The Effect of Event Boundaries on 3-Year-Olds' Novel Category Learning

Alice Xu (alicex@g.ucla.edu)
Department of Psychology, University of California, Los Angeles
1285 Psychology Building, Los Angeles, CA 90095 USA

James W. Stigler (stigler@ucla.edu)
Department of Psychology, University of California, Los Angeles

Catherine M. Sandhofer (sandhofer@psych.ucla.edu)
Department of Psychology, University of California, Los Angeles

Abstract

The Event Segmentation Theory suggests that people naturally divide everyday experiences into distinct units, with event boundaries serving as anchors in long-term memory and aiding recall. These boundaries are ubiquitous in children's daily experiences and may significantly influence learning. This study investigated how event boundaries affect novel category learning in young children. Specifically, 23 English-speaking three-year-olds learned novel object categories under two conditions. In the event boundary condition, objects were moved across two different background contexts, whereas in the control condition, they remained within the same backgrounds. We hypothesized that presenting objects across an event boundary would enhance generalization. Unexpectedly, both conditions yielded similar performance. An order effect emerged, with initially introduced categories showing better performance, suggesting the impact of task structure and children's differing interpretations of event boundaries, particularly among females. This finding opens avenues for further investigation into the role of event boundaries in early category learning.

Keywords: category learning; event boundaries; memory

Introduction

Children's category learning does not take place in a vacuum. Instead, it unfolds within an intricate web of contexts that span spatial and temporal dimensions (for a review, see Horst & Simmering, 2015). This process has demonstrated connections to different cognitive systems (e.g., perceptual, attention, language, memory), with memory as a particularly crucial element among them (Samuelson, 2021; Vlach & DeBrock, 2017; Vlach & Sandhofer, 2014).

The role of memory in category learning can be illustrated in tasks that ask learners to learn labels for object categories. In these tasks, children's initial challenge is encoding the association between an object and its corresponding label. As the learner encounters additional examples from the same category, the learner retrieves and reactivates this word-object association and integrates newly encountered examples with the existing categorical knowledge, resulting in an updated understanding of the category. Through this iterative process, the learner's understanding becomes increasingly refined and flexible. This ongoing interaction, encountering and integrating new examples with existing knowledge, highlights the dynamic nature of category learning across time and space. It has been supported by formal models, such as Word-Object Learning via Visual Exploration in Space (WOLVES), proposed by Bhat et al. (2022).

Context Effects in Children's Category Learning

Contextual information, encompassing physical, temporal, social, and emotional aspects, is crucial in memory and learning processes (Schwarz & Sudman, 2012). During encoding, contexts can become bound to an object-word pair, thereby serving as a retrieval cue when the same context is reencountered. This, in turn, aids in reconsolidation. For example, in one study, 2.5 to 3-year-old children performed better in generalization tasks when they learned a novel category in repeated contexts (Vlach & Sandhofer, 2011). This demonstrates the effectiveness of context-dependent learning. In such scenarios, the shared context acts as an essential cue to facilitate the retrieval of previously established associations. This process enables the elaboration and strengthening of category-related knowledge.

However, the impact of contexts on word learning is not a static phenomenon throughout development (Sandhofer & Schonberg, 2020). Instead, it undergoes changes that vary across age and depend on individuals' memory and language abilities (e.g., Goldenberg & Sandhofer, 2013). Children above four exhibited equally robust generalization performance regardless of whether learning occurred in repeated or varied background contexts. The reduced reliance on shared context for generalization among older children may be because they form and encode associations between objects and words more effectively than younger children. This allows retrieval of these associations without reliance on the shared context, pointing to a developmental shift in how children encode the object-word bindings.

Enhancing Learning Through Contextual Change and Event Segmentation

Building upon developmental shifts in how children encode object-word bindings, an alternative approach focuses on strengthening the encoding of object-word association. This method emphasizes direct associations, such as hearing the word and seeing the object, for retrieval rather than relying

In L. K. Samuelson, S. L. Frank, M. Toneva, A. Mackey, & E. Hazeltine (Eds.), *Proceedings of the 46th Annual Conference of the Cognitive Science Society.*

heavily on contextual cues for recall. This could potentially be achieved through heightened attention or "increased intensity of information processing" (Hard et al., 2011). Such an approach may be particularly beneficial in addressing younger children's context-dependent learning. Enhanced information processing might help form stronger memory traces of the object-word pair within the scene.

This approach is promising, as neurophysiological research underscores the significance of the initial encoding stage in memory consolidation. For instance, Kafkas and Montaldi (2011) demonstrated that both the magnitude of pupillary response and the number of fixations during encoding are reliable predictors of recognition memory strength. Similarly, Wichert et al. (2013) found that the strength of new encoding is crucial for updating consolidated memory, with memory intrusions occurring only when new information was strongly encoded. These insights lead us to an important consideration in real-life learning scenarios. Specifically, they raise the question of whether it is possible to selectively enhance the encoding of memories, particularly those involving object-word binding. If so, what strategies could effectively achieve this enhanced encoding?

The answer to this question may lie within memory research focused on event segmentation. The event segmentation theory (EST) suggests that individuals naturally tend to divide everyday events into meaningful units (for a review, see Zacks et al., 2007). These event boundaries act as anchor points in long-term memory, aiding the recall process (Zacks & Swallow, 2007). The structure of segmentation (i.e., how one segments the event) has been found to influence an individual's memory for the information it contains, and this effect is observed across various contexts, including changes in spatial location, computer windows, or linguistic cues (Pettijohn et al., 2016). Moreover, research has shown that information presented at event boundaries provides a significant and prolonged memory advantage in both adults (Jeunehomme & D'Argembeau, 2020; Swallow et al., 2009) and infants (Sonne et al., 2016). Furthermore, improved memory performance is associated with attention to segmentation, and individuals' ability to segment events predicts their memory performance even at long delays. Individuals whose event segmentation aligned more closely with group norms recalled more information about an event, even a month after encoding (Flores et al., 2017). These findings collectively highlight the pivotal role of event segmentation in shaping memory and underscore its impact on information retention over extended periods.

Despite the relatively limited research on event segmentation in children compared to adults, previous evidence suggests that children represent and maintain event models (Zheng et al., 2020). Furthermore, research has shown that the segmentation process influences memory in a manner similar to that of adults, although there may be qualitative differences in how children segment events (Ren et al., 2021; Yates et al., 2022; Zheng et al., 2020). Children demonstrated high segmentation agreement in tasks involving unitization and dwell time (Zheng et al., 2020), improved accuracy in object recognition for items within the current event (Ren et al., 2021), and enhanced memory for information presented at event boundaries (Sonne et al., 2016). In one study (Sonne et al., 2016), 21-month-old infants viewed a short cartoon featuring an object that appeared abruptly, either at an adult-defined event boundary or between such boundaries. Infants exposed to objects at event boundaries showed better memory retention. This was evidenced in two ways: a preference for novel objects in a visual-paired comparison test and higher accuracy in pointing to familiar objects. In contrast, infants who saw objects between event boundaries demonstrated less accuracy in pointing tests. These results imply that children as young as 21 months may encode information more effectively at event boundaries. Based on these findings, presenting object-word bindings at event boundaries may significantly enhance the encoding of this information. This, in turn, may facilitate the category learning process, where memory plays a crucial role.

The potential impact of event segmentation on category learning also finds support in neural and behavioral evidence from studies on episodic memory and language acquisition. Previous neuroimaging research has revealed that the hippocampus-centered system, responsible for binding item-related and contextual information, mediated the acquisition of novel lexicon in both adults (Breitenstein et al., 2005; for a review, see Davis & Gaskell, 2009) and children (Takashima et al., 2019). Furthermore, behavioral research has shown that the initial learning of pseudoword-referent pairings in adult learners can be predicted by their episodic memory abilities (Hamrick et al., 2019). The close connection between episodic memory and language acquisition, along with the engagement of various memory systems in category learning (for a review, see Ashby & O'Brien, 2005), suggests a reasonable proposition: event boundaries, known to enhance episodic memory encoding, may also promote category learning.

Investigating the role of event boundaries in children's learning is particularly pertinent, given that such boundaries are ubiquitous in children's daily experiences and may play a significant role in how they encode new information. Therefore, the current study aims to investigate the influence of event boundaries on the generalization performance of three-year-old children in novel category learning. These boundaries were delineated through distinct visual contrasts in background colors and patterns. The rationale for using background patterns as an event marker is grounded in research on the role of context in children's learning, which suggests that children's memory and learning are sensitive to changes in background color and patterns (Goldenberg & Sandhofer, 2013). Furthermore, in this study, we define an event boundary as the point where an object passes a visual perceptual boundary within a physical space, analogous to the "events by feet" kind of events[1] referred to by Tversky et al. (2004). This consideration is informed by existing literature that identifies spatial boundaries as potential cues for event segmentation, known to impact memory formation (Rah et al., 2022), and research demonstrating that feature changes can enhance source memory (Siefke et al., 2019).

Current Study

In the current study, children learned two types of novel categories, followed by multiple-choice tests. Children had the opportunity to learn the category for the event boundary category while the exemplar was moved across two distinct background contexts. In contrast, the control category involved presenting the exemplar within distinct background contexts. We hypothesized that presenting the object-word binding at event boundaries would enhance encoding, thereby improving children's generalization performance. One key distinction sets our current study apart from previous research on the context effect in children's novel category learning. While prior studies primarily examined the impact of the context across isolated learning events, our study endeavored to create an experimentally continuous learning environment. This environment allowed for the learning of event boundary categories spanning multiple events. Specifically, unlike many prior novel category experiments that often present one object at a time against an individual background context, our approach simultaneously presented two background contexts and simulated learning as it transitioned from one context to another.

To our knowledge, this exploration marks the first attempt at studying the effect of event boundaries on young children's novel category learning. The previous models of children's category learning (for a review of existing models of cross-situational word learning, see Bhat et al., 2022) have not distinguished the distinct contribution of episodic memory from other memory systems. Therefore, this experiment represents the first effort to provide evidence for the role of episodic memory in novel category learning by investigating how event boundaries influence generalization performance. In addition, we also sought to determine whether the effect of event boundaries on children's novel category learning interacts with gender, given that episodic memory has been shown to exhibit gender differences (for a review, see Asperholm et al., 2019). Since females show a superior ability in verbal episodic memory (Hirnstein et al., 2023), they may also be more adept at using linguistic cues at event boundaries to organize and recall these memories. Thus, we predicted the advantage at event boundaries would be more pronounced in female children.

[1] The other type of events proposed by Tversky et al (2004) is "events by hand," where segmentation is indicated by different successive actions.

Method

Participants

The participants were 23 English-speaking three-year-olds (9 boys and 14 girls, $M_{\text{age}} = 42.05$ months, $SD = 3.58$) recruited from preschools in the Los Angeles area. Among them, 16 were monolingual, and 12 were from non-White backgrounds. Data from an additional two children were excluded from the final sample due to their inability to complete the study. Participants' vocabulary size was measured by the number of words they produced, as reported by their parents using a subset of 159 words from the Developmental Vocabulary Assessment for Parents (DVAP; Libertus et al., 2015). Participants' vocabulary scores ranged from 37 to 143, with a median of 78.5 ($SD = 28.11$).

The sample size was determined using an a priori power analysis with G*Power 3.1.9.7 (Faul et al., 2007), based on the effect size of 0.246 (η^2_p) from Vlach and Sandhofer's 2011 study, which compared 3- to 4-year-olds' novel noun generalization performance in different contexts. According to Cohen's (1988) criteria, this effect size is considered large. With an alpha of .05 and a power of .80, the minimum sample size required for a paired-sample *t*-test is 22, ensuring that our sample size is sufficient for testing the hypothesis.

Stimuli

Thirty novel object categories were selected from A Library for Innovative Category Exemplars (ALICE) Database (Xu et al., under review) and 3D-printed at a size of about ten centimeters for the longest axis. Among these, six pairs of categories were used during both the learning and the testing phases as target categories, each comprising three exemplars (two for learning and one for testing). The remaining categories functioned as distractors, with each one printed one copy. Upon being printed, each object was adorned with a single color. Each pair of target categories was randomly assigned one pair of novel labels among 12 pseudowords (e.g., "biss," "fupp") selected from the Novel Object and Unusual Name (NOUN) Database (Horst & Hout, 2016). Two labels in each pair had an identical number of phonemes. Twelve different fabric patterns, each measuring roughly 30 by 30 centimeters, were used as background contexts.

Design

The study employed a one-way within-subject design, where participants learned a pair of categories of novel objects: the event boundary category and the control category. In the event boundary category, the exemplars were initially presented on one piece of fabric and then transferred to another piece of fabric featuring a distinct pattern. Conversely, for the control category, the exemplars were transferred between two pieces of fabric with identical patterns.

In total, children completed six trials. In each trial, they learned two exemplars from each category during the learning phase. Within each category, two exemplars had the same shape but different colors. It is worth noting that all four objects presented within a single trial had distinct colors.

Two patterns of fabrics, labeled Pattern A and Pattern B, were used in each trial's learning phase. The event boundary category's first presentation occurred against Pattern A and was subsequently transferred to Pattern B, while the second presentation followed the reverse pattern sequence. As for the control category, the first exemplar was presented against Pattern B, while the second was presented against Pattern A.

To counterbalance the order of category presentation, half of the children learned the event boundary category first, while the remaining half started with the control category. Each child was tested for object-label generalization for both categories in each trial. Once the two categories were learned, a novel distractor object, unlabeled, was introduced to the child. In the subsequent testing phase, the child underwent two forced-choice tests for each category to evaluate their ability to generalize the novel category label.

Procedure

At the beginning of the experiment, we introduced the children to what was framed as an engaging game involving exploring new toys. A practice session was used to eliminate children who struggled with instruction compliance. Five familiar items (e.g., a shoe, spoon, or tomato) were displayed on a tray in front of the child during each practice trial. Of these five items, two belonged to the same target category. The experimenter then selected one item (e.g., shoe) from the target category, placed it in an empty bowl, and said, "Look, this is a shoe. Can you find the other shoe and put it in the bowl for me?" In each trial following the initial one, we substituted the pair of objects from the former target category with a new pair from a different category. Children needed to pass at least two of the three practice trials to continue.

Every learning trial was composed of three sequential stages–the learning phase, followed by the distractor phase, and concluding with the testing phase (See Figure 1).

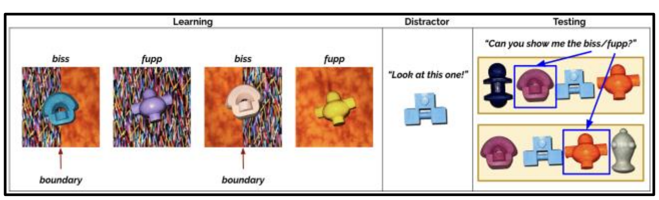

Figure 1: Illustration of Task Structure for a Single Trial

Each learning phase consisted of four presentations of novel objects, with two belonging to the event boundary category and two to the control category. The categories were presented in an alternating manner, and the order of presentation was counterbalanced among the children.

At the beginning of the learning phase, Pattern A fabric was set up in front of the child. In the scenario where the event boundary category was presented first, the experimenter revealed the first exemplar to the child by unwrapping a fabric bag with Pattern B on its inner surface, placed beside Pattern A. The side to which the bag was placed in relation to the pre-existing fabric was determined randomly. Once the bag was opened, Patterns A and B were seamlessly aligned side by side. We encouraged the children to interact with the object, and during this process, we named the object twice (e.g., "Look! This is a biss. Would you like to touch the biss?"). Following this, the experimenter returned the object to its original position on the fabric from which it was unwrapped (Pattern B) and relocated it to the adjacent fabric (Pattern A) while spontaneously naming the object a third time as it transitioned over the boundary between the two fabrics (e.g., "Look, I'm moving the biss over here."). Next, the experimenter enveloped the object with the fabric it rested on (Pattern A) and removed it from the child's field of vision, leaving only the Pattern B fabric in view.

Next, the first exemplar from the control category was presented similarly, unwrapping a fabric bag with Pattern B. At this time, the object moved across two adjacent fabrics that shared the same pattern (Pattern B). After the object was removed, Pattern B remained in the child's sight.

Subsequently, we introduced the second exemplar from the event boundary category similarly by unfolding a fabric bag imprinted with Pattern A. It was then transferred from Pattern A to Pattern B, leaving Pattern A visible. Finally, the second exemplar from the control category was introduced, starting with Pattern A, and moved across fabrics with the same pattern. Once all four items had been presented, the experimenter removed the remaining fabric from sight. In cases where the control category was first introduced, the learning phase started with the experimenter revealing the first exemplar by unfolding a fabric bag that matched the fabric's pattern already in place. The entire learning phase took approximately three minutes.

Immediately after the learning phase, the child was presented with a distractor object from a new novel category they had not encountered before. The experimenter encouraged the child to interact with the object for 30 seconds without explicit labeling (e.g., "Look! You can play with this new one!"). The distractor object ensured that a child would not select the target object during the following testing phase merely based on familiarity.

During the testing phase, children were given two four-option choice tests with the objects on a tray. Each test corresponded to a novel category they had encountered during the learning phase, with the first test matching the category they were first introduced to. In the first test, the four options were: a third exemplar for the event boundary category, a third exemplar for the control category, the same distractor from the distractor phase, and a new novel category that the child had not been exposed to previously. In the second test, the initial three objects from the first test were retained, and the fourth object was switched to a different novel category. Before selecting, the child was encouraged to play with all four objects. Thereafter, the experimenter randomly arranged the four objects in a straight line on the tray and prompted the child to make their choice, for instance, by saying, "Can you put the biss in the bowl for me?" Upon the child making their choice, the second experimenter recorded their response, and the next trial began with the learning phase. The child did not receive feedback regarding their choice. In each trial, we used different objects, labels, and fabrics. The order in which the yoked object and fabric pair were presented remained constant for all children, while the label pairs were randomly assigned across trials.

Results

First, we assessed whether children successfully learned the novel categories. Group-level analysis showed that performance in both the event boundary (M = 2.78, SD = 1.45) and control categories (M = 2.61, SD = 1.41) was above the chance level, suggesting that learning was not merely due to guessing. We defined "above chance" as a success rate higher than 25%. One-sample t-tests confirmed that the performance was indeed above chance for both the event boundary category ($t(22) = 4.26$, $p < .001$, $d = 0.89$) and the control category ($t(22) = 3.78$, $p = .01$, $d = 0.89$).

To address the primary objective of our study, we assessed whether children's generalization scores differed when presented with novel categories at event boundaries as opposed to the control category. A paired-sample t-test showed no significant difference between the two conditions ($t(22) = 0.50$, $p = .62$). Moreover, we counted the number of individuals who performed above the chance level, defined as achieving four or more correct generalizations out of six, based on a binomial test ($p < .05$) conducted at the individual level. Seven children met the criterion in the event boundary category, compared to five in the control category. A Fisher's Exact Test was performed to analyze whether there was a significant difference in children's generalization scores, specifically comparing the number of children performed above and below chance in the boundary category versus the control category. The test result (p= .74) suggests no significant relationship between the different learning conditions and the children's performance. This finding aligns with the earlier paired-sample t-test results, indicating a consistent lack of significant differences between the learning conditions in individual and group-level analyses.

We must consider that children's interpretation of event boundaries might differ significantly from our operational definition, which is based on an object moving across two distinct background fabrics. There was a possibility that children perceive different event boundaries than those we intended, or they might recognize multiple boundaries at varying levels of granularity. Although our definition of an event boundary is nuanced, children may respond to a more general, broad-level boundary influenced by the task's overall structure. For instance, they might perceive the broader transition between trials as an event boundary. Considering these insights about children's potential interpretation of event boundaries, it seemed plausible that the order in which categories were presented might significantly influence children's memory and, therefore, generalization performance. To investigate this possibility, we proposed a 2 by 2 mixed analysis of variance (ANOVA), with learning condition as the within-subject factor and presenting order as the between-subject factor.

Prior to integrating the presenting order into our analysis, we determined whether other factors that might influence generalization performance (e.g., age) differed significantly between children who learned the event boundary category first and those who learned the control category first in each trial. We employed Welch's two-sample t-tests, which revealed no significant differences in children's age ($t(20.45) = 0.81$, $p = .42$) or language scores ($t(17.8) = -0.63$, $p = .53$). Additionally, Fisher's Exact Test indicated no significant difference in gender composition across the groups ($p = .68$).

Our two-way mixed ANOVA identified a significant interaction between learning condition and presenting order, $F(1, 21) = 8.14$, $p = .01$, $\eta^2_p = .28$, suggesting that the sequence in which children encountered learning conditions substantially influenced their performance. Further analysis revealed a significant simple main effect of learning condition within the group exposed first to the event boundary category after a Bonferroni correction ($F(1, 11) = 8.25$, $p = .02$, $\eta^2_p = .43$). Specifically, children scored higher in the event boundary category ($M_{event} = 3.25$, $SD = 0.43$) compared to the control category ($M_{control} = 2.27$, $SD = 0.38$) when they were first introduced to the event boundary category (See Figure 2).

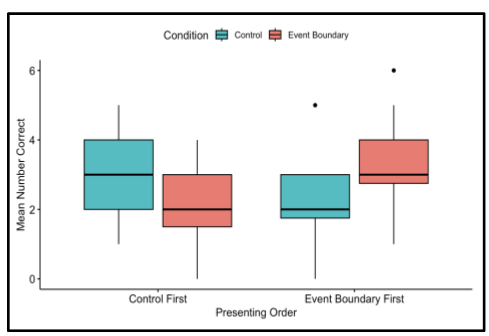

Figure 2: Generalization Score by Condition and Order

To dissect the interaction between learning condition and presentation order further, we extended our analysis to include gender, given that there has been evidence of gender differences in episodic memory (see Asperholm et al., 2019).

We conducted a three-way mixed ANOVA to assess the influence of the learning condition, presenting order, and gender on children's performance. The analysis yielded a significant three-way interaction, $F(1, 19) = 4.75$, $p = .04$, $\eta^2_p = .05$. Diving into the specifics, we found a significant simple two-way interaction between learning condition and presenting order in the female children, $F(1, 7) = 15.90$, $p < .01$, $\eta^2_p = .57$, following a Bonferroni correction. This effect was absent in the male subgroup. Subsequent analysis of the female participants who received the control category first indicated a significant difference in their generalization scores between learning conditions, $F(1, 5) = 11.4$, $p = .02$, $\eta^2_p = .69$. Specifically, female children exhibited significantly better performance in the control condition ($M_{\text{control}} = 3.67$, $SD = 1.51$) compared to the event boundary condition ($M_{\text{event}} = 2$, $SD = 1.41$).

Discussion

This study investigated the impact of event boundaries on category learning in children. We hypothesized that event boundaries, operationalized through moving across two distinct background contexts, would enhance encoding and improve generalization. However, our findings did not consistently support this hypothesis. Interestingly, an order effect was observed—children performed better in generalizing categories learned first in each trial. This suggests that the task structure might influence the children's interpretation of event boundaries, possibly reflected in the observed order effects.

The absence of an effect of event boundaries on novel category learning may stem from our operationalization. We could not predict whether this particular type of boundary would be attended to and influence how children encode their event memories. As a result, the absence of an event boundary effect does not indicate children's inability to represent and segment events. Instead, a more plausible interpretation of our findings is that children recognized and interpreted the task structure, forming their event memory accordingly, which led to an order effect. This explanation aligns with previous research showing that individuals have the ability, as early as infancy, to extract event units from physical actions (Sonne et al., 2016) or goals of others (Kanakogi & Itakura, 2011; see Levine et al., 2019, for a review). Our experiment also encompasses a sequence of altered actions (e.g., the experimenter unfolding the fabric bag, moving the objects, etc.) and changes in goals (e.g., learning about new toys, selecting a toy based on its name, etc.). Consequently, children in our study may parse events using a combination or all of these types of information. It is possible that switching back to the learning phase from the testing phase might be perceived as a salient event boundary, leading to an event boundary advantage for the first learned category. As a result, in a follow-up study, we plan to make the contexts more meaningful, thereby enhancing their recognizability as individual events.

Our results contribute to the developmental understanding of category learning and event cognition by suggesting that the structure of tasks, rather than merely the change of background environments, significantly enhances learning. This finding aligns with research indicating that school-aged children perceive event structures similarly to adults and that their ability to segment events predicts memory performance (Zheng et al., 2020). By focusing on younger children, our study provides indirect evidence about the developmental onset of event comprehension abilities, highlighting the potential impact of event boundaries on both event memory and category learning. Additionally, we observed notable gender differences in perceiving event boundaries. The order effect, where children performed better on categories learned earlier, was predominantly seen in females but not in males. This aligns with previous research identifying gender differences in episodic memory (Herlitz & Rehnman, 2008) and implies that episodic memory might play a crucial role in category learning.

Our findings open avenues for future research on the impact of event boundaries on early category learning. For instance, in the current design, we only assessed generalization after a short-term delay; however, less is known about how learning interacts with event segmentation after a more extended period of consolidation. To investigate this, we can incorporate the same generalization task with a delay of 24 hours, as previous research has suggested that memory consolidation occurs during offline periods, such as sleep (Born & Wilhelm, 2012). System consolidation has been shown to enhance early language acquisition, such as the ability to abstract the rules underlying an artificial language (Gómez et al., 2006; Hupbach et al., 2009). By incorporating this longer delay, we can obtain additional insights into the potential effects of event boundaries.

Furthermore, future studies may investigate how boundary categories are learned, using wearable eye-tracking technology to study attention allocation during learning, thus revealing the specific cognitive processes involved in learning at event boundaries. Another research direction could examine the timing of parents' naming moments for children in naturalistic settings. Event boundaries naturally occur as breaks in ongoing experiences, often coinciding with introducing new information that captures attention. This heightened salience may make parents more inclined to label novel objects during these distinct moments. Further research can shed light on the role of event boundaries in parents' language input and its impact on children's language development.

In conclusion, this study reveals the nuanced relationship between event boundaries and category learning in young children. While our findings challenge the initial hypothesis, they illuminate the significant role of task structure in learning and memory processes. This insight, coupled with observed gender differences, underscores the complexity of early cognitive development and sets a promising direction for future research in this area.

Acknowledgements

We would like to thank the research assistants—Madison Bishop, Ella Hou, Lauren Imai, Lauren Nemeh, and Rachel Siegel—from the UCLA Language and Cognitive Development Lab for their help in data collection. We would also like to express our gratitude to the children, parents, and preschools that participated in the study.

References

Ashby, F. G., & O'Brien, J. B. (2005). Category learning and multiple memory systems. *Trends in Cognitive Sciences, 9*(2), 83-89. https://doi.org/10.1016/j.tics.2004.12.003

Asperholm, M., Högman, N., Rafi, J., & Herlitz, A. (2019). What did you do yesterday? A meta-analysis of sex differences in episodic memory. *Psychological Bulletin, 145*(8), 785–821. https://doi.org/10.1037/bul0000197

Bhat, A. A., Spencer, J. P., & Samuelson, L. K. (2022). Word-Object Learning via Visual Exploration in Space (WOLVES): A neural process model of cross-situational word learning. *Psychological Review*, *129*(4), 640–695. https://doi.org/10.1037/rev0000313

Born, J., & Wilhelm, I. (2012). System consolidation of memory during sleep. *Psychological Research, 76*(2), 192-203. https://doi.org/10.1007/s00426-011-0335-6

Breitenstein, C., Jansen, A., Deppe, M., Foerster, A.-F., Sommer, J., Wolbers, T., & Knecht, S. (2005). Hippocampus activity differentiates good from poor learners of a novel lexicon. *Neuroimage, 25*(3), 958-968. https://doi.org/10.1016/j.neuroimage.2004.12.019

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Davis, M. H., & Gaskell, M. G. (2009). A complementary systems account of word learning: neural and behavioural evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1536), 3773-3800. https://doi.org/10.1098/rstb.2009.0111

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. https://doi.org/10.3758/BF03193146

Flores, S., Bailey, H. R., Eisenberg, M. L., & Zacks, J. M. (2017). Event segmentation improves event memory up to one month later. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 43*(8), 1183–1202. https://doi.org/10.1037/xlm0000367

Goldenberg, E. R., & Sandhofer, C. M. (2013). Same, varied, or both? Contextual support aids young children in generalizing category labels. *Journal of Experimental Child Psychology, 115*(1), 150-162. https://doi.org/10.1016/j.jecp.2012.11.011

Gómez, R. L., Bootzin, R. R., & Nadel, L. (2006). Naps promote abstraction in language-learning infants. *Psychological Science, 17*(8), 670-674. https://doi.org/10.1111/j.1467-9280.2006.01764.x

Hamrick, P., Graff, C., & Finch, B. (2019). Contributions of episodic memory to novel word learning. *The Mental Lexicon, 14*(3), 381-398. https://doi.org/10.1075/ml.19019.ham

Hard, B. M., Recchia, G., & Tversky, B. (2011). The shape of action. *Journal of experimental psychology: General, 140*(4), 586. https://doi.org/10.1037/a0024310

Herlitz, A., & Rehnman, J. (2008). Sex differences in episodic memory. *Current Directions in Psychological Science, 17*(1), 52-56. https://doi.org/10.1111/j.1467-8721.2008.00547.x

Hirnstein, M., Stuebs, J., Moè, A., & Hausmann, M. (2023). Sex/gender differences in verbal fluency and verbal-episodic memory: A meta-analysis. *Perspectives on Psychological Science, 18*(1), 67-90. https://doi.org/10.1177/17456916221082116

Horst, J. S., & Hout, M. C. (2016). The Novel Object and Unusual Name (NOUN) Database: A collection of novel images for use in experimental research. *Behavior Research Methods, 48*, 1393-1409. https://doi.org/10.3758/s13428-015-0647-3

Horst, J. S., & Simmering, V. R. (2015). Category learning in a dynamic world. *Frontiers in Psychology, 6*, 46. https://doi.org/10.3389/fpsyg.2015.00046

Hupbach, A., Gomez, R. L., Bootzin, R. R., & Nadel, L. (2009). Nap-dependent learning in infants. *Developmental Science*, *12*(6), 1007-1012. https://doi.org/10.1111/j.1467-7687.2009.00837.x

Jeunehomme, O., & D'Argembeau, A. (2020). Event segmentation and the temporal compression of experience in episodic memory. *Psychological Research, 84*(2), 481–490. https://doi.org/10.1007/s00426-018-1047-y

Kafkas, A., & Montaldi, D. (2011). Recognition memory strength is predicted by pupillary responses at encoding while fixation patterns distinguish recollection from familiarity. *Quarterly Journal of Experimental Psychology*, *64*(10), 1971-1989. https://doi.org/10.1080/17470218.2011.588335

Kanakogi, Y., & Itakura, S. (2011). Developmental correspondence between action prediction and motor ability in early infancy. *Nature Communications, 2*(1), 341. https://doi.org/10.1038/ncomms1342

Levine, D., Buchsbaum, D., Hirsh-Pasek, K., & Golinkoff, R. M. (2019). Finding events in a continuous world: A developmental account. *Developmental Psychobiology, 61*(3), 376-389. https://doi.org/10.1002/dev.21804

Libertus, M. E., Odic, D., Feigenson, L., & Halberda, J. (2015). A Developmental Vocabulary Assessment for Parents (DVAP): Validating parental report of vocabulary size in 2-to 7-year-old children. *Journal of Cognition and Development*, *16*(3), 442-454. https://doi.org/10.1080/15248372.2013.835312

Pettijohn, K. A., Thompson, A. N., Tamplin, A. K., Krawietz, S. A., & Radvansky, G. A. (2016). Event boundaries and memory improvement. *Cognition, 148*, 136-144. https://doi.org/10.1016/j.cognition.2015.12.013

Rah, Y. J., Kim, J., & Lee, S. A. (2022). Effects of spatial boundaries on episodic memory development. *Child Development, 93*(5), 1574-1583. https://doi.org/10.1111/cdev.13776

Ren, J., Wharton-Shukster, E., Bauer, A., Duncan, K., & Finn, A. S. (2021). Events structure information accessibility less in children than adults. *Cognition, 217*, 104878. https://doi.org/10.1016/j.cognition.2021.104878

Samuelson, L. K. (2021). Toward a precision science of word learning: Understanding individual vocabulary pathways. *Child Development Perspectives, 15*(2), 117-124. https://doi.org/10.1111/cdep.12408

Sandhofer, C., & Schonberg, C. (2020). Multiple examples support children's word learning: The roles of aggregation, decontextualization, and memory dynamics. In *Language and Concept Acquisition from Infancy Through Childhood* (pp. 159-178). Springer, Cham. https://doi.org/10.1007/978-3-030-35594-4_8

Schwarz, N., & Sudman, S. (Eds.). (2012). Context effects in social and psychological research. *Springer Science & Business Media.*

Siefke, B. M., Smith, T. A., & Sederberg, P. B. (2019). A context-change account of temporal distinctiveness. *Memory and Cognition, 47*, 1158-1172. https://doi.org/10.3758/s13421-019-00925-5

Sonne, T., Kingo, O. S., & Krøjgaard, P. (2016). Occlusions at event boundaries during encoding have a negative effect on infant memory. *Consciousness and Cognition, 41*, 72-82. https://doi.org/10.1016/j.concog.2016.02.006

Swallow, K. M., Zacks, J. M., & Abrams, R. A. (2009). Event boundaries in perception affect memory encoding and updating. *Journal of Experimental Psychology: General, 138*(2), 236. https://doi.org/10.1037/a0015631

Takashima, A., Bakker-Marshall, I., Van Hell, J. G., McQueen, J. M., & Janzen, G. (2019). Neural correlates of word learning in children. *Developmental Cognitive Neuroscience, 37*, 100649. https://doi.org/10.1016/j.dcn.2019.100649

Tversky, B., Zacks, J. M., & Lee, P. (2004). Events by hands and feet. *Spatial Cognition and Computation, 4*(1), 5-14. https://doi.org/10.1207/s15427633scc0401_2

Vlach, H. A., & DeBrock, C. A. (2017). Remember dax? Relations between children's cross-situational word learning, memory, and language abilities. *Journal of Memory and Language, 93*, 217-230. https://doi.org/10.1016/j.jml.2016.10.001

Vlach, H. A., & Sandhofer, C. M. (2011). Developmental differences in children's context-dependent word learning. *Journal of Experimental Child Psychology, 108*(2), 394-401. https://doi.org/10.1016/j.jecp.2010.09.011

Vlach, H. A., & Sandhofer, C. M. (2014). Retrieval dynamics and retention in cross-situational statistical word learning. *Cognitive Science, 38*(4), 757-774. https://doi.org/10.1111/cogs.12092

Wichert, S., Wolf, O. T., & Schwabe, L. (2013). Updating of episodic memories depends on the strength of new learning after memory reactivation. *Behavioral Neuroscience, 127*(3), 331–338. https://doi.org/10.1037/a0032028

Xu, A., Son, J. Y., & Sandhofer, C. M. (under review). A Library for Innovative Category Exemplars (ALICE) Database: Streamlining Research with Printable 3D Novel Objects. https://4lic3x.github.io/alice_stl/

Yates, T. S., Skalaban, L. J., Ellis, C. T., Bracher, A. J., Baldassano, C., & Turk-Browne, N. B. (2022). Neural event segmentation of continuous experience in human infants. *Proceedings of the National Academy of Sciences, 119*(43), e2200257119. https://doi.org/10.1073/pnas.2200257119

Zacks, J. M., Speer, N. K., Swallow, K. M., Braver, T. S., & Reynolds, J. R. (2007). Event perception: a mind-brain perspective. *Psychological Bulletin, 133*(2), 273. https://doi.org/10.1037/0033-2909.133.2.273

Zacks, J. M., & Swallow, K. M. (2007). EVENT SEGMENTATION. *Current Directions in Psychological Science, 16*(2), 80–84. https://doi.org/10.1111/j.1467-8721.2007.00480.x

Zheng, Y., Zacks, J. M., & Markson, L. (2020). The development of event perception and memory. *Cognitive Development, 54*, 100848. https://doi.org/10.1016/j.cogdev.2020.100848