Critical Review:
How does sleep impact language development in children under 5 years of age?

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This critical review examines the impact of sleep on language development in infants and young children. A literature search using computerized databases was completed and yielded nine articles meeting the inclusion criteria. Study designs include: longitudinal studies, randomized clinical trials, a mixed quasi-experimental study and a single group post-test only study. Overall, findings are highly suggestive that more mature sleep patterns and longer sleep duration are associated with better longitudinal language outcomes. The evidence regarding the short-term outcomes of sleep, such as a daytime nap, on language learning is less conclusive. Several studies are suggestive of a relationship between a period of sleep after language exposure and language generalization and/or retention. Recommendations for clinical practice and future research are provided.

INTRODUCTION

The National Sleep Foundation (2015) recommends a minimum of 10-14 hours of sleep for children five years of age and under. However, a review of the research indicates that actual sleep time is consistently about 40 minutes less than sleep recommendations (Matricciani et al., 2012). Classroom nap opportunities are also becoming devalued and eliminated due to increased curriculum demands (Kurdziel et al., 2013).

Sleep is known to play an important role in adult learning, cognitive function and consolidation of memories (Stickgold, 2005), while sleep deprivation has a negative impact on cognitive function (Pilcher et al., 1996). Even short naps have been shown to benefit memory encoding in adults. One study (Lahl et al. 2008) showed that adults were able to recall a list of recently learned adjectives significantly better after an ultra-short nap of only 6 minutes, compared to those who remained awake for the same amount of time.

A meta-analytic review (Dewald et al., 2010) found that sleep duration, sleep quality and sleepiness were all related to school performance in children and adolescents, with greater effect sizes found in populations of younger children. Less is known about the impact of sleep on learning in infants and preschool children. Dahl (1996) reported that toddlers often respond to insufficient sleep with irritability, crankiness and short attention span. With this in mind, it can be predicted that sleep deprivation and language outcomes will be negatively correlated in young children.

Speech-language pathologists (SLPs) are often advised to ask about a child's sleep patterns during the initial assessment. However, without knowing the impact of sleep on language, little information can be drawn from these responses. A critical review of the literature will inform SLPs of both the short-term and long-term impacts of sleep on language development. This will influence the development of the child's profile as well as recommendations for parents. Furthermore, if daytime naps are shown to benefit learning, this will have implications for both caregivers and the education system.

OBJECTIVES

The primary objective of this paper was to critically evaluate existing literature regarding the impact of sleep on language learning in children under 5 years of age. The secondary objective was to provide recommendations for clinical practice and future research.

METHODS

Search Strategy

A variety of computerized databases, including Western Libraries, PubMed and Scholars Portal were searched using the following terms: (sleep) OR (sleep consolidation) AND (language acquisition) OR (language learning) AND (infants) OR (preschoolers) OR (children). The search was limited to articles written in English between 2000 and 2016. Other articles matching the selection criteria were obtained from the reference lists of previously searched studies.

Selection Criteria

Studies selected for inclusion were required to investigate the impact of any duration of sleep on language learning, retention or generalization. There were no limits on outcome measures used, as long as they were related to language. Participants needed to be five years or younger when the study began. Studies that exclusively examined a special population (e.g. Down Syndrome) were excluded.

Data Collection
Results of the literature search yielded nine articles that met the selection criteria. The articles included: three longitudinal designs, four randomized clinical trials, one nonrandomized clinical trial, and one single group study.

RESULTS

Natural Language Studies
Longitudinal Designs

Dearing, McCartney, Marshall and Warner (2001) conducted a longitudinal study to examine associations between parental reports of sleep and wakefulness at 7, 19 and 31 months of age with cognitive and language outcomes at 24 and 36 months. Sleep patterns of 62 children were measured via phone interviews with caregivers at each time point. Standardized assessments were used to measure cognitive and language outcomes. Several child and mother covariates were measured, including maternal education level, parenting beliefs, and perceptions of the child's temperament. Appropriate statistical analyses revealed that circadian sleep regulation increases over time and is significantly and positively associated with cognitive and language outcomes, after controlling for maternal and child characteristics.

Gold standard cognitive and language measures were used; however, no reliability scores were reported for these measures. The authors recognized the limitations of using subjective self-report as the sole measure of sleep and wakefulness. The study is limited by a relatively small sample size (N=62), which may impact generalization. This study provides highly suggestive evidence that more rhythmic sleep is associated with higher cognitive and language outcome scores in children under three years of age.

Dionne et al. (2011) investigated if there is an association between parental report of sleep consolidation at 6, 18 and 30 months and language outcomes at 18, 30 and 60 months in a cohort of 1029 twins from the Quebec Newborn Twin Study. The authors also examined the genetic/environmental etiology. Child and mother characteristics such as child birth weight, Apgar score and temperament, maternal education and first language, and family income were assessed using medical records, self-report and interviews with mothers. Language skills were assessed using gold-standard assessments. Infant sleep was measured based on maternal self-report. A subset of 618 children, who completed language assessments at both 18 and 60 months of age, were divided into three groups based on the presence of a language delay: children without delays (n=385), children with transient delays (n=93) and children with persistent or late onset delays (n=140). Language delay was determined using appropriate criteria.

Appropriate statistical analyses revealed that sleep ratios at 6 and 18 months were negatively correlated with subsequent language outcomes, indicating that children with more mature sleep patterns had better language skills up to three and a half years later. However, same-age sleep ratios and language outcomes were not correlated. Results indicated that the six-month sleep variable is mainly influenced by genetics, whereas the 18-month sleep variable is better explained by environmental factors.

Strengths of this study include a large sample size with detailed description of population demographics and data collection, consideration of multiple cofounding variables, and study of development over a relatively wide age range. The authors acknowledged the following limitations: lack of generalizability beyond twin population, non-objective measure of sleep ratios and the correlational nature of the study. These results provide compelling evidence for a relationship between sleep ratios at 6 and 18 months and language outcomes in a cohort of twins.

Touchette et al. (2007) examined if sleep is an independent risk factor for behavioural and cognitive outcomes in a longitudinal study with 1492 families from when the children were five months until six years of age. The study was conducted as part of the Quebec Longitudinal Study of Child Development. Sleep measures were obtained via parental self-report at multiple time periods. A non-standardized questionnaire was completed by the mothers to assess behaviour, including: hyperactivity-impulsivity (HI), inattention, and daytime sleepiness. A gold standard assessment of receptive language was completed at five years and the non-verbal intelligence subtest of a standardized assessment was completed at six years. Multiple potentially cofounding psychosocial variables were also measured.

The participants were divided into four groups based on their developmental sleep patterns: short persistent (n=109), short increasing (n=88), 10-hour persistent (n=920) and 11-hour persistent (n=712). Appropriate statistical analyses indicated that shorter sleep durations were associated with lower receptive language scores, lower non-verbal intelligence scores and higher HI scores. The authors found that low income, low parental education and immigrant status of the mother were associated with lower receptive language scores.

All components of the study were described in sufficient detail. Strengths of this study include a large sample size and consideration of cofounding variables. It was the first study to investigate developmental sleep duration patterns throughout childhood. Although a subjective measure of sleep quantity was used, the authors referenced studies that found high agreement between parental report and actigraphy. Results may not generalize beyond this population (i.e. mainly non-immigrant, Caucasian families) or language area (i.e. receptive). Overall, this study provides compelling evidence that short sleep duration is correlated with increased risk of low receptive language scores at school entry.

Artificial Language Studies
Randomized Clinical Trials (RCTs)

Gomez, Bootzin and Nadel (2006) conducted a between group RCT with 48 healthy 15-month old infants to determine if language abstraction is improved by a period of sleep after exposure to an artificial language. The language required infants to track sequential dependencies between the first and third words in a string of three words. Infants were randomly assigned to three groups: experimental nap, control nap, and no nap. All infants were familiarized with the language for 15-minutes in the home and then tested four hours later in the lab using the head turn preference procedure. During the test phase, infants who stayed awake looked longer at familiar strings whereas, infants in the experimental nap condition looked longer at stimuli consistent with the first test trial (whether familiar or novel). This looking difference in the nap group suggests that these infants were able to apply the language rule to similar but non-identical stimuli from familiarization.

The stimuli and study phases were well described. A recorded voice of the artificial language was used to ensure consistency. The study is limited by sample size and insufficient description of population demographics, recruitment and statistical analyses. Overall, this study provides somewhat suggestive evidence abstraction may be facilitated by a nap after language exposure.

Simon et al. (2016) conducted a mixed RCT on 37 full-term 6.5-month-old infants to determine if sleep supports retention of statistical language acquisition. Infants were randomly assigned to an experimental nap or yoked control wakefulness group. Infants were familiarized with four bi-syllabic artificial words and then tested 15 minutes after awaking from a nap. Polysomnography and a near-infrared camera were used to record infants sleep behaviour and the head turn preference procedure was used to test retention. Infants in the nap group looked longer to part-words during the first block and words during the second block, with no such trial differences found in the wakefulness group.

Strengths include well-described statistical procedures with analysis for outliers, inclusion of a yoked control group, use of an objective sleep measure and high inter-coder reliability. However, results should be interpreted with caution due to the sample size, and marginally significant effects found in the nap group. This study provides somewhat suggestive evidence of a relationship between sleep after learning and the retention of statistical word segmentation.

Werchan and Gomez (2014) conducted a between group RCT with 30 healthy 2.5-year-olds to examine if generalization of word learning is facilitated more by a period of sleep or a period of wakefulness. During the familiarization phase children learned artificial labels for three novel noun categories across different contextual backgrounds. Participants, who were all habitual nappers, were randomly assigned to a nap condition, an immediate test condition or a no-nap condition. Children were tested four hours later using a four-alternative forced-choice recognition test. The no-nap group performed significantly better than both the immediate control and nap conditions.

Strengths of this study include appropriate statistical analyses, an objective outcome measure, use of recorded voice for consistency, inclusion of a baseline control group and consideration of time of day as a cofounding variable. The study is limited by sample size and lacked description of recruitment and demographics of participants. Overall, this study provides compelling evidence that a period of wakefulness, instead of sleep, facilitates generalization of word learning in 2.5-year-old children. The authors proposed that sleep may consolidate both relevant and irrelevant details, limiting the ability to generalize. They also suggested that sleep may only enhance generalization if there is some degree of learning at the time of immediate test, which did not occur in this study. Future research is needed to explore these theories.

Friedrich, Wilhelm, Born and Friederici (2015) conducted a mixed RCT to determine if language generalization in infants occurs via a passive process (i.e. forgetting of irrelevant details) or an active (i.e. reorganization of memory). A total of 90 infants between 9 and 16 months of age with German speaking parents were assigned to either a nap or no-nap condition. During the training phase, all infants were exposed to object-word pairings with (a) specific word

meanings (b) general category meanings, and (c) no meanings. During the test phase, approximately 1.5 hours later, infants were exposed to both correct and incorrect object-word pairings. Event related potentials (ERPs) were recorded during both phases. N200-500 and N400, which are known to indicate the presence of lexical-semantic knowledge, were used as an indication of word learning. Infants in both groups acquired only the specific word meanings during the training phase. During the test phase, infants who napped showed evidence of remembering the specific word meanings, as well as the ability to generalize to novel category exemplars.

All procedures and appropriate statistical analyses were well-described. Effect sizes were not well reported. An objective baseline measure was used during the training phase to ensure groups did not differ in word learning prior to testing. A sufficient sample size was used; however, results may not generalize beyond this population. The results are highly suggestive that sleep may facilitate generalization in infants through an active process of reorganization of memories.

Non-Randomized Clinical Trial

Williams & Horst (2014) used a mixed quasi-experimental study design to explore the impact of repeated storybook reading and a daytime nap on word learning in 48 three-year-old children. Children were quasi-randomly divided into four groups (different story nap, same story nap, different story no-nap, same story no-nap) based on whether they habitually napped. Children were read the same story three times or three different stories. In each book, the children heard two novel words, four times each. Children were tested using a four-alternative forced-choice procedure at four time periods (immediately, 2.5-hours, 24-hours and seven days after the training phase). Story comprehension and storybook enjoyment were measured as potential cofounding variables. Results revealed that children performed best in the same story nap condition. Children in the same story no-nap and different story nap conditions performed the same. Children in the different story no nap condition had the lowest performance.

The study used appropriate statistical analyses and had both high inter-coder reliability and ecological validity. The study had a small sample and used a p-value of 0.1. There were more girls compared to boys in both nap conditions, which should be considered when interpreting results. Overall, this study provides highly suggestive evidence that both story repetition and sleep are correlated with word learning in three-year-old children. Of the two, sleep appears to be a stronger predictor of long-term retention.

Single Group Post-Test Only Study

Hupbach, Gomez, Bootzin and Nadel (2009) conducted two follow-up studies to the study conducted by Gomez and colleagues in 2006. The authors examined (1) if the effect of sleep on language abstraction can be detected 24 hours after exposure; and (2) if the abstraction effect is dependent on an immediate nap after exposure. Both studies tested 24 fifteen-month-old infants 24 hours after exposure to the artificial language. In study one, all children napped within four hours of exposure and in study two, all children stayed awake for at least four hours. All other procedures were the same as the study described above (Gomez et al., 2006). Results indicated that the abstraction effect can be detected 24 hours later, but only if a nap follows shortly after exposure.

The study is limited by a small sample size and limited description of statistical procedures. Any period of sleep less than 30 minutes was considered "no nap." It could be argued that even short naps (e.g. 20 minutes) may benefit learning, as even short periods of sleep have been shown to support memory encoding in adults (Lahl et al., 2008). The results are somewhat suggestive of a relationship between napping shortly after language exposure and abstraction of non-adjacent dependencies 24 hours later.

DISCUSSION

Taken together, results from the longitudinal studies are highly suggestive that more mature sleep patterns and longer sleep durations in early childhood are associated with better language outcomes up to five years later. Results from the artificial language studies are less conclusive. All artificial studies, except one (Werchan and Gomez., 2014), provide suggestive evidence of a positive relationship between daytime sleep and language learning.

Three of the artificial language studies used the head-turn preference procedure as an outcome measure. Although, this is a commonly used procedure when studying language learning in infants, there are limitations that need to be recognized. The procedure is based on the assumption that infants turn towards more interesting events. However, both a novelty preference and a familiarity preference have been observed (Bergmann, Bosch, Fikkert, & Boves, 2013). When looking times differ, it may be more appropriate to conclude that infants detected a difference between stimuli, rather than concluding that learning has

occurred. Secondly, there is no consistent criteria set for the degree of head turn required (e.g. 30 degrees vs. 70 degrees) (Bergmann et al., 2013). Finally, the procedure relies on an observable behaviour in order to infer internal mental processes. Despite these limitations, it can be appreciated that it is difficult to test language learning and cognitive functions during infancy.

The results from the literature review suggest that sleep may impact language learning differently depending on the age of the child. For example, it appears as though sleep facilitates generalization in children under 16-months of age (Friedrich et al., 2015; Gomez et al. 2006), whereas wakefulness facilitates generalization of word learning in children 2.5-years and older (Werchan & Gomez., 2014). Gomez & Edgin (2015) proposed that this shift in sleep-dependent learning across early childhood may be a result of changes in early brain development, particularly within the hippocampus. Future research is needed to explore this hypothesis.

The impact of sleep may also be dependent on the area of language used as an outcome measure. The studies reviewed each measured different language areas including, receptive and expressive language, word retention and/or generalization and statistical language learning. Results may be task specific, therefore, it would be beneficial to conduct studies that examined a wider range of language outcomes using objective, standardized assessments. Future studies should consider not only sleep duration, but also other sleep characteristics such as quality and type (e.g. rapid eye movement, slow-wave sleep).

Dearing and colleagues (2001) suggested that infants may develop more rhythmic sleep patterns via a child-regulated or a caregiver-regulated pathway. Research should consider if one of these pathways results in more favourable language outcomes. Furthermore, research should examine if sleep consolidation can be improved through parenting practices and if so, whether this will influence higher level skills such as language learning.

Future Research Considerations

In addition to the considerations described above, it is recommended that future research:

a) Employ study designs that lend stronger levels of evidence and incorporate larger, more representative sample sizes.
b) Explore how sleep influences language generalization differently across early development and the potential influence of brain-based changes.
c) Take baseline measures of participants to ensure that cognitive and language abilities do not differ prior to the study.

CLINICAL IMPLICATIONS

The natural language studies provide clear evidence for a correlation between sleep and long-term language outcomes. With this in mind, speech-language pathologists can appreciate the importance of asking about sleep problems in young children during the initial assessment. Furthermore, they can interpret sleep abnormalities as a possible risk factor for persistent or late onset language delays (Dionne et al., 2011). Caregivers, educators and educational policy-makers should consider the positive impact that napping may have on language learning.

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