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THE INTERRELATIONSHIP BETWEEN THE EBBINGHAUS AND DELBOEUF ILLUSIONS

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Variation of the size of the context circles in the Ebbinghaus illusion results in a systematic variation of the apparent size of the central test figure that is in accord with a comparative judgmental model of this illusion. However, increasing the distance of the context figures results in a decrease in the apparent size of the test figure regardless of the size of the context circles. This result is not predicted by a judgmental model and indicates a similarity between the Ebbinghaus and Delboeuf illusions.

An explanation for the Ebbinghaus or Titchener circles illusion in terms of the operation of a comparative judgmental mechanism has recently been proposed by Massaro and Anderson (1971). According to their model, the size of the central circle is judged relative to the size of the nonconcentric surrounding or context circles. The contribution of the context figures is determined by their size and number, and weighted in accordance with their distance from the central circle. On the other hand, Cooper and Weintraub (1970) have suggested that the Ebbinghaus illusion (central circle surrounded by nonconcentric circles) is a variant of the Delbouef illusion (central circle surrounded by a concentric circle). They support their contention by demonstrating similar changes in illusion magnitude for these figures when there is a temporal delay between presentation of the central test circle and the surround. This second approach suggests that the ring of nonconcentric circles around the test circle in the Ebbinghaus illusion provides the perceptual configuration of a concentric circle. These two ways of looking at the Ebbinghaus illusion would make similar predictions in some, but not all, situations.

Let us consider the effect of varying the distance between the surrounding circles and the test circle. When Massaro and Anderson (1971) vary this parameter in the condition where the surrounding circles are smaller than the test circle, they find a decrease in the apparent size of the test circle as distance increases. This is in accord with their judgmental model. This finding is also in accord with a model based on the Delboeuf, where the usual finding is that the size of the inner circle decreases steadily as the size of the concentric outer circle increases (Oyama, 1960; Weintraub, Wilson, Greene, & Palmquist, 1969). However, the two approaches make opposing predictions in the Ebbinghaus situation in which the surrounding circles are larger than the test circle. In this situation, which was not tested by Massaro and Anderson, the judgmental model would predict an increase in the size of the test circle (a decrease in the illusion) as the distance between test and surrounding circles increases. On the other hand, prediction from the Delboeuf model would still indicate a decrease in the size of the inner test circle (an increase in the illusion) as the distance between the test circle and larger surrounding circles was increased.

A model of the Ebbinghaus illusion based on the Delboeuf would also predict both an assimilation and a contrast phase as a function of distance between the test circle and the "ring" of nonconcentric surrounding circles. As distance increases, the apparent size of the center circle should appear first larger than, then equal to, and finally smaller than a circle with no surround (Oyama, 1960). In the situation in which the two approaches both predict a decrease in test circle size (surrounding circles smaller than test circle), the judgmental model simply predicts that the apparent size of the center circle surrounded by smaller circles would decrease to equality, while the Delboeuf model predicts that the test circle will actually begin to show an illusion in the opposite direction as the distance continues to increase. In order to test this prediction, an estimate of the apparent size of the test circle without any surrounding circles is needed. This was not provided by Massaro and Anderson (1971).

The judgmental and the Delboeuf models of the Ebbinghaus or Titchener circles illusion make similar predictions when distance is varied in the situation in which the surrounding circles are smaller than the test circles but different predictions for larger surrounding circles. The experiment presented here varies both the size of the inducing circles and the distance between inducing and test circles in order to differentiate between the two proposed bases for the Ebbinghaus illusion. In addition, a test circle with no surrounding circles has been included in this experiment in order to check for the existence of both an assimilation and a contrast phase as the distance between test and surrounding circles is varied.

Method.—All figures were black outline circles. The central test circle was held constant at 14 mm. The test circle was either presented alone, or with four surrounding circles. The diameter of these context circles was 5, 10, 18, or 23 mm. The distance between the proximal edges of the central and context figures was 3, 6, 12, or 24 mm.

Responses were made by rotating a wheel that presented single comparison circles (with no sur-

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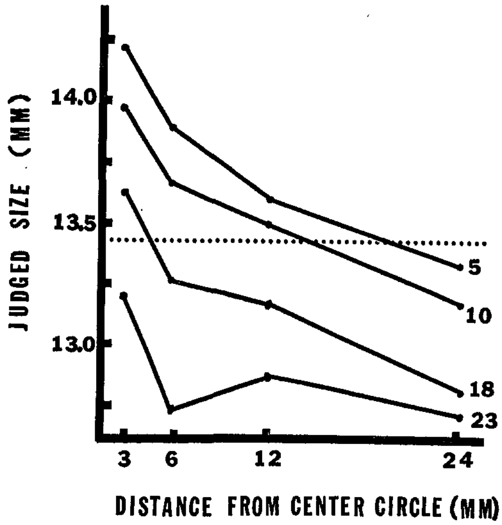

FIG. 1. Mean diameter of comparison circle judged equal to center circle of Ebbinghaus figure plotted as a function of distance from center to surrounding circles. (Size of surrounding circles in millimeters is listed at the right of each curve. The dotted line represents the judged size of a circle with no surrounding elements.)

rounding circles) ranging in diameter from 8.0 to 19.5 mm. in steps of .5 mm. Single circles appeared in a 26-mm. aperture cut into the apparatus.

Fifteen *S*s judged the apparent size of the central test circle once for each stimulus in the set, presented in randomized order. The *S*s were allowed free eye movements and could look back and forth between the stimulus and comparison figures.

Results and discussion.—Figure 1 presents the mean judged circle size for the 17 stimulus configurations used. The dotted line in the figure represents the mean judgment of the size of a circle seen in isolation. The departure from the expected 14 mm. is a constant error probably due to the presence of the aperture through which the comparison circles were viewed.

It is clear that, in general, smaller context circles result in the test circle appearing as larger, while larger context circles result in smaller size estimates for the test figure. The effect of circle size is significant, with F (3, 42) = 22.10, $p < .001$. The effect of the distance of the context circles upon the size estimate is also significant, with F (3, 42) = 15.69, $p < .001$.

The change in size estimates with increasing distance of the context circles helps shed some light on the underlying mechanisms for the Ebbinghaus illusion. For the smaller context circles it is clear that increasing the distance results in a decrease in the apparent size of the test circle, which replicates the findings of Massaro and Anderson (1971). However, for the larger context circles, we find exactly the same decrease in apparent size with increasing distance of the context circles rather than the opposite trend that would be predicted from a comparative judgmental theory. The similarity between the curves for both the larger and the smaller surrounds is supported by a lack of significant interaction between surrounding circle size and distance, F (9, 126) = .47. This decrease in apparent size of the test figure with increasing distance of the context circles, regardless of their size, is in accord with predictions which would be made on the basis of a similarity between the Ebbinghaus illusion and the Delboeuf, but is not in accord with predictions that would be made from a comparative judgmental model. A judgmental theory would predict a decrease in the size of the test circle with increasing distance of the context figures only for the smaller surrounding figures. The larger context circles should produce an increase in apparent size, as the increasing distance between test and inducing figures lowers the weighting of these figures in the comparative judgment.

Further evidence for the similarity of the Ebbinghaus and Delboeuf is illustrated by the fact that for the 10-mm. context circles at the farthest distance (24 mm.), the apparent size of the test circle is actually smaller than the same circle seen without any context figures, sign test, $p < .05$. This reversal from over- to underestimation with large distances between the test and context figures is consistent with the Delboeuf mechanism (Oyama, 1960) and difficult for a simple judgmental theory to handle.

Despite these apparent similarities between variations in the magnitude of the Ebbinghaus illusion and the Delboeuf, it is important to note that no significant amount of assimilation occurred at the closest distances for the 18-mm. and 23-mm. context circles and no significant amount of contrast occurred for the 5-mm. circles at the farthest distances. In addition, the variation in the size of the context circle results in clear apparent-size changes in the test figure, which is consistent with a judgmental theory. Such variation would be difficult to explain in terms of a Delboeuf-type mechanism unless one attempts to utilize the center of gravity of the surrounding context figures rather than the proximal distance as the measure of relative distance between center circle and surround.

Further evidence for a different judgmental component in the Ebbinghaus figure has recently been provided by Coren (1971), who has shown that the illusion can be demonstrated in configurations in which the context circles are physically equal in size to the test circle, but made apparently larger or smaller through the operation of size constancy in a stereoscopic paradigm. Thus, as has been suggested for many other classical visual geometric illusions (Coren, 1970; Over, 1968), the Ebbinghaus illusion appears to be multiply caused, and may even be a compound of several illusions rather than a unitary perceptual distortion.

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FREE RECALL FOLLOWING A SWITCH IN ENCODING CLASS [1]

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Following a Brown-Peterson task in which taxonomic categories were shifted on Trial 5 for the experimental condition but were not shifted for the control condition, *S*s were asked to free recall as many words from all five trials as they could. Results of the free-recall test showed a reduction of the difference between experimental and control conditions for recall of Trial 5 items. There was no difference between experimental and control conditions in free recall of items presented on the first four trials.

In the Brown-Peterson paradigm (Brown, 1954; Peterson & Peterson, 1959), the presentation and/or learning of the first few items interferes with performance on the later items. This buildup of proactive interference (PI) occurs rapidly and reaches a maximum after three or four trials (Keppel & Underwood, 1962). Wickens, Born, and Allen (1963) have demonstrated that the interference may be specific to the class of materials used, such that switching the class of materials after a few trials leads to improved performance on the trial. Wickens (1970) has reviewed a number of studies which have demonstrated this "release from PI," and he assumes that a switch in materials which leads to a release from PI results from a switch in encoding class.

The present study was designed to provide information about what has been learned following a switch in encoding class by asking *S*s to free recall all of the items immediately after the test for retention of the last set of items. The free-recall task should provide evidence about: (*a*) the extent to which the release from PI is due to increased list differentiation as opposed to reduced interference between items (cf. Peterson, 1967) and (*b*) whether the release from PI serves only to improve performance on the "release" items or whether it affects recall of the earlier items. Data relevant to the first point are the free-recall performances of experimental and control *S*s on items that were presented on the release trial as compared to the immediate test performance on these items. Data relevant to the second point are the free-recall performance of experimental and control *S*s on items that were presented prior to the release trial.

A previous, unpublished experiment had indicated that free recall of items presented prior to the release trial was not better, and was possibly worse, following a shift in encoding class than following no shift. The present study was designed as a replication, with appropriate controls and better procedures, of that study.

Method.—Five triads of animal names and five triads of vegetable names were constructed from Bousfield's (1953) lists such that the mean frequency of occurrence between triads was approximately equal. Each triad was typed in a column on a 3×5 in. card.

Each animal triad was paired with a vegetable triad, and both triads within a pair were assigned a three-digit number which was used as a starting number for the counting-backwards task.

Order, materials, and conditions were varied between *S*s. The order variable was a Latin square arrangement of triads for presentation, such that each triad appeared equally often in each of five presentation positions. The Latin square arrangement was fitted to each set of materials, animals and vegetables, to form the control groups. For the conditions variable, experimental groups were defined by interchanging the fifth triad of animal and

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