THE EFFECTS OF SLEEP FOR GENERALIZATION IN 12 MONTH-OLD INFANTS

By

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Abstract

Since infants over-specify acoustic details, segregate exemplars by talker voice, and need enough variation to generalize across exemplars, it has been questioned whether sleep would promote generalization in 12-month-old infants even after they have been exposed to multiple speakers. In order to investigate this question, we placed infants in either a nap or non-nap condition to test whether they were able to generalize only after napping. Sleep was expected to result in retention of the grammatical pattern over acoustic details such as talker voice. These results were not expected for infants who did not nap after being familiarized with a grammatical structure and who remained awake between training and testing for an equal amount of time as the infants who napped. The average looking times between grammatical structures were compared to determine the presence of any significant variation. The current data show non-significant generalization in both nap and no nap conditions. Even after outlier elimination the data still demonstrate non-significant results. Tasks completed during wake hours in both nap and no nap conditions are considered as limitations.
When individuals learn language, many components are taken into account, including grammatical patterns and the many different acoustic details perceived in the speaker’s voice. These details include the speaker’s gender, age, emotional status, and accent. Although these components are considered in adults when learning a language, evidence shows that infants’ representation of language is acoustically over-specific (Newman, 2008). However, over-specification of the acoustic details of different voices prevents infants from generalizing across speakers. Generalization can be defined as the ability to extract information during learning such that the learner can recognize a previous learned pattern in new stimuli. No generalization occurs because infants are unaware of the crucial grammatical information that is needed to retain a language’s grammatical rules. The retention of irrelevant acoustical information prevents infants from extracting grammatical patterns.

Studies have also found that 18-month-old infants can generalize grammatical patterns if they receive sufficient variability (Gómez, 2002). For instance, infants come to learn that certain words such as “the” and “a” are paired with nouns, and that other words such as “was” and “is” are paired with verbs. They learn this connection only after they have received enough auditory input. By being exposed to enough variability of the grammatical patterns among words, infants learn what information is needed to generalize. However, when infants are presented with multiple voices, even with enough variability in grammatical patterns, they cannot generalize across acoustic details. In fact, recent studies have found that infants actually separate exemplars by talkers’ voices (Gonzales, Gerken, & Gómez, manuscript in preparation).

In Gonzales et al., 12-month-old infants were presented with a set of grammatical phrases created with an artificial language. In the first experiment, infants were familiarized to a set of grammatical phrases projected by one female voice but were later tested with a different female
voice for their ability to discriminate new grammatical from ungrammatical phrases. The dependent measure was the difference in listening times between grammatical and ungrammatical phrases. The results indicated that infants were able to generalize and looked more towards the familiarized grammar, even with a novel voice at test. This is believed to have happened because the infants received enough variability in lexical formation to extract a stable pattern (Gonzales, Gerken, & Gómez, 2013). However, during experiment 2, infants were familiarized with half of the examples required for generalization in one talker voice and the other half in a different voice. If infants are able to integrate over the strings across talker voice they should generalize during test, but infants were not able to do so. These results demonstrated that infants separate exemplars by talker voice. Because each voice contains insufficient variability to extract the grammatical pattern infants are unable to extract the grammatical rules.

Taking the above findings into consideration, studies conducted with 15-month old infants demonstrate that naps are essential in promoting retention of a grammatical pattern (Gómez, Bootzin, & Nadel, 2006). When 15-month olds were tested after a nap, they were able to generalize to new strings, whereas infants who did not nap did not generalize. This study suggested using a test paradigm of exposing infants to a learning experience before a naturally occurring nap and then testing them for generalization afterwards. Therefore, we ask here whether sleep will allow generalization even after infants are exposed to multiple talkers. Evidence suggests that sleep contributes to forgetting of specific details of the stimulus but retention of the grammatical rule (Gómez et al., 2006), therefore we predict that infants exposed to the two-talker condition of Gonzales et al. (in preparation) will generalize after sleep, but not when they remain awake for an equal amount of time.
In order to test this hypothesis, a two-condition design was composed in which infants in one group will nap, while those in the other group will not. All of the infants will be randomly selected to listen to either grammar 1 or grammar 2 of an artificial language. Infants in each condition will be tested after a three-four hour delay depending on the napping patterns of the infants. Average looking times will be measured between both grammars.

**Method**

**Participants**

The study currently consists of 23 12-month old infants between 11.5 and 13 months of age with no record of health issues. In order to be eligible for participation, all infants included in the data had a birth term greater than 37 weeks. Infants who weighed less than five pounds eight ounces were also excluded. Foreign language exposure was controlled; infants with more than 10 hours of foreign language were discarded from the data. From the forty-four total participants, nineteen were excluded from the data due to a variety of reasons such as ear infections (n= 1), out of range (n=5), below birth term and weight criteria (n=4), fuss outs (n=3), equipment failure (n=1), incomplete participation (n=1), family history of language therapy (n=2) and incomplete naps (n=2). All infants were recruited from the Tucson, Arizona area, including the suburbs of Vail and Sahuarita. Infants were recruited at events such as the Tucson Annual Baby Fair, Festival of Books and through local pediatricians. Each participant was familiarized in their home and then tested at the Child Cognition lab at The University of Arizona. After discarding the infants above in the nap condition, there were 7 males and 7 females ($M=12.07$ $sd=0.42$), and in the No Nap condition, 7 males and 4 females ($M=12.10$ $sd = 0.49$). About 9 more infants need to be tested, 3 in the nap and 6 in the no nap condition, and future discards are expected to occur. Any participants whose listening time to grammatical
versus ungrammatical phrases were 2 or more standard deviations from the mean were eliminated from the data.

**Materials**

The study uses an artificial language that follows a grammatical pattern mimicking patterns in English sentences such as “The boy was running.” In this sentence, “the”, a determiner, is paired with the noun “boy”, and “was”, an auxiliary, is paired with the verb “running”. To represent this pattern, two monosyllable a-words (alt, ush) were paired with (X) words and two other monosyllable b-words (ong, erd) were paired with (Y) words. The words in the Y category are all monosyllabic (frin, lorse, narf, thrive, brez, drak,) while X categorical words are disyllabic (freevit, gelshry, masgrin, shrappo, bevit).

Two sets of grammar patterns were constructed. Grammar one (G1) followed the pattern aX bY, and grammar two (G2) consisted of aY bX. G1 phrases are presented as aX bY and bY aX and G2 as aY bX and bX aY. For each grammar, two randomized lists of 72 sentences with 3 unique aX and bY phrases were assigned to Talker 1 whereas the other 3 unique aX and bY phrases were assigned to Talker 2. For each language, XX Talker 1 and XX Talker 2 blocks were alternated to create a total exposure period of 8 minutes. Figure 1.0 further displays the language design.
Figure 1.0: From Gonzales (2013). The 2-talker condition from Experiment 1 in this figure demonstrates the stimuli and the interleaving of talker by block used during familiarization in the present study.

**Familiarization stimuli:**

During the home visit, the infants were assigned randomly to listen to either G1 or G2 (see description of the procedure below).

**Test Stimuli:**

Infants were tested with strings from G1 and G2 on separate trials where the illegal grammar violates the pattern from familiarization. If familiarized to G1, aXbY the illegal pattern is aYbX, violating the infant’s grammatical rule.

**Procedure**

Each infant is randomly assigned to either a nap condition or a no nap condition. For infants in the no nap condition, an experimenter visits the infant’s home at a time where they would be expected to stay awake for a time period of three or four hours. In the nap condition,
the infant’s home is visited 30 minutes before their routine nap where a nap is defined as sleep duration of more than 30 minutes. For both of the above conditions, during the home visit, a trained experimenter exposes the infants to either G1 or G2. The grammar exposed during familiarization becomes the infant’s legal grammar. With the usage of the audio program DMDX, the infant listens to an 8-minute clip and is allowed to play with non-musical toys throughout this time. Parents are instructed to eliminate any talking and any other audio stimulation. After the exposure to the grammatical phrases, an active-watch is placed on the infant’s ankle to record activity throughout the following three or four-hour period. Consent, sleep questionnaire and general information forms are all filled out during the home visit.

After a time period of three to four hours, the infants visit the lab and are tested using the Head Turn Preference Procedure. The test booth contains three lights, two speakers and a video recorder. The infant sits on the mother’s lap, facing a center light between lights to the infant’s right and left at the infant’s ear level. At the beginning of each trial, the center light blinks in order to obtain the infant’s attention. Once the infant looks at the center light, the right or left light begins to blink. It is not until the infant turns her head or eyes at least 30 degrees towards the blinking light that the grammatical string of words are played. Both new grammatical and ungrammatical phrases are played during test, assigned randomly to either the right light or left light on each trial. The stimulus continues to play on each trial until the infant turns away from the blinking sidelight for more than two seconds. Infants are tested across a series of 16 trials, where the grammatical and ungrammatical stimuli alternate randomly. In another room, an experimenter records the infant’s looking times and the infant’s direction of looking. A debriefing is conducted at the end of the experiment for the parent. Any infant in the no nap condition who slept for more than 30 minutes between testing and training was considered a
discard. Infants in the nap condition had to sleep a minimum of 30 minutes to meet the criterion for taking a nap.

**Results**

A t-test was utilized to measure significance between conditions. Based on prior work (Gómez et al., 2006) we hypothesized that the effect of sleep on generalization would be to contribute to the forgetting of the irrelevant acoustic details in favor of the grammatical pattern, but not if they remain awake for an equal amount of time.

The current data suggests a non-significant relationship for the nap condition, \( t(13) = 0.69, p > .05 \). A non-significant difference in the average looking time is seen between the legal grammar and illegal grammar in the nap condition (Legal: \( M = 8.04 \) sec, Illegal: \( M = 8.58 \) sec). In the no nap condition, infants who did not nap between familiarization and test, a t-test also shows a non-significant relationship between grammars, \( t(10) = 0.93, p > .05 \). The difference in average looking times did not vary significantly, with legal (\( M = 9.26 \) sec) and illegal (\( M = 9.14 \) sec) trials. After the elimination of data 2 points 2 standard deviation below or above the mean, the results change slightly. A t-test for the nap condition, \( t(13) = 0.71, p > .05 \), still showed a non-significant relationship. However, average looking time between legal and illegal grammar changed with legal (\( M = 7.74 \)) and illegal (\( M = 7.36 \)). In the no-nap condition t-test demonstrated \( t(10) = 0.45 \) with legal (\( M = 8.62 \)) and illegal (\( M = 9.57 \)). Figure 1.2 shows datum with the outliers removed. Although the null results do not change with outlier elimination the results seem to display an increase to attention towards the legal grammar in the nap condition. The no-nap condition still displays no difference. Studies have shown that infants are believed to direct their attention to stimuli they are more familiar with, but this effect is not reflected in the current data. In the No Nap condition, with no significant difference between the average looking times
we infer that infants are not generalizing. Regardless of condition, the infants do not forget all
the necessary details such as the talker’s voice or gender and do not generalize. Without the
forgetting of acoustic details in sleep, the infants in this condition are not generalizing across the
speakers.

Figure 1.1 displays results in both nap and no nap conditions. Red bars represent the illegal
grammar’s average looking time and the blue bar looking times to the legal grammar.
Figure 1.2 graphs the average looking times between legal and illegal grammars between nap and no nap condition after outlier removal.

**Discussion**

Infants failed to generalize in either condition. A possible explanation for the failure to observe a nap effect, reflected in a difference in average looking times could be accounted for by the activities in each condition. In the Nap condition, infants are familiarized 30 minutes before their nap, where they are expected to nap for more than 30 minutes in the 3 or 4-hour delay. Infants in the No Nap condition are visited at a time when they remain awake and are interacting with others for four hours. The difference in interaction amongst both conditions varies. It could be argued that the infants in the No Nap condition are being exposed to more environmental stimuli than the Nap infants. However because infants in the Nap condition do not nap throughout the whole four hours, they also are exposed to environmental stimuli. Thus both groups receive external input that could interfere with generalization.
Future studies could be conducted to analyze whether 12 month olds have sufficient slow wave sleep in their naps to benefit from synaptic downscaling (Tononi & Cirelli, 2006). Throughout a day, individuals interact with the environment, create new memories, and make decisions. During wakefulness synaptic energy, capacity, and strengths are maximized by the total information received in a day. It is during slow wave sleep that synapses are thought to return to baseline and prepare for a new day of learning (Tononi, & Cirelli, 2006): here weak links are either downscaled or eliminated completely. Thus, while infants nap, synaptic homeostasis should eliminate weakly linked acoustic details such as the gender of the person, but retain the grammatical rule, because this occurs in every stimulus regardless of talker voice, allowing infants to generalize despite the different speakers. However, if there is insufficient slow wave sleep during a nap, the cerebral cortex would not have the space or energy required to retain new information. This process is essential during development in infants, because it is during this time that a vast amount of synaptic growth is occurring. During development the connections between strong synaptic neurons are stored for long-term processing. If infants vary in the quality of their slow wave sleep, and thus the degree to which they can benefit from synaptic downscaling, it may be that infants with greater levels of slow wave sleep benefit more whereas infants with less slow wave sleep benefit less. We are not able to test this hypothesis with the current results because we did not use polysomnographic (PSG) sleep recording. In future studies PSG should be conducted on infants in a nap condition in order to measure slow wave activity.

Another study that could be conducted following the design of the current study consists of a sleep reactivation component. Sleep reactivation activates neural processes during sleep if participants are exposed to a replay of the familiarized stimulus played when they were awake.
By producing an overlap of the similar memory it allows for a stronger connection between synapses (Lewis & Durrant, 2011). This concept could be applied to infants in the Nap condition to see the effects of sleep reactivation enable strengthening of the pattern and generalization across multiple speakers.
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References


