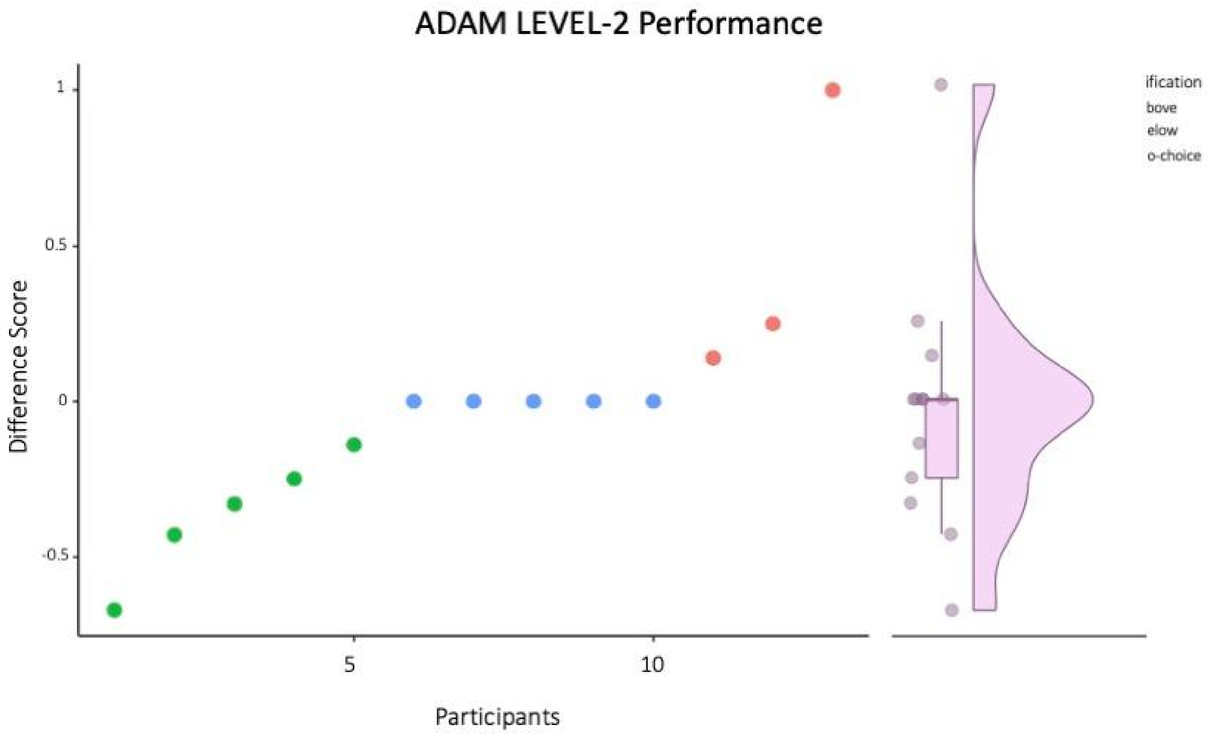

Figure 6. ADAM Game Level 2 Performance Analysis of All Participants

Infants attaining a score of 0 or higher in the initial phase proceeded to engage in the second experimental stage, Level 2. The graphical representation in Figure 6 underscores the observation that a reduced number of participants were capable of achieving difference scores exceeding a particular threshold presenting a median point below zero with a right skewed distribution. To elucidate this point further, a mere 3 out of the total cohort of 13 infants managed to attain a favorable score, thereby successfully completing the level they were in. In contrast, 5 participants encountered challenges in their performance, yielding negative scores. Additionally, 5 infants exhibited a distinct response pattern, marked by performances that neither surpassed nor fell below the established difference score benchmark.

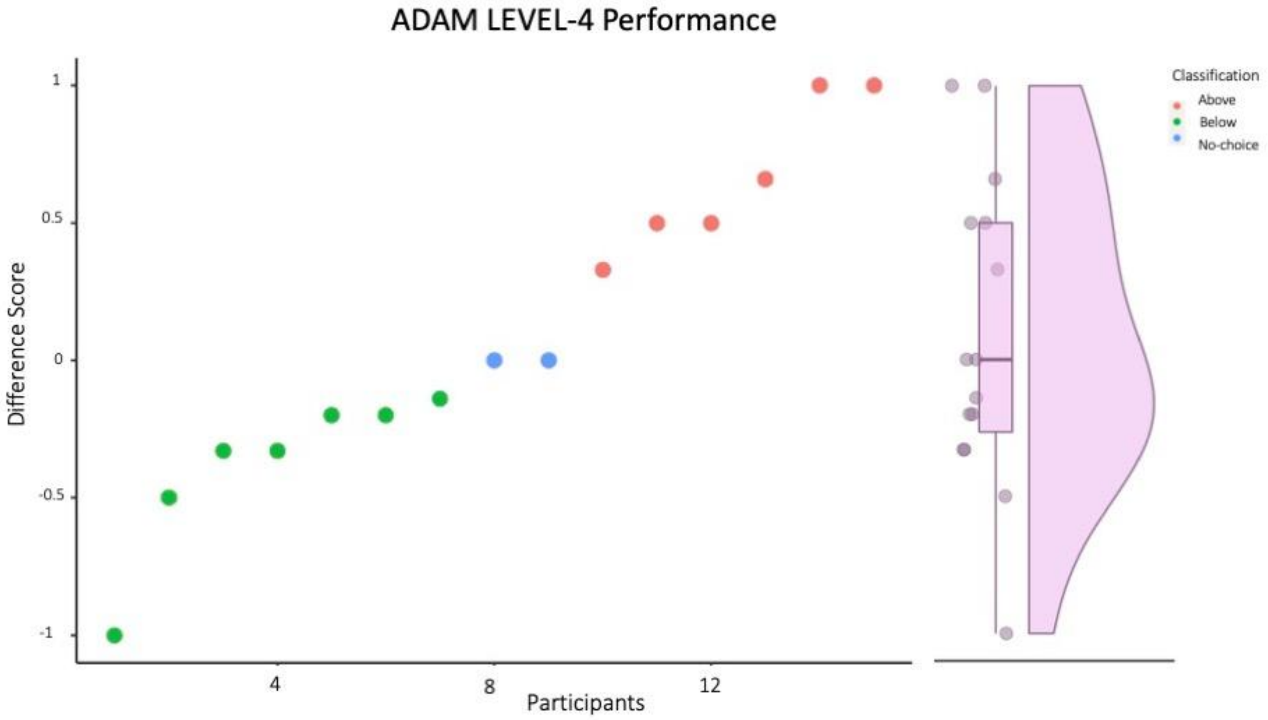

Figure 7. ADAM Game Level 4 Performance Analysis of All Participants

In Figure 7, the data illustrates a nearly balanced distribution among infants in terms of their performance relative to the difference score in ADAM 4. Notably, 6 participants achieved positive scores, while an equivalent number of 7 participants registered negative scores. Additionally, it is pertinent to highlight that, within the cohort of 15 infants who successfully completed Level 4 in the ADAM Game experiment, a distinctive subgroup comprising 2 infants exhibited an intriguing characteristic: an absence of discernible difference scores in their performance outcomes.

4.2.1 Phonological Working Memory Span of the Sample

In accordance with the outcomes of the two ADAM assessments, each child's performance was systematically evaluated and assigned a score within a four-tiered range, spanning from 1 to 4. The scoring criteria were rigorously defined as follows: If a child exhibited a favorable performance in both ADAM 3 and ADAM 4, they were assigned a score of 4. In the event that a child secured a positive score in ADAM 3 while obtaining a negative score in ADAM 4, a score of 3 was attributed to their performance. Moreover, if the child's performance yielded negative or neutral results in ADAM 3 but positively in ADAM 2, their score was designated as 2. In cases where none of these aforementioned conditions were met, a score of 1 was conferred upon the child.

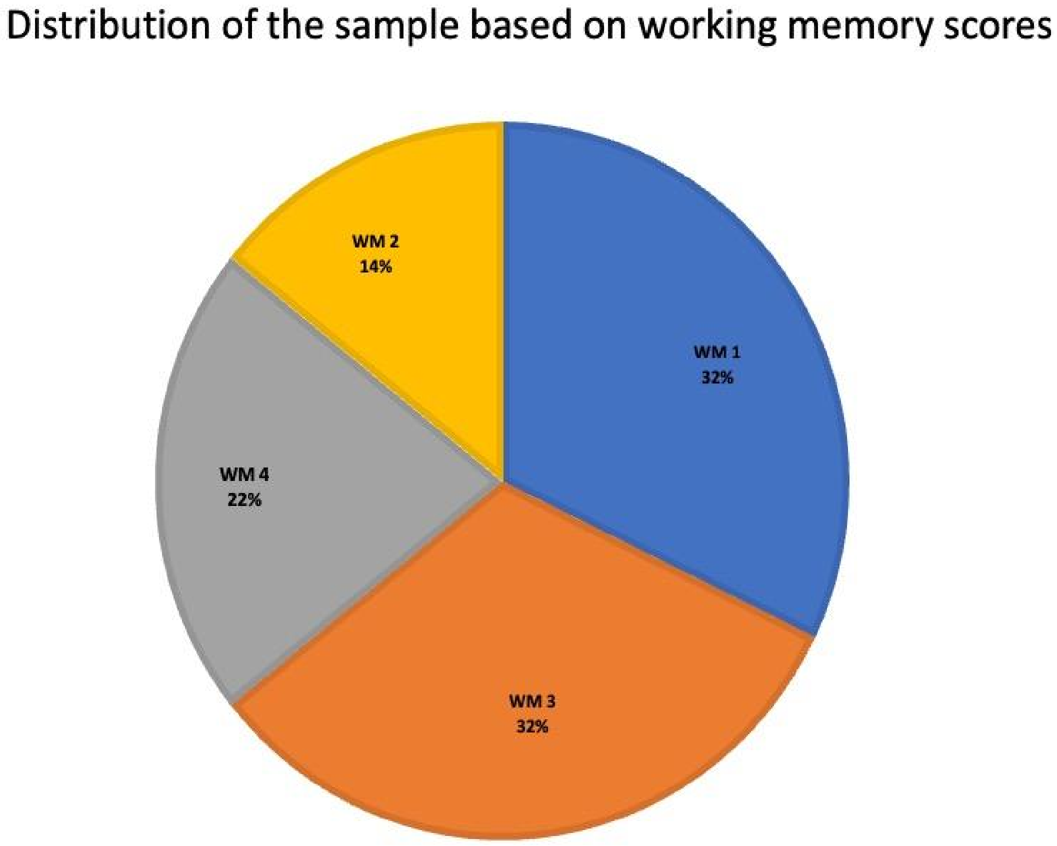

Figure 8. Distribution of Working Memory Scores

The pie-chart representation depicted in Figure 9 pertaining to working memory distribution reveals several noteworthy observations. Specifically, it is discernible that a substantial proportion, approximately one-third of the participants, garnered a working memory score of 1. Further analysis demonstrates that 14% of the participants achieved a score of 2, indicative of their inability to progress beyond Level 3 in the ADAM game, despite their commendable performance at Level 2. A significant segment, constituting 32% of the infants, was assigned a working memory score of 3, denoting their successful navigation through Level 3 while encountering challenges at Level 4. Conversely, 22% of the participants were awarded a score of 4. Notably, in comparison to the cohort that received a score of 1, this subset comprises a relatively smaller number of participants who managed to achieve positive scores at both Levels 3 and 4 in the ADAM game, thereby highlighting a distinct performance pattern.

The relationship between participant's responses and age

The results obtained from the Spearman correlation analysis indicate that, within this sample, there exists no statistically significant association between working memory and the age of the participants (Spearman's rank correlation coefficient, r_s = 0.04, p-value = 0.84).

An additional metric routinely employed for the evaluation of participant responses pertains to the temporal interval required for a child to discern a designated sequence, commonly referred to as "latency." The data reveals an average latency of 675 milliseconds, accompanied by a standard deviation of 281 milliseconds.

In Figure 9, an inverse correlation with the age of the child was observed. As the chronological age of the child advances, there is a discernible reduction in latency time.

However, it is noteworthy that this inverse correlation did not attain statistical significance (Spearman's rank correlation coefficient, r_s = -0.25, p-value = 0.21).

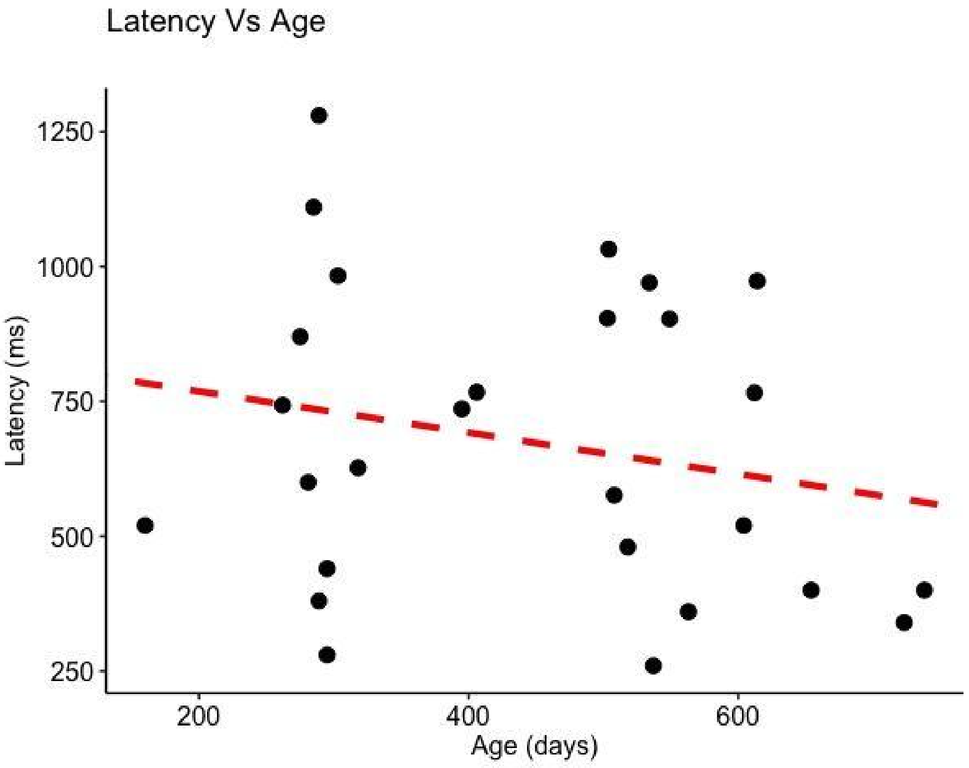

Figure 9. The relationship between participant’s responses and age

In order to evaluate the achieved statistical power within the context of this correlational analysis, a post hoc power analysis was conducted employing G*Power. The resultant estimation of the statistical power for this analysis indicates an approximate value of

80%, based on the sample size (N=28) and the computed effect size of 0.50.

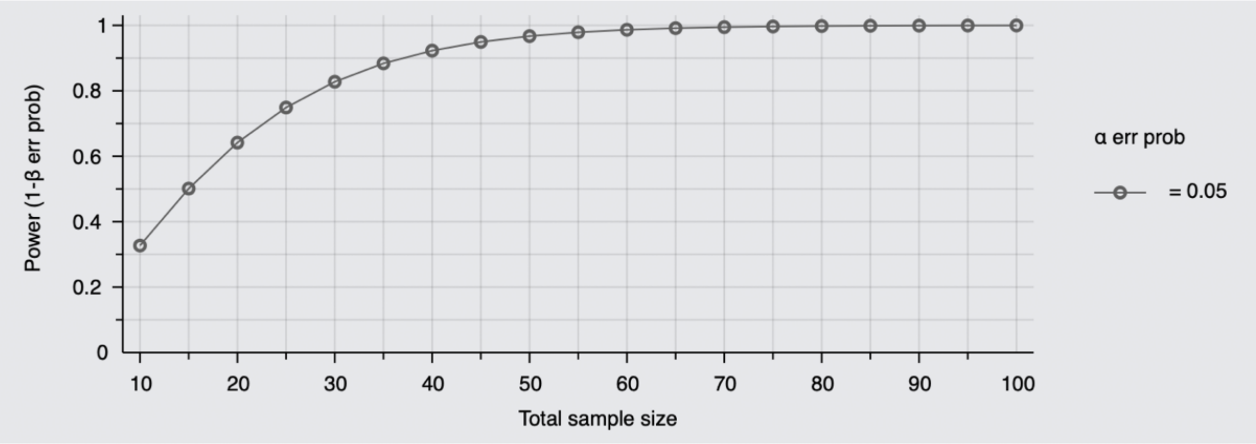

Figure 10. Correlation bi-variate normal model to estimate the achieved power

4.3. The Relationship Between Auditory Working Memory and Sleep

4.3.1. Effective sleeping time at night and Phonological Working Memory

The examination of the relationship between nocturnal effective sleep duration and working memory, while controlling for the influence of age, reveals that neither the focal predictor variable within the model (comprising total sleep time; t=0.21, p=0.84) nor age (t=-1.03, p=0.31) significantly account for the variance observed in working memory (R-squared = -0.04, F(2,19) = 0.58, p = 0.57). (See figure 11).

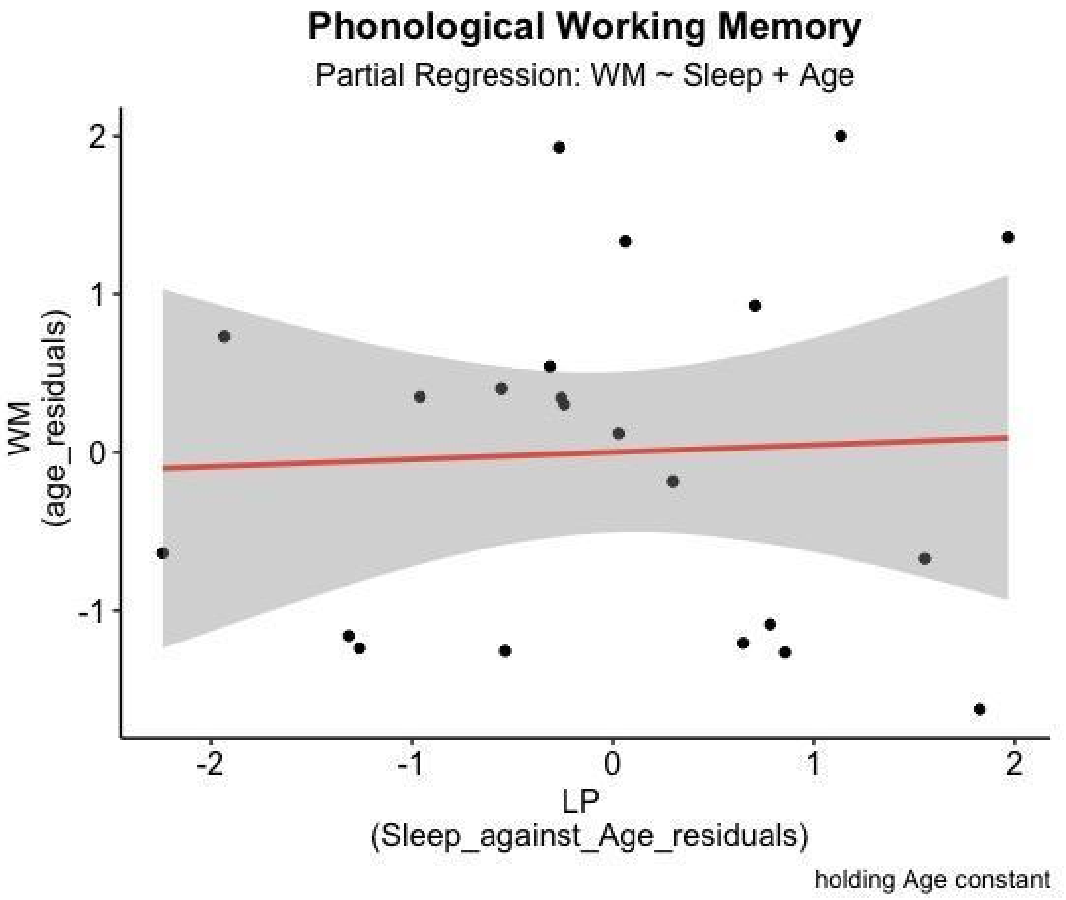

Figure 11. The plot for the partial correlation between working memory and language comprehension. The linear regression generates the red line fit while controlling for age, with the 95% confidence interval boundary represented by the grey area.

4.3.2. Naps during the Day and Phonological Working Memory

In the context of the analysis examining the association between working memory and the frequency of daytime naps, with the age of the children held as a controlled variable, the findings indicate that neither the primary predictor variable of interest within the model (comprising the number of naps; t=0.61, p=0.55) nor age (t=-0.26, p=0.79) significantly elucidate the variability in working memory. Furthermore, the model that includes age as a relevant predictor fails to attain statistical significance, as evidenced by an R-squared value of -0.02, an F-statistic of F(2,19) = 0.74, and a p-value of 0.48 (as depicted in Figure 12).

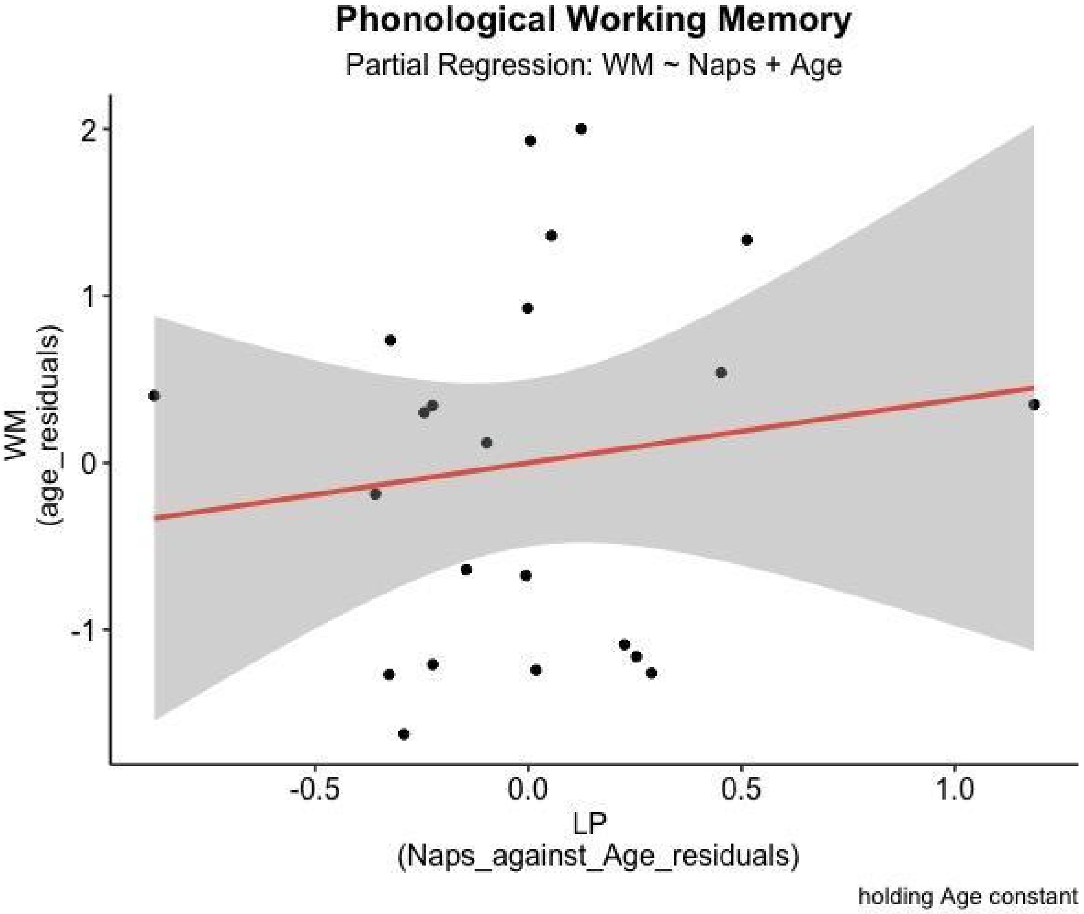

Figure 12- Partial regression plot illustrating the relationship between working memory and number of naps during the day. The linear regression generates the red line fit while controlling for age, with the 95% confidence interval boundary represented by the grey area.

4.3.3. Sleep Efficiency and Phonological Working Memory

The regression analysis, which delves into the connection between working memory and sleep efficiency, with the age of the children considered as a control variable, reveals that neither the primary predictor variable of interest within the model (comprising sleep efficiency; t=0.81, p=0.42) nor age (t=-1.28, p=0.21) substantially contributes to the explanation of the variance observed in working memory. Furthermore, the model that incorporates age as a relevant predictor fails to reach statistical significance, as indicated by an R-squared value of -0.009, an F-statistic of F(2,19) = 0.90, and a p-value of 0.42 (as depicted in Figure 13).

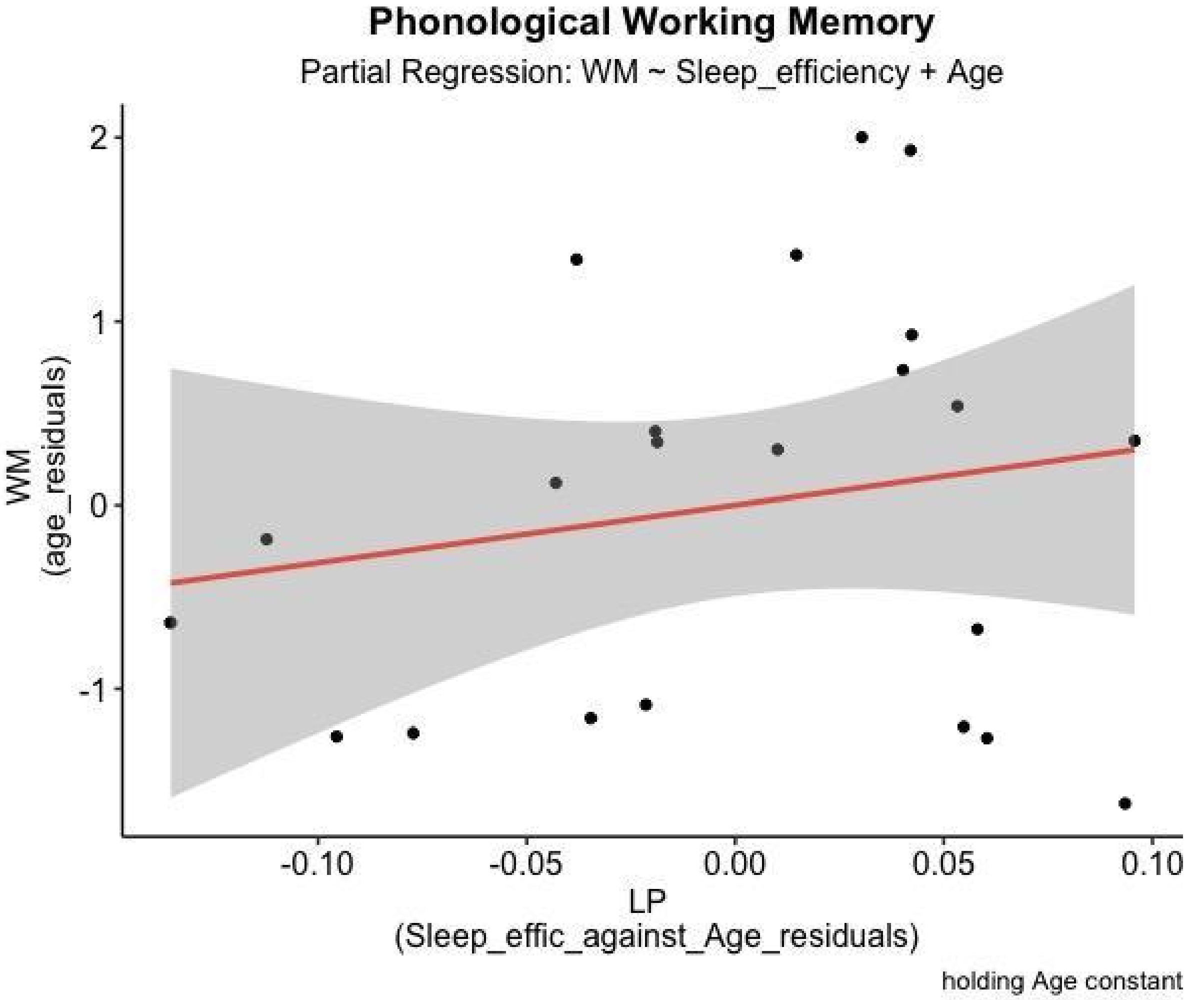

Figure 13- Partial regression plot illustrating the relationship between working memory and number of naps during the day. The linear regression generates the red line fit while controlling for age, with the 95% confidence interval boundary represented by the grey area.

Noticeably, age appears associated with sleep efficiency in this group, however the correlation only approaches significance R 2 = .33, p =.12 (See Figure 14).

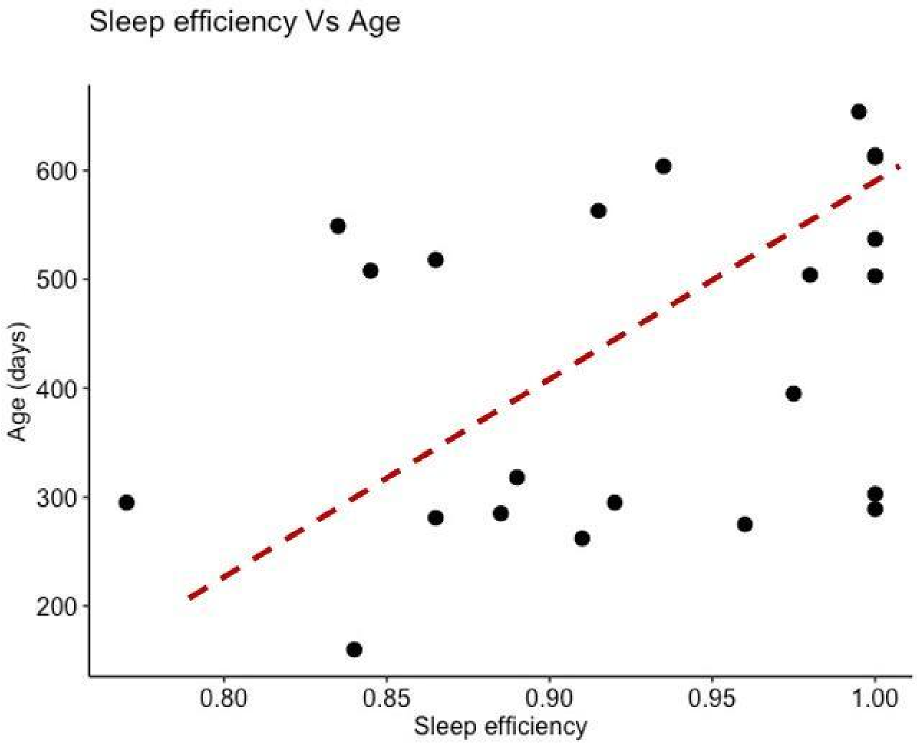

Figure 14. The relationship between sleep efficiency and the age of participants

4.3.4. Sleep Efficiency and Speed of Processing

A Pearson's correlation analysis was carried out in order to investigate the relation between processing speed (Latency of the responses in the ADAM test) and participants' sleep efficiency. The results indicate that this correlation approaches significance in this group, R 2 = .39, p =.07 (See Figure 15).

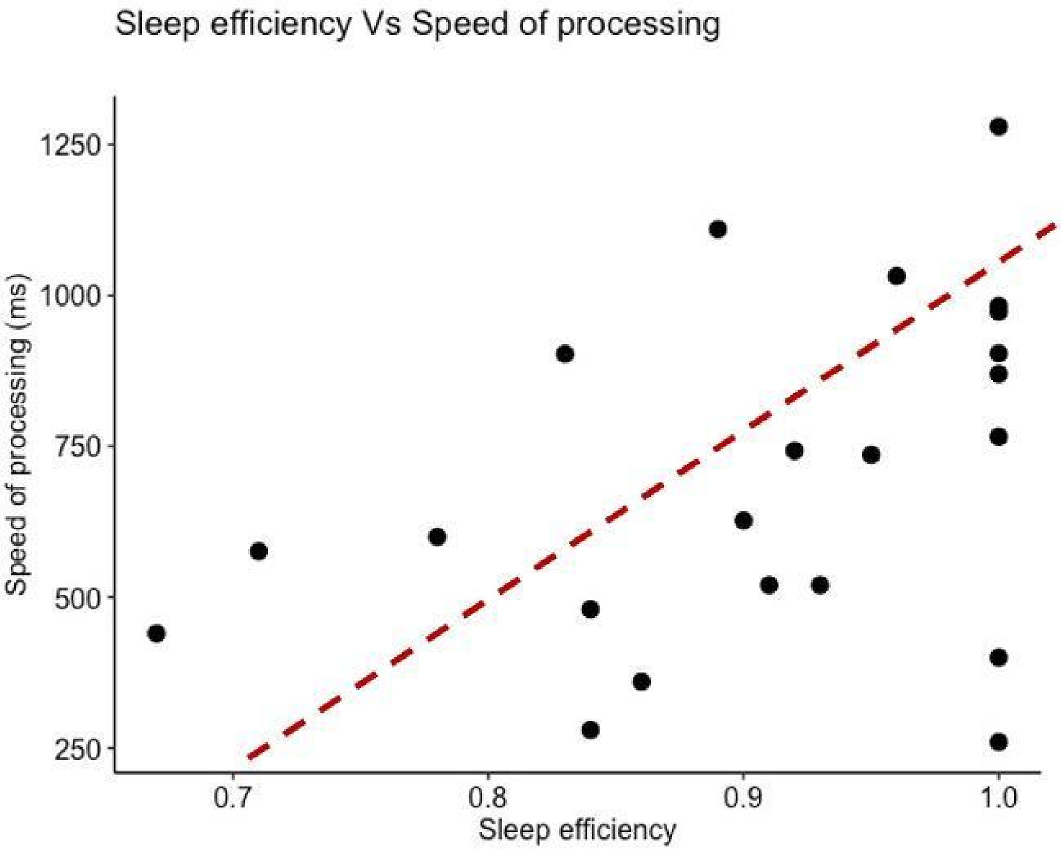

Figure 15. The relationship between sleep efficiency and speed of processing of participants age

CHAPTER 5

Discussion

5.1. Discussion of Key Findings

In the pursuit of addressing our research inquiries, our study embarked on an in-depth exploration of the auditory working memory capacities of a diverse group of infants, ranging from 6 to 25 months of age. This investigative endeavor was facilitated through the meticulous application of the Adaptive Memory (ADAM) experiment, an experimental tool for assessing phonological working memory pre-verbally. This preliminary analysis, designed to unearth the intricacies of phonological memory within this specific age cohort of Turkish infants, has yielded a treasure trove of valuable insights.

Our methodological approach involved administering a series of ADAM tests, the results of which were meticulously scored, with values assigned ranging from 1 to 4 based on the participants' performance. The data analysis led us to the computed mean value for phonological memory span, which stood at 2.44. This result suggests an approximate two-item memory capacity, shedding light on the developmental trajectory of auditory working memory in Turkish infants. Hence, a literature review on previous studies on working memory, suggests that this is one of the first studies addressing phonological working memory capacities in young children, and a truly pioneer study in a Turkish sample.

As we delve into the depths of this initial investigation, it is imperative to recognize the broader significance of our research. This study not only contributes to our understanding of early cognitive development but also offers a unique perspective on the elaborate interplay between auditory working memory and age in infants. Our findings indicate that, within the examined sample, there was no evidence for a substantial link between working memory and age. While there is an apparent trend suggesting a decrease in response latency with increasing age, this trend did not reach the threshold for statistical significance. The lack of significance in this case, given the trend, might be adduced to lack of statistical power (post-hoc effect size =.50). This finding paves the way for further inquiries in the field, emphasizing the importance of continued research efforts in elucidating the complex processes underlying cognitive development during early childhood.

Moreover, our findings prompt a reevaluation of the potential factors that influence phonological memory in infancy. By shedding light on the preliminary aspects of phonological working memory in Turkish infants, we underscore the need for a comprehensive approach to this area of study. This investigation is but a stepping stone in a larger and more complex journey to understand the multifaceted dimensions of cognitive development and its critical role in shaping individual differences in early childhood.

The examination of the relationship between working memory and various aspects of sleep within our research, provides initial insights into the complex interplay among these variables.

Firstly, our analysis of the influence of sleep duration and age on working memory outcomes reveals that neither variable significantly contributes to the variability in working memory performance. In contrast with our findings, Bernier et al. (2013) suggest that elevated proportions of nocturnal sleep, relative to the total sleep duration, at both 12-13 and 18 months emerged as significant predictors of enhanced executive functioning at 18 and 26 months of age. This research also reports that greater percentages of nocturnal sleep at the age of 12 months are indicative of enhanced executive functioning, as exemplified by performance in the WPPSI Matrix Reasoning assessment at 48 months of age. However, as in the present research, no discernible correlation was observed between the overall duration of sleep and the broader construct of general cognitive ability (Bernier et al., 2013). One of the potential factors influencing this difference is dependent measures that were used. For instance, Bernier et al. (2013) tested general intelligence through a standardized test

(WPPSI-III), whereas our study solely tested auitory working memory via a test specifically designed to measure auditory working memory. Furthermore, our findings are different than previous research which found a connection between various sleep measures and cognitive development, with shorter night sleep duration in early childhood linked to lower school-entry cognitive performance and well-regulated circadian sleep at 19 months associated with better cognitive abilities (Horvath & Plunkett, 2015).

Secondly, our exploration of the connection between working memory and the frequency of daytime naps, while controlling for the influence of children's age, indicate that neither the number of daytime naps nor age significantly explains the variance in working memory. Furthermore, the inclusion of age as an influential predictor does not attain statistical significance. Nonetheless, as aforementioned, Horwath et al. indicate that infants who engaged in a post-training nap exhibited enhanced performance in object-word pair learning during the subsequent test trial compared to children who did not nap (2015). Therefore, differently from our findings, Belia et al. (2022) reported in their review, that increased nighttime sleep is linked to enhanced memory for words, and both nighttime sleep and daytime naps may play crucial roles in the maturation of infants' memory. One of the main reasons of the difference between their's and our findings might be that they focus on word learning where semantic related associations are also formed (Belia et al., 2022). Whereas, our research focuses on auditory working memory.

This contrast among the findings highlights the complexity of the relationship between napping, cognitive functions, and age, and it suggests the need for further research to understand these relationships more comprehensively.

In addition, no significant findings were obtained from our regression analysis, which explored the connection between working memory and sleep efficiency, while taking the age of the children into account as a control variable. Neither the primary predictor variable, sleep efficiency, nor the age variable significantly contributes to the explanation of the variance observed in working memory. The model that integrates age as a predictor also falls short of statistical significance. Although statistical significance was not achieved in our analysis, there is research showing that sleep might improve working memory. For instance, Nieto et al. (2010)'s results unveiled significant links between shorter nighttime sleep duration and poorer working memory performance in preschoolers. In addition, Gibson et al. found that sleep efficiency and longer proportions of night sleep were significantly associated with better cognitive problem-solving skills in 11-13 month old infants according to parental reports (Gibson et al., 2012). Thus, while our study did not establish a significant relationship, it is essential to consider the cumulative evidence in the field that suggests a potential role for sleep in augmenting working memory.

Lastly, our Pearson's correlation analysis explores the association between processing speed, indicated by response latency in the ADAM test, and participants' sleep efficiency. The findings suggest that this correlation approaches statistical significance within this specific group, with a notable R-squared value and a marginally significant p-value. This trend emphasizes the potential importance of sleep efficiency. This finding is in line with aforementioned research by Stickgold & Walker (2013) as they suggest that while sleeping, our brains undergo transformations that turn unstable initial memory traces into more enduring ones, improving the effectiveness of stored memories, but sleep deprivation can disrupt these processes, impairing memory retention and recall. Moreover, our finding are not only in agreement with the results of Paavonen et al. (2010)'s study but also extend their findings, since their study was carried out in 8 year old children. In their research, they suggest that insufficient sleep duration and poor sleep quality are associated with decreased processing speed in cognitive evaluations in 8 year old children. Furthermore, they also found an apparent connection between diminished sleep quality and compromised attention and reaction time which aligns with our observations regarding response latency (Paavonen et al., 2010).

In conclusion, our research sheds light on the intricate relationships between working memory, sleep, and age. While the initial analyses did not yield statistically significant associations, the complex interaction of these variables necessitates further investigation to uncover potential moderating factors and better understand the dynamics at play in working memory performance.

5.2. Theoretical and Practical Implications

Theoretical Implications

The results of our preliminary study investigating the auditory working memory capacities of infants aged 6 to 25 months, employing the Adaptive Memory (ADAM) experiment, offer valuable theoretical and practical implications across various domains. These implications stem from the multifaceted aspects of our research, including the evaluation of sleep duration, daytime naps, sleep efficiency, and age on working memory outcomes.

Recent research challenges the traditional view that sleep merely stabilizes existing memories, highlighting its active role in memory consolidation and learning. Rasch and Born (2013) emphasize the importance of sleep in facilitating cognitive function. Hahn et al.'s 2019 study further supports this notion, showing that sleep significantly benefits word pair memory retention in adolescents, but its impact appears to be less pronounced in children, suggesting that the relationship between sleep and memory may depend on an individual's developmental stage. In essence, sleep plays a proactive role in memory processes, particularly in adolescents, by preserving newly acquired information and enhancing memory, while its effect on children might differ.

Hence, our findings of an approximate two-item memory capacity in Turkish infants within the specific age cohort of 5-26 monh olds is in line with these instances, as it challenges and enrichs existing cognitive development theories. This data opens up new avenues for theoretical exploration in this field. Researchers and theorists may need to reevaluate and expand upon their existing frameworks to accommodate the intricacies of auditory working memory in infants.

Furthermore, our study contributes to the broader field of developmental psychology. It offers valuable insights into the developmental trajectory of auditory working memory in infants and the role of various factors, such as sleep, age, and daytime naps. These insights can be used to refine existing developmental theories, paving the way for more nuanced perspectives on early cognitive development.

Underscoring the complex relationship between sleep, age, and working memory, the theoretical implications of our study extend to sleep and memory interaction theories, which may need to consider the unique dynamics of auditory working memory in infants. Future research in this area may explore how these interactions evolve as children grow older.

Finally, the theoretical implications of our findings provide a foundation for the development of early intervention strategies. The importance of aligning activities and interventions with infants' cognitive abilities, as highlighted by our study, can influence the theoretical foundations of early childhood education. It encourages a shift towards age-appropriate materials and experiences that consider infants' working memory capacity.

Practical Implications

Our findings, which established an approximate two-item memory capacity in this specific age cohort of Turkish infants, hold significance for early intervention strategies. Educators, caregivers, and child development specialists can benefit from this knowledge by tailoring activities and interventions that align with infants' cognitive abilities.

Developers of educational materials and resources can utilize our results to design age-appropriate materials that cater to the observed memory capacity. This can enhance the effectiveness of early learning programs and contribute to better cognitive development in infants.

The improvement procedures for diagnostic and assessment tools needed for infants in the 6 to 25-month age range can also benefit from our study. Healthcare professionals can utilize this information for early identification and monitoring of developmental issues related to auditory working memory. This can lead to timely interventions and improved developmental outcomes.

Parents and caregivers can benefit from a better understanding of the cognitive abilities of infants within this age group. Armed with knowledge about their child's auditory working memory capacity, they can create stimulating and developmentally appropriate environments that enhance early cognitive development.

Researchers in the field of cognitive development can build upon our findings to explore further the intricacies of auditory working memory in infants. The complexity of the interplay between sleep, age, and working memory, as observed in our study, calls for continued research and consideration of additional moderating factors.

Finally, healthcare professionals specializing in child development and clinical assessments may need to adapt their theoretical frameworks to encompass the insights from our study. The diagnostic and assessment tools used for infants within the 6 to 25-month age range should consider auditory working memory capacity as an essential factor.

In conclusion, our research not only contributes to practical applications but also significantly enriches the theoretical landscape of cognitive development, especially in the context of auditory working memory in infants. As we continue to explore the complexities of cognitive development, our study serves as a theoretical cornerstone for further investigations, offering new perspectives and insights into this critical phase of early childhood. These theoretical implications expand our understanding of auditory working memory and its role in cognitive development, ultimately benefiting researchers, theorists, and professionals working in child development and education.

5.3. Limitations

The study presented in this paper encompasses several noteworthy limitations that warrant consideration. To begin with, it is essential to recognize the limited sample size comprising only 22 Turkish infants, which emerges as a crucial restriction. Given the potential lack of representativeness of this sample in relation to the broader infant population, the ability to generalize the findings is compromised. In order to establish stronger and conclusive outcomes, it would be advantageous to incorporate a larger, more diverse sample size in future investigations.

Another factor of significance to acknowledge is the cultural and linguistic context of the participants. The exclusive focus on Turkish infants restricts the applicability of the results to infants from diverse cultural and linguistic backgrounds. It is crucial to note that infants originating from different regions and backgrounds may manifest varied outcomes. Consequently, attempting to generalize the existing outcomes beyond the particular context of Turkish infants presents a challenging endeavor, specifically due to the potential influence of cultural and linguistic factors, which may lead to different outcomes for infants from diverse backgrounds.

Moreover, the evaluation of sleep and its impact on working memory is restrained by the reliance on parent-reported sleep diaries. The potential biases or inaccuracies inherent in parental reporting may influence the reliability of the data concerning sleep records.

Enhancing the accuracy and validity of the findings can be achieved by employing more objective measurement tools, such as polysomnography, in forthcoming research endeavors.

Additionally, the ecological validity of the study may be compromised due to the online implementation of the ADAM experiment. The use of online platforms might not fully replicate real-life scenarios and the natural auditory stimuli that infants encounter. Consequently, the applicability of the study's findings to everyday situations could be undermined. Conducting experiments within more ecologically valid settings, such as in-person laboratory environments, would bolster the ecological validity of the research.

In light of these limitations, it is crucial to acknowledge and consider them when interpreting the results of this exploratory study. Addressing these limitations in future investigations will contribute to a more comprehensive understanding of the topic at hand.

5.4. Recommendations for Future Research

Firstly, future research should focus on refining and tailoring educational materials based on the observed memory capacity in infants. Investigating how different content and formats affect cognitive development can help create even more effective early learning programs.

Secondly, an aim to enhance diagnostic and assessment tools for infants in the 6 to 25-month age range should be another focus of future studies. Improvements in the early identification of auditory working memory-related developmental issues can lead to more timely and precise interventions, ultimately resulting in better developmental outcomes.

Thirdly, researchers of this area can delve into the development of education programs for parents and caregivers to help them better understand the cognitive abilities of infants within this age group. These programs could provide guidance on creating stimulating and developmentally appropriate environments to further enhance early cognitive development.

Furthermore, to gain a deeper understanding of the complex interplay between sleep, age, and working memory in infants, future research should delve into additional moderating factors usch as technology and screen time. Exploring these interactions can provide a more comprehensive picture of auditory working memory development in early childhood.

Lastly, expanding on the theoretical landscape of cognitive development, particularly within the context of auditory working memory in infants, should be a priority for future research. Investigating the underlying mechanisms such as rehearsal and retrieval, and what factors affect these mechanisms is very important in gaining more insight about this topic. Moreover, investigating the extent of neuronal activities behind these mechanisms and the brain regions involved in these processes provide valuable insights into the theoretical aspects of cognitive development during this critical phase of early childhood.

In summary, these recommendations encompass a wide range of areas, from educational materials and diagnostic tools to parental education and theoretical exploration, all of which contribute to advancing the field of early childhood auditory working memory development.

CONCLUSION

In conclusion, this study aimed to investigate the correlation between auditory working memory performance and sleep quality in Turkish infants while also laying the foundation for future research exploring the influence of cultural factors on auditory working memory development and sleep patterns. The findings from our analysis did not reveal a statistically significant association between working memory and the age of the participants. Additionally, our examination of latency data showed an average latency, with a noted inverse correlation with the age of the child; however, this correlation did not reach statistical significance.

Furthermore, our analysis did not identify significant relationships between working memory and variables such as sleep duration, daytime naps, and sleep efficiency, even when accounting for age as a control variable. Nevertheless, these findings only imply that there is need for more research with higher number of participants as some studies show significant relationships between sleep and working memory performance (Rasch & Born, 2013).

While the study's statistical outcomes did not demonstrate significant associations, they serve as a foundation for future research to expand our understanding of the intricate relationship between auditory working memory and sleep quality in Turkish infants. The pursuit of such research can provide valuable insights into the developmental trajectory of these cognitive functions and the influence of cultural factors on this process.

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APPENDIX

Uyku Gunlugu

Gun1:
(GECE VE GUNDUZ TUM UYKULARI ICIN)
1. bebeginizi uykuya siz mi yatirdiniz yoksa kendi kendine mi uykuya daldi?_____________
2. uyudugu saat :
3. uyandigi saat:
4. bebeginizi siz mi uyandirdiniz kendi kendine mi uyandi?__________________________
5. uyudugu yerin kosullari nasildi? (kisaca bahseder misiniz? Ornegin odasinda uyudu, arabada uyudu gibi)

Saglik bilgisi:
1.Cocugunuzun uykusunu bozacak olagandisi bir durum var mi?______________________
2 Uyurken horladi mi?____
3.Uykuyu bozabilecek diger nedenler var mi? (ornegin dislerinin cikmasi, normalden fazla aglamasi, usutme, son gunlerde rahat nefes alamamasi gibi)_________________________

Gün 2:
1. bebeginizi uykuya siz mi yatirdiniz yoksa kendi kendine mi uykuya daldi?_____________
2. uyudugu saat :
3. uyandigi saat:
4. bebeginizi siz mi uyandirdiniz kendi kendine mi uyandi?__________________________
5. uyudugu yerin kosullari nasildi? (kisaca bahseder misiniz? Ornegin odasinda uyudu, arabada uyudu gibi)

Saglik bilgisi:
1.Cocugunuzun uykusunu bozacak olagandisi bir durum var mi?______________________
2 Uyurken horladi mi?____
3.Uykuyu bozabilecek diger nedenler var mi? (ornegin dislerinin cikmasi, normalden fazla aglamasi, usutme, son gunlerde rahat nefes alamamasi gibi)_________________________

Gün 3:
GECE VE GUNDUZ TUM UYKULARI ICIN)
1. bebeginizi uykuya siz mi yatirdiniz yoksa kendi kendine mi uykuya daldi?_____________
2. uyudugu saat :
3. uyandigi saat:
4. bebeginizi siz mi uyandirdiniz kendi kendine mi uyandi?__________________________
5. uyudugu yerin kosullari nasildi? (kisaca bahseder misiniz? Ornegin odasinda uyudu, arabada uyudu gibi)

Saglik bilgisi:
1.Cocugunuzun uykusunu bozacak olagandisi bir durum var mi?______________________
2 Uyurken horladi mi?____
3.Uykuyu bozabilecek diger nedenler var mi? (ornegin dislerinin cikmasi, normalden fazla aglamasi, usutme, son gunlerde rahat nefes alamamasi gibi)_________________________

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