Stimulus configuration in selective attention tasks*

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The possibility that perceptual configuration of stimulus elements impairs the ability to attend selectively to individual elements was tested with two-element stimuli, constructed by placing two curved lines in close proximity. Ss rapidly classified series of these stimuli which could differ on both elements or on only one with the second held constant. It was hypothesized that if the two elements formed a configuration, then Ss should have difficulty attending selectively to the element relevant for classification while filtering information from the other element. This result was obtained in one experiment with both stimulus elements oriented vertically, and it is concluded that these stimuli were perceived as unanalyzed, nominally related shapes. In another experiment, with one stimulus element oriented horizontally, selective attention to the relevant element was possible.

When two or more elements are present at once in the visual field, they may appear to form a unitary configuration, or they may appear simply as a collection of separate elements. Perceptual organization of elements into integral wholes was a primary concern of the Gestalt psychologists, and they formulated a number of rules governing such organization, which were based for the most part on the principles of proximity and similarity (Wertheimer, 1923). Studies aimed at isolating the factors responsible for perceptual organization continue to this day (Beck, 1966; Olson & Attneave, 1970).

The "crucial experiments" used by the Gestalt psychologists to demonstrate the laws of perceptual organization were based on appeals to the phenomenal experience of the O. Progress has been made by Gillam (1972) on establishing a criterion of organization that is less dependent on subjective report; however, her method depends on perceived motion from a dynamic display, and so it is not clear how applicable it may be to general questions of perceptual organization.

In the present study, the problem of configuration is viewed within the context of information processing, specifically as a problem related to perceptual independence (Garner & Morton, 1969). That is to say, if elements of a stimulus form a configuration, there should be processing consequences of that fact, since it should be impossible to process individual elements completely independently of each other. More specifically, if elements are organized into a larger unit, then selective attention to individual elements in the configuration should not be possible.

In order to use an information processing approach, it is necessary to consider each stimulus as one of a set of stimuli, with the discriminations between the various stimuli in the set as the different information processing

tasks. For these purposes, the stimuli may be defined dimensionally, and in the main experiment of the present study there are two stimulus dimensions (left and right element), each with two levels (left and right curvature of a parenthesis). These stimuli are shown in Fig. 1A. Other stimuli used are shown in Fig. 1B.

The primary process of concern in this experiment is selective attention. The experimental paradigm used closely follows one employed by Garner and Felfoldy (1970) in a series of experiments investigating the independence of primary stimulus dimensions such as brightness and hue in the perceptual process. Comparison of performance in three types of processing tasks allows the independence of stimulus dimensions to be evaluated. In all three tasks, S classifies stimuli on the basis of a single relevant dimension; what differentiates the three is the nature of the second, irrelevant dimension. In the first task, discrimination is required between stimuli which differ only on the one relevant dimension; the second dimension is held constant, and so carries no information. Thus, the task can be successfully performed with selective attention to the relevant dimension. An example of this task would be discriminating Stimulus LL from Stimulus RL in Fig. 1A. Here, of course, the left element is relevant, while the right one is constant. This task, where stimuli

Fig. 1. (A) The four stimuli used in the main experiment, along with their identifying codes. (B) The four stimuli used in the supplemental experiment.

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vary on a single dimension, serves as a *control* condition. In the second task, the stimuli to be classified vary on two dimensions, but the variation in the two is perfectly *correlated*. Since the two dimensions are correlated, either may be thought of as relevant, but only one need be processed in order to perform the task. An example of this task would be discriminating Stimulus LR from Stimulus RL. The third task also involves stimuli which vary on two dimensions, but here the variation in the two dimensions is completely uncorrelated or *orthogonal*. Again, as with the two other tasks, this discrimination can be performed with selective attention to the relevant dimension alone. An example of this task would be discriminating Stimuli LL and LR from Stimuli RL and RR. Here, again, the left element is relevant, the right one, irrelevant.

The use of these three tasks can provide converging operations which differentiate alternative processing concepts. With respect to selective attention, the simplest outcome is for all three tasks to yield equivalent performance. The conclusion would then be that attention was paid only to the relevant dimension in each task, since it is only the nature of the irrelevant (and presumably filtered) dimension which differentiates the three tasks. However, by making the simple assumption that S will always use processing mechanisms which best facilitate his carrying out the assigned task, more complex outcomes might be anticipated.

As one example, consider the results obtained by Garner and Felfoldy (1970). With some pairs of dimensions, it took S longer to complete the orthogonal task than the control task. Thus, selective attention was deemed not possible, since S would have attended to a single dimension and ignored irrelevant, interfering information if he had been able to do so. With such dimensions, however, S showed an improvement in processing speed when the correlated task was performed. This improvement could have occurred only if in some way information had been integrated, i.e., not selectively attended. With different pairs of dimensions tested, either interference was obtained for the orthogonal task along with facilitation for the correlated task or neither interference nor facilitation was obtained. This clear pair of outcomes from the three tasks led to the concept of dimensional integrality for those dimensions showing interference and facilitation, and dimensional separability for those showing neither.

But these are not the only possible outcomes from this set of three experimental tasks, and different outcomes will lead to different processing concepts. Suppose, for example, that interference (relative to the control task) occurred with the orthogonal task, but there was no facilitation with the correlated task. This outcome would be surprising in one sense, since it would be to S's advantage to integrate information if he could do so. Such an outcome would indicate that the dimensions were not really treated as dimensions by S, but rather that the dimensions simply served to generate

nominally related stimuli—forms, in the present case. If such nominally defined forms were generated, then the obtained interference effect in the orthogonal condition should be expected, since this condition would have become, for S, a grouping task; Keele (1970) and Gottwald and Garner (1972) have shown that grouping tasks, which involve many-to-one mappings of stimuli to responses, do lead to increased processing times. However, in such a case, there is no reason to expect the correlated task to provide an increased speed of processing, since for S any pair of nominally related stimuli is equivalent to any other pair.

With this type of outcome, it is still reasonable to talk about a failure of selective attention, since S in fact cannot attend to part of a whole form, even when it is to his advantage to do so. However, this failure is best interpreted as being due to the configurational properties of the stimuli, and such properties are different from the integral properties found by Garner and Felfoldy (1970) with dimensions such as the hue and brightness of visual stimuli.

The purpose of the present experiment is, then, to investigate the role of selective attention in the context of these three experimental operations, with stimulus dimensions which can form simple visual figures.

METHOD

Stimuli

The four different stimuli used in the main experiment are shown in Fig. 1A. These stimuli were typed on 6.3 x 8.9 cm white cards, oriented vertically. The left and right parenthesis keys of a pica-type electric typewriter were used to generate the stimuli. One parenthesis pair was centered in the upper half of each card. Each parenthesis was approximately 3 mm tall and the spacing between the parentheses was about 5 mm. At a typical viewing distance of 30 cm, these stimuli subtended a visual angle of approximately 1 deg.

For notational purposes, each stimulus in the figure has been labeled with two letters which specify the levels on the two dimensions. The letters L and R refer to levels and indicate left and right curvature of the parenthesis. The first letter indicates the level of the first, or left-hand, dimensional element, and the second letter indicates the level of the second, or right-hand, element.

Conditions

Stimuli were arranged into decks of 32 cards each. There were eight such decks in all, each representing a different experimental condition.

One Dimension

There were four conditions, in each of which only the relevant element varied, while the irrelevant element was the same for all 32 cards in a deck. Thus, in these conditions, each of the four decks contained only two different stimuli. These four decks provided control conditions. As can be seen in Fig. 1A, these four discriminations correspond to the four sides of the square formed by the four stimuli: LL vs RL and LR vs RR (where the first element is relevant) and LL vs LR and RL vs RR (where the second is relevant). In each of these decks, 16 of the cards contained one of the stimuli and 16 contained the other.

Correlated Dimensions

There were two conditions, in which both the first and the second elements varied, but in a perfectly correlated manner. Thus, in both of these conditions, as in the control conditions, each deck contained only two different stimuli. These two conditions correspond to the two diagonals in Fig. 1A: LL vs RR and LR vs RL. Again, each of these two decks contained 16 cards bearing one of the stimuli and 16 bearing the other. Because of the perfect correlation between the elements in each of these two decks, either the first or the second element may be considered relevant.

Orthogonal Dimensions

There were two conditions in which both the first and the second element varied, but in a completely uncorrelated or orthogonal manner. In both of these conditions, each deck contained four different stimuli. The first of these two conditions required discrimination of the stimuli in the left column from those in the right column in Fig. 1A: LL and LR vs RL and RR. Here, of course, it is the first element that is relevant. The second of these conditions required discrimination of the stimuli in the top row from those in the bottom row in Fig. 1A: LL and RL vs LR and RR. Here, the second element is relevant. Both of these decks contained 32 cards, 8 each of the four different stimuli.

Supplemental Experiment

A separate, supplemental experiment followed the main experiment. This experiment included conditions that were identical to those described above, but used the stimuli shown in Fig. 1B. Conditions involving these stimuli were of interest because, while these have exactly the same elements and interelement spacing as the original stimuli, they seem phenomenally, at least, to form weaker configurations. These stimuli were constructed by rotating the right-hand element of the original stimuli so that this new element now curved either up (U) or down (D). Three decks of cards were assembled, corresponding to the following three conditions: two one-dimension conditions, serving as controls, were LU vs RU and LD vs RD; and one condition with orthogonal dimensions, LU and LD vs RU and RD. In all three conditions, the left element was relevant for classification.

Procedure

The task in both experiments was speeded classification of a deck of cards into two piles. On each trial, S was handed a well-shuffled deck of cards, face up, along with example cards indicating the particular discrimination required for that deck. When S was ready, E initiated the trial by pressing a footswitch which started a timer and served as a cue for S to begin sorting. Ss were instructed to sort as fast as possible, but without making errors, and were allowed to use any strategy they wished. Following each sort, S was informed of his sorting time, which was recorded along with the number of errors made. Each S sorted all eight decks in the main experiment one time as a practice block and then eight more times in blocks containing each condition, for a total of 72 sortings per S, of which 64 were counted. The order of conditions was counterbalanced across Ss. The supplemental experiment began immediately after the conclusion of the main experiment and used the same procedure.

Subjects

Of the 16 Ss used (5 females), whose mean age was 22 years, 2 were fulfilling a requirement of the undergraduate introductory psychology course at Yale and 14 were paid \$2/h to serve in a single session lasting slightly over 1 h. Of the 16, 8 Ss (4 females) participated in the supplemental experiment.

Fig. 2. Sorting times for the eight conditions in the main experiment.

RESULTS

The results of the main experiment are shown in Fig. 2. Analysis of variance of sorting times revealed that the eight conditions were a significant source of variance [$F(7,105) = 38.1, p < .001$]. Mean sorting time for the four one-dimension control conditions was 14.42 sec per deck. The two conditions with correlated dimensions averaged 14.44 sec, nearly identical to the time for the control conditions. In fact, for 8 of the 16 Ss, the conditions with correlated dimensions were faster on the average, while for the remaining 8, those with a single dimension were faster. The two conditions with orthogonal dimensions, however, proved to be substantially more difficult and required on the average 16.99 sec per deck. Here, all 16 Ss showed a loss in sorting rate relative to the control conditions ($p < .001$, sign test). This loss, which averaged 2.57 sec per deck, was still quite marked in the final, eighth, block of trials at 1.94 sec per deck. Thus, the interference effect did not diminish much with practice.

Since the most pronounced effect above was the difference between the two conditions using orthogonal dimensions and the six others, a second analysis of variance was performed, which omitted the former two, to examine the remaining differences among the latter six. These were also significant [$F(5,75) = 8.39, p < .001$]. These differences make it unlikely that the absence of any improvement in the conditions with correlated dimensions, relative to the controls, was due to a simple performance limit on Ss' sorting rates. In fact, the two conditions with correlated dimensions differed significantly from one another ($p < .05$, Newman-Keuls test), with one of them being the fastest of these six conditions while the other was slowest.

By contrast, the results from the supplemental experiment using the stimuli from Fig. 1B show no

interference effect. Sorting times for the two one-dimension control conditions, LU vs RU and LD vs RD, averaged 14.36 and 14.49 sec per deck, respectively, while the condition with orthogonal dimensions, LU and LD vs RU and RD, required an intermediate time of 14.47 sec [$F(2,14) < 1$]. Thus, the interference effects found in the main experiment did not occur with these stimuli.

Errors in both experiments averaged well under 1% and were too few to warrant analysis.

DISCUSSION

The most pronounced effect in the main experiment was that all 16 Ss found it easier to classify stimuli which differed only on the relevant dimension than stimuli where the irrelevant dimension also varied, orthogonally to the relevant one. This result by itself is sufficient to justify the conclusion that Ss were not able to attend selectively to one element of these stimuli while ignoring, or filtering, the other.¹ Thus, this finding supports the notion that these elements are indeed perceived as configurations, and that the elements cannot be, or at least normally are not, perceived independently. Further support for this view comes from comments made by many Ss following the sessions, that they were perceiving the element pairs as whole shapes and so were, for the most part, discriminating shapes and not the component elements. This result also complements the data of Clement and Weiman (1970). They showed that when discriminating simple matrix-type dot patterns, Ss apparently process whole patterns and are reluctant to use the logically simpler strategy of basing their decisions on the presence or absence of a dot in a particular cell of the matrix.

A second finding was that it was no easier to classify stimuli when both dimensions varied in a completely correlated manner than when only one dimension varied. In other words, Ss were not able to take advantage of the redundancy provided by the second element. Moreover, this absence of a redundancy gain does not appear to be due to a simple limit on Ss' sorting performance.

This overall result, then, conforms to what we would expect if the dimensions serve only to generate a set of nominally defined forms or configurations. While it is true that the stimuli are formally definable in terms of two dichotomous dimensions, this experimental outcome makes clear that these are dimensions only for E, and do not serve that function for S. Thus, the distinction between the control conditions involving variation on a single relevant dimension and the correlated conditions involving covariation on both dimensions is quite inappropriate. That is to say, the fact that these two formal dimensions, left element and right element, are correlated physically means little if these dimensions are not represented in the perceptual process.

These conditions, involving either a single dimension or correlated dimensions, are, then, six instances of just one type of task, namely, the discrimination of two configurations or shapes. Whether other dimensions of shape are relevant for these discriminations is not clear, nor, in fact, has the need for such a dimensional representation been established. As an alternative, the assumption can be made that these shapes are treated nominally, or categorically, in the perceptual process, without regard to the similarities or distances between their representations in psychological space. In effect, this assumption is that the stimuli are being discriminated in template fashion.

In line with this argument, the performance decrement found in the two orthogonal conditions should be interpreted as being due to the task requirement of grouping. The failure of selective attention with such stimuli leads to nominally defined stimuli, and the increased processing time is due only to the many-to-one mapping required in the grouping task. It is a different kind of interference from that obtained with integral dimensions, in which dimensions still exist perceptually but cannot be excluded from attention.

Recall that there were significant differences in sorting time among the six two-stimulus conditions. If these configurations are related only nominally, how can the differences among these six discriminations be interpreted? That is to say, if all of the six pairs of stimuli are equally similar, what other factor could account for the differences among them in discrimination time? An experiment by Clement and Varnadoe (1967) suggested that pattern goodness, another Gestalt concept, may be involved in the discrimination process. They showed that good patterns were discriminated more quickly than poor ones, and argued from this that good patterns are encoded more rapidly than poor ones. Since stimuli must necessarily be encoded before they can be compared, total discrimination time must measure encoding time as well as comparison time.

Do the stimuli of the present study differ in pattern goodness? Garner and Clement (1963) showed that the goodness of a pattern is related to the size of the subset of different patterns generated by reflections and rotations of that pattern in increments of 90 deg: The smaller this subset of equivalent patterns, the better the pattern. According to this criterion, Stimuli LR and RL are better than Stimuli LL and RR. With the former, any reflection or 90-deg rotation yields one of only two different patterns; with the latter, four different patterns are generated, and in fact, these are the same four for LL and RR. Direct goodness ratings gathered informally in our laboratory corroborated this ordering, yielding the following sequence from best to worst: LR, RL, LL, and RR. Following this ordering, predictions can be made for the relative difficulty of the various two-stimulus discriminations in the main experiment. For example, the stimuli LR and RL should be encoded most quickly

and thus should show the shortest discrimination time. LL and RR should be encoded most slowly and thus show the longest discrimination time. The present results bear out these predictions. Agreement between the remaining predictions and the observed sorting times is sufficiently close to justify further consideration of this approach.

The import of the main experiment is, then, that physically separate stimulus elements may be treated perceptually as belonging to a single configuration. Just what properties of stimuli are responsible for configuration are not yet well understood, but it is reasonable to assume that element proximity is one such factor. At some separation, the elements of the present stimuli could surely be attended to selectively. However, the results of the supplemental experiment show that with the same class of elements and the same interelement spacing, configuration does not always result; the elements comprising the stimuli in that experiment could be attended to selectively. Evidently, proximity is a necessary, but not sufficient, condition for configuration. Even when the elements are close enough to allow configuration, the particular nature of the elements is crucial in determining whether configuration actually does occur.

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NOTE

1. One explanation for the decline in performance when orthogonal dimensions are used is that responses associated with the irrelevant element are competing with those for the relevant element. In the main experiment, each S was required to classify according to each element, so that such a response competition could have been built up. However, pilot data were collected for the main experiment under conditions which were unlikely to produce response competition, where for any S only the first or the second element was ever relevant; these data showed interference effects comparable to those reported above. Also, if response competition were operating, one would expect the LR vs RL discrimination, where competition is maximal, to be slower than the LL vs RR discrimination, where it is minimal.

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