THE ROLE OF SLEEP AND VARIABILITY IN THREE YEAR OLD VERB LEARNING

By

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Abstract

At a young age children are able to acquire new verbs constantly. Two factors influencing this ability are of particular interest to this paper: variability and sleep. Previous studies have shown that toddlers can extend a verb to a novel actor when variability at training is minimal (Maguire et al. 2008) and that naps improve generalization (Gomez et al. 2006). Two groups of children (those who nap regularly and those who do not) were taught two new non-word verbs during training. One or four actors performed the new verbs. After training, participants either took a nap or stayed awake. Twenty-four hours later, during the test phase, participants saw two clips played side by side simultaneously. Each clip was of one of the verb learned. Participants were then asked to point to the girl who is, for example, “blicking”. Children who napped after training did better on the Memory Test than those who did not. No group differences in regards to sleep after training were found for the Generalization Test. We can conclude from this that naps may boost memory of new verbs, if not the ability to generalize them.
Introduction

It seems obvious to note that children learn language by interacting with the people in their lives. However, it is more difficult to describe the particular components of those interactions and the surrounding environment that impede or promote language acquisition. One area of particular interest is verb learning in toddlers. When children first begin to speak, they use mostly nouns (Gentner, 1982). It is not until about two years of age, when children first put words into sentences, that verb usage explodes (Justice, 2010). This paper studies two major factors in toddler verb acquisition: exemplar variability and sleep.

Maguire, Hirsh-Pasek, Golinkoff, and Brandone (2008) explored the influence of variability on toddler verb learning. They proposed two theories. First, that a variety of examples allow children to extract the details of the action from the exemplars. That is, multiple representations help children overcome their bias towards objects (Behrend, 1990). The same word is used for each slightly different context. Therefore, children are forced to highlight the commonalities across actors – which, due to the differences among actors, must be the action. Maguire et al. (2008) then posit a second theory. They explain that less variability could also be beneficial to a toddler’s ability to learn verbs. Showing them the same example multiple times allows them time to become familiar with the objects involved. Once they are familiarized, they can concentrate on the action at hand.

The first explanation seems more plausible given the following information. Gómez (2002) showed that children and adults need high variability in order to learn a grammatical structure. Perry, Samuelson, Malloy, and Schiffer (2010) found that 18-month-old infants were able to best learn a new object category when the training examples were highly variable. Richtsmeier. Gerken, Goffman, and Hogan (2009) varied the frequency of non-words that they
exposed four-year-olds to. They found that children remembered and produced the non-words the best when they were frequent and spoken by multiple speakers. This indicates, again, that variability is useful for word learning.

The key, however, may lie in the stimuli used in each of these studies. The first study focused on grammatical structure – which, while similar to verb learning, is not the same as learning the meaning and understanding the usage of individual verbs. The second study taught toddlers nouns and the final focused on meaningless syllable strands. None of these studies taught verbs. This is important in the analysis of this support because verbs are different. Verbs are learned after nouns (Maguire, 2006) in part because they are more difficult to learn (Gentner, 2006). Nouns, especially concrete object names, have transparent semantic meanings. It is clear that pointing at a furry, four-legged house pet with pointy ears indicates “cat.” This transparency is usually absent for verbs. In a study done Gillette, Gleitman, Gleitman, and Lederer (1999), adult participants watched videotapes of mothers playing naturally with their children. Key nouns and verbs were beeped out of the audio. Each time participants heard a beep, they were asked to make their best guess as to the actual word. Participants selected the correct noun 45% of the time. Verb conjectures were correct only 15% of the time, indicating that guessing verbs from environmental input is more difficult than correctly identifying the noun (Gillette et al., 1999). This is likely due to a lack of transparency in verb definitions. If it is difficult for adults to guess verbs in a familiar context, it is even more difficult for children to learn verbs in novel contexts.

The Maguire et al. (2008) study alluded to earlier concluded that minimal variability is better for toddler verb acquisition. This is surprising considering the extensive literature in support of variability’s advantage for word learning. Their design, however, had one major flaw.
Participants learned two new verbs, each paired with a novel action. At test, they were asked to identify one of the novel verbs by selecting between an action they had just learned and one they had never seen before. Most 3-year-olds can reason that when asked to identify something, they should pick the item they have seen before. It goes to reason then that these participants were not displaying new knowledge but rather identifying a familiar object. This would be easier after being familiarized in the one variant condition. They saw the same person doing the same action four times making it easier to remember than four unique girls completing the action in slightly different ways. Although their study does not seem to show that the toddlers learned the label for the action, it does make an important contribution. Maguire et al. (2008) showed that an action was easier to remember if it was completed multiple times by the same person. Therefore, low variability may aid verb learning by making it easier to remember the action. The next step would be to remember the label.

The variability debate is confounded by the sleeping schedules of unique children. Many studies have documented the positive effects of sleep in both children and adults. A literature review by Rebecca Gómez and colleagues (Gómez, Newman-Smith, Breslan, & Bootzin 2011) highlights sleep development across the lifetime. Sleep cycles begin to develop in the womb in order to facilitate neural growth. Infants sleep 12 to 17 hours in 3 to 4 hour cycles throughout the day. As the infant grows into an elementary school student, daily naps transition from multiple to one to none and sleep becomes concentrated in one large block at night. Regular and efficient sleep schedules lead to higher cognitive functioning in infancy. As the child grows, sufficient sleep remains positively correlated with cognition. A study with toddlers showed that those who were not sleeping as much as their peers performed worse on a standardized vocabulary assessment (Touchette et al., 2007). Studies with high school students have shown that going to
sleep earlier and staying asleep longer correlates with higher grade point averages (Wolfson and Carskadon, 1998). Finally, research with adults has shown that nighttime sleep enhances memory consolidation (e.g. Stickgold, 2005).

This research demonstrates the cognitive benefits of regular and sufficient sleep. What is of interest to the topic at hand is how sleep affects word learning. One study by Gomez, Bootzin, and Nadel (2006) showed that napping after learning helped 15-month-old infants abstract a general grammatical rule from auditory stimuli. Half of the infants were presented with grammar A and the other half with grammar B. Grammar B had the same rule as grammar A (that the first syllable was always paired with the third) but with different syllable pairings. Half of the infants napped following training and half did not. At test four hours later, both groups were presented with both grammars and their looking times were measured. Those children who did not nap showed a preference for the grammar they were trained with. The children who did nap in between training and test preferred whichever grammar they heard first at test – demonstrating that they remembered the rule (but not the specific syllables) and were able to apply the rule to whichever string type they encountered first.

A follow-up study conducted in 2009 by Hupbach, Gomez, Bootzin, and Nadel used the same procedure but tested the infants after twenty-four hours instead of four. They found that infants needed to nap within four hours of training in order to remember anything during test the next day. Both groups slept through the night and had at least one nap, making their total sleep comparable. Sleeping a certain amount of hours during that 24 hour period was not enough. The infants needed a nap within four hours to show evidence of learning from day one on day two. Those infants that napped generalized the rule and showed preference to the first grammar they heard on day two.
Together these studies show that infants need to nap regularly in order to retain new information (in this case, language). Additionally, these naps help boost generalization of new knowledge rather than boost the specifics. These studies also demonstrate the benefit of a twenty-four hour gap between training and test. Testing a full day after training ensures that most participants receive the same amount of sleep. Therefore any significant effects can be attributed to the nap schedule rather than wakefulness.

Sleep helps older children, teenagers, and adults retain new knowledge. However, less is known about the effects of sleep on children between the ages of 2.5 and 5. This is a period of transformation from many naps to none. How does this transition affect learning? A recent study by Lam, Mahone, Mason, and Scharf (2011) showed some interesting trends. First, they noticed that the more hours a child spent in a daytime nap the fewer hours they spent asleep in the evening – meaning that most children slept the same percentage of the day. If they slept less at night they made up for it with a nap. They also found that naps correlated negatively with scores on a standardized vocabulary test. The researchers hypothesized that the cessation of naps indicated a cognitive maturation. They also noted that nighttime sleep might be more beneficial for toddler development than sleep at naptime. Since daytime naps detract from total nighttime sleep they may in fact impede cognitive development. These findings seem contrary to previous research as well as the results of the present study. Alternatively, they may describe a period of transition out of necessary napping.

Finally, an in press paper by Werchan and Gómez (2013) found that naps did not help toddlers generalize novel noun labels to new settings. In fact, toddlers could better identify the newly learned object if they did not sleep following training. This finding opposes results from adult sleep research. The authors hypothesized that it may be due to an inability of toddlers to
inhibit their attentions towards extraneous detail. Sleeping then amplifies their memories of both consequential and inconsequential information. Not sleeping allows them to forget what they don’t need. These findings work in conjunction with Lam et al. (2011) as both indicate that less napping may have cognitive benefits.

In summary, it seems that variability helps language acquisition – for nouns especially. Verbs, however, are unique from nouns in that they are acquired later and are more difficult to learn. Finally, children have a bias towards objects. Therefore, actions may be easier to identify if performed repeatedly by the same person – allowing the child time to move beyond the objects in the scene. The present study hopes to confirm the results of Maguire et al. (2008) and expand on them by using a more rigorous test. We hypothesize that the one variability condition will be easier to learn than the four variability condition. Additionally, this study examines the effect of sleep on verb learning. With the support of the infant and adult literature, we hypothesize that those children who sleep after a nap will do the best. By including both children who nap regularly (nappers) and those that do not (no nappers) we hope to address conjectures posited by Lam et al. (2011). With their paper as evidence, we hypothesized that those children who are no longer napping will perform better than children who still nap regularly in conditions where both groups are required to stay awake after learning, as their transition to not napping may be indicative of greater cognitive maturation and more adult-like consolidation. Ultimately, the results of this study will inform the toddler word learning literature by providing further evidence for variability and sleep.
Method

Participants

This study included two groups of children 36-38 months old ($M = 37.11$, $SD = 1.01$). The first group napped on a regular basis (four or more days a week). The second group, at the time of the study, was not napping regularly. Naps were taken on three or fewer days of the week or not at all. Participants were excluded due to technical difficulties ($n = 2$), pre-existing language impairment ($n = 1$), age ($n = 3$), scheduling issues ($n = 2$), lack of English ability ($n = 1$) or failure to respond during the training phase ($n = 8$). At the time of submission for this paper there were 22 children (13 females, 9 males) in the napper group and 9 children (6 females, 3 males) in the no napper group.

Participants were randomly assigned to the one or four exemplar condition as well as the sleep or wake condition. In the one exemplar condition, the child saw the same girl perform one action four times and a second girl perform a second action four times. In the four exemplar condition, the participant saw four girls perform the first action one time each and four new girls perform a second action one time each. For the sleep condition, children slept within 3.5 hours of training ($M = 1.94$). For the wake condition, children watched the training video at a time when they would not sleep for at least 5.5 hours ($M = 6.91$). For example, they were familiarized shortly after waking up in the morning and did not sleep until their nap in the early afternoon.

Apparatus

Each child partook in two sessions, one at their home and one in lab. For this reason, we used two apparatuses. During the home visit, each child was trained on a Dell laptop. Training videos were presented using Windows Media Player and sound was played from built-in speakers. During the lab visit, participants were seated in a chair 46 inches from a 40” x 29 7/8”
screen. The experimenter sat directly behind the child and recorded their responses. The child could not see the experimenter and therefore was not influenced by any accidental behavior on the experimenter’s part. A video recorder fixed above the screen recorded the child’s actions. These videotapes were later coded for accuracy by a blind coder.

Materials

Each participant was trained with movies created with Adobe Premiere 6.5. The movies each featured one of eight different female actresses performing one of two novel, intransitive actions. For the first action, the actor lunged forward and pointed her arm towards the camera. The second action required the actor to place her hands on her knees and cross them back and forth. During training, the participants heard an audio-recorded female voice label each action. They saw one actor perform one action at a time (see Figure 1). At test, the same voice asked the child to point to one of two actions shown side by side on the screen (see Figure 2).

Procedure

Training and test phases were separated by a twenty-four hour period. On the first day, the experimenter visited the child in their home. The child watched a video that introduced them to the novel verb labels (see Figure 1 and Table 1).

On the second day, the child was tested in the Child Cognition Lab (see Apparatus, above). Testing consisted of point practice and three unique tests. Prior to entering the booth, a brief pointing introduction occurred. The child was asked to point to something in the playroom, either their mom or a nearby toy. This confirmed that the child was comfortable enough with the experimenter to listen to their requests. Upon entering the booth, three practice trials were administered. On the screen three pairs of common pictures were presented, one pair at a time. The experimenter then asked the child to point to a certain picture. The first two trials were
nouns (e.g., car, ball) while the last was a verb (e.g., running, flying). Children were required to successfully complete two out of the three trials in order to remain in the study. Eight children were discarded due to failure of the practice phase.

Following the practice phase, a picture of smiling babies was displayed on the screen in order to refocus the child’s attention. After this, the first test phase – the generalization phase – began. Two videos were displayed side by side on the screen (see Figure 1). Both showed a novel female actor performing one of the two actions the child learned the previous day. The recorded female voice then asked the child to point to one or the other verb. Four trials, two for each verb, were presented in randomized order. Additionally, the appearance of each girl on one side or the other was balanced. Each trial was 13 seconds long and was followed by a picture of a smiling baby. As the picture was displayed, the female voice asked the child, for the first time, to find blicking or rooping. While the video played, she asked a second time (See Table 2 for the script).

Following a silent attention getter, the second test phase began. It ran exactly the same as the first but with different stimuli. This time the two girls were familiar. They performed the same action they did during the training video the previous day. This served as a check for the first test. While the child may or may not have been able to generalize to novel actors, they should be able to match the new word with the girl who they first attached it to during training. Alternatively, seeing familiar girls may serve as reminder of what they learned on the first day.

After another silent attention getter, the final test phase began. This was a replication of Maguire et al. (2008). Again, the auditory stimuli were presented in the same fashion and both actors were novel. This time, however, one actor performed an action the child had never seen before. The child, therefore, saw a novel girl performing a familiar action next to a novel girl
performing a novel action. This should be the easiest of the three tasks. Whether or not the child was able to connect the word to a certain action, they should be able to distinguish between an action they have seen before and one they have not. This test is by far the simplest of the three. Poor performance on this third test reflects a lack of learning on the first day.

Results

Each of the three tests consisted of four questions. A response was considered accurate if the child pointed to the correct side of the screen. Responses were then tallied out of four. A child could score a 0%, 25%, 50%, 75%, or 100% on each test. Therefore, at the conclusion of the study, each child had three percentile scores. Because two options were present for each test trial, chance was 50% (see Fig. 3 for a summary of results).

Due to unequal group sizes between nappers and no nappers, we analyzed the groups separately. The nappers were analyzed using a 2 (Sleep After Training: yes or no), x 2 (Variability: one or four actors), x 2 (Gender: male or female) ANOVA to determine which group would best be able to generalize what they learned on day one to a novel situation. A second 2 (Sleep After Training: yes or no), x 2 (Variability: one or four actors), x 2 (Gender: male or female) ANOVA was conducted to determine group differences of performance on the Memory Test. A final 2 (Sleep After Training: yes or no), x 2 (Variability: one or four actors), x 2 (Gender: male or female) ANOVA analyzed group differences on the Maguire Replication Test. The ANOVAs examining the Generalization Test and the Maguire Replication Test revealed no significant differences among our independent variables: Sleep After Training, Variability, and Gender. Only The Memory Test revealed significant effects. First, we found an effect of Sleep After Training, such that the sleep kids ($M = .69, SE = .076$) showed greater retention scores than the wake kids ($M = .43, SE = .075$; $F(1,22) = 5.923, p < .03$). Second, there
was an effect of Gender, such that females \( (M = .692, SE = .064) \) scored higher than males \( (M = .389, SE = .084; F(1,22) = 5.020, p < .05) \). While these results show a difference in groups, they do not indicate whether the higher performing group learned from the training videos. In order to determine whether or not the sleep group learned, we performed t-tests for the napper group’s performance against chance on the Memory Test. We found that the sleepers performed above chance \( (t(11) = 2.46, p = .032) \) and the wake kids did not \( (t(10) = -1, p = .34) \).

After analyzing the napper group, we performed a \( 2 \) (sleep after training: yes or no), \( x 2 \) (variability: one or four actors), \( x 2 \) (gender: male or female) ANOVA for the no nappers. As with the first ANOVA, this was performed once for each of the three dependent variables: the percentage of correct responses for the Generalization Test, the Memory Test, and the Maguire Replication Test. The ANOVAs examining the Generalization Test, the Memory Test and the Maguire Replication Test revealed no significant differences between Sleep After Training, Variability, or Gender.

Although no significant results were found between groups on the Generalization Test, we wanted to determine if any of the groups were learning. A group might not significantly outperform the other, but they might still retain something. In order to determine which groups performed above chance on the Generalization Test, six additional t-tests were performed for each of the six unique groups: Napper Sleep 1var, Napper Sleep 4var, Napper Wake 1var, Napper Wake 4var, No Napper Wake 1var, and No Napper Wake 4var. Those children in the napper sleep 1var condition performed significantly above chance \( (t(5) = 2.739, p = .04) \). The rest of the participants did not. Finally, a t-test comparing the Napper Wake children against chance was also insignificant.
Discussion

This paper hoped to explain how variability and sleep affect toddler verb acquisition. Although previous research into language acquisition mostly defines variability as useful, specific work in verb learning found the opposite (Maguire et al., 2008). Following this previous work in verb acquisition, we hypothesized that limited variability at training would help generalization the most. Our results supported this hypothesis. The only group that showed evidence of generalization was those nappers who took a nap after training and were trained with only one actor. While this is some evidence for the usefulness of minimal variability in word learning, it is limited. Two other groups were also trained with only one actor per verb and they did not show evidence of learning. Therefore, we cannot look at variability alone. We must also discuss sleep’s effect on learning.

We hypothesized that sleeping immediately after training would best aid learning. Our results indicate that napping after training boosts performance on the memory task with nappers in the nap group showing better retention than nappers and non-nappers in the wake groups. Nappers in the one variability group who napped performed significantly better on the generalization test than those who did not nap. This indicates that sleeping after exposure to new information leads to the extraction of a verb-action relation, which boosts retention, and generalization of that knowledge. This may also explain the lack of an effect of sleep on the generalization test in the four variability napper nap group. If during the nap, all details from the training are consolidated, generalization would be difficult – if not impossible. This is consistent with the findings of Werchan and Gómez (2013). They found that napping impeded the generalization process because toddlers remembered all the details (both necessary and extraneous). Unlike their findings, a period of wake in our study did not statistically improve
generalization – regardless of variability. However, anecdotally, those children who nap regularly but stayed awake after training generalized above chance in the four-variability condition ($M = .65, SE = .127$). The lack of significance in this result is due mostly to lack of participants in this condition. If more participants improve this result, it could mean the following. Sleep boosts retention of all details. The four variability condition is then aided by a period of wake that allows the child to forget the details and remember the action.

Taken together, the results from the napper nap and napper wake groups suggest that if children are able to extract a relation (one variability condition) they both remember and can generalize that relation the next day. Encountering variability in the four variability condition does not appear to aid extraction of the relation (as reflected by poor generalization in the nap group). However, wake may contribute to forgetting of relevant details so that children in this condition do show a benefit 24 hours later. A caveat is that children in this group do not show comparable performance on the memory test. Thus, additional data will be necessary for drawing final conclusions.

Finally, we hypothesized that those children in the wake condition who usually nap would do worse than the non-nappers. Due to uneven group sizes, this comparison is difficult to make. As group sizes increase and even out in sample size, a more accurate analysis will be possible. At the moment we have a few significant results and some trending data. As the group sizes increase we hope our results become more significant. This will allow for a more complete analysis of the data.

Our final test was a replication of Maguire et al. (2008). This final test served as a basic memory check for participants. We would expect that those children who nap after training will do well on this test even if their scores on the first two tests are poor. We found this to be the
case for the napper sleep one variability group ($M = .63, SE = .125$) and the napper sleep four variability group ($M = .81, SE = .051$). The only other group with averages above chance on the third test was the no napper wake one-variability condition ($M = .65, SE = .127$). This may be additional evidence for the memory boost gained by seeing one action repeated identically multiple times. It could also be emerging evidence that those children who have transitioned out of napping have different needs for consolidation. In other words, they do not need sleep during the day to show retention after twenty-four hours. While these trends are interesting, more participants are needed to come to any real conclusions.

Conclusion

Many factors influence children’s ability to learn verbs. We looked at variability and sleep in depth. Although more data is needed to make specific claims, we conclude that children need to sleep an adequate amount of hours in a twenty-four hour period in order to retain new information. It would seem that in different situations, children could benefit from both minimal and maximal variability. This is understandable given the real world situations they encounter. More research needs to be completed in order to fully understand the process of verb acquisition.
References


Manuscript submitted for publication.

Appendix A: Figures

Figure 1. Cartoon depictions of visual stimuli set-up for training

Figure 2. Cartoon depictions of visual stimuli set-up for test trial
Figure 3. Mean scores separated by condition and individual tests
Appendix B: Tables

Table 1. Auditory and Visual Training Stimuli Order (four exemplar condition)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Script (after Maguire et al., 2008)</th>
<th>Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center</td>
<td>Now watch blicking!</td>
<td>Baby</td>
</tr>
<tr>
<td>Video 1</td>
<td>Do you see her blicking? Watch her blicking!</td>
<td>Actress 1: Action A</td>
</tr>
<tr>
<td>Center</td>
<td>We’re going to see more blicking!</td>
<td>Baby</td>
</tr>
<tr>
<td>Video 2</td>
<td>Hey, blicking! Do you see her blicking? Watch her blicking!</td>
<td>Actress 2: Action A</td>
</tr>
<tr>
<td>Center</td>
<td>More blicking!</td>
<td>Baby</td>
</tr>
<tr>
<td>Video 3</td>
<td>Look! She’s blicking! Watch her blicking! She’s blicking!</td>
<td>Actress 3: Action A</td>
</tr>
<tr>
<td>Center</td>
<td>We’re going to see more blicking!</td>
<td>Baby</td>
</tr>
<tr>
<td>Video 4</td>
<td>Wow! More blicking! She’s blicking. Watch her blicking!</td>
<td>Actress 4: Action A</td>
</tr>
</tbody>
</table>

*Immediately upon completion of training for the first action, training for the second action begins. The script and video order are identical with the word “rooping” replacing “blicking”*

+The one exemplar condition the script remains the same; however, the first video played is repeated for each ensuing trial.

Table 2. Auditory and Visual Test Stimuli Order

<table>
<thead>
<tr>
<th>Trial</th>
<th>Script (after Maguire et al., 2008)</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center</td>
<td>Find blicking!</td>
<td>Baby</td>
<td></td>
</tr>
<tr>
<td>Video 1</td>
<td>Point to the girl who’s blicking! Can you point to the one who is blicking?</td>
<td>Actress 5: Action A</td>
<td>Actress 6: Action B</td>
</tr>
<tr>
<td>Center</td>
<td>Find rooping!</td>
<td></td>
<td>Baby</td>
</tr>
<tr>
<td>Video 2</td>
<td>Point to the girl who’s rooping! Can you point to the one who is</td>
<td>Actress 6: Action A</td>
<td>Actress 5: Action B</td>
</tr>
<tr>
<td></td>
<td>Action 1</td>
<td>Action 2</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>Center</td>
<td>Find rooping again!</td>
<td>Baby</td>
<td></td>
</tr>
<tr>
<td>Video 3</td>
<td>Point to the girl who’s rooping! Can you point to the one who is rooping?</td>
<td>Actress 5: Action A</td>
<td>Actress 6: Action B</td>
</tr>
<tr>
<td>Center</td>
<td>Find blicking again!</td>
<td>Baby</td>
<td></td>
</tr>
<tr>
<td>Video 4</td>
<td>Point to the girl who’s blicking! Can you point to the one who is blicking?</td>
<td>Actress 6: Action A</td>
<td>Actress 5: Action B</td>
</tr>
</tbody>
</table>

*This same pattern is repeated for each of the three tests. Only the videos for the second and third tests change; the audio and general order remain the same.

+Who performs what action and on what side of the screen is balanced across trials, tests, and conditions.