THE MECHANISMS OF THE TEMPORAL RELEASE FROM PROACTIVE INTERFERENCE

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SUMMARY

The release from proactive interference (PI) is a well-studied phenomenon, but its cause is elusive. When a release in PI is caused by changes in the content of to-be-remembered items, the more accurate retrieval is likely a result of changes in context (Watkins & Watkins, 1975). However, changes in context do not readily explain the cause of PI release resulting from a temporal delay. Instead, it could be that during the delay subjects disengage from intrusive information from previous trials. The ability to disengage from no-longer-relevant information is related to fluid intelligence (Gf). I predicted that this ability to disengage, as defined by fluid intelligence, is the driving factor of the time-based release from PI. In order to test this prediction, I administered a free recall task to individuals of high and low Gf. The time between the last two lists was lengthened to cause release. The time manipulation did not cause a release from PI; essentially, this result represents a failure to replicate. Limitations of the study and potential methodological issues are discussed.

CHAPTER 1

INTRODUCTION

Despite what may seem intuitively obvious, memories for past events do not simply fade over time. Forgetting is more analogous to losing an item; it still exists, but it cannot be found. The loss of these items in long-term memory is often due to proactive interference (PI) – that is, the tendency for past memories to interfere with the retrieval of newer memories (Postman, 1961). Even though the causes of forgetting in long-term memory had been well established, there was contention over whether or not short-term memory operated under similar principles. Some researchers argued that, rather than through interference, forgetting in short-term memory occurred as a result of the memory trace decaying (Peterson & Peterson, 1959). However, with research from Keppel and Underwood (1962) and others that followed them, it became increasingly apparent that forgetting in long-term memory and short-term memory both occurred as a result of interference.

The PI release paradigm became particularly prevalent in supporting the interference side of the debate. Typical research in the paradigm showed that the forgetting caused by interference could be alleviated by changing aspects of the to-be-remembered material (Wickens, 1970). Research has found that this increase can be explained under a contextual view of memory. This perspective of memory stated that aspects of the environment are encoded alongside the critical material. Large amounts of overlap in these random contextual elements at different encoding times lead to large amounts of PI (Watkins & Watkins, 1975). It followed logically that changing aspects of the to-be-remembered material changed the context of encoding, leading to a decrease in the amount of PI.

However, there is a second type of PI release that is not as easily explained. Namely, it has been found that increasing the time between encoding decreases the amount of PI (Kincaid & Wickens, 1970). This result is difficult to incorporate into the contextual view of memory; the content of the to-be-remembered material remains constant, yet the amount of PI reduces. It has been argued that larger intervals of time allow more variation in the random contextual elements that are encoded (Gorfein, 1987). As a result, the contextual cues used in the present will more closely match the context of more recent encoding episodes, making them easier to retrieve. However, even direct manipulations of context have failed to cause a release from PI (see, for instance, MacLeod, 1975). Thus, the extent to which PI can be released from *random* changes in context occurring in a controlled experimental setting is questionable. There may be some other mechanism that causes a reduction in PI over time.

Shipstead and Engle (2012) suggested that fluid intelligence (i.e., novel reasoning ability) may be related to forgetting. Contrary to intuition, they stated that individuals who are higher in this fluid intelligence ability are more capable of forgetting extraneous information. Following their research, I propose that the cause of the time-based release from PI is related to this fluid intelligence ability. Thus, I will take an individual differences approach to show that individuals of higher fluid intelligence show a greater release from PI over time than do individuals who are lower in fluid intelligence.

CHAPTER 2

A HISTORY OF PI RELEASE

Interference vs. Decay

The idea that human memory is divided into two systems, primary (short-term) memory and secondary (long-term) memory (James, 1890), has prompted countless questions in the field of psychology. One of these questions – how do we forget? – prompted a large-scale debate between two competing theories: forgetting through interference, and forgetting through trace decay. Research in the 1950s showed decisively that forgetting in long-term memory was governed by interference (Postman, 1961). However, the cause of forgetting in short-term memory turned out to be much less simple.

Peterson and Peterson (1959) predicted that items within short-term memory decayed over time. They gave subjects 3-letter strings, which they called trigrams, and asked them to recall the strings after a variable period of time. Subject accuracy sharply decreased as this period of time, the retention interval, was increased. However, Keppel and Underwood (1962), using the same task, showed that forgetting in short-term memory instead occurred as a result of proactive interference building up across trials. The critical difference was in the way accuracy was analyzed; Keppel and Underwood looked at accuracy across trials rather than over time. They found substantial amounts of forgetting as more trials had been completed, but the length of the retention interval itself did not hinder accuracy.

Release from Proactive Interference

More evidence for the interference account came from Wickens, Born, and Allen (1963). They found that the forgetting seen in the Peterson task could be reversed if the class of material being learned was changed – a phenomenon known as the release from PI. The typical PI release paradigm involved a variation of the Peterson task. Subjects were presented trigrams which they were asked to recall after a retention interval. All trigrams preceding the last trial were drawn from the same class of material (e.g., all were letters or digits), and the final trial contained material of a different class. The magnitude of the PI release was dependent on how disparate the two classes of information were. For instance, a greater PI release was found when switching from fruit words to profession words rather than from fruits to vegetables (Wickens, Dalezman, & Eggemeier, 1976). These content switches were not limited to semantic changes; changes in content language and content modality (i.e., visually presented vs. orally presented) also produced a large PI release (Wickens, 1970).

Kincaid and Wickens (1970) showed that a release from PI could also be obtained by manipulating time. They gave subjects several trials of the Peterson task; however, they changed the length of time between the last two trials (the inter-trial interval; ITI) rather than the content of the trigrams. Accuracy for the last trigram increased as the ITI lengthened, out to 45 seconds. They suggested that the interfering memory traces decayed over time. However, a study by Turvey, Brick, and Osborn (1970) showed that relative time is more important than absolute time with respect to interference effects. Essentially, increasing the ITI increased the distinctiveness of the current trial, while the previous trials blended together.

Mechanisms of the Release

Although the buildup and release of proactive interference are very robust findings within the psychological literature, the mechanisms that produce these effects in a memory task have not clearly been explained. Two potential hypotheses were proposed by Wickens (1970). The first one, the attentional hypothesis, stated that the loss of accuracy across trials is a product of waning attention. As the task proceeds, the use of attentional resources decreases, so the encoding of new items becomes less effective. The increase of accuracy observed on the release trial is a result of the subject reengaging attention, making encoding more effective. Engle (1975) tested this hypothesis using pupil size as an index of attention (i.e., more dilation indicates more attention). As the hypothesis predicted, pupil size decreased with successive trials. However, pupil size did not increase on the release trial, suggesting that the attentional hypothesis was incorrect.

The second hypothesis, the cue overload hypothesis, suggested that PI effects were a result of changing effectiveness of cues used to retrieve items from secondary memory (Watkins & Watkins, 1975). As more trials occurred, a single retrieval cue became associated with an increasing amount of items; the probability of recalling a correct response decreased due to the sheer number of intruding responses. When there was a switch in item content, however, a different retrieval cue was used – one with fewer associated responses. Gardiner, Craik, and Birtwistle (1972) provided support for this hypothesis. Rather than the Peterson task, they used an immediate free recall task to look at PI effects. The content switch was between two subcategories of a larger category; for instance, subjects would see wildflower words on the buildup trials and garden flowers on the release trial – both of which were part of the more general "flower" category. When they were provided the subcategory name after presentation of the final trial words, PI release occurred. However, if the subcategory name was not provided, there was no evidence of release. Essentially, the name was used as a new cue to retrieve items from secondary memory, thus increasing recall accuracy. The group that did not receive the subcategory name presumably used the same cue as the previous trials, so accuracy did not increase.

Researchers have also focused on how individual differences in ability are related to PI effects. This research has paid particular interest to individual differences in working memory capacity (WMC), due to its importance in retrieval and blocking interference (e.g., Rosen & Engle, 1997; Unsworth & Engle, 2007). While WMC consistently relates to the buildup of PI, so far there has been only negative evidence for the role of working memory in PI release (Kane & Engle, 2000). Bunting (2006) looked at the relationship between fluid intelligence (Gf) and proactive interference. Fluid intelligence is similarly related to the buildup of PI, but is less important in PI release; the correlation to Gf becomes weaker after release.

Nearly all of the research examining the mechanisms of PI release has focused on content-related release. It is a general assumption that all PI release operates under the same mechanisms. However, there is evidence suggesting that the time-related release and content-related release are different. For instance, the magnitude of PI release observed from a change in content is typically greater than that observed from a change in time; the initial content-related release study had a PI release of 91%, compared to the release of 74% in the first time-related release study (Wickens, Born, & Allen, 1963; Kincaid & Wickens, 1970). Also, adopting the view of Gorfein (1987), the time-based release may be affected by changes in random contextual elements in the environment due to differences in time between trials. The relative time between trials in a content-release is constant, so environmental context plays less of a role. These discrepancies warrant an analysis of the mechanisms behind the time-related release from PI. I believe that this discrepancy can be solved by examining individual differences in performance; subjects who are better at disengaging from intruding information should be more capable of blocking interference over time.

CHAPTER 3

METHOD AND MATERIALS

Subjects

Subjects were selected from an existing database within the Attention and Working Memory Lab. Selection criteria included being between the ages of 18 and 35, having normal eyesight and hearing, and being in the top or bottom quartile of fluid intelligence. An individual's Gf score was computed as a z-score composite from performance on the Ravens Advanced Progressive Matrices (Raven, Raven, & Court, 1998), Letter Sets (Ekstrom, French, Harman, & Dermen, 1976), and Number Series (Thurstone, 1938) tasks administered previously in a screening procedure. A total of 80 individuals participated in this study – 40 subjects from the top quartile of Gf scores, and 40 from the bottom quartile. One subject did not follow instructions and was therefore not included in the analyses. Subjects were compensated with a twenty dollar check upon completion.

Design

The experiment was 2x2x5 mixed factorial design. High and low Gf subjects completed five trials of a free recall task. Fluid intelligence is a blocking variable. The ITI between the last two (pre- and post-release) trials is a between-subjects variable. The ITI between all lists is 6 seconds for the control group. For the experimental group, the ITI between the first four trials is 6 seconds; however, the ITI between the last two trials is 144 seconds. The 144 second interval corresponds to the 45 second ITI used by Kincaid and Wickens (1970). Their 45 second ITI was three times the combined length of their retention interval and recall interval (10 seconds and 5 seconds, respectively). Likewise, the experimental ITI of 144 seconds is three times the length of the combined retention (18 seconds) and recall (30 seconds) intervals. Additionally, trial number is a within-subjects variable; the analyses focus on the last two trials. The dependent variables of interest are recall accuracy. Recall accuracy is calculated as the total number of correct responses divided by the number of words in the list.

The 60 experimental words were selected to be concrete nouns with one syllable and five letters. These words were randomized into the 5 experimental lists. These lists were then counterbalanced. The analyses combine all of the word counterbalance conditions.

Materials

The task was on computers using E-Prime 2.0. Subjects were run in a sound-proof booth to block out distracting sounds. Responses were recorded using a microphone in order to obtain accurate times for each response.

Procedure

Subjects were randomly assigned to the ITI conditions when they entered the lab. Subjects were run in separate rooms, so that the speaking of each subject would not be a distraction to the others. After giving consent, subjects were taken into a sound-proof booth to start the task. The subjects performed 5 lists of a free recall task, interlaced with an antisaccade task (Hallet, 1978) between lists. They were told that the study assessed multi-tasking ability, so performance on both parts was important. Each free recall list contained twelve 5-letter nouns. Each word was presented for 750 ms, followed by a 250 ms delay. Following the presentation of the last word was an 18 s retention interval. A retention interval was used to displace items into secondary memory, and therefore maximize the amount of PI (Craik & Birwistle, 1971). During the retention interval, subjects performed prosaccade and antisaccade trials (Unsworth, Schrock, & Engle, 2004) to prevent rehearsal (henceforth called the *rehearsal preventative task*). Each trial lasted 6 s. At the beginning of each trial, a circle (indicating a prosaccade trial) or triangle (indicating an antisaccade trial) was displayed in the center of the screen for 1,500 ms. A "+" fixation point was then presented for 1,000 ms, immediately after which a "*" flashed on one side of the screen for 200 ms. Following this flash, the target letter ("O" or "Q") appeared on the opposite side of the screen for 300 ms and was immediately masked. The subject had to indicate which letter appeared by pressing the corresponding key on the keyboard; subjects had 3,000 ms to give an answer. At the end of the retention interval, a recall screen appeared prompting subjects to say into a microphone the words they can remember from the previous list. Subjects were given 30 s to recall as many words as they can. After the recall period ended, there was an inter-trial interval of 6 s, during which subjects again performed the rehearsal preventative task. After the ITI, subjects received the next list of words. Prior to the final trial, some subjects received an ITI of 144 s rather than 6 s; subjects did the rehearsal preventative task during this time as well.

CHAPTER 4

RESULTS AND DISCUSSION

Average recall accuracies for each condition are shown in Table 1. PI release is negative for the short ITI conditions, suggesting further buildup of PI. On the other hand, the long ITI conditions have positive release values, suggesting an increase in accuracy on list five. Figure 1 displays recall accuracy graphically. There is not much decrease in accuracy from list one to list four in any group, and the increase in accuracy on list five is not particularly massive.

A 2 x 2 x 2 mixed ANOVA was employed to analyze the data, with fluid intelligence (high, low) as a between-subjects factor, inter-trial interval (6 s, 144 s) as a between-subjects factor, and trial number (pre-release trial, post-release trial) as a within-subjects factor (the results of which are presented in Table 2). There is a main effect of fluid intelligence on accuracy; subjects with high Gf did better on the recall test than low Gf subjects. However, no other effects were significant. Critically, the two-way interaction between ITI and trial number is not significant; $F(1,75) = 2.01$, $p = .16$.

The lack of a ITI x Trial Number interaction suggests that PI release was not obtained; accuracy on the final list was not greater than the previous list after a long delay. This seriously limits the ability to make any meaningful conclusions about the data. There cannot be a difference in release between the fluid intelligence groups if no PI release was obtained in the first place. Thus, the role of fluid intelligence in the time-based release from PI cannot be assessed in this study.

The lack of PI release likely stemmed from one (or a combination) of three issues: (1) use of a free recall task to build up PI, (2) use of prosaccade and antisaccade as the rehearsal preventative task, and/or (3) error in using only one data point. The free recall task used here contained twelve words per list; this is much higher than the number of items used by Peterson and Peterson (1959). It could be that all of the PI buildup occurred *within-list*, and that PI was completely release between lists. This would explain the large difference in accuracy on the first trial, as well as the relatively flat distribution of accuracy across the five trials for all groups. Despite what seemed intuitive at the time the study was designed, the prosaccade and antisaccade trials may have failed to prevent subjects from rehearsing items. This would result in high Gf subjects performing much better than low Gf subjects, and low PI buildup. Again, this pattern was obtained in this dataset. Lastly, measurement error is high when only one data point is used (in this case, the difference between list 5 and list 4). A more robust, less error-prone measure of release could have been obtained if the free recall task was doubled or tripled.

Thus, the research question remains: what causes the time-based release from PI? Gorfein (1987) currently provides the best explanation for the phenomenon, but further investigation into the topic is warranted.

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APPENDIX A: TABLES AND FIGURES

Table 1: Mean accuracy for the dependent variables

Condition	List 1 Accuracy	List 2 Accuracy	List 3 Accuracy	List 4 Accuracy	List 5 Accuracy	PI Release
High Gf, 6 s ITI	6.00	4.50	4.75	5.35	5.05	-0.30
High Gf, 144 s ITI	5.75	4.80	4.60	5.10	5.30	0.20
Low Gf, 6 s ITI	3.53	2.95	2.68	2.68	2.58	-0.10
High Gf, 144 s ITI	3.80	2.80	2.65	2.70	3.25	0.55

The list accuracy values reflect the average number of words correctly recalled for that list.
PI Release is the average difference between list 4 and list 5 accuracy

Table 2: ANOVA summary table

Source	SS	df	MS	F	p
List Number	0.29	1.00	0.29	0.18	0.67
Gf Group	226.79	1.00	226.79	58.43	<.001
ITI Group	1.16	1.00	1.16	0.30	0.59
ListxGf	0.73	1.00	0.73	0.45	0.51
ListxITI	3.29	1.00	3.29	2.01	0.16
GfxITI	1.16	1.00	1.16	0.30	0.59
ListxGfxITI	0.06	1.00	0.06	0.04	0.85
Error	291.12	72.00	4.04		
Total	524.60	79.00			

List Number represents list 4 and list 5 accuracy. Gf Group represents the Gf manipulation, and ITI Group represents the delay manipulation.

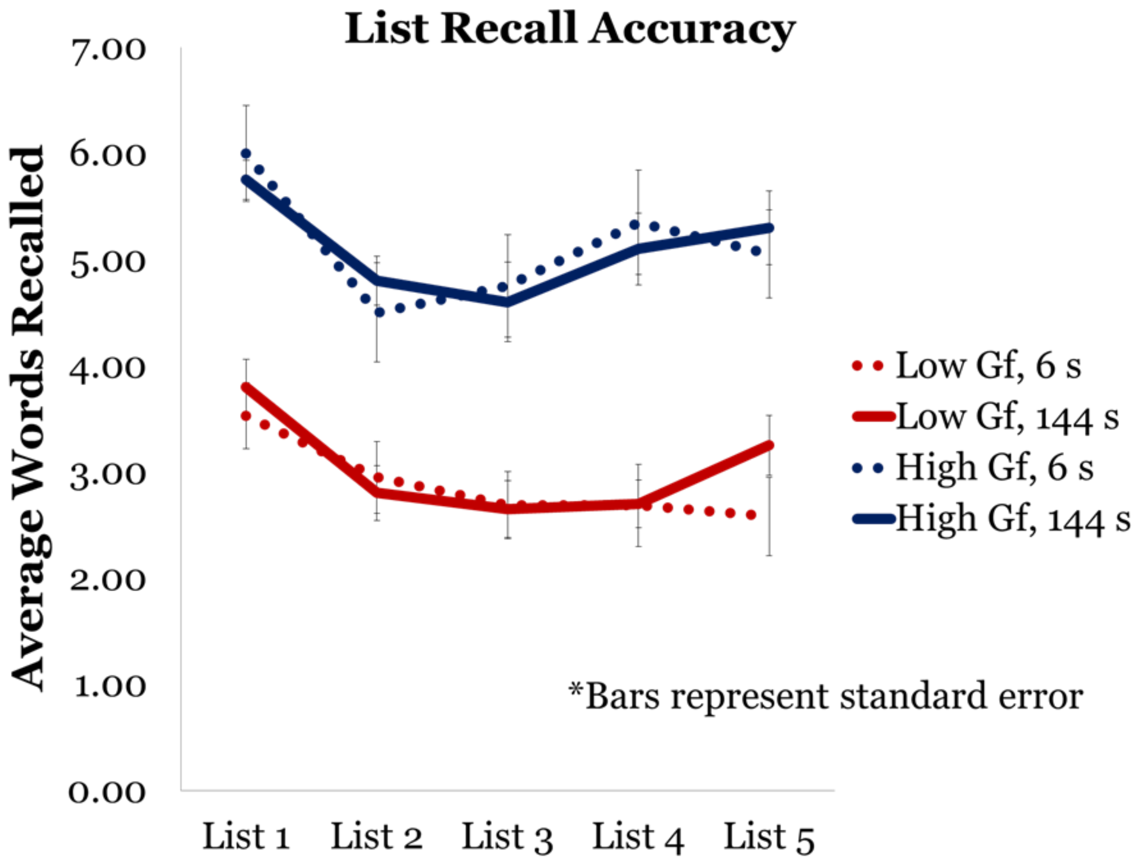

Figure 1. Free recall accuracy for each list of words.