They worked at their own speed, but most finished in about 30 min.

RESULTS

The reliability of the test of achievement of each concept, computed by the Kuder-Richardson method (No. 20), is shown in Table 1. With the exception of CANARD and perhaps DIZEN they are adequate for present purposes.

Mean scores for the six conditions for each word are given in Table 1. Analysis of variance showed a significant F at the .01 level between conditions for each word, and the mean for the 12-sentence condition was higher than the mean for the zero condition in every case. Obviously the Ss learned something of the meaning of these difficult concepts in a few minutes, and the mean for a few words approached the maximum score of five.

The rates of learning were quite irregular, however. Duncan's range tests performed on the six conditions for each word indicate that the significant differences were inconsistent. For example, the one-sentence condition for MARMO-REAL was significantly different from all other conditions except the 12-sentence condition. Any generalization about the shape of the learning curve under these conditions is questionable, but the bottom line in Table 1, from which the relatively unreliable data of CANARD and DIZEN have been omitted, gives a reasonable first approximation.

DISCUSSION

The variations in the results for the different words are probably due to the difficulty of writing twelve equally

valuable sentences. It is possible also that the test items were more relevant to some sentences than others. The results obtained when these variations are smoothed by summing across words suggest that rate of learning words in the context of sentences is a decreasing function not unlike learning curves obtained in more conventional experiments.

Methodologically, this experiment demonstrates that systematic study of concept learning through context is possible and that under present conditions the learning proceeds quite rapidly. The data at hand suggest that eight sentences would be sufficient for comparisons between different materials and different conditions. Further work directed toward the specific contribution of each sentence to the acquisition of meaning is in progress.

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Comment on Schurman: Effects of an artificial pupil in visual perception¹

R. HILZ and C. R. CAVONIUS, *The Eye Research Foundation, Bethesda, Md. 20014*²

Schurman's equipment did not include an artificial pupil, and his results cannot be interpreted as evidence supporting the use of an artificial pupil in visual research.

Schurman (1968) reported an experiment which purports to demonstrate the effect of an artificial pupil on visual perception. Unfortunately, this study is based on an unconventional concept of the nature of an artificial pupil. An artificial pupil by definition replaces the natural pupil as the aperture stop for the eye, whereas Schurman's diaphragm, because of its size and distance from the O, acts as a field stop. This failure to distinguish between the functions of field and aperture stops results in several incorrect statements about an artificial pupil. An artificial pupil does not "limit the amount of retina illuminated" because (like a camera diaphragm) it is located in a plane which is not imaged on the retina. It does not "eliminate stray and scattered light from a point source" (whatever that may be), nor does it act as a "lens of infinite focal length and zero curvature," which of course is no lens at all.

In order to be effective, an artificial pupil should be located in, or close to, the plane of the natural pupil, and must be smaller than the natural pupil. Schurman's diaphragm, on the other hand, was located 8 in. from the eye, and was substantially larger than either the natural pupil or the largest dimension of the stimulus pattern. Therefore, this diaphragm cannot intercept any part of the light from the stimulus pattern which reaches the eye. In short, Schurman's explanation of his experimental results is almost certainly

incorrect. Without further information about his apparatus or the variance of his data, we can only speculate that his field stop improved contrast by reducing stray light from sources other than his stimuli.

Schurman is correct in stating that an artificial pupil increases the depth of field. However, artificial pupils smaller than about 1.5 mm degrade the retinal image by increasing the effects of diffraction. When working at low luminance levels, any artificial pupil may degrade performance by reducing retinal illumination. An artificial pupil may also distort the perceived size of stimuli, due to accommodative effects (Biersdorf & Baird, 1966).

It is probably not feasible to set down definite rules for the use of artificial pupils, since the best pupil size will depend on parameters such as luminance level, accommodation, and visual task. Diameters of about 3 mm are commonly found to be optimal (Riggs, 1965). The artificial pupil should be located near the eye or be optically placed in the plane of the natural pupil, as in Maxwellian view. While a field stop may improve visual performance in some cases (as it seems to have done for Schurman), it does not increase the depth of field nor reduce the aberrations of the eye.

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NOTES

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