Retrieval Order Variation in a Deferred Imitation Task: Assessment of Item-Relational Information Processing Among Infants

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Abstract

Recent deferred imitation experiments are shedding new light onto the development of declarative memory during early infancy and revealing interesting new facets, for example, that infants process novel information on more than one level. In the current study with 13-month-old infants we examined relational information processing of novel, unrelated events with a deferred imitation task. Participants saw an experimenter perform specific actions with multiple objects and their imitation of actions was assessed after 30-minutes using identical and altered object orders. Only infants who received objects during recall in the identical order as seen during the demonstration exhibited significant recall for actions. This pattern of results was corroborated by an analysis of response latencies. The current study confirmed that infants encode information about novel events on more than one level and that there appears to be a developmental shift between 11- and 13-months of age with regard to information processing. Because various infancy research methods demonstrate successful application in clinical populations (Gerhardstein, Kraebel, & Tse, 2006; Rovee-Collier & Cuevas, 2006), and imitation in particular (i.e. Baer, Petersen, & Sherman, 1967; Nadel, 2002), new data from deferred imitation studies can be of potential value for work in clinical and therapeutic settings.

Keywords: deferred imitation, declarative memory, infant cognition, memory development, information processing.

Item-Specific and Item-Relational Information Processing of Memory Material

The interest in imitation for pure and applied research is so great because of its fundamental importance to basic processes in the process of socialization and cognitive development (i.e. language and memory development in particular). In terms of pure research, imitation paradigms provide researchers with an invaluable, nonverbal tool to explore the process of remembering over time or what is referred to as "declarative memory" development starting from 6-months of age. With clinical populations imitation serves both a diagnostic and therapeutic function. For example, using an imitation procedure Baer, Petersen, & Sherman. (1967) successfully established a large repertoire of new behaviors among severely to profoundly retarded children ages 9- through 12 years, who had previously displayed no imitative behavior. Subsequent to this the established readiness to imitate was utilized to create initial verbal repertoires in two of the subjects. The study by Baer et al. (1967) demonstrates, on the one hand, that imitation is an extremely effective learning mechanism even for special clinical populations based merely on an appropriate demonstration by a model. On the other hand, the study by Baer et al. (1967) points out nicely that an established predisposition to imitate behaviors can generalize to a new task.

Whereas the study by Baer et al. (1967) demonstrates a generalization in the children's readiness to imitate in a new situation, another aspect of generalization with regard to the transfer of learned behaviors acquired through observation of a model to a new context has been of great interest in recent years in part because the flexibility of behavior learned in an imitation paradigm in one context to a new one is one hallmark characteristic of declarative memory (Eichenbaum & Cohen, 2001). Thus, maintenance and generalization of learning is critical to what is cognitively referred to as "declarative" memory. Baddeley (1982) distinguished two types of context. Intrinsic context

determines the mechanism of how a target item is encoded, so that changing the context during testing requires subjects to recognize something very different from what they originally encoded. An example of intrinsic context might be the sentence in which a target word was presented or the scene in which an image appears. Extrinsic context does not influence how a target item is encoded, but includes aspects of the background such as where the item was learned. Virtually all research with deferred imitation has focused on changes in extrinsic context including changes in testing location, location appearance, or social context (Hanna & Meltzoff, 1993; Learmonth, Lamberth, & Rovee-Collier, 2005; 2006). Only recently has there been research involving a manipulation of intrinsic context with a deferred imitation task, namely the alteration of retrieval order in order to study the specificity of infants' memory for the organization of test items in a sequence of modeled actions (Knopf, Kraus, & Kressley-Mba, 2006).

Memory researchers have long been interested in how retention is affected by the organization of to-be-remembered materials. Organization refers to the specific relations among the elements embodied in a configuration (Puff, 1978). Such relations can be characterized by serial input position, for example, or by a meaningful relation between to-be-remembered items (Puff, 1978; Tulving, 1983). Hunt and Einstein (1981) suggest that at the cognitive level of understanding two types of information processing can be differentiated by the extent to which common features shared by separate events are encoded, namely item relational and item-specific processing. Hunt and Einstein (1981) describe relational information processing as the abstraction of relational information shared by the elements or events at input. Item-specific information processing, on the other hand, emphasizes the importance of information specific to separate discrete input events. Prior research suggests a dissociation between these two types of information processing while demonstrating that a combination of item–specific and item–relational information leads to better memory than either alone (Einstein & Hunt, 1980).

Results across numerous studies employing different nonverbal tasks demonstrate that young infants employ item-relational information processing, namely that they encode relations among elements in a configuration (Adler, Gerhardstein, & Rovee-Collier, 1998; Bhatt & Rovee-Collier, 1996; Cornell & Bergstrom, 1983; Haaf, Lundy, & Coldren, 1996; Leslie, 1984; Merriman, Rovee-Collier, & Wilk, 1997; Oakes & Cohen, 1990), even before they realize their meaning (Rovee-Collier, 1996). For example, Rovee-Collier and associates have employed the mobile conjugate reinforcement task in several studies to demonstrate that 6-month-old infants encode the serial position of test stimuli within a sequence of 3 items (Gulya, Gallucio, Wilk, & Rovee-Collier, 2001; Gulya, Sweeney, & Rovee-Collier, 1999). These studies show that infants encode serial order among randomly ordered stimuli sequences. In other studies employing the habituation technique it can be shown that young infants encode spatial and temporal relations between stimuli (Leslie, 1984; Oakes & Cohen, 1990). These results show that young infants also perceive causal relations between abstract stimuli very early on in their development.

What the above-mentioned studies have in common is that they use experimental techniques requiring thorough exposure to test stimuli to examine or activate non-declarative memory either through an operant learning task or the successive repeated presentation of test stimuli and events. It is common to use behavioural techniques, and indeed the preferred method, to study cognitive phenomena in infants (Malcuit & Pomerleau, 1996). Because prior research with the mobile task has provided evidence that infants forget feature relations sooner than the individual features that comprise those relations (Bhatt & Rovee-Collier, 1996), it might be conversely argued that the learning or retention of feature relations requires more exposure to test stimuli. Hence, it is interesting to examine aspects of relational information processing among infants in nonverbal tasks that are not based on incremental or associative learning because these are more analogous to the verbal tasks traditionally employed to study relational information processing with children and adults. Furthermore, because imitation in general is an interesting task because of its relevance to the process of socialization and language development, and partly because of its potential value as an efficient training technique for children who require special methods of instruction (Baer et al., 1967), it is

interesting to examine how well normally-developing children in this age range can generalize what they have learned through observational learning without reinforcement, practice, or repetition (transfer learning to a new context) after a change in intrinsic context.

Variations in an Imitation Task Demonstration to Test Memory for Structure among Infants

Imitation paradigms have has been increasingly employed to investigate key aspects of declarative memory in preverbal children including the formation of action representations. Imitation in this context refers to the reproduction of an observed action which is absent during recall, thereby requiring infants to access an internal representation to guide his or her present behaviour (Meltzoff, 1985; Piaget, 1951). Imitation is thought to provide a measure of nonverbal cued or free recall (McDonough, Mandler, McKee, & Squire, 1995) because infants must "reconstruct" what they have seen based on a brief observation of a modelled behaviour without motor practice, not merely recognize that a current scene is related to an older one (Bauer, Wiebe et al., 2006; Meltzoff, 1985).

The discriminative stimulus (S^D) in a deferred imitation experiment is the modelled behaviour (Baer et al., 1967). To guarantee stimulus control and ensure that infants and small children are demonstrating a newly learned behaviour through observation of a model as opposed to emitting a behaviour elicited by the stimuli themselves or based on previous experience prior to participation in an experiment, target actions are designed to fulfil criteria of novelty, including a low rate of spontaneous production, which is usually tested in pilot work prior to a study and later assessed in a baseline measurement during an experiment. Only if the observed rate of imitation after modelling significantly exceeds the spontaneous production of target behaviours do researchers conclude that learning has occurred. This experimental technique helps eliminate the probability that the test items alone substantially induce target action production during a test for imitation. The extent to which the items in a series and/or their structure might serve as cues during a test phase subsequent to a demonstration is a different issue.

Jean Mandler, Patricia Bauer, and their associates were among the first to exploit the structure of memory material in a nonverbal imitation task during a demonstration in order to examine infant memory for stimulus organization. The *elicited imitation paradigm* is particularly well-suited for investigating temporally-ordered recall of demonstrated sequences because children receive all props simultaneously in test phases and must reproduce an ordered sequence without any perceptual support about the temporal order of modelled events. For this reason, such imitation tasks closely resemble those of verbal recall paradigms (Bauer, Wiebe et al., 2006). With this method different types of multi-step events are used as memory material (familiar events; novel events; enabling events in which one action in a sequence is temporally prior to and necessary for a goal or an outcome; novel events lacking a-priori relations between actions) are employed to examine ordered recall based on temporal order and content order. Elicited imitation studies have consistently shown superior deferred recall of actions embedded in an enabling sequence compared to an arbitrary sequence (i.e., Mandler & McDonough, 1995).

Results from the elicited imitation paradigm beautifully illustrate that infants differentially process action sequences based on their inherent structure. However, their work still leaves a few questions open. There is no data available for immediate and delayed recall of arbitrarily ordered action sequences among 9- and 11-month-olds (see Bauer, Hertsgaard, Dropik, & Daly, 1998, for a summary). For example, research with the elicited imitation paradigm has shown that even as early as 9-months of age infants reproduce part of an enabling sequence (Carver & Bauer, 1999, 2001). However, there was never an explicit comparison made with the same age group with an arbitrarily-ordered sequence. If the 9-month-olds on the average were imitating one part of a 2-step sequence in those studies, it is conceivable that an age-matched comparison group might have also imitated on average one action of a 2-step arbitrary sequence. Starting at 13-months of age, however, infants immediately reproduce arbitrarily ordered sequences, but not after a delay (Bauer & Mandler, 1992).

In summary the results of prior studies provide no direct comparison of 11- and 13-month-olds nor is there currently an assessment of memory for structure of arbitrarily ordered sequences at 11-months of age. Furthermore, it seems plausible that there is a developmental gap between being able to freely reproduce ordered sequences and being able to encode structure. Perhaps infants detect structure before being able to demonstrate it behaviourally to this extent; therefore there is no way to ascertain whether young infants encode or even synthesize structure among isolated elements irrespective of their capability to freely reproduce ordered sequences with the elicited imitation procedure. However, more recent data may help close this gap.

Variations in Retrieval in an Imitation Task to Test Memory for Structure among Infants

Elicited imitation studies have capitalized on stimulus structure during the *demonstration* phase in order to test for memory of stimulus structure. However, a newer adaptation of the method of deferred imitation entails a variation during the process of remembering, often referred to as *recall,* in order to assess if infants also encode inter-item structural attributes among unrelated events (Knopf et al., 2006). In this experimental variation, the recall order of items was varied in comparison to the original demonstration order, whereby infants reproduced fewer actions when the recall order differed from the demonstration order compared to another group of infants where the object order remained constant across demonstration and recall phases. This suggests something about what might be going on cognitively, that is, it provides evidence that infants encoded order information about unrelated items, which was manifested in a serial task. Hence, this experimental variation may be better suited to determining whether infants detect structure among items in a series prior to being able to freely reproduce this structure.

To extend earlier findings by Knopf and colleagues (20006), we conducted the current study, with an older age group of 13-month-olds. Age intervals of 2 or 3 months appear to be particularly appropriate for assessing developmental change in memory capacity based on previous studies (Bauer & Mandler, 1992; Herbert, Gross, & Hayne, 2006; Kressley & Knopf, 2006; Learmonth et al., 2005, 2006). Because a combination of item-relational and item-specific information leads to superior recall than either type alone (Hunt & Einstein, 1981), we expected children who received objects in the same order during recall to demonstrate better memory performance. However, because item-relational information is more susceptible to decay after intervals than item-specific information (Bhatt & Rovee-Collier, 1996) and prior research with the elicited imitation paradigm shows a that with increasing age children are better adapt at recalling arbitrary action sequences and by 13-months of age are capable of immediately reproducing arbitrarily-ordered action sequences (Bauer et al., 1998), we didn't expect such a large discrepancy between the two retrieval conditions (same and mixed order) than was observed in the previous study with younger infants (Knopf et al., 2006).

We assessed how well infants remember by performance via target action completion and response latencies. In addition, measurements of response latencies were obtained as a dependent variable. As a measure of stimulus control and maintenance of stimulus control, latency recording is an important process variable. Larger latencies are often suggestive of longer time to remember. Response latencies have traditionally been assessed as a dependent variable in verbal tests examining item-relational and item-specific information processing. Latency as a dependent variable in nonverbal tasks with infants has also been proven valid. Meltzoff (1985; 1988; 1995**)** assessed response latencies as a further measure of contextual control of remembering. He observed, for example, that children in a demonstration condition completed target actions significantly faster than those in an age-matched control group – a further index that children were deliberately imitating actions instead of engaging in exploratory manipulations (Meltzoff, 1985). More recently a similar effect was found for the shortest latencies in an imitation study with 9- to 15-month-old infants for children who saw a demonstration compared to those who did not see a demonstration (Elsner, Hauf, & Aschersleben, 2007).

Method

Participants

Thirty infants (19 female, 11 male) 13-months-old (*M* = 395.7 days, *SD* = 8.69) participated in the experiment. Infants were recruited by visits to mother-child recreational groups, notices to local pediatricians and by word of mouth. All infants met pre-established subject characteristics for admission into the study based on criteria employed by Meltzoff and Moore (2002) which includes a pregnancy that is 40 ± 2.5 weeks long and a birth weight of at least 2500 g. Infants were principally of western European descent. Three additional infants were excluded from the final analysis because they did not meet pre-established subject characteristics for admission into the study (*n* = 1), one child was very shy and did not touch the toys (*n* = 1), and one child due to procedural error (*n* = 1). Participation was voluntary and all participants received a small gift for their participation.

Apparatus

The stimuli used in this experiment were four objects either constructed in the laboratory or commercially available items, which were specially modified for the experiments and have been employed in previous studies (Goertz, Knopf, Kolling, Frahsek, & Kressley, 2006; Knopf et al., 2006; see Kressley & Knopf, 2006 for an illustration of test objects). The employment of four objects with the age group included in the current study reflects a middle range based on previous work in the field, which typically utilize between two to six target actions with children in this age range (i.e., Barr, Dowden, & Hayne, 1996; Bauer & Mandler, 1992; Heimann & Meltzoff, 1996; Meltzoff, 1995).

The first target action involved half of a bright red plastic nested barrel half (5.5 cm x 8 cm) and a small wooden spatula (16.5 cm x 3 cm). The second object was a small, blue metal tin can (4.5 cm x 4.5 cm). The third object was a yellow battery-run plastic drum (3.5 cm x 9 cm x 11 cm). There was one large red button (diameter: 5 cm) on the top of the drum as well as three smaller buttons in different colors on the side. A blue drumstick (length: 8 cm) was attached to the drum by a string. The fourth object was a pink stuffed animal the shape of a pig (15 cm x 20 cm x 7 cm) wearing a hand-constructed linen hat (diameter: 4.5 cm) attached to the pig with Velcro.

Procedure

Infants participating in the study were randomly assigned to the demonstration (*n* = 20) and control group (*n* = 10) as well as across object orders (*same* or *mixed*) as they became available. The item order for the demonstration phase was selected in order to minimize the similarity between individual items with regard to object composition or color, and movement required for a target action. No a-priori structure between the separate actions exists (cf. Knopf et al., 2006; Kressley & Knopf, 2006).

All infants were tested at the university's baby lab. An interview prior to the experiment was conducted to explain the purpose of the study, details of the procedure, and obtain informed consent. A warm-up toy was given to the child. At the beginning of each session, the parents were seated at a table (70 cm x 70 cm), and the infant was placed on the caregiver's lap. The child's hips were firmly supported by the accompanying adult so that children could freely move both arms and had optimal access to objects placed on the table.

Demonstration Session

The action "barrel" was demonstrated by inserting the spatula into the barrel-half. The action "tin can" was demonstrated by shaking the can up and down three times. The target action "drum" was demonstrated by pressing the large red button on the surface with the attached drumstick. For the target action "pig" the experimenter removed the linen hat attached with Velcro. After the infant appeared comfortable and interacted with the experimenter, infants in the demonstration saw the first

target action demonstrated four times within 30 s. This procedure was repeated for the remaining three actions. For the children in the control the warm-up phase was extended to the approximate time needed to complete the demonstration (210-300 sec). All target actions were novel for the current age groups according to criteria provided by Meltzoff (1988) in that none of the target actions had been put in relation with the particular objects employed in the current study. This was assessed by asking caregiver's whether they had the same or similar test objects at home. None of the caregiver's reported having the same test objects at home. Even in the few cases where the parents reported having a similar object at home (i.e., another stuffed animal, plastic cups), in none of the cases did caregivers report observing their children complete the target actions employed in the current study with those objects.

Test Session

The object order conditions during remembering situations (retrieval) compared to demonstration was varied in the following way. In the s*ame condition* the sequence was*:* Animal, drum, tin can, and barrel (n = 15) and in the *mixed condition* the retrieval order*:* Tin can, barrel, animal, and drum (n = 15) was used. Following demonstration or extended warm-up phase there was a delay of 30 min. Deferred imitation involving delays of ten or more minutes is thought to be a measure of long-term memory (Barnat, Klein, & Meltzoff, 1996; Hanna & Meltzoff, 1993; Heimann & Meltzoff, 1996). During the delay all infants had the opportunity to engage in intervening play with distracter toys, which were physically dissimilar to test props (cf. Heimann & Meltzoff, 1996).

After the delay and a second warm-up phase, a test for deferred imitation was administered to infants in all three-demonstration conditions. Children were given each of the props sequentially for 30 s in one of the possible objects orders (*same* or *mixed*) and the behavior of the children within this time interval was videotaped. If the child became distracted during any of the phases, the experimenter tried to redirect the child's attention to the prop by saying, "[child's name] look over here," or "look at this." The experimenter refrained from calling the props by name or saying any part of the target action.

Test Scoring and Inter-Rater-Reliability

Two independent scorers were initially trained with pre-existing video material and operational definitions with a dichotomous yes/no code to a criterion of 92 percent inter-rater reliability prior to scoring infant behavior in the current study independently of one another. Scorers were blind to the specific hypotheses under investigation. The target action "barrel" was scored as a correctly imitated if the child put the spatula into the barrel. Moreover the child had to look at the prop or at the experimenter while performing the target action. This constraint was introduced in the coding of target actions to help minimize the inclusion of data from accidental executions of the target actions. The target action "tin can" was scored if the infant shook the can with one or both hands more than twice vertically or horizontally. The target action "drum" was scored, if the child took the drumstick with one hand and pressed the large red button with it. Finally, the target action "pig" was scored, it the child tried to remove the hat.

Both percent inter- and intra-rater-reliability and kappa were calculated for target action completions. The inter-rater reliability was 94.1 % (κ = .88), while intra-rater reliabilities for 5 randomly selected children were 99.1 % for one rater and 97.5 % for a second rater. All discrepancies between raters were resolved by consensus to 100 % agreement. Preliminary analyses indicated that there were no significant effects of gender on performance. As such, the data were collapsed across gender for all subsequent analyses.

This dichotomous scoring procedure was supplemented by recording the latency times for executed target acts as an additional indication of goal-directedness and intent (cf. Meltzoff, 1985, 1988). If the target act was demonstrated, the latencies were obtained by subtracting the time of target act execution from the trial onset time. The time span allowed for latency reliability between two scorers was 5 s. The inter-rater reliability for latencies of actions scored as completed was 92 % agreement.

Results

Target Action Completion

A score for each test phase (baseline and delayed imitation) was calculated for each infant by summing the number of target behaviors he or she exhibited during the respective tests (range 0 to 4). The mean number of target actions performed across conditions is provided in Table 1. As is shown, more target actions were retrieved in the three demonstration groups than in the control groups. In line with our hypotheses there is a consistent trend of more target actions completed after a demonstration compared to the baseline phase.

Table 1

Average Number of Actions Completed and Response Latencies Across Test Phases and Object Orders

Condition	Object Order	
	Same	Mixed
	Mean (SD)	*Mean (SD)*
Target Action Completion		
Baseline	1.00 (0.71)	1.40 (0.89)
Deferred Imitation	2.80 (1.03)	2.70 (1.34)
Response Latencies		
Baseline	17.00 (8.83)	13.63 (10.90)
Deferred Imitation	6.25 (2.67)	10.38 (4.80)

Note. Target action completion scores range from 0 to 4, whereas the range for response latencies is from 1 to 30 sec.

Essential to demonstrating that potential differences in memory during a test for long-term recall were a function of item-relational versus item-specific information processing and not due to a priori structure of stimulus materials is showing that the spontaneous rate of responding to both object orders (*same* and *mixed*) were comparable. The descriptive data for the control groups across object orders reveals consistent baseline performance irrespective of object order (*same*, $M = 1.00$, $SD = 0.71$; *mixed*, $M = 1.40$, $SD = 0.89$), which did not differ statistically, $t(8) = 0.78$, ns. The similarity in the spontaneous realization of the target actions regardless of presentation order is an evidence for the fact that no a-priori item-relational information seems to exist.

To be sure that the rate of target actions completion reflected memory and not pre-existing knowledge, additional statistical analyses to compare the mean number of target actions completed in respective conditions (control versus demonstration group) were conducted. A mixed 2 (Test Condition) x 2 (Object Order) ANOVA was conducted for completion of target actions as a function of demonstration and recall condition revealing a main effect of Test Condition, $F(1, 26) = 13.48$, $p < .001$. Object Order during recall phases did not reveal a significant main effect, $F(1, 26) = .13$, ns, nor was there a significant interaction between Test Condition and Object Order. Further analyses were conducted to examine the main effect of Test Condition, showing that infants who received objects in the *same* order during the test phase demonstrated significant memory for actions compared to the

control group, $t(13) = 3.48$, $p < .004$, whereas children receiving test props in a different *mixed* order during a test for deferred imitation did not execute significantly more target actions than the corresponding control group, $t(13) = 1.95$, $p < .07$. This pattern of results is consistent with our hypothesis that children receiving test objects in the same order during recall would demonstrate better memory overall than infants who received objects in an altered order after a delay.

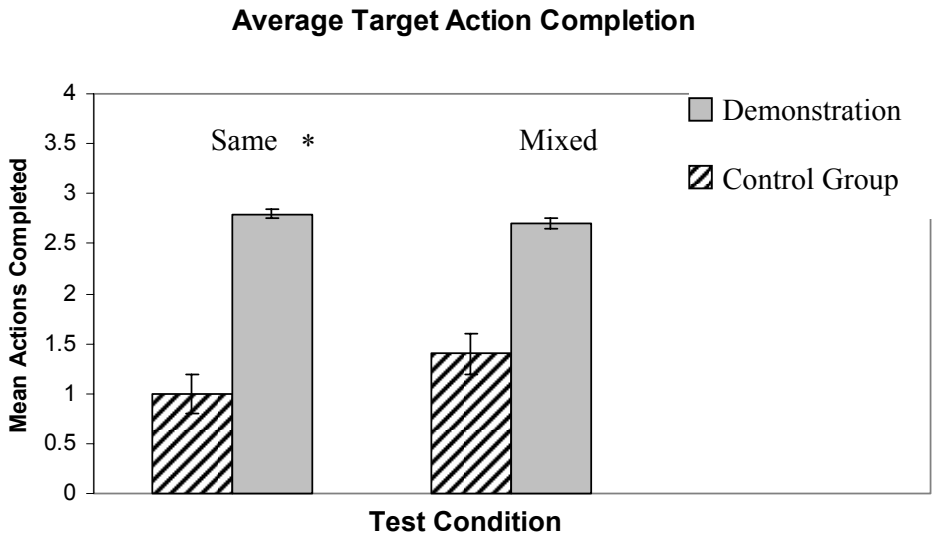

Figure 1. Average number of target actions (± 1 SE) performed by 13-month-olds across conditions. An asterisk indicates that a group completed significantly more actions than infants the baseline control group.

Response Latencies

Response latencies across conditions are also provided in Table 1. In order to assess the speed of responding as a function of test condition and object order a mixed 2 (Test Condition) x 2 (Object Order) ANOVA was conducted for the response times for completion of target actions revealing a main effect of Test Condition, $F(1, 23) = 7.49$, $p < .01$, but no main effect for Object Order during recall, $F(1, 23) = .02$, ns, or significant interaction between Test Condition and Object Order. Further statistical analysis showed that there was no difference in the speed of responding in the control group as a function of object order during the test phase, $t(6) = .48$, $p < .65$. However, consistent with our hypotheses, the infants who saw a demonstration and received objects in the *same* order during a test for deferred imitation responded significantly faster than the corresponding children in the control group, $t(12) = 3.64$, $p < .003$. Furthermore, the children who saw a demonstration and received objects in the *same* order after a delay responded significantly faster than children who received test props in a *mixed* order after the demonstration and delay, $t(17) = 2.34$, $p < .03$. These results are again consistent with our hypotheses because they demonstrate a memory effect based on latency scores as well as significantly slower responding when the object order was altered during recall.

Discussion

Behavioural methods and processes have long history in the study of cognitive phenomena (Malcuit & Pomerleau, 1996; Rovee-Collier, & Cuevas, 2006). In particular, imitation is a critical process for a wide range of behavioural outcomes including language learning and social development, which should be studied. Remembering is a behavioural process that suggests underlying cognitive structures. Prior data across an array of experimental paradigms shows that young infants are particularly adept at detecting specific relations among elements embodied in a configuration – even before they realize their significance or meaning. Results from the elicited imitation paradigm show that infants are capable of perceiving and reproducing relations among tasks in a series (Bauer & Mandler, 1992). But a newer variation of the standard imitation procedure shows that infants also encode relational information among arbitrarily ordered items in a sequence. While the selection or presentation order of stimulus material has typically been manipulated to investigate this type of information processing in an infant's remembering, a more recent experimental technique has capitalized on variations during retrieval (Knopf et al., 2006).

At the cognitive level, if infants encode both item-specific and item-relational information during a demonstration, than an altered object order during a test for long-term recall disrupts access to encoded item-relational information. At the behavioural level, this might be considered a generalization failure. This result was obtained in the previous study (Knopf et al., 2006). The current study was designed to replicate and extend this finding with 11-month-olds demonstrating that object order variations during a long-term memory test impair deferred imitation.

The pattern of results for target action completion demonstrated superior recall for children who received identical object orders in both the demonstration and test phases of the experiment (*Same* Condition) compared to children who received test objects in an altered order during a test for long-term recall than they had seen during the demonstration (*Mixed* Condition). Only the infants in the *Same* Condition demonstrated a significant level of remembering for target actions compared to a corresponding baseline condition. This result confirms the hypothesis that a combination of item-relational and item-specific information processing is superior to item-specific information processing alone. The use of item-relational information, which infants might have encoded during the demonstration was disrupted by having infants receive test stimuli in an altered order during the deferred imitation test. This result is consistent with an earlier experiment by Knopf et al. (2006). Taken together the high specificity of children's memory with regard to object order observed in the prior and current study provides further evidence that the objects themselves do not suffice as cues to elicit significant levels of deferred imitation. Also in line with our expectations, the absolute difference in performance between the *Same* and *Mixed* retrieval conditions was marginal. With increasing age infants are better capable of reproducing arbitrarily-ordered actions indicating more efficient item-specific information processing. As infants get older they are also better at generalizing across a variety of proximal and distal context changes. The pattern of results of target action completion in the current study was corroborated by an analysis of reaction latency times. Here again a similar result pattern emerged with significantly faster target completion in the *Same* condition compared to all other conditions showing that identical object order during demonstration and recall facilitated a faster response and that an altered order during recall was detected by infants.

The results of the current study add to a growing body of evidence showing how remarkably well infants learn bits of new information – and even link these together – merely through a single brief observation of these events. If this is true for infants, then this fact could be of potential use for work with clinical populations. For example, clinical sub-populations such as patients suffering from inability to remember after brain injury or due to age or retarded individuals typically need to (re)learn and reproduce action sequences (i.e. in order to acquire or maintain independent living). The parameters of facilitating the return of stimulus control for infants' imitation can be of great help to applied researchers and this area has received very little study. Intervention techniques employing

imitation procedures could benefit by taking findings from infancy imitation research into consideration and capitalize on the concept of item-relational information processing as a learning aide for the development of optimal learning programmes.

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