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"Acid bath" effects on storage and retrieval PI

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Sixty undergraduates participated in a memory experiment designed to examine the storage component of PI in the Brown-Peterson task. PI was built up in 24 blocks of four trials by presenting items from common taxonomic categories. Memory items were auditorily presented, and, in addition, subjects viewed slides shown during the study and retention stages of each trial. On the critical fourth trial of each block, experimental subjects viewed a slide showing the prior three memory items while attempting to memorize a fourth item from the same category. Contrary to the predictions of "acid bath" theory, the storage component of memory showed a trend toward release from PI when an item was studied and retained in the presence of similar prior items. Simple recall measures showed a trend toward the predicted PI exacerbation on the experimental fourth trials. However, a Bayesian storage and retrieval analysis (Chechile & Meyer, 1976) revealed that these effects were confined to the retrieval component of memory. The results are interpreted to suggest a model for storage PI similar to Conrad's modified decay model.

Recent findings have lent support to the view that both storage and retrieval processes are involved in the buildup and release of proactive interference (PI) in Brown-Peterson memory tasks. Chechile and Butler (1975), Conrad (1967), Dillon (1973), Petrusic and Dillon (1972), Posner and Konick (1966), and Reitman (1974) have all reported data implicating an important role for storage-like processes in PI. The role of retrieval-like processes has also been reported frequently in the buildup and release of PI. Baddeley (1972), Bennett and Bennett (1974), Chechile and Butler (1975), Gardiner, Craik, and Birtwistle (1972), Levy and Jowaisas (1971), and Loftus and Patterson (1975), among others, have reported data demonstrating retrieval processes in PI. One long-standing and plausible explanation for the dynamics underlying retrieval PI has been described in terms of response competition at the time of test. Following such a concept, decrements in retrieval efficiency could result because items that have been encoded similarly on salient dimensions are correspondingly difficult to discriminate during a retrieval search.

It is more difficult to describe a simple mechanism by which the storage of an item could be disrupted because of its similarity to prior items. Posner and Konick (1966) and Posner (1967) have proposed that the effects of prior items on the storage of a new item might be analogous to the way an acid acts on a piece of metal. The longer a piece of metal remains in an acid bath, the more indistinguishable its features become. Furthermore, the stronger the acid, the more rapid is the erosion of the features. In Posner's analogy, the strength of the "acid" which acts on an unrehearsed item in the labile stages of storage is positively related to the item's similarity to prior items. Forgetting results from the loss of distinguishing features that takes place during the retention stage of the Brown-Peterson task. If Posner's analogy is accurate, then storage PI acts to reduce the amount of time an item is discriminably available, either for testing or for subsequent processing into deeper levels of encoding. Gorfein (1974) has pointed out that the "acid" of Posner's theory should also vary with the recency of the similar items. This principle would be required by findings such as those of Gorfein (1974), Loess and Waugh (1967), and Peterson and Gentile (1965), which show that the PI effect gradually disappears with lengthening intertrial intervals up to 2 min.

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One strategy to test the version of Posner's (1967) theory described here would be to vary the strength of the "acid" and then measure how the storage component of PI is affected. As discussed previously, PI strength must vary with the amount of time separating a current item from previous ones. Consequently, increasing the exposure and recency of prior items should increase "acid" strength. In the limiting case, presenting prior items for a second time, immediately before the current item, should result in an exacerbation of the PI effect on the current item's storage.

Recently, Chechile (Note 1) and Chechile and Meyer (1976) have developed a Bayesian statistical procedure that analytically separates the storage and retrieval components of forgetting in a Brown-Peterson task. Chechile and Butler (1975) have extended the procedure to the buildup and release of Brown-Peterson PI. In general, the separation procedure involves constructing a probabilistic task analysis for a task in which recall trials are randomly supplemented with forced-choice recognition trials followed by a 3-point confidence judgment.

Storage and retrieval measures are both defined as probabilities, θ_s and θ_r, respectively. The storage probability is defined as the proportion of trials on which a subject sufficiently stores the target item. The probabil-

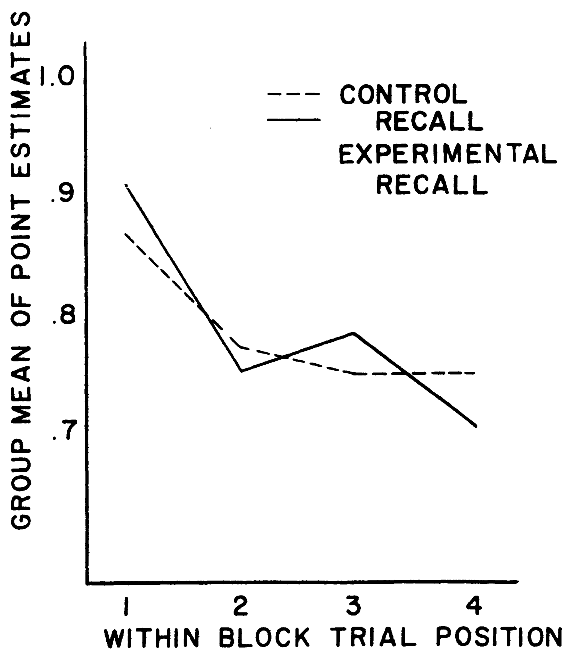

Figure 1. Mean recall proportions for groups, plotted as a function of within-block trial position.

ity of retrieval is defined as the proportion of trials on which the subject successfully retrieves the item, given sufficient storage. The probability of correct recall is then the product $\theta_s \cdot \theta_r$, since correct recall requires both sufficient storage and successful retrieval. Storage loss and retrieval loss are found to be separate, independent components of Brown-Peterson forgetting (Chechile & Butler, 1975; Chechile & Meyer, 1976; Chechile, Note 1; Gerrein, Note 2).

In extending the procedure for the separation of storage and retrieval to the present study, distributions for θ_s and θ_r will be computed for each subject at each within-block trial position. According to the predictions of "acid bath" theory, θ_s should be lower for those trials where similar prior items are re-presented immediately before the current item.

METHOD

Subjects

Sixty undergraduates at Tufts University participated in the study in order to fulfill a course requirement. All spoke English as their native language and reported having normal hearing.

Design and Materials

An experimental session consisted of 24 blocks, with four auditorily presented Brown-Peterson trials in each block. All memory and test items within a given block were selected randomly from the same taxonomic category (Battig & Montague, 1969). On any trial, memory could be tested with one of three measures: recall, old recognition, or distractor recognition. Equal proportions of the three types of memory measures were distributed randomly across the 24 trials at each within-block position.

Subjects were tested under one of two slide viewing conditions. Thirty experimental subjects performed the auditorily presented memory tasks and viewed slides showing three different words on each trial. Slide words for Trial Positions 1, 2, and 3 were selected randomly from the 1 to 50 per million section of Thorndike and Lorge (1944). However, on the fourth trial of each block, the experimental subjects viewed a slide showing the three memory items used earlier in that block. Thirty control subjects were tested under identical conditions for Trials 1, 2, and 3 of each block, and differed only in the slide presented at each fourth trial position. On these trials the control group viewed three words from a new, unrelated taxonomic category.

Apparatus and Procedure

The tape-recorded instructions and experimental trials were played on a Sony TC-630 stereo tape recorder and delivered over Koss Pro-4A stereo headphones. Slides were presented with a Kodak Carousel 750 projector. The projector was controlled by a Uher F-422 diapilot, responding to signals recorded on the inaudible fourth band of the tape. These signals were recorded to present each slide 1 sec before the beginning of the memory trial.

Each Brown-Peterson trial consisted of three stages: the presentation of the memory item, a 12-sec retention interval, and a test cue followed by the subject's response and confidence rating. The slide for each trial was presented 1 sec before the memory item and remained on until the end of the retention interval. The memory item was spoken in a male voice from the left headphone. Immediately afterward, a randomly selected three-digit number was spoken in a female voice over the right headphone. The subject was required to recognize all three words of the slide, repeat the memory item, and then count backward by threes. After 10 sec of counting, one of two types of test cues were spoken in the male voice from the left headphone. If the cue was the word "recall," the subject was allowed 1.5 sec to verbally report the memory item. If any other word was presented, the subject was required to decide whether or not that word was the memory item for that trial. The subject's "yes" or "no" response was followed by his confidence rating for that response (a number from 1 to 3, with 3 being most certain). The subject was not told which type of cue to expect.

Within each block, trials were separated by a 4-sec interval. A 20-sec rest interval was allowed between blocks. Subjects were given one practice trial with each type of test cue before the experimental session.

RESULTS AND DISCUSSION

A standard Bayesian analysis of a normal model was used to test the reliability of experimental effects. Priors were indifferent over the interval 0 to 1.00 for μ, the group mean of the N point estimates, and for log σ, the log of the standard deviation of the point estimates. Posterior marginal distributions for $t = (\mu - \bar{X})\sqrt{N}/S$ are then distributed as a Student t with $N - 1$ degrees of freedom (cf. Box & Tiao, 1973, pp. 92-101). The value for p reported with each effect refers to its reliability, and essentially corresponds to the value $(1 - \alpha)$ in a classical analysis.

Figure 1 shows group means for correct recall proportions, plotted as a function of within-block trial position. Within-subject difference scores between the first and third trial positions indicate a reliable PI buildup in recall for both the experimental group ($t = 3.11$, $df = 29$, $p > .997$) and for the control group ($t = 2.59$, $df = 29$, $p > .99$). Recall measures also show that the fourth-trial

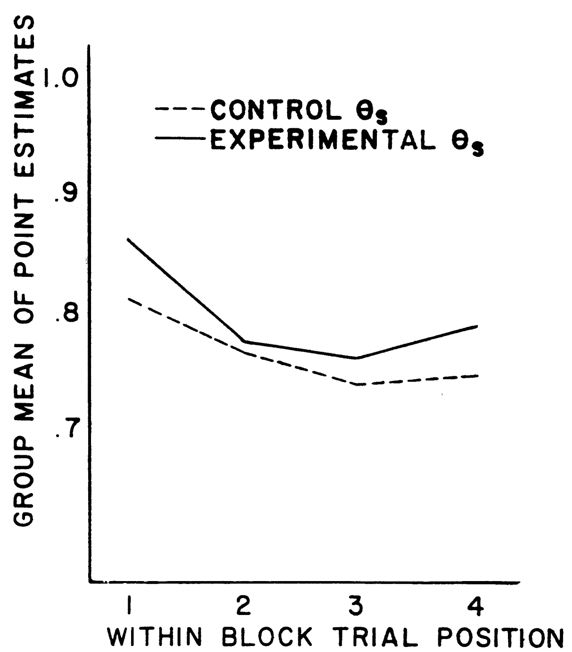

Figure 2. Group means of point estimates for the probability of sufficient storage, plotted as a function of within-block trial position.

performance of the experimental group dropped below that of the control group. This difference indicates a trend toward greater PI for the fourth item when it was studied and retained in the presence of similar prior tiems. Although the difference cannot be considered reliable ($t = .723$, $df = 58$, $p \cong .75$), it is in the direction of the prediction of "acid bath" theory.

However, the results of the storage and retrieval analysis indicate very clearly that the buildup of PI in this experiment was composed of decrements in both the storage and the retrieval components of memory.

Figure 2 shows group means for θ_S plotted as a function of trial position. Within-subject difference scores between the first and third trial positions indicate a highly reliable storage decrement for both the experimental group ($t = 11.23$, $df = 29$, $p > .9999$) and the control group ($t = 3.48$, $df = 29$, $p > .998$). The difference between the experimental and control curves does not approach reliability over the first three trial positions ($t = .738$, $df = 58$, $p \cong .76$). Figure 2 also shows that storage increased from Trial Position 3 to Trial Position 4 in both the experimental and control groups. Rather than exacerbating storage PI, as predicted by "acid bath" theory, the presence of the three prior items produced a trend toward release of PI. The divergence of the two curves at Trial Position 3 prevents a clear interpretation of any difference between groups at the fourth trial position. But within-subject difference scores between Trial Positions 3 and 4 indicate a strong trend toward PI release for the experimental group ($t = 1.45$, $df = 29$, $p > .92$) but not for the control group ($t = .88$, $df = 29$, $p \cong .81$).

Figure 3 shows group means for θ_r plotted as a function of trial position. Within-subject difference scores between the first and third trial positions indicate a highly reliable retrieval decrement for both the experimental group ($t = 3.87$, $df = 29$, $p > .999$) and the control group ($t = 3.54$, $df = 29$, $p > .999$). Figure 3 also shows that the fourth trial retrieval performance of the experimental group dropped below that of the control group. A between-group comparison indicates a strong trend toward greater retrieval PI for the experimental group ($t = 1.39$, $df = 58$, $p > .91$).

The findings of both storage and retrieval involvement in the buildup of PI are highly reliable for both the experimental and control groups, and are consistent with earlier storage-retrieval analyses of Brown-Peterson PI (Chechile & Butler, 1975). The independence of the estimates of these two parameters is indicated by their opposite trends under the same manipulation in this experiment. Simple recall measures provide some support for the "acid bath" theory. However, when the interfering effects of re-presenting the three buildup items are separated into storage and retrieval components, "acid bath" predictions are contradicted, in that the exacerbation of PI was confined to the retrieval component rather than further disrupting storage. Additionally, the storage component actually showed some trend toward release from PI.

Greater retrieval difficulties for the experimental group would be consistent with increased response competition, as described earlier in this report. However, the experimental group's trend toward a fourth trial release is more consistent with Conrad's (1967) modified

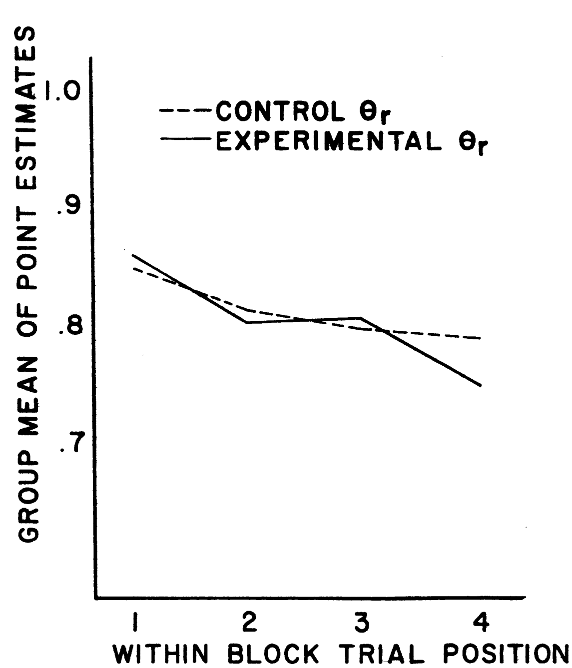

Figure 3. Group means of point estimates for the probability of sufficient retrieval, plotted as a function of within-block trial position.

decay model of storage PI. Conrad has suggested that PI affects labile storage by exacerbating the ongoing decay of an item's distinguishing features. The greater the similarity between a current item and the remnants of prior items already present in labile storage, the fewer, and perhaps less salient, are the features available to preserve discrimination. Conrad has incorporated the concept of decay with response competition for deeper and more durable encodings. In the context of his modified decay model, re-presenting prior items may be analogous to overlearning, in that lost features were made available to contrast and discriminate interfering items during rehearsal and transfer.

REFERENCE NOTES

1. Chechile, R. *The relative storage and retrieval losses in short-term memory as a function of the similarity and amount of information processing in the interpolated task.* Unpublished doctoral dissertation, University of Pittsburgh, 1973.

2. Gerrein, J. *Organizational, storage, and retrieval factors in alcohol-induced forgetting.* Unpublished doctoral dissertation, Tufts University, 1976.

REFERENCES

Baddeley, A. Retrieval rules and semantic coding in short-term memory. *Psychological Bulletin,* 1972, **78**, 379-385.

Battig, W. & Montague, W. Category norms for verbal items in 56 categories. *Journal of Experimental Psychology,* 1969, **80**, 1-46.

Bennett, R., & Bennett, A. PI release as a function of the number of prerelease trials. *Journal of Verbal Learning and Verbal Behavior,* 1974, **13**, 573-584.

Box, G., & Tiao, G. *Bayesian inference in statistical analysis.* Reading, Mass: Addison-Wesley, 1973.

Chechile, R., & Butler, K. Storage and retrieval changes that occur in the development and release of PI. *Journal of Verbal Learning and Verbal Behavior,* 1975, **14**, 430-437.

Chechile, R., & Meyer, D. A Bayesian procedure for separately estimating storage and retrieval components of forgetting. *Journal of Mathematical Psychology,* 1976, **13**, 269-295.

Conrad, R. Interference or decay over short retention intervals? *Journal of Verbal Learning and Verbal Behavior,* 1967, **6**, 49-54.

Dillon, R. Locus of proactive interference effects in short-term memory. *Journal of Experimental Psychology,* 1973, **99**, 75-81.

Gardiner, J., Craik, F., & Birtwistle, J. Retrieval cues and release from proactive inhibition. *Journal of Verbal Learning and Verbal Behavior,* 1972, **11**, 778-783.

Gorfein, D. Time release from PI as a function of amount of PI present. *Journal of Experimental Psychology,* 1974, **103**, 201-203.

Levy, C., & Jowaisas, D. STM: Storage interference or storage decay? *Journal of Experimental Psychology,* 1971, **88**, 189-195.

Loess, H., & Waugh, N. Short-term memory and inter-trial interval. *Journal of Verbal Learning and Verbal Behavior,* 1967, **6**, 455-460.

Loftus, G., & Patterson, K. Components of short-term proactive interference. *Journal of Verbal Learning and Verbal Behavior,* 1975, **14**, 105-121.

Peterson, L., & Gentile, A. PI as a function of time between tests. *Journal of Experimental Psychology,* 1965, **70**, 473-478.

Petrusic, W., & Dillon, R. Proactive interference in short-term recognition and recall memory. *Journal of Experimental Psychology,* 1972, **95**, 412-418.

Posner, M., & Konick, A. On the role of interference in short-term retention. *Journal of Experimental Psychology,* 1966, **72**, 221-231.

Posner, M. Short-term memory systems in human information processing. *Acta Psychologica,* 1967, **27**, 267-284.

Reitman, J. Without surreptitious rehearsal, information in short-term memory decays. *Journal of Verbal Learning and Verbal Behavior,* 1974, **13**, 424-429.

Thorndike, E., & Lorge, I. *The teacher's word book of 30,000 words.* New York: Teacher's College Press, Columbia University, 1944.

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