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PUPILLARY MEASUREMENT AND RELEASE FROM PROACTIVE INHIBITION[1]

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Summary.—One of the explanations of release from proactive inhibition in short-term memory is that the subjects re-attend to the items on the release trial because the items are different from the previous ones. It is further assumed that this increase in attention causes the release items to be learned better than the preceding items. This experiment measured the pupils of the subjects' eyes while they were participating in a proactive-inhibition release-type task. The results showed no increase in attention, as indexed by pupil size, on the release trial. This did not support the attentional explanation of the proactive-inhibition release phenomenon.

It is now generally recognized that the semantic information transmitted by a word symbol is the result of the encoding of some set of features, attributes or dimensions. For example, Osgood, Suci, and Tannenbaum (1957) conceived the meaning of a word to be a vector in *n* dimensional space with different words having different values on the various dimensions. Encoding seems to be generally defined as the process by which the physical stimulus elicits these various dimensional values, codings, or associations.

Several methods have been developed to investigate the nature of semantic encoding and to discover the dimensions involved. Perhaps the most prolific method is the one making use of build-up of proactive inhibition and the release from that inhibition when subsequent words are of a different semantic nature than those on earlier trials. Wickens (1970), in a very extensive research program using the proactive-inhibition release technique, has found some semantic features which would seem intuitively obvious, some not so obvious and has disproven the relevancy of others that might seem obvious. The typical procedure is to present to the subject a ready signal of some sort for several seconds, three items which he is to later recall, a rehearsal preventative task of some sort for about 20 sec. and then a cue to recall the three verbal items. If items similar in nature are presented on succeeding trials a marked reduction in performance will occur from Trial 1 to Trial 3. If items of a different nature are presented on Trial 4 the performance on those items will improve in direct proportion to the degree of dissimilarity to the previous items.

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The release from proactive inhibition is a very stable phenomenon and one which is obtained over a broad range of experimental situations. But relatively little is understood about the process underlying the phenomenon. We just do not know what is going on that causes relatively intelligent people to show a 60 to 70% decrement in recall after nine words and then allows that recall performance to recover on the very next trial. This ignorance about the dynamics of the situation does not seem to nullify the usefulness of the procedure or the validity of the resulting data. However, to understand fully the encoding process we must try to achieve some understanding of why the release phenomenon occurs.

One explanation of proactive-inhibition release that is given frequently is in terms of perceptual-attentional factors. Kintsch (1970) proposes that the items at the beginning of a list, i.e., on the first trial, always receive the subject's fullest attention. But if items similar in nature are presented on the following trials the subject will gradually cease attending to them. However, when the new type of items are presented on Trial 4, the attention of the subject is presumably seized from the throes of the doldrums and this causes these novel items to be processed into short-term memory. Kintsch (1970) says the proactive-inhibition release is a type of Von Restorff effect or that both are a result of the same process.

The attentional hypothesis assumes that the performance decrement is due to storage failure rather than an inability to retrieve the items. There is, indeed, some evidence that the build-up of proactive inhibition and release is due to storage phenomena. Cary (1973) presented items in a Wickens-type task and half of his subjects recalled the items in a normal manner and half of the subjects were instructed to not recall the words but to concentrate on the rehearsal preventative task. On a forced-choice recognition test given later a typical curve for build-up and release of proactive inhibition was found for both groups. In other words, even without a memory requirement a later retention test showed better performance for Trial 1 items than Trial 3 items and a release when the nature of the items was changed.

There is little or no empirical support, however, that the release of proactive inhibition is due to a change in the attention of the subject. In fact, many of the changes in type of material will go unnoticed by the subject and still result in significant release (Wickens, 1970). There is also an unpublished study by Wittlinger (1967) in which he measured Galvanic Skin Response during a release experiment and found no relationship between the GSR and amount of release. However, GSR has not been an effective index of attention, particularly as it relates to complex processes such as memory.

The present study makes use of a seemingly valid index of attention in a complex mental task. This technique is simply to measure the pupil of the subject's eye while he is involved in some mental task. The original work, reported by Hess and Polt (1964), and many other studies since then by Kahneman, Peavler, and others have shown rather conclusively that the pupillary response is a very good indicator of the amount of mental capacity the subject is allocating at a given time. The finding is essentially that as the attentional demands on the subject involved in a mental task increase, his pupil will show a corresponding increase in size. The relationship of the pupillary response to memory load was demonstrated by Kahneman and Beatty (1966). They read subjects strings of 3 to 7 digits and measured the pupil as the digits were read in and while the subjects responded. Kahneman and Beatty observed that the pupil gradually increased as the digits were read to the subject, maintained the enlarged position during a slight pause, and decreased as the subject verbally recalled the string.

The purpose of the present research was to use the technique of monitoring pupil size during a Wickens-type task to determine whether release is due to changes in the focus of attention on the part of the subject.

Method

Materials

Two lists of 15 words each were chosen. The two lists differed on the evaluative dimension of the semantic differential, one from the positive end and one from the negative end of the dimension. The reason for choosing this particular shift dimension was because Peavler and McLaughlin (1967) had shown that there was no differential pupillary response to evaluative positive and evaluative negative words. The two lists were divided into five triads each and these triads were counterbalanced within list and over trials so that each triad occurred on each trial an equal number of times.

Subjects

Each of the four groups was comprised of 20 subjects. The subjects were volunteers from the Ohio State University area and were paid $1.50 each for their time. Subjects were alternatively assigned to groups as they arrived at the laboratory.

Apparatus and Procedure

The subject was seated in a relatively dark room in front of a Smith-Kline Precision infra-red optical Scanner that scanned the pupil approximately 60 times per second. The subject focused on the image of a small red light that was reflected by mirror to simulate optical infinity. There was a small white light above the subject's forehead and inside the visual field that yielded less than one foot candle at the subject's eye. The head of the subject was restrained by a velcro band but a chin rest was not used so that the lower jaw might be free for giving oral responses. Eight to 10 min. were allowed for the subject to adapt to the darkness of the room and the general apparatus. After the subject was instructed that the experiment was going to begin, the pupil was monitored for 10 sec. with no mental load. This was used as baseline data as was 10 sec. of postexperimental monitoring. After the initial baseline period, the subject received five trials on a Wickens-type release task. He first heard the word "ready" over earphones, three words at about a one per second rate, a three-digit number which he subtracted from by threes for about 21 sec. and then the word "recall." He was given about 10 sec. to recall the three words before the next trial began. The subject made the subtractions and recalled the words out loud. There were four basic groups. Group PP received evaluative positive triads on all five trials while Group NN received evaluative negative triads on all five trials. Groups PN and NP received evaluative positive and evaluative negative triads, respectively, on Trials 1 to 4, and words from the opposite pole of the evaluative scale on Trial 5. These last two groups were the shift or experimental groups while the two former groups were the non-shift or control groups.

Results and Discussion

The recall score was simply the number of words recalled on a trial irrespective of order of presentation. These results are shown in Fig. 1. With the exception of the unusually high performance for the PN group on Trials 3 and

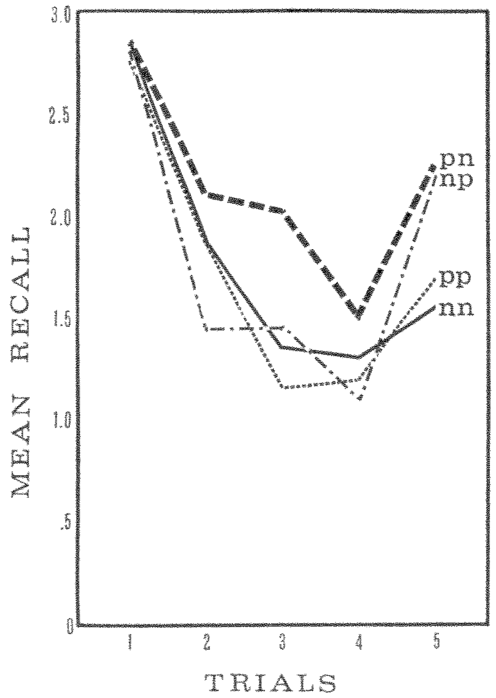

FIG. 1. Mean recall over trials for the positive-positive (pp), positive-negative (pn), negative-negative (nn) and negative-positive (np) groups

4, these are typical data for a release experiment. The release was significant with the interaction between experimental and control groups over Trials 4 and 5 being statistically reliable ($F_{1,76} = 4.02$, $p < .05$).

The pupillary data are those of most interest in this experiment. The output from the optical scanner was converted to a continuous record by a chart recorder. The measurement of the pupil was taken from the continuous record at 1-sec. intervals and these numbers became the raw data for each subject. This analog to digital conversion yielded 190 data points for each of the 80 subjects. Mean pupil size for all the subjects across trials is shown in Fig. 2. There are several rather striking features of these data. When the first three words were presented, there was a sharp dilation of the pupil and this enlarged dilation continued for 10 to 15 sec. into the trial. The curve then became relatively stable for the remainder of the trial period. When the recall cue was given, there was another slight increase in pupil size, possibly indicating the beginning of search. After several seconds into the recall period, however, the pupil began a sharp decrement which continued up to the time the next trial began. As can be seen in Fig. 2, there was great regularity to the pupil size across the trial-recall cycles. On each trial there was an increase at the beginning of the trial, asymptote for the remainder of the trial and decrease during the recall segment. It should also

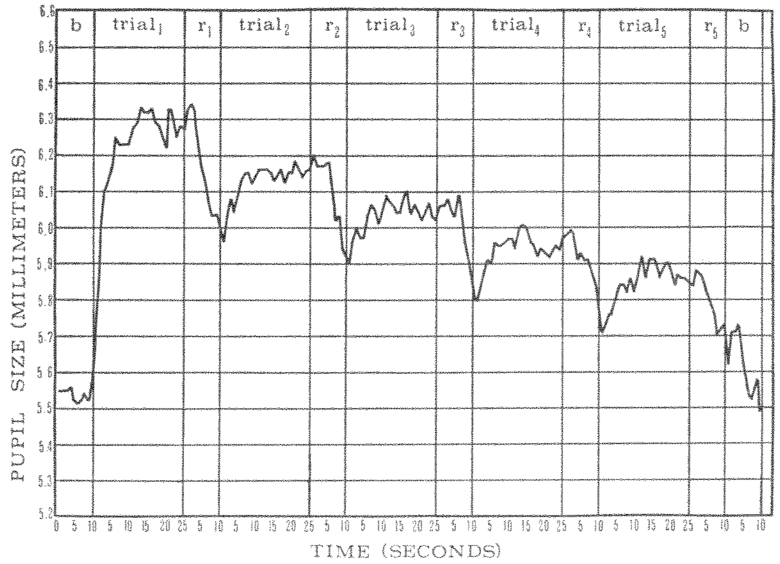

FIG. 2. Mean pupil size in millimeters for all subjects over the five trials. The *b* at the top of the figure designates the baseline periods, the *trial* designates the period from when the ready signal was heard to when the recall signal was heard and the *recall* designates the period from when the recall signal was heard to when the ready signal for the next trial occurred.

be noticed that the asymptote on each trial became progressively lower. This is indicated by the fact that the high point of each trial showed a significant decrease over trials ($F_{4,304} = 29.17$, $p < .01$). The initial point of each trial period also showed a significant decrement over trials ($F_{4,304} = 4.93$, $p < .01$). Another interesting finding was that the difference between the beginning point, i.e., the first point of each trial, and the high point of each trial gets significantly smaller over trials ($F_{4,304} = 12.33$, $p < .01$).

Thus, if we use the pupillary response as an indicator there does seem to be some waning of attention over the trials on the Wickens task. But the attention explanation of release proposes an increase in attention, therefore in pupil size, on the release trial when the semantic nature of the words is changed. The pupillary data for the four separate groups are shown in Fig. 3. The first observation is that there are seemingly large differences among the four groups. The differences, however, are primarily due to changes in distance from the horizontal axis and not in general form or quality. All four curves in Fig. 3 exhibit more or less the same characteristics described in the over-all curve in Fig. 2.

The following analyses were performed on the data in Fig. 3: (a) 4 × 5 (4 groups × 5 trials) analysis of variance on the mean of each presentation trial period, (b) 4 × 5 analysis on the initial point of each presentation trial period, (c) 4 × 5 analysis of the highest point in each presentation trial period, (d) 4 × 5 analysis on the difference score obtained by subtracting the initial point

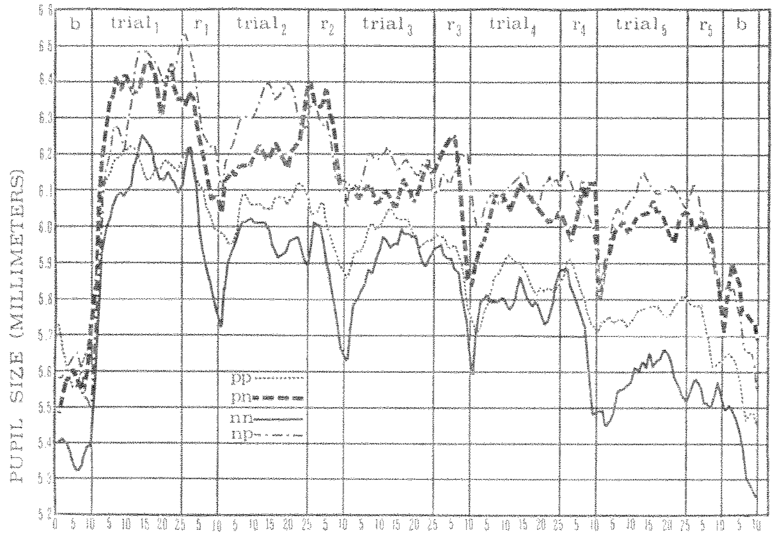

FIG. 3. Mean pupil size for the positive-positive (pp), positive-negative (pn), negative-negative (nn), and negative-positive (np) groups over the five trials. The labels at the top are the same as in Fig. 2.

in each presentation trial period from the highest point in that period, (e) 4 × 2 analysis of the last point in the recall period of Trial 4 and the first point in the presentation period of Trial 5, (f) one-way analysis on the Point 1-High Point difference score (alluded to in analysis d) for just presentation Trial 5, (g) *t* test on the Point 1-High Point difference score for Trial 5 with the experimental groups collapsed to give one group and the control groups collapsed to give the other group, (h) 4 × 2 × 2 analysis for the first point and the mean of points 2 to 5 of the presentation trial for Trials 4 and 5 for the four groups. The first four analyses have already been referred to when discussing Fig. 2 and those *F* ratios were the only ones in all four analyses that were significant. In other words the differences that did obtain were all due to trial effects, primarily the constriction of pupil size over trials. In none of the four analyses were there significant differences among the four conditions nor interactions of conditions and trials.

The primary concern, however, was with the difference between experimental and control groups on Trials 4 and 5. As can be seen in Fig. 3, there are slight differences across the two trials but the shift groups are not much different from the non-shift groups. There is certainly not the dramatic increase in pupil size on Trial 5 for the shift groups that would be expected if release results from the new material recapturing the subject's attention. The 4 × 2 analysis of the last point in the recall period of Trial 4 and the first point in the presentation of Trial 5 resulted in non-significant $F_{3,76}$ of 1.3. As mentioned previously, analysis (d), the analysis of the difference score for all five trials, did not yield any significant interactions. However, rather than accept the null hypothesis so quickly, the data were subjected to further analysis. A one-way analysis on the Point 1-High Point difference score for the four groups on Trial 5 yielded a non-significant result ($F_{3,76} = 1.7$, $p > .10$). However, when the experimental groups were collapsed and a *t* test performed on the two resulting groups of data a score of borderline significance was obtained ($t = 2.08$, $df = 78$, $p < .05$).

If the attention of the subject is drawn to the new material, then there should be an increase in pupil size over the first five seconds of the presentation trial for the experimental groups and not for the control groups. A 4 × 2 × 2 analysis of variance was done on Point 1 of the presentation trial and the mean of Points 2 to 5 and for the four groups. Again the trials variable was significant ($F_{1,76} = 6.06$, $p < .01$), meaning that there was a significant decrease in pupil size from Trial 4 to Trial 5. There was a significant increase in pupil size from the first point of the presentation trial to the mean of points 2 to 5 ($F_{1,76} = 6.26$, $p < .01$). The interaction that would be predicted by the attentional hypothesis is the Groups × Trials × Points interaction and this did not reach significance ($F_{3,76} = 1.28$, $p > .21$). A similar analysis was performed on data for Point 1 and Points 2 to 5 from Trial 5 only; the Groups × Points interaction did not reach significance ($F_{3,76} = 1.28$, $p > .28$) nor did the main effect of Groups ($F_{3,76} = .52$, $p > .67$).

The next step was to take the four subjects in each of the release groups that showed the most release and the four that showed the least release and analyze their pupillary data separately. If the attentional hypothesis is to receive any support at all, it should certainly appear in this analysis. Table 1 shows the mean increase in pupil size for (a) Point 1 to mean of Points 2 to 5 and (b) Point 1 in the range Point 2 to Point 5. As one can see from the table, there is little difference in these data for the high releasers and low releasers and the differences which do occur are in the wrong direction.

TABLE 1
MEAN INCREASE IN PUPIL SIZE (IN MM) FOR HIGH AND LOW RELEASERS

Trial	Subjects	Increase from point 1 to mean of points 2-5	Increase from point 1 to the high point of presentation phase
4	High Releasers	.08	.17
	Low Releasers	.12	.16
5	High Releasers	.02	.13
	Low Releasers	.18	.25

While the pupillary data are rather noisy, particularly, between groups, there is almost no support from all the analyses for the attentional hypothesis. The one t test of a difference between experimental and control groups for the difference score between Point 1 and the High Point of the whole presentation period was barely significant. However, this difference appears to be rather meaningless in light of all the other analyses and the small differences obtained when a distinction was made between high releasers and low releasers.

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