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Review

# Novel word learning in older adults: A role for sleep?

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ABSTRACT

Sleep is an offline period during which newly acquired semantic information is transformed into longer-lasting memories. Language acquisition, which requires new word learning and semantic integration, is preferentially benefitted by a period of sleep in children and young adults. Specific features of sleep (e.g., sleep stage characteristics) have been associated with enhanced language acquisition and generalization. However, with increasing age, even in healthy individuals, sleep quality and quantity decrease. Simultaneously, deficits in word retrieval and new word learning emerge. Yet it is unknown whether age-related alterations in language ability are linked with alterations in sleep. The goal of this review is to examine changes in language learning and sleep across the lifespan. We consider how sleep detriments that occur with aging could affect abilities to learn novel words and semantic generalization and propose hypotheses to motivate future research in this area.



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## 1. Introduction

Language is the system by which limitless ideas are conveyed through a limited set of spoken or written units. Humans are

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unique in their development of expansive lexicons that continue to evolve throughout the lifespan. Learning new words and incorporating them into the lexicon is a strong determinant of academic achievement in children and adolescents (Marzano, 2004). Importantly, word learning is not unique to development. The learning of new vocabulary into adulthood is imperative for succeeding in a number of areas, such as within the scientific community (Hayes, 1992) and may challenge the ability of older adults to acquire the technical terminology in evolving occupations. Additionally, new language learning has been associated with structural and functional changes within the brain in both younger and older adults (see review: Li, Legault, & Litcofsky, 2014). As such, a better understanding of the ways in which new words are learned can benefit individuals across a range of ages and disciplines.

Novel word learning and language acquisition are benefited by sleep in young adults and children. The complementary learning systems framework is often cited as the process through which new words are learned (Davis & Gaskell, 2009). In this model, the hippocampal system encodes novel words rapidly, while the neocortical system is involved in the more gradual integration of the novel words into the existing lexicon (Frankland & Bontempi, 2005; O'Reilly & Norman, 2002). During an 'offline' period of disengagement, such as during a period of sleep, information is transferred from hippocampal to neocortical storage, protecting the information from interference, and gradually becoming independent of hippocampal activation (Diekelmann & Born, 2010; Spencer, 2013).

However, sleep (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004), language learning (Nyberg, Bäckman, Erngrund, Olofsson, & Nilsson, 1996), and sleep-dependent consolidation of newly learned information (Wilson, Baran, Pace-Schott, Ivry, & Spencer, 2012) all change across the lifespan, and each are decremented by aging. As such, it is likely that the role of sleep in novel word learning is affected by aging. The aim of this review is to examine the role of sleep in language acquisition across the lifespan and how this might change in older adulthood.

## 2. Sleep and language

### 2.1. Sleep and language acquisition

Sleep benefits memory (see review: see Stickgold, 2005), particularly for declarative information (Gais & Born, 2004). For example, when sleep follows learning of either semantically related (Plihal & Born, 1997) or unrelated (Wilson et al., 2012) word-pairs, memory retention across a delay containing sleep is greater than when compared to retention across an equivalent period of wake.

The majority of research examining the relationship between sleep and novel word acquisition has been conducted in developmental and young adult populations. For example, napping improves novel word retention and generalization in infants aged 9 and 16 months of age (Friedrich, Wilhelm, Born, & Friederici, 2015; Horváth, Myers, Foster, & Plunkett, 2015). Similarly, fifteen-month old children exposed to an artificial language were better able to abstract and generalize language rules to novel stimuli following a nap compared to performance following an equivalent interval of wake. Interestingly, however, there were no significant nap-related differences on veridical recall (Gómez, Bootzin, & Nadel, 2006; Hupbach, Gomez, Bootzin, & Nadel, 2009). In 3-year-old children, napping led to an increased ability to identify novel objects with nonsense word names in a children's book. This design mimicked the way in which children are often naturally exposed to new words. Importantly, this nap-related improvement in word retention was long-lasting, still present seven days later (Williams & Horst, 2014). Likewise, a sleep benefit can be seen in foreign language learning in late adolescence, a time in which many students are exposed to new language learning through their education. English-speaking high school students (17 years of age) were better able to remember English-German vocabulary word pairs when nocturnal sleep followed learning compared to when daytime wake separated learning and recall (Gais, Lucas, & Born, 2006).

Recently, work from our lab demonstrated that overnight sleep also benefits the veridical memory involved in novel word learning in young adults (Kurdziel & Spencer, 2015). In this study, college students (18–30 years of age) were asked to learn rarely used word-definition pairs from their native English language. This paradigm allowed us to probe the way in which new vocabulary is typically added to the lexicon in higher education. Using novel English words for native English speakers also allows for pre-existing language rules to be used during encoding. Following 12 h that contained sleep or 12 h of daytime waking, students were shown the definitions of the encoded items and were asked to recall the correct word. Sleep protected memory for the novel words, whereas waking led to significant forgetting, thus supporting the role of sleep on veridical memory for novel words in young adults.

### 2.2. Sleep and lexical integration

In addition to being critical for language acquisition, sleep has also been shown to be important for integrating new words into the lexicon. In one such study, children between the ages of 5 and 12 years encoded novel words that shared syllables with known English words, and were tested on a lexical competition task following a delay. In the lexical competition task, if the new words (e.g. *biscal*) became part of the lexicon, they should compete with, and slow the recognition of, the existing phonological counterparts (e.g. *biscuit*). Lexical competition was only observed in the condition in which sleep followed encoding of the novel words, suggesting that sleep is necessary to integrate novel words into the existing lexicon (e.g. Henderson, Weighall, Brown, & Gareth Gaskell, 2012). Similar sleep-dependent lexical integration in young children has been observed across a number of different paradigms. For instance, when real novel words were used in place of artificial language (e.g. the novel *hippocampus* competing with the existing *hippopotamus;* (Henderson, Weighall, & Gaskell, 2013), sleep is, again, essential for competition effects. Likewise, when novel artificial words (e.g. *daffodat* competing with *daffodil*) were learned as part of a storybook, and were thus encoded through a more naturalistic incidental exposure, lexical competition was greatest following sleep (Henderson, Devine, Weighall, & Gaskell, 2015).

The role of sleep in lexical development is also supported by studies in young adults. Dumay and Gaskell (2007) demonstrated that overnight sleep benefited both veridical recall of newly learned artificial words, as well as the incorporation of those words into the existing lexicon. It is important to note, however, that novel word integration can be achieved in the absence of sleep, but only with repeated additional exposures across the day to both the novel words and the associated existing lexical counterparts (Lindsay & Gaskell, 2013).

Language acquisition and integration is complex, and multiple processes are necessary for successful learning. As such, the role of sleep in language learning must be examined from all perspectives. Generalization of newly acquired language rules is one such aspect of language acquisition. Fenn, Nusbaum, and Margoliash (2003) assessed the role of sleep in the generalization of phonological categories across varying acoustic patterns. A naturalistic spoken language learning task was used such that training on a subset of artificial monosyllabic consonant-vowel-consonant words