

Changes in pupil size during an imagery task without motor response involvement¹

HERB M. SIMPSON AND ALLAN PAIVIO
UNIVERSITY OF WESTERN ONTARIO

A previous study showed that pupillary dilation is associated with attempts to generate mental images to stimulus words, image arousal being indicated by a key press. The present study revealed similar but attenuated dilation effects when the key press response was eliminated. The difference can be interpreted in terms of motivational effects of task difficulty, or arousal effects associated directly with the motor response.

It has been demonstrated that pupillary dilation is a sensitive correlate of cognitive activity (e.g., Hess & Polt, 1964; Lowenstein & Loewenfeld, 1962). Paivio & Simpson (1966) found that pupillary dilation occurred when Ss attempted to generate "mental images" suggested by stimulus words, and interpreted this as an "arousal" effect related to the difficulty of the cognitive task involved. The finding that pupillary dilation was greater to abstract than to concrete words is also consistent with the above interpretation, inasmuch as imagery ratings and reaction time data from previous research (e.g., Paivio, in press) have indicated that it is more difficult to generate images to abstract words. A further analysis of the second of two experiments reported by Paivio and Simpson indicated that maximum pupillary dilation occurred sooner (3.5 as compared to 4.5 sec.) to concrete than to abstract words. A correlation across words was also computed for each S between the time at which S's pupil was a maximum and the time when he pressed the telegraph key (the index of image arousal). Fifteen of the 20 correlations were positive and eight of these were significant, indicating a relation between speed of the key press and speed of dilation. None of the negative correlations was significant. This finding is consistent with the interpretation that S generates an image or, at least, decides that an image has been elicited and, consequently, presses the key. The event of "imaging" or "deciding" is reflected in the increased pupil diameter and this response is more rapid in the case of concrete than abstract words. It could be argued, however, that pupillary dilation resulted from the key pressing response itself rather than from cognitive activity. Accordingly, the present study was designed to determine the effect of the imagery task on pupil size when the key press is eliminated.

Method

The method was essentially the same as the second experiment described by Paivio & Simpson (1966) with the main exception that the telegraph key was removed. Briefly, Ss were presented with words and instructed

to imagine an object or event related to the word. The stimuli were 12 nouns, six of which are relatively concrete and six abstract. The concrete nouns exceed the abstract in their rated capacity to evoke imagery. Half of each class of words are relatively pleasant and half unpleasant in meaning. Each word, in the form of a 35 mm slide, was presented for 10 sec., and was preceded by a 10 sec. presentation of a blank slide of matched brightness. The slides were projected on a screen at the back of a box-like compartment. S was seated at the front of the compartment and continuous photographs of S's right eye were taken by a 16 mm movie camera operating at a filming speed of 2 frames per sec. The processed movie film was examined frame by frame on a 4 x 6-in. film editor, and the pupil diameter thus magnified was measured with a millimeter ruler by an assistant who had no knowledge of the stimulus conditions that were involved.

The Ss were 17 Introductory Psychology students, 11 females and six males.

Results

Pupil size was averaged for all words of a type (e.g., concrete-pleasant) as well as for the appropriate control conditions for each frame. Figure 1 shows the pupillary changes over time, i.e., photographic frames for concrete and abstract words and their respective control conditions. The data from the 20 frames were collapsed into four equal time blocks and analyzed using a 2 by 2 by 4 repeated measures analysis of variance with stimulus conditions (word vs. control slides), concreteness, pleasantness, and blocks as variables. The resulting main effects indicate that only the difference

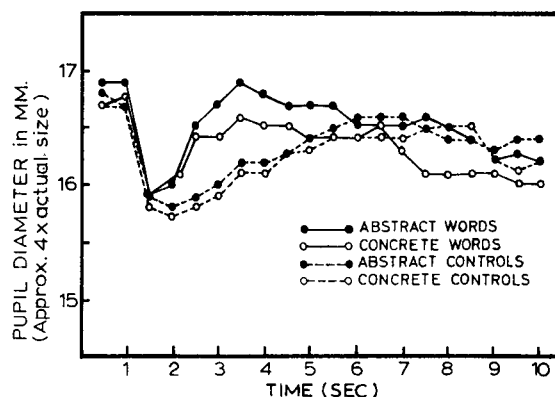


Fig. 1. Mean pupil size for Ss viewing abstract and concrete words under instructions to generate images, and while viewing blank control slides.

between words and control conditions approached significance ($F=3.19$, $df=1/16$, $p < .10$). Since the previous research (Paivio & Simpson, 1966) had shown that dilation, on the average, was greatest at 3.5 and 4.5 sec. for concrete and abstract words, respectively, an analysis of variance was also performed on the second time block alone (i.e., from 3 to 5 sec. inclusive), with stimulus conditions and concreteness as variables. The main effects indicated greater dilation to words than control slides ($F=33.62$, $df=1/16$, $p < .01$), but the crucial effect of word concreteness, which appears as an interaction of concreteness-abstractness by word-control conditions, again was not significant ($F=1.00$, $df=1/16$).

Despite the relatively smaller effects in the present study, the graphical representation of the data reveals a pattern of pupillary reactions similar to those obtained in the two previous experiments by Paivio and Simpson. In order to evaluate the apparent consistency of the effects across studies, statistical analyses were conducted including experiments as a variable. A complete comparison was possible only with the second experiment in the earlier study, which was entirely comparable to the present one but involved a key press response (the first of the earlier experiments did not include a within-Ss control condition). Accordingly, an analysis of variance was first performed, with the two studies, words vs. control stimulus conditions, concreteness, and blocks as variables (Ns in the studies were equated by random elimination of Ss). Only the studies by word-control interaction was significant ($F=10.15$, $df=1/32$, $p < .01$), reflecting the reduced overall effect of the imagery task in the present study. A further comparison across all three experiments was possible on the word data alone, excluding control conditions,² since the concrete-abstract variable was identical in every case. A 3 by 2 by 4 analysis of variance was therefore performed, with studies, word concreteness, and blocks as variables (after further random elimination of Ss to equate Ns at 14 in each study). None of the interactions involving studies was significant, demonstrating consistency over experiments in the pupillary response to words. The critical main effect of word concreteness was significant ($F=6.46$, $df=1/39$, $p < .05$), however, indicating greater dilation to abstract than concrete words.

Discussion

The results of the present study, when compared with Experiment 2 of the previous paper (Paivio & Simpson, 1966), indicate a general attenuation of the pupillary reaction when the key press response is excluded from the imagery task. The diminution may be related to the motivational effect of requiring S to make an overt response to indicate image arousal. It is presumably a more demanding situation when S is required to indicate fulfillment of the task and the difference in task difficulty is reflected in the relatively greater pupil size under the condition requiring an overt response. Alternatively, the key press may contribute directly to arousal level, thereby affecting pupil size. Even in the absence of the motor response, however, some effect remains. The dilation to words is clearly significant in the expected time block. Furthermore, although the concrete-abstract difference was not statistically significant within the present study alone, the pattern of pupillary reactions is similar to that obtained in the two previous experiments—sufficiently so that concreteness does not interact with studies, but the main effect of this variable is significant over the three experiments. These findings indicate that pupillary dilation is reliably associated with attempts to generate images to words and this dilation is consistently greater to abstract than to concrete words.

References

- Hess, E. H., & Polt, J. M. Pupil size in relation to mental activity during simple problem solving. *Science*, 1964, 143, 1190-1192.
- Lowenstein, O., & Loewenfeld, I. E. The pupil: In H. Davson (Ed.), *The eye*. Vol. III. New York: Academic Press, 1962. Pp. 231-267.
- Paivio, A. Latency of verbal associations and imagery to noun stimuli as a function of abstractness and generality. *Canad. J. Psychol.*, in press.
- Paivio, A., & Simpson, H. M. The effect of word abstractness and pleasantness on pupil size during an imagery task. *Psychon. Sci.*, 1966, 5, 55-56.

Notes

1. Thanks are due to Ray Steeves for his assistance with the study.
2. An analysis of variance of only the control conditions in the second of the earlier experiments and the present one indicated no differences in pupillary reactions to control stimuli for concrete and abstract words, thus justifying a direct comparison of reactions to the concrete and abstract words alone.