Video Article

Examining Recall Memory in Infancy and Early Childhood Using the Elicited Imitation Paradigm

Angela F. Lukowski[1], Helen M. Milojevich[1]

[1]Department of Psychology and Social Behavior, University of California-Irvine

Correspondence to: Angela F. Lukowski at angela.lukowski@uci.edu

URL: https://www.jove.com/video/53347
DOI: doi:10.3791/53347

Keywords: Behavior, Issue 110, Cognitive development, elicited imitation, recall, memory, preverbal, infants, children

Date Published: 4/28/2016

Citation: Lukowski, A.F., Milojevich, H.M. Examining Recall Memory in Infancy and Early Childhood Using the Elicited Imitation Paradigm. *J. Vis. Exp.* (110), e53347, doi:10.3791/53347 (2016).

Abstract

The ability to recall the past allows us to report on details of previous experiences, from the everyday to the significant. Because recall memory is commonly assessed using verbal report paradigms in adults, studying the development of this ability in preverbal infants and children proved challenging. Over the past 30 years, researchers have developed a non-verbal means of assessing recall memory known as the elicited or deferred imitation paradigm. In one variant of the procedure, participants are presented with novel three-dimensional stimuli for a brief baseline period before a researcher demonstrates a series of actions that culminate in an end- or goal-state. The participant is allowed to imitate the demonstrated actions immediately, after a delay, or both. Recall performance is then compared to baseline or to performance on novel control sequences presented at the same session; memory can be assessed for the individual target actions and the order in which they were completed. This procedure is an accepted analogue to the verbal report techniques used with adults, and it has served to establish a solid foundation of the nature of recall memory in infancy and early childhood. In addition, the elicited or deferred imitation procedure has been modified and adapted to answer questions relevant to other aspects of cognitive functioning. The broad utility and application of imitation paradigms is discussed, along with limitations of the approach and directions for future research.

Video Link

The video component of this article can be found at https://www.jove.com/video/53347/

Introduction

The importance of recall memory cannot be overstated: this ability allows humans to report on mundane aspects of their day, such as what happened at their dentist appointment that morning, as well as their most significant life events, such as their wedding day or the day their child was born. Understanding the development of this ability is complicated, however, in that the verbal report methods used to examine recall memory in adults cannot be employed in studies with preverbal infants and children. For this reason, researchers developed a behavioral method known as elicited or deferred imitation to study recall memory before infants and children can discuss the past using language. This manuscript describes the procedure for implementing one version of the elicited or deferred imitation procedure with infants and children from 6 to 24 months of age. The described procedure is unique in that it that allows for the assessment of memory for the individual components of events as well as memory for temporal order information.

Piaget was among the first to indicate that deferred imitation was an index of representational ability.[1] He based this conclusion in part on observations of his own children. For instance, Piaget reported that his 16 month-old daughter, Jacqueline, re-enacted a tantrum that she had seen demonstrated approximately 12 hr earlier by a friend. Importantly, Jacqueline imitated the event in the absence of her friend and after a relatively lengthy delay. For these reasons, Piaget reported that Jacqueline must have encoded and maintained a representation of the event so that she could re-enact it after a delay, in the absence of ongoing perceptual support for what she had witnessed earlier. Based on this observation and others, Piaget stated that the ability to recall the past emerged in the second year of life, as children were concurrently developing the ability to engage in symbolic representation (as evidenced by advances in language and pretend play).

More recently, the elicited or deferred imitation procedure has been standardized and is now extensively used to study recall memory and related abilities in preverbal and early-verbal children. In the procedure developed by Patricia Bauer,[2,3] participants interact with three-dimensional materials used to create a novel sequence of events for a brief baseline period. A researcher then demonstrates how to complete the sequence of events, oftentimes with narration. Either immediately (immediate imitation) or after a delay ranging from minutes to months (deferred imitation), the participant is allowed the opportunity to imitate. The data are coded to determine whether the child performs (a) the demonstrated actions and (b) whether they are produced in the correct temporal order relative to baseline or relative to novel control sequences presented at the same session (see reference[4] for additional information). Comparable but distinct imitation procedures have been developed and used by other researchers, including Andrew Meltzoff[5] and Harlene Hayne.[6,7]

Multiple arguments have been proposed to indicate that the type of memory assessed in the elicited or deferred imitation procedure is declarative or explicit in nature (instead of non-declarative or implicit; see reference[8] for information on the multiple memory systems perspective). Although an exhaustive list of relevant arguments can be found in other sources,[9-14] three of the primary points are provided here. One indication that the type of memory being assessed is explicit or declarative in nature is that children talk about events that were experienced behaviorally in the context of the imitation procedure once they gain access to language;[15,16] because implicit or non-declarative memories cannot be accessed using language, evidence of later verbal accessibility strongly suggests that the type of memory under investigation is declarative or explicit. Another argument is that individuals with damage to the medial temporal lobe[17] or the hippocampus[18] are impaired on age-appropriate imitation tasks. Because declarative or explicit memories rely on the functioning of the hippocampus and associated medial temporal lobe structures,[19] evidence of reduced performance by individuals with brain damage to these regions suggests that the type of memory assessed is declarative or explicit. The third argument to indicate that imitation assesses recall memory in particular is that there is no perceptual support available to cue memory for temporal order information.[13] Although the sequence materials themselves might serve to cue recall for individual target actions, the props used to complete the event provide no useful information as to the temporal order in which the target actions must be completed. As such, temporal order information must be encoded upon event demonstration and maintained over time. For these reasons, the elicited imitation procedure is commonly regarded as the gold standard for studying recall memory in preverbal and early-verbal infants and children (see references[10,13,14,20-22]).

Use of the elicited imitation procedure has provided a strong foundation for understanding advances in recall memory over the first three years of life. As discussed in previous reviews,[4,23,24] developments in recall are evident in the duration of time over which memories are retained and in the robustness of established memories. In terms of duration, researchers have indicated that 6-month-old infants recall one step of a 3-step event sequence for up to 24 hr.[6,25] By the time infants are 9 months of age, they remember the individual target actions that comprise a 2-step event sequence for 1 month.[26,27] Memory for temporal order information is less robust, such that only approximately 50% of infants remember the order in which a 2-step sequence was previously demonstrated. When infants are 10 months of age, memory for individual target actions is retained for 6 months and temporal order information is maintained for 3 months.[27] Only 10 months later, when children are 20 months of age, evidence of memory for temporal order information is apparent over durations of 12 months (and may even be evident for longer – 12 months was the longest duration over which the participants tested[28]).

When considering the robustness of recall, age-related changes are apparent in the number of exposures required to support retention and in the ability to flexibly apply learned information. For example, 6-month-olds require as many as 6 exposures to evidence memory over a 24 hr delay,[6] whereas 20 month-olds need only one exposure to demonstrate recall after 1 month.[29] In terms of representational flexibility, 12 month-olds do not generalize their learning across exemplars that only differ in color. Eighteen month-olds generalize their learning across cues that differ only in color, but do not demonstrate generalization when novel exemplars differ in both color and form. At 21 months, however, generalization across cues is more robust, such that children flexibly apply their learning to novel exemplars that vary on both dimensions.[7] Moreover, research suggests that generalization is not born of forgetting: children retain information about the specific features of the original events as they flexibly apply their learning in new situations.[30,31]

The goal of this manuscript is to describe the elicited imitation procedure developed by Bauer in detail. The method described herein is unique in that the procedure allows for assessment of both memory for individual actions demonstrated by the researcher as well as memory for temporal order. As indicated previously, it is important to note that there is no perceptual information present within the individual props to cue the order in which the specific actions should be completed. Therefore, memory for pairs of actions completed in the correct temporal order is a more stringent test of recall relative to reproduction of individual target actions.

The three-dimensional stimuli used in the elicited imitation procedure are commonly created from commercially-available toys or constructed out of plastic and/or wood. The stimuli depict events that are either novel to the participants (such as making a gong or a merry-go-round) or events with which children may have had previous experience (such as feeding a baby or putting a teddy bear to bed; see references[2,3,32] for studies that compare mnemonic performance on familiar versus novel events). Event sequences are further classified as being constrained by enabling relations, having arbitrary associations, or are mixed, such that they include some steps that are linked by enabling relations and others that are arbitrary in nature. Steps of sequences constrained by enabling relations must be completed in a specified temporal order for the sequence end-state to become apparent (although the sequences must be constructed so that children can perform all of the actions in any order). **Figure 1** shows a three-step event sequence that is constrained by enabling relations.[33] For studies with children younger than 20 months of age, sequences constrained by enabling relations are most often utilized, as children of these ages demonstrate chance performance (*i.e.*, completing fewer than 50% of the demonstrated pairs of actions on sequences with arbitrary associations;[34] see references[2,28,32,35-37] for studies that compare mnemonic performance on events with different sequence constraints).

Figure 1: Example of the Three-step Enabling Event Sequence Make a Shaker. The left panel shows the first step of putting the block into one of the nesting cups; the middle panel shows the second step of assembling the nesting cups; the right panel shows the third step of shaking the assembled apparatus. The target actions must be performed in the correct temporal order for the sequence end-state to be realized, although the sequence materials are constructed so that the actions can be completed in any order. Figure and portions of the caption reproduced with permission from references.[33,42] Please click here to view a larger version of this figure.

The elicited imitation procedure is most frequently used with infants and children ranging in age from 6 to 24 months (although methodological alterations can be made to accommodate the testing of older children and adults[17,18]). Typically developing or control participants are commonly recruited so that they are born at term (38 ± 2 weeks) and have not experienced any pre- or perinatal conditions that might negatively impact brain development and recall memory, as conditions such as preterm birth[38,39] and gestational diabetes[40,41] have been associated with reduced recall. In addition, researchers should be aware of the native language of the participants[33,42] if verbal labels will be used during sequence demonstration or as retrieval cues.

Protocol

The administration instructions provided here are similar to those that have been approved previously by the Institutional Review Board at the University of California, Irvine.

1. Equipment

1. Test participants in a child-safe room that has an adult-sized table with three chairs (one for the researcher, one for the parent, and one for the child). Alternatively, test children in their homes at their own table or on a portable table provided by the researchers.
2. Use a video camera placed on a tripod to record the child (audio and video) as he/she participates in the study. Place the video camera so that the recording clearly shows the participant and the object of his/her gaze as well as each of the completed target actions.

2. Testing Procedures

1. Warm-up
    1. Seat the child directly across from the researcher at the adult-sized table. Sit children younger than 13 months old on the lap of a parent. Sit older children on a booster seat that is attached to an adult-sized chair unless they request to sit on the parent's lap. If the child is seated in a booster seat, sit the parent at the table next to the child.
    2. Engage the child in play with age-appropriate toys unrelated to the study so as to establish comfort with the researcher and the testing environment. Next, show children younger than 13 months old how to put a shape into the top or the side of a commercially-available shape sorter toy while narrating the action by saying, "Put it in."[26,27,43-45] Give older children a plastic ball and Slinky. Roll the ball across the table while saying "Roll it" and then put the ball inside of the Slinky while saying, "Put it in."
    3. Conduct each demonstration twice in succession before allowing the child the opportunity to imitate.
    4. Proceed once the child has interacted and shared toys with the researcher.

2. Baseline
    1. Put the sequence materials for the first event on the table; ensure that the same standardized order is used across participants.
    2. Push the props towards the child while providing a general verbal prompt to encourage interaction with the sequence materials, such as, "What can you do with this stuff?".
    3. Provide positive reinforcement as the child interacts with the props, both when he/she performs the target actions and when he/she is engaging with the sequence materials more generally. For example, say, "Good job!" or "That's a neat idea!" as the child explores the props. If the child does not interact with the first sequence at baseline, repeat Section 2.1.2.
    4. If the child appears distracted, call his/her name or tap on the sequence materials in an attempt to redirect his/her attention to the task.[28] Ensure that the props are not tapped in a manner that is suggestive of target actions or the order of their completion. Avoid use of phrases that suggest temporal order information, such as "What do you do next?" or "Then what?".
    5. Allow children younger than 13 months between 1½ and 2 minutes to interact with the props.[26,27,43-45] Terminate the baseline period for older children when the child engages in repetitive or off-task behaviors such as mouthing the props, repeatedly banging them on the table, or dropping them on the floor.[28,31,33,42] Model each sequence immediately after the baseline phase of testing for that sequence is terminated.

3. Sequence Modeling
    1. Bring the sequence materials back to the researcher's side of the table.
    2. Return the sequence materials to their original, standardized positions in the researcher's lap (so the child cannot see what the researcher is doing) and put them back on the table.
    3. Make eye contact with the child. Provide him/her with the name of the sequence using infant-directed speech. For example, for the event Make a Shaker, say, "I can use this stuff to Make a Shaker. Watch how I Make a Shaker with this stuff."
    4. Perform each target action with narration. For the event Make a Shaker, put the block into one of the two nesting cups while saying, "Put in the block." Cover one of the nesting cups with the other while saying, "Cover it up." Shake the assembled apparatus while saying, "Shake it!".
    5. Put all of the props back on the table, make eye contact with the child, and say, "That's how I Make a Shaker with this stuff!".
    6. Ensure that the child watches the researcher complete each of the demonstrated actions. If the child appears distracted, see Section 2.2.4.
    7. Return the sequence materials to their original positions as indicated in Section 2.3.2.
    8. Re-model the actions required to complete event sequence one more time (2 demonstrations total) as indicated in Sections 2.3.3, 2.3.4, 2.3.5, and 2.3.6.
    9. If immediate imitation is not permitted, repeat Sections 2.2, 2.3, and 2.4 for each of the remaining event sequences in turn.

4. Immediate Imitation
    1. Bring the sequence materials back to the researcher's side of the table.
    2. Return the sequence materials to their original, standardized positions (so the child cannot see what the researcher is doing) and put them back on the table.
    3. Push the props towards the child while providing the name of the event sequence as a retrieval cue. For example, when testing immediate imitation for Make a Shaker, say, "You can use this stuff to Make a Shaker. How do you Make a Shaker just like I did?".
    4. Allow children younger than 13 months old between 1½ and 2 minutes to interact with the props.[26,27,43,44] Terminate the imitation period for older children when the child engages in the repetitive or off-task behaviors listed in Section 2.2.5.[28,31,33,42]

5. Provide positive reinforcement as the child interacts with the sequences as indicated in Section 2.2.3.
6. Repeat Section 2.2.4 if the child appears distracted during the imitation period.
7. If immediate imitation is permitted, repeat Sections 2.2, 2.3, and 2.4 for each of the remaining event sequences in turn.

5. Additional Re-exposure Sessions (After Delays of Days to Weeks)
    1. Complete the warm-up procedure described in Section 2.1.2.
    2. Re-model the included event sequences as described in Section 2.3.
    3. If immediate imitation is permitted, complete the immediate imitation procedure as described in Section 2.4. If immediate imitation is not permitted, allow the child to play with commercially-available distracter toys between sequence demonstrations so as to maintain his/her interest in the task.[26,28,43,46]
    4. Repeat Sections 2.5.2 and 2.5.3 for each of the remaining event sequences in turn.

6. Delayed Recall
    1. Complete the warm-up procedure described in Section 2.1.2.
    2. Put the sequence materials for the first event on the table; ensure that the same standardized order is used across participants and sessions.
    3. Push the props towards the child while providing the name of the event sequence as a retrieval cue. For example, when testing delayed recall for Make a Shaker, say, "You can use this stuff to Make a Shaker. How do you Make a Shaker with this stuff?".
    4. Allow children younger than 13 months old between 1½ and 2 minutes to interact with the props.[26,27,43-45] Terminate the imitation period for older children when the child engages in the repetitive or off-task behaviors listed in Section 2.2.5.[28,31,33,42] Participants may or may not reproduce the demonstrated target actions during the delayed recall period.
    5. Provide positive reinforcement as the child interacts with the sequences as indicated in Section 2.2.3.
    6. Repeat Section 2.2.4 if the child appears distracted during the delayed recall period.
    7. Repeat Sections 2.6.2 through 2.6.6 for each of the remaining event sequences in turn.

7. Data Coding and Reduction
    1. Create coding rules for each event. The coding rules sheet includes description of when the child receives credit for completing an action and when credit is not awarded. Award credit when the child achieves the action demonstrated by the researcher or when the child clearly attempts to complete the action (intention can be determined in part by watching the child's gaze). Importantly, in all cases, write coding rules so that the child can complete the target actions in any order.
    2. Create a data coding sheet that lists each of the included event sequences and the possible steps for each event.
    3. Have research assistants code videos that have been previously coded by the principal investigator or a senior lab member.
    4. While watching the videos, circle each target action completed by the child in the temporal order in which the actions are produced.
    5. Compare the codes by assigning a plus to each agreement and a minus to each disagreement. Train research assistants up to a reliability criterion of at least 90% on three consecutive participants before allowing them to code the study data.
    6. Compute the overall reliability by dividing the total number of agreements to the total number of codes. More commonly, reliability is coded by counting only the first occurrence of each coded action so as to reduce the likelihood of receiving credit for actions performed by chance or trial-and-error.[26-28,31,33,42-45]
    7. Have the trained coder score the remaining videos or have the tester code the data as they are collected (recommended only when participants are 13 months or older[29,31]).
    8. Reduce the data to determine the number of target actions and pairs of actions produced for each event at each phase of testing (for example, baseline, immediate imitation, and delayed recall). Only the first occurrence of each target action is commonly considered during data reduction so as to reduce the likelihood of awarding credit for actions produced by chance or trial-and-error.[28] Count the number of unique target actions that were coded by sequence (for example, a participant would receive a score of 3 target actions if he/she produced the following sequence of actions: 3-1-2-3).
    9. Count the number of pairs of actions completed by sequence when considering only the first time each target action was completed (for example, a participant would receive a score of 1 pair of actions if he/she produced the following sequence of actions: 3-1-2-3; a participant would also receive a score of 1 pair of actions if he/she produced the following sequence of actions: 1-3-2-1).
    Note: The maximum number of target actions possible is the total number of steps in the sequence, whereas the maximum number of pairs of actions is the maximum number of target actions possible minus one.
    10. Create averages indicating the number of target actions performed at each phase of testing (baseline, immediate imitation, and delayed recall, for example), and for each condition (if applicable).
    Note: The elicited imitation procedure is administered and scored in the same way whether researchers use sequences with enabling, mixed, or arbitrary associations.[28]

Make a Shaker			
	Baseline		
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	Actions: _____
1	2	3	Pairs: _____
	Immediate Imitation		
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	Actions: _____
1	2	3	Pairs: _____
	Delayed Recall		
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	
1	2	3	Actions: _____
1	2	3	Pairs: _____

Figure 2: Sample Data Coding Sheet for the Three-step Enabling Event Sequence Make a Shaker. The three target actions ("Put it in," "Cover it up," and "Shake it") are shown multiple times for each of three phases of testing (baseline, immediate imitation, and delayed recall). Space is also provided to record the number of target actions and pairs of actions completed at each phase. Please click here to view a larger version of this figure.

Representative Results

A recent elicited imitation study examined whether child language comprehension moderated the relation between the use of supportive adult language at sequence demonstration when recall was assessed behaviorally at encoding (immediate imitation) and at delayed recall 1 week later.[33] Sixteen month-old children were presented with 6 novel 3-step event sequences that were constrained by enabling relations. After a brief baseline period, a researcher demonstrated each of two event sequences in three different conditions. Sequences modeled in the maximally supportive condition were narrated with language that was specific to those events, for both the name of the sequence and the included action phrases. Sequences modeled in the moderately supportive condition were narrated with language that was specific to those events when considering the name of the sequence only; general attention-getting phrases were used in place of the specific action phrases. Sequences modeled in the minimally supportive condition were narrated with general attention-getting phrases in place of both the specific sequence names and action phrases. Encoding was assessed using immediate imitation after modeling was complete, and the researcher demonstrated each event once more after the immediate imitation period ended.

One-week delayed recall was assessed in a two-phase process. First, the researcher cued recall by presenting children with the sequence materials along with a general verbal prompt. Second, once the child stopped producing new target actions, the researcher cued recall with the name of the event. Dependent measures were the average number of target actions and pairs of actions performed. Dependent variables were reduced separately by condition (sequences presented with maximally supportive, moderately supportive, and minimally supportive language) and by phase of testing (at the first session, baseline and immediate imitation; at the second session, before the sequence name was provided and total performance). Children were assigned to high and low comprehension groups using parent-reported English language comprehension scores on the MacArthur-Bates Communicative Development Inventory: Words and Gestures (MCDI).[47]

Mixed ANOVAs were conducted to analyze performance at baseline compared to performance at immediate imitation, as an index of encoding. Additional analyses compared performance at baseline to performance at both phases of delayed recall testing at the second session (before the provision of the specific prompt and total performance) to determine whether infants remembered the presented information over the 1 week delay and whether the provision of the sequence name facilitated recall.

Analyses revealed that although children encoded both target actions and their order, neither child language comprehension nor condition was associated with encoding. Performance differences were found after the 1 week delay, however. Specifically, when considering performance before the provision of the sequence name, children in the high comprehension group produced more target actions when maximally supportive language was used at encoding relative to children in the low comprehension group. Furthermore, children in the high comprehension group produced more target actions when maximally supportive language was used at encoding than when minimally supportive language was used at encoding; the opposite effect was apparent for children in the low comprehension group, as they produced more target actions when minimally supportive language was used at encoding relative to when maximally supportive language was used (see **Figure 3**).

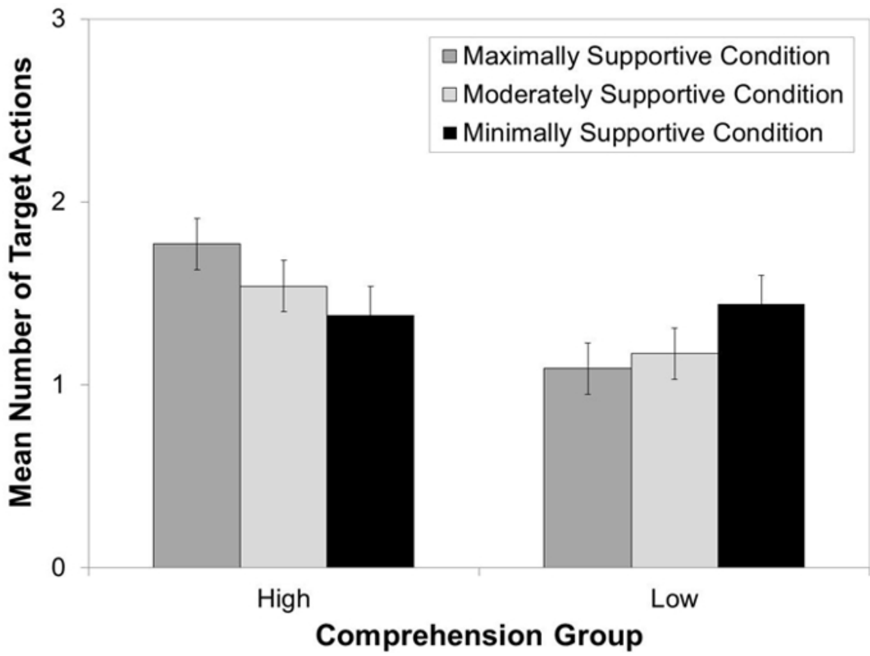

Figure 3: Simple Effects Analyses on the Significant Group x Condition Interaction Before the Provision of the Specific Verbal Prompt for Target Actions (means ± standard errors). Findings revealed that children in the high comprehension group performed more target actions on sequences presented in the maximally supportive condition relative to children in the low comprehension group. In addition, children in the high comprehension group produced more target actions on sequences presented in the maximally supportive condition relative to the minimally supportive condition, whereas the opposite pattern was found for children in the low comprehension group. Figure and caption reproduced with permission from reference.[33] Please click here to view a larger version of this figure.

Correlations conducted among variables from the MCDI and elicited imitation performance further confirmed associations between increased language comprehension and recall performance. At the second session, scores from the MCDI were positively associated with recall performance before the provision of the sequence name and in total on both dependent measures. Overall, these findings suggest that child language comprehension moderates the effect of supportive adult language at sequence demonstration when recall is assessed after a 1 week delay but not at immediate imitation.

Discussion

Over the past 30 years, many researchers have used elicited or deferred imitation procedures to examine the development of recall memory in infancy and early childhood. One advantage of imitation procedures is that they are highly versatile: as such, they can be modified and adapted to answer various questions relevant to cognitive development. For example, the elicited imitation procedure has been administered in combination with electrophysiological indices of recognition memory so as to examine relations between encoding and consolidation/storage processes and long-term recall; the elicited imitation procedure has been subject to minor procedural modifications that allow for the study of cognitive abilities known as executive functions; and the elicited imitation procedure has been recently used to examine cognitive development in special populations and in groups of infants and children exposed to environmental insults. These areas of research are discussed next.

Researchers have paired the elicited or deferred imitation procedure with the recording of event-related potentials (ERPs)[48] both shortly after sequence demonstration and after more extended delays so as to relate evidence of encoding and consolidation/storage to long-term behavioral recall. In these studies,[49-52] a researcher presents infants with novel event sequences using an elicited or deferred imitation paradigm. After sequence demonstration, the participant is fitted with a stretchy cap that contains small electrodes. ERPs are recorded as participants view photographs of previously-modeled and novel event sequences. The recording of these post-synaptic potentials is time-locked to the presentation of the stimulus and is averaged by condition (responses to pictures of previously-modeled or novel sequences) after data collection is complete. Although ERPs cannot be used to determine the source of the signal due to relatively poor spatial resolution, ERPs provide temporal information on the order of milliseconds, thereby allowing for a window into the time course of cognitive processing.[48]

Research conducted to date using elicited imitation in combination with the recording of ERPs has implicated post-encoding processes as a significant source of variability in long-term recall. For instance, one study[50] reported that 9-month-old infants encoded the modeled event sequences, as indicated by differential processing of previously-modeled and novel stimuli in an ERP assessment conducted shortly after sequence demonstration. When infants were tested 1 week later, however, infants did not show evidence of differential processing of previously-modeled and novel sequences as a group. Instead, evidence of consolidation/storage was only found for a subset of infants. When grouped based on their performance at the 1 month delayed recall assessment, only those infants who correctly recalled the temporal order of at least one previously-modeled sequence also differentially processed previously-modeled and novel stimuli at the 1 week ERP; those infants who did not recall temporal order also did not show evidence of consolidation/storage. More recent behavioral work confirms and extends these findings by further implicating post-encoding processes as a significant source of variability in long-term recall memory from infancy to early childhood.[53-56]

Another advantage of elicited or deferred imitation procedures is that they are highly versatile, such that minor procedural modifications result in tasks that provide information as to other aspects of cognitive functioning. As indicated earlier, researchers have examined representational flexibility across contexts in imitation paradigms by modeling event sequences in one context and assessing memory for them in another.[57,58] Generalization across cues has been assessed by modeling event sequences with one set of stimuli and testing them at a later time using perceptually distinct, functionally identical analogues.[30,42,45,59,60] Aspects of executive functioning have also been examined using elicited imitation paradigms. Planning has been assessed by modeling only the final step of an event sequence to participants, ultimately requiring them to deduce the previous steps necessary to achieve the sequence end-state.[61,62] The ability to resist interference from extraneous stimuli has also been examined in imitation paradigms by testing memory for previously-modeled events in the presence of extra materials that are unnecessary for realizing the end- or goal-state of the target sequence.[62,63]

The elicited or deferred imitation procedure can also be easily implemented in studies with special populations or to examine environmental impacts on early cognitive development. When considering work done with special populations, the elicited or deferred imitation paradigm has been used to examine cognitive functioning in children who have experienced environmental insults (such as gestational diabetes,[40,41] early maltreatment,[64] or institutionalization[65]) or genetic abnormalities (such as Down syndrome[66]). In terms of environmental impacts, researchers have studied associations between early linguistic experience (monolingualism versus bilingualism) and generalization across cues;[67,68] attention has also been devoted to better understanding relations between habitual infant sleep[44] and sleep after learning[69] on recall memory and generalization.

When considering special populations in particular, results indicate that the elicited imitation paradigm is sensitive to group differences in recall memory. For example, 12 month-old infants born to mothers with gestational diabetes performed remembered fewer pairs of actions after a 10 min delay relative to infants born to control mothers.[41] Similar impairments in memory for temporal order information have been obtained when comparing recall memory in children with Down syndrome relative to typically developing controls matched on developmental age.[66] The results obtained from studies of children who have experienced early adversity may have implications for education and intervention programs. For instance, recent work indicates that participation in social skills therapy was associated with increased encoding and 1 month delayed recall of target actions for children with Down syndrome relative to children who had not participated in this intervention. Additional experimental work is needed to identify causal relations.

Despite the aforementioned utility of elicited or deferred imitation paradigms, the results from imitation paradigms are only valid to the extent that care is taken when planning empirical investigations and administering study protocols. Researchers should ensure that the recruited participants were born at term and have not experienced any health conditions or environmental circumstances that may negatively impact recall performance (unless these characteristics are relevant to the research question being investigated in a particular study). As the procedure is administered, researchers must be certain that the participant was watching the demonstration of the events, as participants cannot be expected to encode or retain over the long term what was not witnessed initially. To ensure that children watch the demonstration, the researcher must monitor the child's gaze during sequence demonstration to ensure that the child is looking at the props as the demonstration is completed. If the child becomes distracted during the demonstration, the researcher must pause the demonstration and redirect the child's attention by tapping on the props or by calling the participant's name.

Critically, researchers must also minimize parental involvement in the task by asking parents to avoid assisting their child during the imitation phases. This request should be made of parents during the warm-up period and may be repeated as necessary during testing. Parents could also be asked to engage in another activity, such as completing questionnaires, as their child participates in the elicited imitation assessment. If parents demonstrate target actions to the child or by help them complete target actions during the imitation phases, the affected data should be excluded from analysis. Finally, researchers must standardize the procedure as much as possible across participants so that the stimuli are put on the table in the same order, the actions are modeled in the same way, and the sequence names and action phrases are said the same number of times.

Additional work should be conducted using the elicited imitation paradigm so as to improve our understanding of the underlying cognitive processes associated with enhanced recall memory, either through the use of behavioral manipulations designed to impact encoding,[51,54] consolidation/storage, and/or retrieval[53] processes or through the use of neuropsychological techniques. Additional work should also be conducted to further our understanding of cognitive development in individuals undergoing atypical developmental trajectories, as this work in particular could have significant implications for the development and application of intervention programs. Finally, work should be conducted to examine the impact of the social environment on recall memory and related abilities. The elicited or deferred imitation technique could serve to address each of these questions, either when used alone or when combined with other methodological techniques. For this reason, the elicited imitation procedure should be of broad interest to developmental scientists attempting to further our understanding of cognitive development in infancy and beyond.

Disclosures

The authors have nothing to disclose.

Acknowledgements

The author thanks members of the UCI Memory and Development Lab for their comments on a draft of this manuscript as well as their assistance with manuscript preparation.

References

1. Piaget, J. *The origins of intelligence in children.* International Universities Press, New York, NY (1962).
2. Bauer, P., Mandler, J. One thing follws another: Effects of temporal structure on on-to two-year-olds' recall of events. *Dev Psychol.* **25** (2) 197-206 (1989).
3. Bauer, P., Shore, C. Making a memorable event: Effects of familiarity and organization on young children's recall of action sequences. *Cogn Dev.* **2** (4), 327-338 (1987).
4. Bauer, P., DeBoer, T., Lukowski, A. In the language of multiple memory systems: Defining and describing developments in long-term declarative memory. In: *Short- and Long-Term Memory in Infancy and Early Childhood: Taking the First Steps towards Remembering.* Oakes, L., and Bauer, P., eds., Oxford University Press, 240-270 (2007).
5. Meltzoff, A. Immediate and deferred imitation in fourteen- and twenty-four-month-old infants. *Child Dev.* **56** (1), 62-72 (1985).
6. Barr, R., Dowden, A., Hayne, H. Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behav Dev.* **19** (2), 159-170 (1996).
7. Hayne, H., MacDonald, S., Barr, R. Developmental changes in the specificity of memory over the second year of life. *Infant Behav Dev.* **20** (2), 233-245 (1997).
8. Squire, L. Memory systems of the brain: A brief history and current perspective. *Neurobiol Learn Mem.* **82** (3), 171-177 (2004).
9. Bauer, P. What do infants recall of their lives? Memory for specific events by one- to two-year-olds. *Am Psychol.* **51** (1), 29-41 (1996).
10. Bauer, P. Long-term recall memory: Behavioral and neuro-developmental changes in the first 2 years of life. *Curr Dir Psychol Sci.* **11** (4), 137-141 (2002).
11. Bauer, P. New developments in the study of infant memory. In: *Blackwell Handbook of Research Methods in Developmental Science.* Teti, D., ed., Blackwell Publishing, 467-488 (2004).
12. Bauer, P. *Remembering the Times of Our Lives: Memory in Infancy and beyond.* Erlbaum (2007).
13. Mandler, J. Recall of events by preverbal children. In: *The Development and Neural Bases of Higher Cognitive Functions.* Diamond, A., ed., New York Academy of Science, 485-516 (1990).
14. Meltzoff, A. The implications of cross-modal matching and imitation for the development of representation and memory in infancy. In: *The Development and Neural Bases of Higher Cognitive Functions.* Diamond, A., ed., New York Academy of Science, 1-31 (1990).
15. Bauer, P., Wenner, J., Kroupina, M. Making the past present: Later verbal accessibility of early memories. *J Cogn Dev.* **3** (1), 37-41 (2002).
16. Cheatham, C., Bauer, P. Construction of a more coherent story: Prior verbal recall predicts later verbal accessibility of early memories. *Memory.* **13** (5), 516-532 (2005).
17. McDonough, L., Mandler, J., McKee, R., Squire, L. The deferred imitation task as a nonverbal measure of declarative memory. *Proc Natl Acad Sci.* **92** (16), 7580-7584 (1995).
18. Adlam, A-L., Vargha-Khadem, F., Mishkin, M., de Haan, M. Deferred imitation of action sequences in developmental amnesia. *J Cogn Neurosci.* **17** (2), 240-248 (2005).
19. Squire, L., Zola-Morgan, S. The medial temporal lobe memory system. *Science.* **253** (5026), 1380-1386 (1991).
20. Nelson, K., Fivush, R. Socialization of memory. In: *The Oxford Hanbook of Memory.* Tulving, E., and Craik, F., eds., Oxford University Press, 283-295 (2000).
21. Rovee-Collier, C., Hayne, H. Memory in infancy and early childhood. In: *The Oxford Handbook of Memory.* Tulving, E., and Craik, F., eds., Oxford University Press, 267-282 (2000).
22. Squire, L., Knowlton, B., Musen, G. The structure and organization of memory. *Annu Rev Psychol.* **44** (1), 453-495 (1993).
23. Bauer, P., Memory. In: *Oxford Handbook of Developmental Psychology.* Volume **1**, Zelazo, P., ed., Oxford University Press, 505-541 (2013).
24. Lukowski, A., Bauer, P. Long-term memory in infancy and early childhood. In: *The Wiley Handbook on the Development of Children's Memory.* Edition **1**, Bauer, P., and Fivush, R., eds., Wiley-Blackwell, 230-254 (2014).
25. Collie, R., Hayne, H. Deferred imitation by 6- and 9-month-old infants: More evidence for declarative memory. *Dev Psychobiol.* **35** (2), 83-90 (1999).
26. Carver, L., Bauer, P. When the event is more than the sum of its parts: 9-month-olds' long-term ordered recall. *Memory.* **7** (2), 147-174 (1999).
27. Carver, L., Bauer, P. The dawning of a past: The emergence of long-term explicit memory in infancy. *J Exp Psychol Gen.* **130** (4), 726-745 (2001).
28. Bauer, P., Wenner, J., Dropik, P., Wewerka, S. Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monogr Soc Res Child Dev.* **65 (4)**, 1-204 (2000).
29. Bauer, P., Leventon, J. Memory for one-time experiences the second year of life: Implications for the status of episodic memory. *Infancy.* **18** (5), 755-781 (2013).
30. Bauer, P., Dow, G. Episodic memory in 16- and 20-month-old children: Specifics are generalized but not forgotten. *Dev Psychol.* **30** (3), 403-417 (1994).
31. Bauer, P., Lukowski, A. The memory is in the details: Relations between memory for the specific features of events and long-term recall in infancy. *J Exp Child Psychol.* **107** (1), 1-14 (2010).
32. Bauer, P., Travis, L. The fabric of an event: Different sources of temporal invariance differentially affect 24-month-olds' recall. *Cogn Dev.* **8** (3), 319-341 (1993).
33. Lukowski, A., Phung, J., Milojevich H. Language facilitates event memory in early childhood: Child comprehension, adult-provided linguistic support and delayed recall at 16 months. *Memory.* **23** (5-6), 848-863 (2015).
34. Wenner, J., Bauer P. Bringing order to the arbitrary: One- to two-year-olds' recall of event sequences. *Infant Behav Dev.* **22** (4), 585-590 (1999).
35. Bauer, P. Holding it all together: How enabling relations facilitate young children's event recall. *Cogn Dev.* **7** (1), 1-28 (1992).

36. Bauer, P., Fivush, R. Constructing event representations: Building on a foundation of variation and enabling relations. *Cogn Dev.* **7** (3), 381-401 (1992).
37. Bauer, P., Mandler, J. Putting the horse before the cart: The use of temporal order in recall of events by one-year-old children. *Dev Psychol.* **28** (3), 441-452 (1992).
38. Cheatham, C., Bauer, P., Georgieff, M. Predicting individual differences in recall by infants born preterm and full term. *Infancy.* **10** (1), 17-24 (2006).
39. Rose, S., Feldman, J., Jankowski, J. Recall memory in the first three years of life: A longitudinal study of preterm and term children. *Dev Med Child Neurol.* **47** (10), 653-659 (2005).
40. DeBoer, T., Wewerka, S., Bauer, P., Georgieff, M., Nelson C. Explicit memory performance in infants of diabetic mothers at 1 year of age. *Dev Med Child Neurol.* **47** (8), 525-531 (2005).
41. Riggins, T., Miller, N., Bauer, P., Georgieff, M., Nelson, C.. Consequences of low neonatal iron status due to maternal diabetes mellitus on explicit memory performance in childhood. *Dev Neuropsychol.* **34** (6), 762-779 (2009).
42. Phung, J., Milojevich, H., Lukowski, A. Adult language use and infant comprehension of English: Associations with encoding and generalization across cues at 20 months. *Infant Behav Dev.* **37** (4), 465-479 (2014).
43. Bauer P., Wiebe, S., Waters, J., Bangston, S., Reexposure breeds recall: Effects of experience on 9-month-olds' ordered recall. *J Exp Child Psychol.* **80** (2), 174-200 (2001).
44. Lukowski, A., Milojevich, H., Sleeping like a baby: Examining relations between habitual infant sleep, recall memory, and generalization across cues at 10 months. *Infant Behav Dev.* **36** (3), 369-376 (2013).
45. Lukowski, A., Wiebe, S., Bauer P. Going beyond the specifics: Generalization of single actions, but not temporal order, at 9 months. *Infant Behav Dev.* **32**, 331-335 (2009).
46. Bauer, P., Hertsgaard L., Wewerka S. Effects of experience and reminding on long-term recall in infancy: Remembering not to forget. *J Exp Child Psychol.* **59** (2), 260-298 (1995).
47. Fenson, L., Marchman, V., Thal, D., Dale, P., Reznick, J., Bates, E. *MacArthur-Bates Communicative Development Inventories: User's Guide and Technical Manual.* Edition **2**, Paul H. Brookes (2007).
48. Handy, T. *Event-related Potentials: A Methods Handbook.* MIT Press (2005).
49. Bauer, P. et al. Electrophysiological indexes of encoding and behavioral indexes of recall: Examining relations and developmental change late in the first year of life. *Dev Neuropsychol.* **29** (2), 293-320 (2006).
50. Bauer, P., Wiebe, S., Carver, L., Waters J., Nelson C. Developments in long-term explicit memory late in the first year of life: Behavioral and electrophysiological indices. *Psychol Sci.* **14** (6), 629-635 (2003).
51. Lukowski, A., Wiebe, S., Haight, J., Deboer, T., Nelson, C., Bauer, P. Forming a stable memory representation in the first year of life: Why imitation is more than child's play. *Dev Sci.* **8** (3), 279-298 (2005).
52. Carver, L., Bauer, P., Nelson, C. Associations between infant brain activity and recall memory. *Dev Sci.* **3**, 234-246, (2000).
53. Bauer, P. Developments in declarative memory. *Psychol Sci*. **16** (1), 41-47 (2005).
54. Pathman, T., Bauer, P. Beyond initial encoding: Measures of the post-encoding status of memory traces predict longterm recall in infancy. *J Exp Child Psychol.* **114** (2), 321-338 (2013).
55. Bauer, P., Larkina, M., Doydum A. Explaining variance in long-term recall in 3- and 4-year-old children: The importance of post-encoding processes. *J Exp Child Psychol.* **113** (2), 195-210 (2012).
56. Pathman, T., Bauer, P. Beyond initial encoding: Measures of the post-encoding status of memory traces predict longterm recall in infancy. *J Exp Child Psychol.* **114** (2), 321-338 (2013).
57. Barnat, S., Klein, P., Meltzoff, A. Deferred imitation across changes in context and object: Memory and generalization in 14-month-old infants. *Infant Behav Dev.* **19** (2), 241-251 (1996).
58. Hanna, E., Meltzoff, A. Peer imitation by toddlers in laboratory, home, and day-care contexts: Implications for social learning and memory. *Dev Psychol.* 29 **(4)**, 701-710 (1993).
59. Herbert, J. The effect of language cues on infants' representational flexibility in a deferred imitation task. *Infant Behav Dev.* **34** (4), 632-635 (2011).
60. Herbert, J, Hayne, H. Memory retrieval by 18-30-month-olds: Age-related changes in representational flexibility. *Dev Psychol.* **36** (4), 473-484 (2000).
61. Bauer, P., Schwade, J., Wewerka, S., Delaney, K. Planning ahead: Goal-directed problem solving by 2-year-olds. *Dev Psychol.* **35** (5), 1321-1337 (1999).
62. Wiebe, S., Lukowski, A., Bauer, P. Sequence imitation and reaching measures of executive control: A longitudinal examination in the second year of life. *Dev Neuropsychol.* **35** (5), 522-538 (2010).
63. Wiebe, S., Bauer, P. Interference from additional props in an elicited imitation task: When in sight, firmly in mind. *J Cogn Dev.* **6** (3), 325-363 (2005).
64. Cheatham, C., Larkina, M., Bauer, P., Toth, S., Cichetti, D. Declarative memory in abused and neglected infants. In: *Advances in Child Development and Behavior. Varieties of Early Experience: Implications for the Development of Declarative Memory in Infancy.*Volume **38**, Bauer, P., ed., Elsevier, 161-183 (2008).
65. Kroupina, M., Bauer, P., Gunnar, M., Johnson, D. Institutional care as a risk for declarative memory development. In: *Advances in Child Development and Behavior. Varieties of Early Experience: Implications for the Development of Declarative Memory in Infancy.*Volume **38**, Bauer, P., ed., Elsevier, 137-159 (2008).
66. Milojevich, H., & Lukowski A. Recall memory in children with Down syndrome and typically developing peers matched on developmental age. *J Intellectual Disabil Res.* **60** (1), 89-100 (2016).
67. Brito, N., Barr, R. Influence of bilingualism on memory generalization during infancy. *Dev Sci.* **15** (6), 812-816 (2012).
68. Brito, N., Barr, R. Flexible memory retrieval in bilingual 6-month-old infants. *Dev Psychobiol.* **56** (5), 1156-1163 (2014).
69. Seehagen, S., Konrad, C., Herbert, J., Schneider, S. Timely sleep facilitates declarative memory consolidation in infants. *Proc Natl Acad Sci.* **112** (5), 1625-1629 (2014).