Proactive and Retroactive Interference Effects in Development

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Abstract

Infants and children are avid learners. This constant aggregation of new knowledge, however, can interfere with past and future learning. Proactive interference (PI) occurs when past learning interferes with new learning, while retroactive interference (RI) is the attenuation of memory for previous learning as a result of new knowledge. Previous work has demonstrated that adults and children display PI and RI effects, but the developmental trajectories of these effects are less clear. The current study developed a new associative learning paradigm to concurrently test PI and RI in preschoolers and adults. Results demonstrated the presence of RI, and these effects were stable across age groups, suggesting that the mechanisms that modulate RI effects may already be mature in these age groups. No PI effects were found in either group, however. This surprising result suggests the role of associative complexity as a possible modulator of PI in these age groups.

Keywords: Learning; memory development; proactive interference; retroactive interference.

Interference effects

Infants and children are avid learners: they constantly acquire new knowledge. This new knowledge not only expands their sense of the world, but also affects what they already know and what they will learn in the future (Wixted, 2004). Some of these effects are counterintuitive: (1) acquired knowledge may interfere with future learning, the process known as proactive interference (PI), and (2) acquired knowledge may attenuate memory for previously learned information, the process known as retroactive interference (RI). PI and RI effects are particularly important to study in early development because doing so will help determine what factors benefit or detract from the aggregation of early knowledge.

These sources of forgetting may play a role in many early cognitive domains, such as categorization (Mareschal, Quinn, & French, 2002) and word learning (Levy-Gigi & Vakil, 2010). Imagine, for example, that a child with bilingual parents learns the word "cat," but is later introduced to the word "gato." Mapping "gato" onto the child's category of cats may be more difficult than learning an entirely new concept in Spanish since the category is already associated with "cat" (PI). Additionally, the mapping between the word "cat" and the category of cats will likely be weakened as a result of learning to associate the category with a second word (RI).

Interference effects have been the focus of a great deal of research. It is clear, for example, that interference occurs in many different learning systems, including connectionist networks (French, 1999; Ratcliff, 1990) and human adults (Bower, Thompson-Schill, & Tulving, 1994; Wixted, 2004). In adults, RI effects may be modulated by similarity between learning sets as well as mental effort, such that more interference is demonstrated with greater similarity and increased cognitive load (Dewar, Cowan, & Della Sala, 2007; French, 1999; Wixted, 2004). Additionally, RI seems to be modulated by the engagement of networks in the hippocampal region and surrounding cortices (McClelland, McNaughton, & O'Reilly, 1995; Wiskott, Rasch, & Kempermann, 2006). Conversely, PI effects seem to be modulated by executive functions such as attentional control and inhibition of prepotent responses (Baker, Friedman, & Leslie, 2010; Dick, 2012; Kiesel et al., 2010), and appear to be attenuated by activity in prefrontal regions of the cortex (Badre & Wagner, 2005).

Interference in development

Although the majority of research concerning PI and RI has focused on adults, some evidence suggests that interference effects may also be present early in human development. For example, infants demonstrate RI in a visual recognition task (Turati, 2008) as well as a mobile reinforcement paradigm (Rossi-George & Rovee-Collier, 1999), and demonstrate PI in visual facial recognition (Tyrrell, Snowman, Beier, & Blanck, 1990).

Despite the fact that interference occurs across development, the development of the ability to resist each kind of interference is less clear. There is some evidence that RI effects are relatively stable between preschool and school years. Howe (1995) demonstrated that RI effects were similar in preschoolers (approximately 4.5 years) and kindergarteners (approximately 6 years old) in a paired-associate recall task. Similar findings were reported in 4- and 7-year-olds, using a game-based paradigm (Lee & Bussey, 2001). It is unclear, however, whether there are developmental differences in RI if a wider age range is considered. In contrast, developmental differences in PI have been reported. Kail (2002) performed a meta-analysis on PI effects in children ages 4-13 years old, as well as an experiment with children in grades 3-6 and undergraduate adults. Both the meta-analysis and experimental results

indicated a decrease in PI effects across these developmental time scales.

The current study was conducted to investigate any differences in PI and RI between preschoolers (5-year-olds) and adults. To do so, we developed a new associative learning paradigm that would be appropriate to measure interference effects in both children and adults (Experiment 1) as well as provide a control for memory decay when specifically measuring RI (Experiment 2). This paradigm has the advantage of testing for both types of interference in a manner that is appropriate for children and adults.

Experiment 1

To examine developmental differences in PI and RI, we developed a new associative learning task that allows us to study both types of interference within a single paradigm. In this task pairs of objects were associated with an outcome in three phases. In the first phase, participants learned to predict outcomes based the identities of paired objects; in the second phase, objects were re-paired to stimulate new learning, while in the final phase participants were presented again with the original pairs.

We expected to finds both types of interference in children, whereas the extent to which these effects are present in adults was less clear. Previous research suggests that RI effects are present in adults, to the extent that the learned material is sufficiently similar and cognitively challenging across phases (Dewar et al., 2007; French, 1999; Wixted, 2004). Also, given that cognitive control abilities are substantially more advanced in adults and given that PI effects depend on cognitive control (Baker et al., 2010; Dick, 2012; Kiesel et al., 2010), we expected that PI effects, if found, should be greater in children than in adults.

Method

Participants Twenty-six undergraduates at The Ohio State University (20 females) and 34 children (m = 5.2 years, SD = 0.23 years, 14 females) from the surrounding Columbus community participated in this experiment. Children were tested at local preschools. Adults received course credit and children received stickers for their participation.

Six children did not complete the task due to fatigue (n=5) or computer error (n=1). The data from these children were removed from all analyses. Additionally, since the focus of this study was on interference between new and previous learning, we required that participants demonstrate accuracy greater than 70% in the initial learning phase of the experiment to be included in the analysis. In this way, we only included participants who demonstrated learning that could induce PI or be subject to RI. This learning criterion resulted in the removal of three adults and ten children. Our final experimental sample, therefore, consisted of 23 adults (17 females) and 18 children (m = 5.3 years, SD = 0.27 years, 8 females).

Stimuli Experimental stimuli consisted of eight objects with common shapes and colors (e.g. blue circle). Each trial consisted of the presentation of a pair of objects and a visual occluder that resembled a pipe splitting into two ends (see Figure 1). This occluder design was implemented such that an object disappearing behind the occluder could reappear on either side. Crucially, the outcome of the trial (i.e. where the object reappears) depended on the identities of the object pairings.

The object pairings, color of the visual occluder, and color of the background varied by phase: In the first phase, four object pairs were presented along with a white occluder on a dark grey background. In the second phase, objects were repaired and presented with a black occluder on a light grey background. Stimuli in the third phase were identical to those presented in the first phase. The purpose of varying the object pairings was to create interference between learning sets, while contextual information was varied so that new learning would not be too difficult to encode.

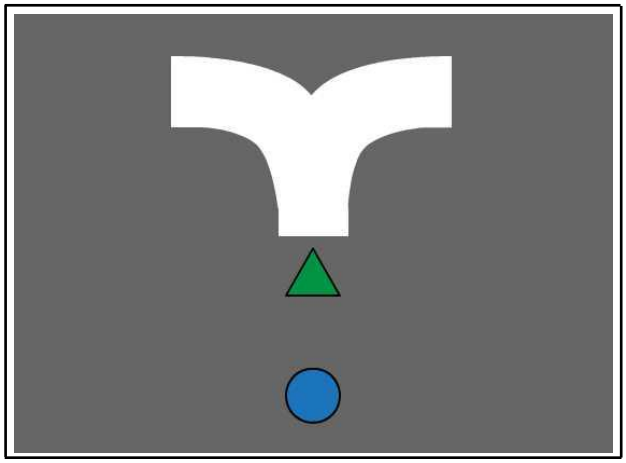

Figure 1: An example trial in phase 1

Procedure The task was computer-based, and stimuli were presented using E-Prime. To encourage interest in the task, children were tested using a touch-screen computer (adults were tested with a standard screen). In each trial two objects were presented with a visual occluder as described above. One object was situated directly above the second object, and the relative position of each object in the pair was counter-balanced across trials. The participant was told that one object would move into the occluder and come out on one side, and was asked to predict on which side of the occluder the object would reappear. Responses were made using the left or right arrows on a keyboard (adults) or by touching the relevant area of the touch-screen (children). Immediately after a response was given, the bottommost object would rise and hit the topmost object, which would move directly into the occluder before reappearing on one side approximately one second later. In addition to seeing the outcome of the object movement, participants were given explicit feedback: adults heard a high or low tone corresponding to correct and incorrect responses, respectively, while children were given explicit verbal feedback by the experimenter (e.g. “That’s right, it does go

to that side!") in addition to the tone. The side of the object's reappearance was predicted by the object pair. In this way, subjects were able to learn the contingency between object pairs and outcomes.

The identity of the object pairings depended on the phase of the experiment: phase 1 consisted of learning four pairs of objects (such that two pairs reappeared on the left side of the occluder and two on the right). The objects were re-paired in phase 2, such that new learning required subjects to create new associations with the same objects and potential outcomes. The third phase was identical to the first phase, except that order of stimulus presentation varied between phases. Table 1 illustrates the abstract structure of object and outcome pairings in this experiment. For phases 1-3, each letter represents an object, while the outcome indicates the side of the object's reappearance from the occluder. Note that each pair in phase 2 includes an object that was associated with the opposite outcome in phase 1.

As noted above, the visual context of these stimuli changed between the phases to facilitate learning and recognition of different learning outcomes in the different phases. Participants were not informed that the context would change between the phases, nor were they told that they would be learning new associations in phase 2 or that they would be relearning the associations from phase 1 in the third phase. Forty trials (10 per pair of objects) were presented to each participant per phase, for a total of 120 trials. Subjects were invited to take short breaks between phases.

Table 1: Abstract object and outcome structure for Experiment 1.

Phase 1	Phase 2	Phase 3	Outcome
A – B	A – F	A – B	Left
C – D	C – H	C – D	Left
E – F	E – B	E – F	Right
G – H	G – D	G – H	Right

Results

The central question of interest was whether children and adults would demonstrate differing amounts of proactive and retroactive interference effects. To address this question, trials in each phase were divided into 5 blocks (8 trials per phase) to closely examine the learning trajectories of these groups (see Figure 2).

To measure PI we compared the beginning (i.e. first block) of phase 1 to the beginning of phase 2: a decrease in accuracy in the second block would indicate PI. To measure RI we compared the end (i.e. last block) of the first phase to the beginning of phase 3: since the object pairs were identical in the two phases, a decrease in performance between these blocks would indicate RI. A series of analyses of variance (ANOVAs) and t-tests was used to statistically measure PI and RI.

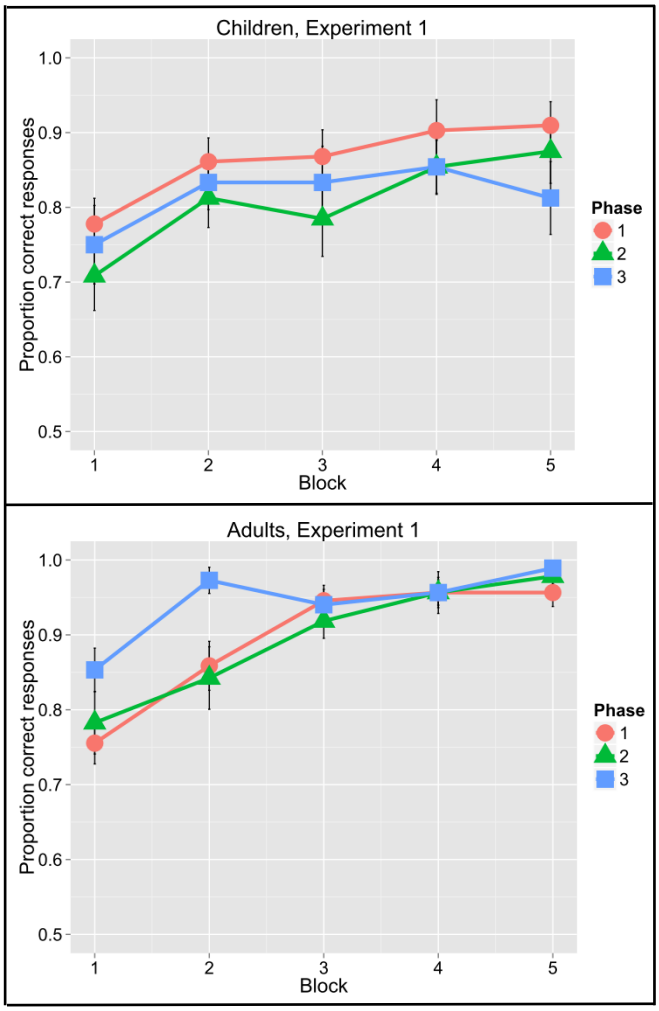

Figure 2: Accuracy in Experiment 1 by block for each phase in children (top) and adults (bottom), with standard error bars.

Proactive Interference To test PI effects, an ANOVA with block as a within-subject factor and age as a between-subject factor was performed on the proportion of accurate responses for the first block of the first and second phases (see Figure 3). There were no significant main effects of block or age, and no interaction between these factors (p's>.2). To more directly test PI effects we conducted paired-sample t-tests between the first blocks of phases 1 and 2 separately for children and adults. The difference between blocks was not significant for children, $t(17)=1.17$, $p>.2$, or adults, $t(22)=.49$, $p>.6$. These results suggest that PI was not a factor in this experiment in children or adults.

Retroactive Interference To test RI effects, an ANOVA with block as a within-subject factor and age as a between-subject factor was conducted on accuracy scores in the last block of phase 1 and the first block of phase 3 for children and adults. A significant main effect of block, $F(1,39)=20.53$, $p<.001$, indicated that accuracy decreased in

the beginning of phase 3 across age groups. There was also a main effect of age, $F(1,39)=4.07$, $p=.05$, suggesting that overall accuracy in these blocks was higher in adults No interaction, however, was found between block and age, $p>.3$, suggesting that the difference between blocks did not vary as a function of age. The strong main effect of block suggested that RI may be found in individual age groups. Indeed, separate paired-samples t-tests revealed a significant difference in accuracies between the end of phase 1 and the beginning of phase 3 for children, $t(17)=2.94$, $p<.01$, $d=0.69$, as well as adults, $t(22)=3.55$, $p<.01$, $d=0.74$. These results suggest that RI did occur in both children and adults, and that interference did not differ between groups.

One possible explanation for these retroactive interference effects is that subjects simply forgot the relevant associations learned in phase 1 as a result of the time passed between phases 1 and 3. If this is the case, then the information learned in phase 2 did not interfere with performance in phase 3 but merely served a placeholder for the passage of time. To determine if this was the case, a second experiment was performed to control for memory decay.

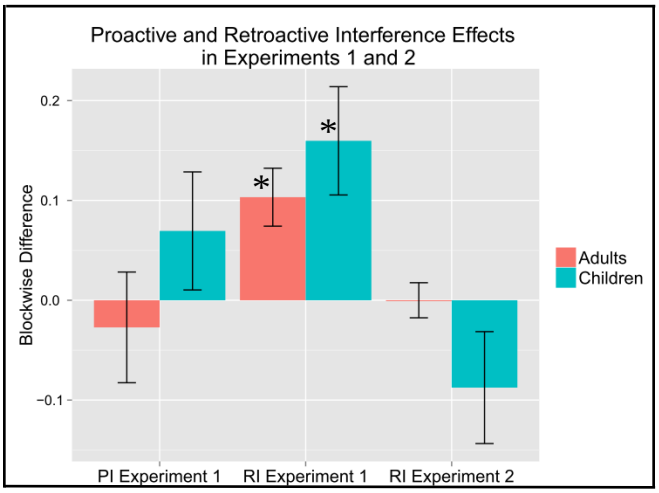

Figure 3: PI and RI effects in Experiments 1 and 2. PI effects were calculated as the difference in accuracy between block 1 of phase 1 and block 1 of phase 2; RI effects were calculated as the difference in block 5 of phase 1 and block 1 of phase 3. Positive values indicate interference; negative values indicate facilitation. * $p<.05$

Experiment 2

One potential interpretation of the RI effects found in Experiment 1 is that participants did not experience interference from learning new associations in phase 2 but simply forgot the associations learned in the first phase due to memory decay. To determine if this was the case, Experiment 2 minimized new learning while retaining the same task structure in the second phase of the task. If the RI effects found in Experiment 1 were due to memory decay, then performance in the beginning of phase 3 should also be attenuated in this experiment in the absence of new learning. If accuracy has not declined at the start of phase 3, however, we can be confident that the results of Experiment 1 were indeed due to interference and not decay.

Method

Participants Twenty-six adult undergraduates (17 females) and 21 5-year-old children (m = 5.3 years, SD = 0.21 years, 13 females) participated. Three children did not complete the experiment due to fatigue (n=2) or because they were unable to complete the task before the end of the preschool session (n=1). Using the same learning criterion described above, three adults and eight children were further removed from the analysis for failure to demonstrate sufficient learning in the first phase of the task. The final analysis, then, included 23 adults (14 females) and 10 children (m = 5.2 years, SD = 0.13 years, 6 females).

Stimuli The stimuli presented in phases 1 and 3 were identical to those in Experiment 1. In the second phase, however, pairs of objects were replaced with horizontally oriented arrows pointing to the left or right side of the screen. This was done so that participants could easily predict the outcome of each trial based on the direction of the arrows. In this way, participants continued performing the same task but with minimal new learning. The occluder and background colors in phase 2 were the same as in Experiment 1.

Procedure The procedure was the same as in Experiment 1: participants were presented with two objects (phases 1 and 3) or two arrows (phase 2), and predicted on which side of a visual occluder an object or arrow would reappear.

Results

The purpose of this experiment was to determine if the attenuation of performance in Experiment 1 could be explained by memory decay. As such, accuracies in the last block of phase 1 and the first block of phase 3 were compared, as in Experiment 1 (see Figure 4 for the learning curves of each phase for children and adults, and Figure 3 for the differences between the target blocks). An ANOVA with block as a within-subject factor and age as a between-subject factor revealed a main effect of block that was approaching significance, $F(1,31)=3.77$, $p=.06$. However, in contrast to Experiment 1 (where performance dropped in phase 3 compared to phase 1), in this experiment, performance actually improved in phase 3. There was a significant main effect of age, $F(1,31)=6.5$, $p<.05$, indicating that adults' accuracy was higher across blocks, as in Experiment 1. The interaction between block and age was approaching significance, $F(1,31)=3.77$, $p=0.6$, possibly reflecting a greater improvement in children's accuracy in the beginning of phase 3 from the end of phase 1. Individual t-tests indicated that the difference between these blocks was not significant in children ($p>.1$), or adults ($p=1$). These

findings suggest that simple forgetting cannot explain interference effects observed in Experiment 1.

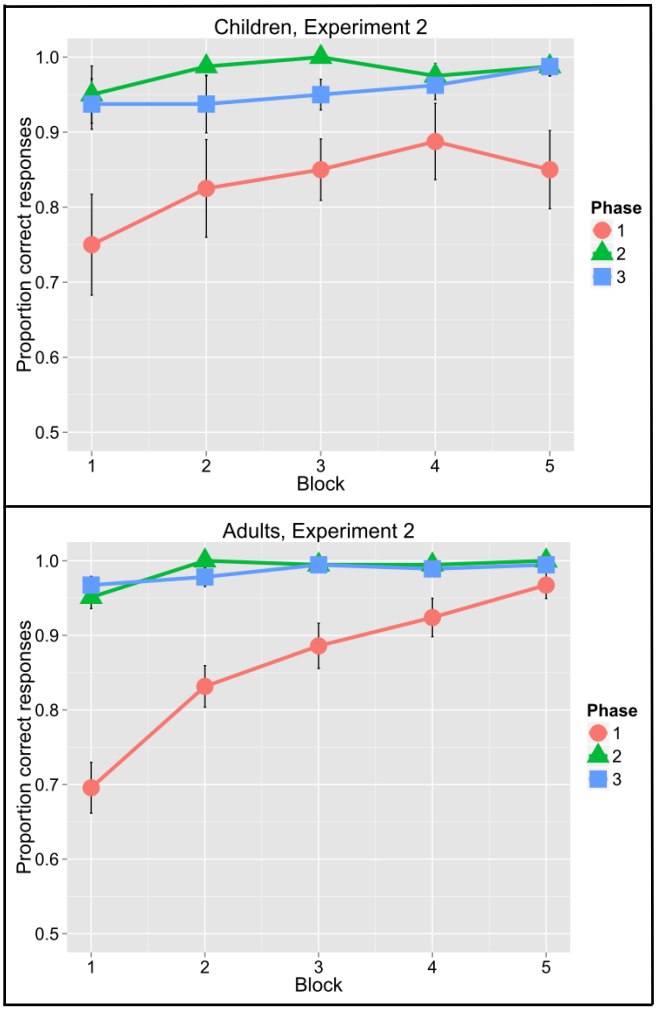

Figure 4: Accuracy in Experiment 2 by block for each phase in children (top) and adults (bottom), with standard error bars.

General Discussion

This study investigated proactive and retroactive interference effects in preschoolers and adults. Results indicated comparable levels of RI in children and adults, but demonstrated no PI in either group. These results support recent claims that RI seems to be a particularly potent source of forgetting in humans (Wixted, 2004).

Additionally, our findings replicate and extend previous demonstrations that RI seems to produce consistent levels of interference across age groups. Specifically, these results provide new evidence that RI effects are stable from the preschool years into adulthood. This consistency may be the result of the early development of the neural systems involved in modulating RI, specifically the hippocampal formation (McClelland et al., 1995; Wiskott et al., 2006). Recent work suggests that the hippocampus and surrounding areas in the medial temporal lobe have functionally developed by the age of five years (Alvarado, 2000; Bauer, 2008), which is consistent with our findings of stable RI effects following this age.

The results of this study are inconsistent, however, with the previous literature suggesting the presence of PI in children (e.g. Baker et al., 2010) and adults (e.g. Kiesel et al., 2010), as well as its decline with development (Kail, 2002). Why was PI not a factor in this task? One possibility is that the structure of the learned associations was not conducive to this type of interference. Each object in the stimulus set appeared only in a single pair (which was associated with a single outcome), such that each object in a pair was perfectly predictive of a given trial's outcome (see Table 1). As such, it was not necessary to encode an association between the two objects in the pair. This simple structure may have reduced demands on executive function, which might not have been the case if more complex structures were presented. Recall that PI is typically linked to executive functions (Baker et al., 2010; Dick, 2012; Kiesel et al., 2010), which are sub-served by the prefrontal cortex (Badre & Wagner, 2005). Also recall that the areas of the prefrontal cortex sub-serving executive function mature relatively late (Bunge & Zelazo, 2006). Therefore, it is quite surprising that PI effects did not transpire in young children. Perhaps the task was too easy to yield such effects (although it was not too easy to yield RI effects).

More broadly, the study of interference effects in development can potentially shed light on a number of important developmental phenomena. Word learning, for example, may depend in large part on associations between sounds and referents (Smith, Jones, Yoshida, & Colunga, 2003). Recent work has suggested that 12- and 14-month old infants raised in a monolingual or bilingual environment do not differ in their ability to learn simple word-object pairings (Byers-Heinlein, Fennell, & Werker, 2013). An intriguing possibility is that language background may instead influence the ability to form more complex associations (e.g. between words, referents, and identity of the language).

Many questions await future research. For example, creating more complexity in the structure of associations, such that three-way bindings between $object_1$, $object_2$, and the outcome are necessary for learning, will help us test the hypothesis that PI is modulated by associative complexity, possibly through increased demands on executive function. Additionally, mapping interference effects in more (particularly younger) age groups will allow us to determine whether interference effects are subject to developmental change and the time scales at which such change occurs. Understanding the mechanisms and developmental time course of these effects will allow us to understand a potentially fundamental aspect of learning and memory and how these processes interact early in life.

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