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Evidence for the abstractive encoding of superficial position information in visual patterns

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When presented a series of patterns inside a frame, subjects unintentionally retained information concerning the frame-relative location of the elements composing the patterns; they could use this superficial information to estimate the frequency with which the elements occurred at various locations within the frame. There were two aspects of the results that supported the hypothesis that this superficial element-location information was abstractively encoded and, therefore, retrievable independent of the patterns comprising the elements: (1) Correlations between actual and estimated frequency remained significant after the effects of pattern recall were partialled out, and (2) correlations were enhanced by assuming that the frequency estimate for each location was affected by the imprecise coding of position for elements falling in surrounding locations. Additional experiments indicated that an orienting task emphasizing pattern recall resulted in very inaccurate estimation of element-location frequency, and intentional instructions improved the precision of position coding for individual elements.

Subjects unintentionally retain what appear to be meaningless, superficial aspects of various stimuli. For example, Jacoby and Brooks (1984) demonstrated that the speed of picture identification was enhanced when the same picture had been seen on a previous occasion; the repetition of superficial details that were irrelevant to the identification of the picture facilitated its identification the second time it was presented. Similarly, many experiments (e.g., see Hock, Throckmorton, Webb, & Rosenthal, 1981; Jacoby & Hayman, 1987) have provided evidence for the retention of information concerning the case in which letter strings are printed. Kolers (1976) has shown that the speed with which subjects reread a series of passages was enhanced by exact repetition of the typographical characteristics of the passages, even though more than a year had passed since their initial reading.

Jacoby and Brooks (1984) have argued that the superficial characteristics of stimuli may or may not be encoded, depending on subjects' expertise with the stimuli and the demands of the processing task. They have further argued that when superficial characteristics are encoded, they can be integrated with the meaning or content of the stimuli to the extent that the superficial information cannot be retrieved without also retrieving the meaningful content. This integration, according to Jacoby and Brooks, is indicative of nonanalytic, nonabstractive aspects of perception and memory.

The question addressed in the present research was as follows: When superficial stimulus information is retained, must it be integrated with the meaningful content of the stimuli, or can it be abstracted from the latter and enter into judgments independently? Although it is easy to conceive of instances suggestive of abstraction, a close examination of such instances raises questions concerning what would constitute a proper test of the abstraction hypothesis. Consider, for example, a subject who many years ago participated in one of Kolers's experiments. The subject might remember that he/she had read inverted passages, but not remember the content of the passages. There are two reasons for minimizing the importance of this as evidence against integration and in support of the abstraction hypothesis. First, superficial stimulus information concerning the orientation of the text may not integrate with the semantic content of the text, because it instead combines with other information related to the experimental context (e.g., the room, the time of year, characteristics of the experimenter, etc.) to form an integrated episodic memory concerning participation in a reading experiment with inverted passages. That is, the orientation of the text might be recalled independently of its semantic content, but orientation may not have been abstractively encoded such that it was retrievable independent of other episodic information. Second, recalling that the text in Kolers's experiment was inverted without recalling the content of the text is insufficient evidence against integration, because the savings obtained in rereading Kolers's passages came from repeating the processing operations required for reading inverted text, not

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remembering that the text was inverted. The semantic content of the text is more likely to integrate with superficial information pertinent to the processing of the content than with general descriptors of text characteristics (e.g., that it was inverted).

It follows from the above remarks that a proper test of the abstraction hypothesis would require that the following criteria are met: (1) The encoded information is superficially related to the semantic content of the stimuli, (2) it is unlikely to combine with the general experimental context to form an integrated episodic memroy, and (3) it is potentially relevant to the efficient processing of the semantic content of the stimuli.

In the experiments reported in this study, visual patterns were used to test for whether superficial characteristics of a series of stimuli can be abstractively encoded, independent of the semantic content of the stimuli. Each pattern was composed of five circles inside a square frame, with 16 possible locations (4×4) for the circles. Since the patterns filled five locations in a 3×3 matrix of possible locations, each was placed in one of the four quadrants of the larger 4×4 frame. Patterns like these have the potential to be meaningful. They might be similar to familiar shapes, subjects might learn a name for each, or subjects might learn to categorize them on the basis of their similarity to other patterns (Posner & Keele, 1968). In each of these cases, the semantic content of a pattern (that which makes it recognizable or categorizable) probably includes a description of the spatial relations among its component elements. The locations of individual elements relative to the surrounding frame constitute superficial information that is irrelevant to the semantic content of the patterns.

Following the presentation of a series of patterns, subjects unexpectedly were required to estimate, across the full set of patterns, the frequency with which the component elements of the patterns occupied each of the 16 locations within the frame. Having subjects make judgments that depended on the frame-relative location of individual pattern elements met our criteria for a proper test of the abstraction hypothesis. First, the frame-relative location of individual pattern components constitutes superficial information. Second, it is unlikely to integrate with the general experimental context in which the patterns are presented; subjects may remember participating in an experiment in which they made judgments about unfamiliar patterns, but information related to the occurrence of circles in the upper left corner of the frame is unlikely to be part of an episodic memory of the experiment. Third, it is plausible for the retention of information concerning element-location frequency to contribute to the efficient processing of the patterns; faster processing of spatial relations among the component elements of a pattern could result if the pattern processor has access to information regarding the likely locations of individual pattern elements.

Assuming subjects can accurately estimate frame-relative, element-location frequency, the critical question concerns the manner in which the frequency-of-occurrence estimates are generated. Support for the abstraction hypothesis would be obtained if it could be shown that frequency estimates for each location were based on the retrieval of individual pattern elements, and their associated position codes, independent of the retrieval of the patterns comprising the elements. Evidence against element abstraction would be obtained if frequency estimates for each location depended on the retrieval of patterns with elements at the locations being tested. That is, a location might receive a relatively high frequency-of-occurrence estimate if a relatively large number of patterns with elements at that location were retrieved, and a relatively low estimate if few such patterns were retrieved. Evidence that frequency judgments depended on pattern retrieval would be consistent with the hypothesis that superficial, frame-relative location information is retrievable only in conjunction with the relational (semantic) information in each pattern.

A method for determining whether estimates of element-location frequency were based on the retrieval of individual pattern elements, independent of the retrieval of the patterns comprising the elements, has been introduced for letter strings by Hock, Malcus, and Hasher (1986) (see also Hock & Hasher, 1989). The method follows the logic of Tversky and Kahneman's (1973) availability heuristic. When applied to patterns, it involved the following. After the presentation of the patterns, subjects first estimated element-location frequency and then recalled as many of the patterns as possible. For correctly recalled patterns (i.e., patterns for which the relations among pattern elements were correctly recalled), we determined the frequency with which each location within the frame was occupied by an element. For each subject, we then computed a partial-correlation coefficient in which the recall frequency for each location was "partialled out" of the correlation between the actual and estimated frequency. If a significant partial-correlation coefficient remained (with the effect of pattern recall held constant), it could be concluded that subjects' estimates were based on superficial, element-level position information that was abstracted from the patterns comprising the elements.[1]

A converging method for testing the abstraction hypothesis was based on the assumption that if frequency estimates were based on the retrieval of abstracted, element-level memory units, the accuracy of the estimates would depend on how precisely the frame-relative positions of the elements were coded. For example, if a location with a low frequency of occurrence was surrounded by locations with high frequencies of occurrence, imprecise position coding for the surrounding elements could result in frequency estimates for that location being too high. That is, elements appearing in the surrounding locations could be misplaced at the location for which element frequency is being estimated. The procedure for assessing confusion among imprecise position codes for individual elements is described in detail in the Results section of Experiment 1. It involved calculating an effective frequency for each location by combining the actual frequency of element occurrence for the location with the actual frequencies of occurrence for surrounding, potentially confusable locations. If correlations between estimated and effective frequency (including the frequencies of surrounding locations) are greater than correlations between estimated and actual frequency (ignoring the frequencies of surrounding locations), it would indicate that judgments were affected by the position codes associated with individually abstracted pattern elements (in this case, elements in locations surrounding the location being estimated).

EXPERIMENT 1

The subjects in Experiment 1 were presented a series of patterns without being told that they would subsequently be asked to estimate the frequency with which each location within the frame was occupied by the component elements of the patterns. During the initial presentation of the patterns, one group of subjects was instructed to determine, for each pattern, whether or not three of the circles composing the pattern were aligned vertically or horizontally. A second group of subjects was instructed to determine, for each pattern, whether or not three of the circles composing the pattern were aligned diagonally. These tasks were selected because they were expected to produce differences in performance consonant with the well-established advantage in the processing of vertical/horizontal orientations over the processing of diagonal orientations (i.e., the *oblique effect*; Appelle, 1972). In addition to providing evidence for the unintentional encoding of information that is the basis for accurate estimation of element-location frequency, Experiment 1 tested the hypothesis that superficial element-level position information can be abstracted from the patterns comprising the elements. As indicated above, this involved determining whether or not estimates of element-location frequency were based on pattern retrieval and assessing the effects of imprecise position coding on estimation accuracy.

Method

Subjects. Sixty-four undergraduate students at Florida Atlantic University participated in Experiment 1 for course credit in an undergraduate psychology class.

Stimuli. Each pattern was composed of five empty circles whose locations were defined in terms of an imaginary 3×3 matrix of possible element locations. With the constraint that every row and column of the imaginary 3×3 matrix had to contain at least one circle per pattern, 17 different patterns were generated (Garner & Clement, 1963). The 3×3 matrix was located in one of four positions within a frame large enough to accommodate 16 possible element locations (4×4). That is, the 3×3 matrix was placed in one of the four quadrants of the larger 4×4 matrix. Each of the 17 3×3 patterns was presented twice, each time in the same quadrant within the 4×4 matrix.

We were unable to avoid compositional constraints that resulted in circles being located in the middle locations of the 4×4 matrix with the greatest frequency and circles in the corner locations of the 4×4 matrix with the least frequency (side locations were intermediate). However, the orientation of each of the 17 Garner and Clement (1963) patterns and its location within the 4×4 matrix were selected to independently maximize the range of frequencies for the corner, side, and middle locations. The 17 patterns, as well as the frequency with which each of the 16 locations in the 4×4 matrix was occupied by a circle, are presented in Figure 1. Frequencies varied from 4 to 12 for the four corner locations, from 2 to 20 for the eight side locations, and from 6 to 28 for the four middle locations.

The set of 34 patterns described above was presented in one of four orientations: (1) all in the arbitrarily defined 0° orientation (which determined the frequency distribution of Figure 1), (2) all rotated 90°, (3) all rotated 180°, or (4) all rotated 270°. Separate groups of subjects viewed the patterns in one of the four orientations in order to balance out possible effects of top-down and/or left-right scanning biases on the subjects' estimates of how often locations within the frame were occupied by circles.

The presentation of stimuli and the recording of responses were controlled by a Data General Eclipse computer. The stimuli, white

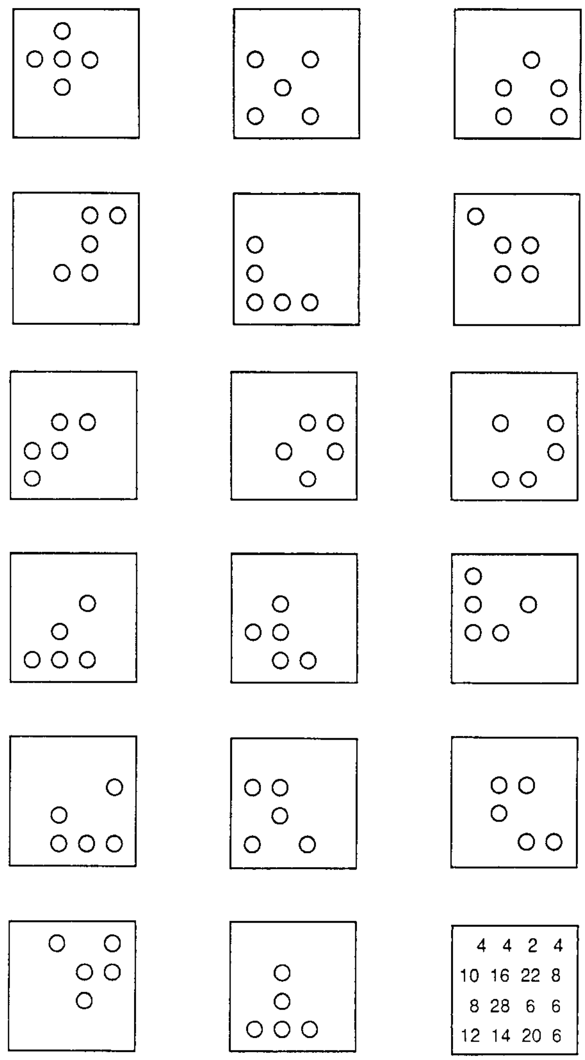

Figure 1. The 17 different patterns presented in their 0° orientation (the actual patterns were white on black rather than black on white). The frequencies with which circles occupied each of the 16 possible locations within the frame for these patterns are presented in the frame in the lower right corner (each pattern was presented twice).

patterns on a black background, were presented on an Electrohome monitor. A 9.0×9.0 cm white frame was always present in the center of the screen (the lines defining the frame were 0.1 cm thick). There were no grid lines presented inside the frame. The patterns, each composed of five unfilled circles with a diameter of 1.0 cm, were presented inside the frame.[2] When viewed from a distance of 42.5 cm, a visual angle of 12.1° was intercepted by the frame and a visual angle of 1.3° was intercepted by each circle.

Procedure. The experimental procedure consisted of three phases. During Phase 1, the subjects were presented with the 34 patterns in random order and were given one of two detection tasks. One group of 32 subjects was required to press one button if there were three circles within a pattern that were vertically or horizontally aligned (16 of the 34 patterns met this requirement) and the other button if there was no vertical or horizontal alignment among the circles. A second group of 32 subjects was required to press one button if there were three circles within a pattern that were aligned in either a left or right diagonal (12 of the 34 patterns met this requirement) and the other button if there was no diagonal alignment.

To facilitate the detection of aligned circles, a small dot was placed in the center of three of the five circles composing each pattern (each dot had a diameter of 0.1 cm). The three circles containing a dot remained the same for the two presentations of each pattern. In the *vertical/horizontal* condition, these dots were placed in vertically or horizontally aligned circles. For patterns without a vertical or horizontal alignment, the three dots were assigned randomly to three different circles in each pattern. In the *diagonal* condition, the three dots were placed in three diagonally aligned circles. For patterns without a diagonal alignment, the three dots were randomly assigned to three different circles in each pattern.

Each pattern was presented for 1 sec. The intertrial interval also was 1 sec, except for the occasional trials on which the subjects required more than 1 sec to respond. Then, a 1-sec delay was introduced between the subject's response and the presentation of the next stimulus. The subjects were instructed to respond as quickly and as accurately as possible; they were not told to expect any sort of memory test. Reaction times (RTs) from the onset of each pattern and errors were recorded during Phase 1 of the experiment.

Estimates of element-location frequency were obtained during Phase 2. Sixteen different stimuli were presented during the estimation phase, each being a single circle inside the frame. The circle for each stimulus was located at 1 of the 16 possible locations in the 4×4 matrix (grid lines were not presented). The order of presentation for the 16 estimation stimuli was randomized. On each estimation trial, the number 15 was presented 7.0 cm below the center of the frame. This number represented the midpoint of the range of element-location frequencies (2 to 28). The subjects were told that the frequency with which a circle was presented at each of the indicated locations varied from 1 to 30, and were instructed to change the number 15 on the screen to a number that reflected their estimate of element-location frequency over the full set of patterns they had just seen (out-of-range estimates were not accepted by the computer).[3]

In Phase 3 of Experiment 1, the subjects were provided with a sheet of paper with 20 empty 4×4 matrices (including grid lines) and given 10 min to recall as many of the patterns they had seen during Phase 1 as possible (they were required to provide five elements for each attempted reproduction). The data from Phase 3 were used to determine whether the subjects' frequency estimates for each location were derived from patterns they could recall that contained circles at the locations being tested.

Results

Performance in orienting tasks. Mean RTs and error rates for Phase 1 are presented in Table 1. The fact that responses obtained for correct detections were faster than those obtained for correct rejections is typical of the RT literature. RTs were significantly slower in the diagonal condition than in the vertical/horizontal condition [$F(1,62) = 4.85, p < .05, MS_e = 32{,}410$]. This result was typical of the oblique effect (Appelle, 1972). Error rates were very similar in the two detection conditions.

Table 1
Mean Reaction Times (in msec) and Percent Errors for the Phase 1 Orienting Tasks

Phase 1 Task	Response Type	Mean Reaction Time	Percent Errors
	Experiment 1		
Vertical/Horizontal Alignment	Yes	945	6.5
	No	1056	3.5
Diagonal Alignment	Yes	1022	7.5
	No	1070	2.3
	Experiment 2		
Present/Absent	Present	845	3.5
	Absent	865	2.2
	Experiment 3		
Counting	2	932	2.0
	3	996	4.8

Accuracy of frequency estimation. That the subjects were capable of estimating element-location frequency was indicated by the correlations between the actual and estimated frequencies for each location in the 4×4 matrix, which were computed individually for each subject. Although these correlations were, on average, relatively small, they were positive for 78% of the subjects in the vertical/horizontal condition and 84% of the subjects in the diagonal condition. In this experiment, as well as the experiments that follow, individually computed correlation coefficients served as descriptive statistics. The computation of mean correlation coefficients and t tests were based on Fisher's r to z transformation. The means of the actual/estimate correlations (see Table 2) were significantly greater than 0 [$r = 0.34$, $t(31) = 5.14, p < .001$; $r = 0.33$, $t(31) = 5.72$, $p < .001$; for the vertical/horizontal and the diagonal conditions, respectively]. The correlations obtained for the two conditions were not significantly different from each other [$t(62) < 1.0$].[4]

Effect of pattern retrieval on frequency estimation. As indicated in the introduction, the critical test of the abstraction hypothesis was performed by determining whether or not the subject's ability to estimate element-location frequency depended on the retrieval of the patterns comprising the elements. Following the frequency estimation phase of the experiment, the subjects were required to recall as many of the patterns as possible. Our initial analysis of the abstraction hypothesis was based on only correctly recalled 3×3 patterns. To be scored as correct, all five circles composing a pattern had to be recalled in their correct relative locations and the pattern had to be in the correct orientation, regardless of whether it was recalled in the correct quadrant of the 4×4 matrix.[5]

Recall levels were very low. The subjects correctly recalled 6.4% of the patterns in the vertical/horizontal condition (42.9% of which were recalled in the correct quad-

Table 2
Means of Individually Computed Correlation Coefficients Between Estimated Frequency (Obtained During Phase 2) and Actual Frequency for the 16 Locations Within the Frame

Phase 1 Task	Correlation	Partial Correlation	Partial Correlation (Relaxed Criterion)
	Experiment 1		
Vertical/Horizontal Alignment	0.34	0.29	0.27
Diagonal Alignment	0.33	0.28	0.23
	Experiment 2		
Present/Absent	0.35	0.31	0.30
Pattern Memory	0.17	0.11	0.10
	Experiment 3		
Counting	0.28	0.25	0.23
Intentional	0.35	0.33	0.27

Note—We computed the partial correlations by partialling out the effect of recall frequency (determined from the Phase 3 recall data) from the actual/estimate correlation.

rant) and 9.2% of the patterns in the diagonal condition (52.0% of which were recalled in the correct quadrant). We counted the frequency with which each location was occupied by an element in a subject's correct-recall protocols. For each subject, we then computed a partial-correlation coefficient in which the recall frequency for each location was partialled out of the correlation between the actual and estimated frequency for each location. The mean partial-correlation coefficients were only slightly reduced from the mean correlation coefficients observed without partialling out recall-frequency; the correlations remained positive for most of the subjects (81% in the vertical/horizontal condition; 78% in the diagonal condition). The means of the actual/estimate correlations (with recall-frequency partialled out) were significantly greater than 0 [$r = 0.29$, $t(31) = 4.43$, $p < .001$; $r = 0.28$, $t(31) = 4.13$, $p < .001$; for the vertical/horizontal and diagonal conditions, respectively]. The partial correlations obtained for the two conditions were not significantly different from each other [$t(62) < 1.0$].

The same analyses were repeated, but with a relaxed scoring criterion that counted a recalled pattern as correct if it was a rotated or mirror-image reversal of an original pattern. Percentage recall with the relaxed criterion increased to 25.9% and 28.5% in the vertical/horizontal and diagonal conditions, respectively. Although mean partial-correlation coefficients were slightly reduced, they remained reliably greater than 0 [$r = 0.27$, $t(31) = 4.08$, $p < .001$; $r = 0.23$, $t(31) = 3.49$, $p < .01$] and insignificantly different from each other [$t(62) < 1.0$].

Since significant actual/estimate correlations were obtained after the contributions of pattern retrieval were partialled out, the results provided evidence that the subjects' estimates of element-location frequency did not rely on pattern retrieval and, therefore, could be attributed to the retrieval of frame-relative position codes associated with individual pattern elements.

Encoding precision. The analyses performed in this section, as well as the section that follows, required more precise measurement of estimation accuracy than did the preceding analyses. Therefore, instead of computing individual correlation coefficients for each subject, we computed a group correlation coefficient for all the subjects participating in a condition on the basis of their mean estimated frequency at each location.

As indicated in the introduction to this paper, the hypothesis that subjects would abstract element-level position information from the patterns was also tested by assessing the effects of coding precision on the accuracy of frequency estimation. This involved calculating the effective frequency for each location by taking account of the frequency of occurrence in potentially confusable, surrounding locations (i.e., its adjacent surround). We summed, for each of the 16 locations in the 4×4 matrix, the frequencies of occurrence for all the adjacent locations, including diagonally adjacent locations (e.g., the total adjacent-surround frequency for the location in the lower right corner of Figure 1 was 32). The effective frequency for each location was its actual frequency plus k (a variable weighting factor) times the total frequency of its adjacent surround. Since we had no preconceptions concerning an appropriate value for k, we computed the correlation between mean estimated frequency and the hypothetical effective frequency for values of k ranging from 0 to 1. The results of these computations are presented in Figure 2. In evaluating these results, we were looking for an increase in the size of the correlation relative to that obtained when k was 0 (i.e., when the adjacent surround was not taken into account).

For the vertical/horizontal condition, the size of the correlation between the mean estimated frequency and the effective frequency (for all 16 locations) increased from 0.72, when $k = 0$ (i.e., the surround frequencies were not included), to a maximum of 0.90, when $k = .3$ (see Figure 2). A smaller increase in overall estimation accuracy was observed for the diagonal condition: The size of the correlation between mean estimated frequency and the effective frequency (for all 16 locations) increased from 0.75, when $k = 0$, to 0.82, when $k = .2$ (see Figure 2).

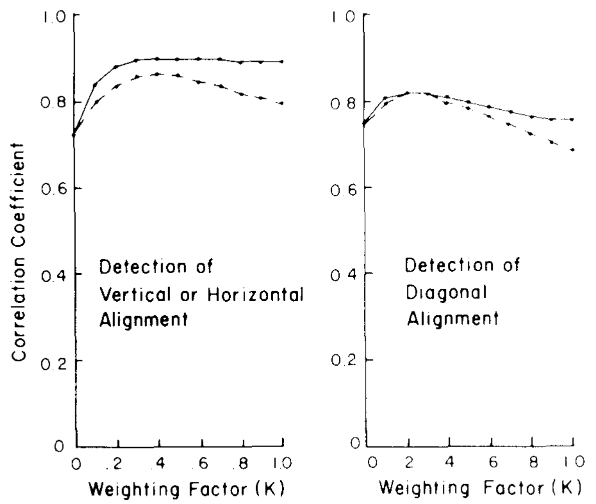

Figure 2. Experiment 1: For the vertical/horizontal and diagonal conditions, correlations between mean estimated and effective frequency for the 16 locations within the frame. Each correlation was computed for a different value of *k*, which weights the contribution of occurrence frequencies at surrounding locations in relation to a location's actual occurrence frequency in determining the effective frequency of occurrence for the location. The solid lines represent correlations based on the adjacent surround, and the broken lines represent correlations based on the rectilinear surround.

The above results indicate that the adjacent surround influenced the subjects' frequency estimates. While this could be attributed to the imprecision of position coding for surrounding locations, another possibility is that the occurrence of elements in surrounding locations influenced estimation accuracy by introducing confusions in retrieval for elements with similar position codes. This could occur if element location was encoded with sufficient precision for the horizontal or vertical component of the memory code for one element to be the same as the horizontal or vertical component of the memory code for an element at another location. To test whether or not estimates of element location frequency were influenced by confusions in retrieving position codes for individual elements, we computed the *rectilinear surround* for each location by summing the frequencies of element occurrence for all the locations to its left, its right, above it, and below it (e.g., the total rectilinear-surround frequency for the location in the lower right corner of Figure 1 was 64). Our computation of effective frequency thereby included the frequencies for all locations with the same horizontal or vertical memory code as the location being estimated.

The hypothetical effective frequency for each location, its actual frequency plus k times the total frequency of the element's rectilinear surround, was correlated with mean estimated frequency for values of k ranging from 0 to 1. The results of these computations are presented in Figure 2. For the vertical/horizontal condition, the increase in the size of the correlation between mean estimated frequency and the effective frequency (for all 16 locations) was smaller than that observed when the computation of effective frequency was based on the adjacent surround. This indicated that the accuracy with which the subjects estimated element-location frequency in the vertical/horizontal condition was limited by the imprecision of the position codes associated with individual elements rather than by confusion in the retrieval of relatively precise position codes. For the diagonal condition, the contrast between the influence of the adjacent surround and the rectilinear surround was smaller, but in the same direction as that observed in the vertical/horizontal condition.

Compositional constraints. Of concern in this section was whether or not the subjects based their frequency-of-occurrence estimates for each location on their awareness of compositional constraints regarding where circles were most likely to be located (i.e., they were constrained to occur in the middle of the frame more often than in the side or corner locations of the frame). If the subjects were aware of this constraint, they could have done an adequate job of estimating element-location frequency without remembering anything about the information presented during Phase 1 of the experiment. The logic behind the analyses performed in this section was that the subjects' awareness that the corner locations were constrained to be lower in frequency than were the middle or side locations would not allow them to differentiate between the frequencies for each of the four corner locations, each of the eight side locations, or each of the four middle locations.

The first step in evaluating whether the subjects' estimates were influenced by their awareness of compositional constraints was to determine the mean frequency estimate at each of the 16 locations in the 4×4 matrix. This was done independently for the 32 subjects in the vertical/horizontal condition and the 32 subjects in the diagonal condition. We then computed the correlation between the mean estimated and actual frequency independently for the four corner locations, the eight side locations, and the four middle locations. The three correlations in the vertical/horizontal condition were all positive: 0.95, 0.72, and 0.21, for the corner, side, and middle locations, respectively. Since the number of degrees of freedom associated with each correlation was too small to test their statistical significance, our determination of their reliability rested on the repetition of these positive correlations in the diagonal condition. For the latter, the correlations were again positive: 0.99, 0.77, and 0.54, for the corner, side, and middle locations, respectively. We could conclude, therefore, that the observed correlations beween actual and estimated frequency were not due to the subjects' awareness of compositional constraints in the location of the dots.

Discussion

Prior to the frequency estimation phase of Experiment 1, the subjects did not anticipate that they would be asked to estimate element-location frequency. When they were instructed that they would be required to estimate how often circles appeared at various locations within the frame, virtually every subject protested that they would be unable to perform the estimation task. Similar protests were received during the experiments reported later in this paper (the unexpected nature of the test was, with the exception of 2 subjects, always confirmed by post-experimental interviews). The subjects were assured that people always do much better than they expect at this task and were encouraged to try hard and give their best guesses. Their success at estimating element-location frequency, although modest, was obtained despite their certainty that they lacked the knowledge to perform the estimation task.

The results of Experiment 1 provided evidence that the subjects, without intentional effort, encoded the positions of the constituent elements of visual patterns. Analyses based on mean estimated frequencies indicated that an important source of inaccuracy in the subjects' estimates of element-location frequency was the imprecision with which they encoded the frame-relative position of individual elements rather than confusion in the retrieval of elements with similar position codes. This evidence that the subjects' abstracted element-level position information from the patterns (otherwise there would not have been confusions among the locations of the elements) converged with evidence that we obtained by analyzing pattern-recall data. The latter analysis indicated that if the subjects had estimated the frequency of occurrence for each location by retrieving patterns with elements at the locations being estimated, we would not have observed a significant actual/estimated correlation after the frequency with which each element appeared in the subjects' correct-recall protocols was partialled out. The results therefore supported the abstraction hypothesis in indicating that superficial information involving the frame-relative location of individual pattern elements was abstractively encoded such that it was retrievable independent of the patterns comprising the elements.

Finally, the oblique effect observed in so many different perceptual tasks (Appelle, 1972) was also observed in our Phase 1 detection data. RTs were significantly slower when the subjects looked for diagonal alignments than when they looked for vertical or horizontal alignments. Our memory results, however, did not provide the consistent vertical/horizontal advantage that is typical of perceptual tasks. More patterns were correctly recalled in the diagonal condition than in the vertical/horizontal condition, and, for frequency estimation, the vertical/horizontal condition had no apparent advantage over the diagonal condition.

EXPERIMENT 2

The results of Experiment 1 provided evidence that superficial information regarding the frame-relative position of individual pattern elements can be abstractively encoded, so that it can be retrieved independent of the patterns comprising the elements. Two analyses supported this conjecture—one involving the effects of pattern recall on frequency estimation, the other the influence of a location's adjacent surround on frequency estimations for the location. Experiment 3 will provide further evidence that the effect of a location's adjacent surround on frequency estimates for the location is due to imprecision in position coding for individual pattern elements, rather than imprecision in pattern recall (i.e., recalling patterns with elements in the location being tested, but in addition recalling patterns with elements in surrounding locations). In Experiment 2, we provide further evidence that basing frequency estimates on pattern recall could not account for the subjects' ability to estimate element-location frequency.

A potential problem with the partial-correlation procedure used in Experiment 1 to evaluate the effect of pattern recall on estimation accuracy was the low level of recall in the incidental learning conditions. Experiment 2 added another approach to assessing the influence of pattern recall. It introduced an orienting task that emphasized pattern-recall, the rationale being that if estimates of element-location frequency depend on the retrieval of patterns with elements at the location being tested, estimation accuracy should be improved by a task manipulation that increases the recallability of the patterns (including recalling the patterns in the correct quadrant of the 4×4 matrix of possible element locations). In Experiment 2, therefore, we contrasted estimation accuracy for an orienting task emphasizing pattern recall with an orienting task emphasizing element-level processing.

Method

Subjects. Sixty-four undergraduate students at Florida Atlantic University participated in Experiment 2 for course credit in an undergraduate psychology class.

Procedure. The stimuli and experimental procedure, with the exception of the tasks introduced in Phase 1, were identical to those of Experiment 1. However, the dots presented inside the circles were arranged in accordance with the Phase 1 tasks used in Experiment 2. On one occurrence of a pattern, a dot was presented in the center of one of the circles; on the other occurrence of the pattern, a dot was not presented. The order of this assignment of dots (zero vs. one per pattern) was randomized.

For one group of 32 subjects, the Phase 1 task for each pattern involved detecting a circle with a dot inside it. The subjects in the *present/absent* condition were required to press one button if there was a dot present and the other button if there was no dot present. They were instructed to respond as quickly as possible while keeping their errors to a minimum and were given no indication that they would have to remember anything about the patterns. The 32 subjects in the *pattern memory* condition saw the same patterns (and dots inside the circles) as did the subjects in the present/absent condition, but they did not have a discrimination task; they were instructed to try to remember each pattern. However, they were not told that they would be asked to estimate the number of times a circle appeared in each of the locations within the frame (prior to recalling the patterns).

Results

Performance in orienting tasks. Mean RTs and error rates are presented in Table 1. There was little difference in performance for present and absent responses.

Accuracy of frequency estimation. As in Experiment 1, correlations between the actual and estimated frequencies for each location in the 4×4 matrix were relatively small, but they were positive for 92% of the subjects in the present/absent condition and 78% of the subjects in the pattern memory condition. The means of the actual/estimate correlations (see Table 2) were significantly greater than 0 [$r = 0.35$, $t(31) = 7.64, p < .001$; $r = 0.17$, $t(31) = 3.24, p < .02$; for the present/absent and pattern memory condition, respectively]. The correlation obtained for the pattern memory condition was significantly lower than that obtained for the present/absent condition [$t(62) = 2.55$, $p < .05$].

Effect of pattern retrieval on frequency estimation. The subjects correctly recalled 6.3% of the patterns in the present/absent condition (41.1% of which were recalled in the correct quadrant) and 16.7% of the patterns in the pattern memory condition (64.8% of which were recalled in the correct quadrant). The difference between the two conditions was statistically significant [$t(62) = 4.55$, $p < .001$]. Partial correlations in the present/absent condition were positive for 81% of the subjects, and the mean partial-correlation coefficient was only slightly reduced from the mean obtained without partialling out recall frequency; the mean was significantly greater than 0 [$r = 0.31$, $t(31) = 5.75$, $p < .001$]. In the pattern memory condition, however, partial correlations obtained for individual subjects were more evenly divided between positive and negative values (69% had positive correlations). Also, the mean partial-correlation coefficient was sufficiently reduced so that it was no longer significantly different from 0 [$r = 0.11$, $t(31) = 1.76, p > .05$]. The partial correlations obtained for the present/absent and pattern memory conditions were significantly different from each other [$t(62) = 2.58$, $p < .02$]. With the relaxed criterion for scoring recalled patterns as correct, percentage recall increased to 21.5% in the present/absent condition and to 29.8% in the pattern memory condition; the difference in recall remained significant [$t(62) = 2.47, p < .02$]. Partial correlations were virtually identical to those obtained with the more stringent scoring criterion.

Encoding precision. The correlations between mean estimated frequency and the effective frequency for each location (determined by accounting for the frequency of surrounding locations) are presented in Figure 3. For the present/absent condition, the correlation between mean estimated frequency and effective frequency (based on the adjacent surround) increased from 0.76, when $k = 0$, to a maximum of 0.93, when $k = .3$. A smaller increase was obtained when effective frequency was based on the rectilinear surround: The correlation between mean estimated frequency and effective frequency increased from 0.76, when $k = 0$, to 0.89, when $k = .3$. For the pattern memory condition, computing the effective frequency of each location did not increase estimation accuracy when effective frequency was based on the adjacent surround, and it only slightly increased estimation accuracy when effective frequency was based on the rectilinear surround.

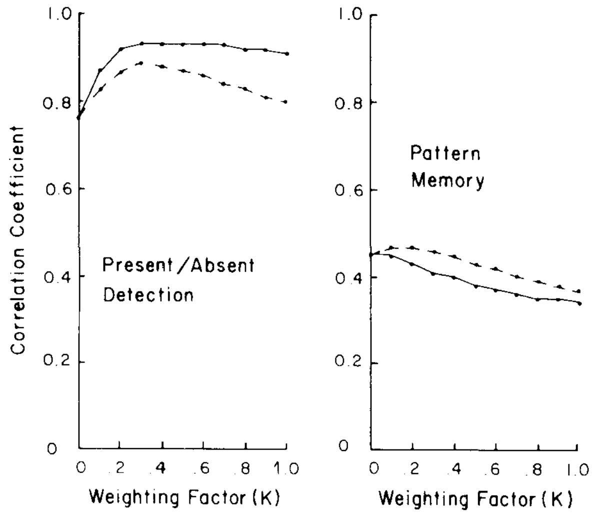

Figure 3. Experiment 2: For the present/absent and pattern memory conditions, correlations between mean estimated and effective frequency for the 16 locations within the frame. Each correlation was computed for a different value of k, which weights the contribution of occurrence frequencies at surrounding locations in relation to the location's actual occurrence frequency in determining the effective frequency of occurrence for the location. The solid lines represent correlations based on the adjacent surround, and the broken lines represent correlations based on the rectilinear surround.

Compositional constraints. Large correlations between mean estimated and actual frequency in the present/absent condition were obtained for the corner ($r = 0.97$) and side locations ($r = 0.87$), but not for the middle locations ($r = 0.10$). All three correlations were strongly positive in the pattern memory condition: 0.99, 0.66, and 0.55, for the corner, side, and middle locations, respectively. We again could conclude that the observed correlations between actual and estimated frequency were not due to the subjects' awareness of compositional constraints in the location of the dots.[6]

Discussion

The results of Experiment 2 were consistent with Jacoby and Brooks's (1984) assertion that the encoding of superficial information is task-dependent. Whether or not the subjects abstracted superficial, frame-relative element-position information from the patterns depended on their orienting task during the initial presentation of the patterns. The two indicators of the abstraction of element-level position information used to evaluate the results of Experiment 1 supported the abstraction hypothesis in the present/absent task, which required element-level processing, but did not support it in the pattern memory task, which did not require element-level processing. That is, only in the present/absent condition was a significant actual/estimate correlation obtained after the effects of pattern retrieval were partialled out, and only in the present/absent condition was there evidence of confusion in element-level position codes. The low correlations between actual and estimated frequency obtained when pattern recall was an explicit aspect of the orienting task indicated that it could not have accounted for estimation performance as an implicit estimation strategy in the element-level condition of Experiment 2 or in the conditions of Experiment 1. Otherwise, the increased recallability of patterns in the pattern memory condition would have been accompanied by an increase, rather than a decrease, in the accuracy with which the subjects estimated element-location frequency (especially since the percentage of correctly recalled patterns that were recalled in the correct quadrant of the 4×4 matrix was greater in the pattern memory condition than the present/absent condition, and the likelihood that a correctly recalled pattern would be recalled in the correct location was greatest for the patterns that were most likely to be recalled).

The very low levels of pattern recall obtained in the present/absent condition provided further evidence that the estimation of element-location frequency did not depend on the retrieval of pattern-level units. Pattern-level units cannot contribute to judgments of element-location frequency unless they are retrieved. Since it could be argued that pattern retrieval is underestimated by the pattern-recall task, we conducted a supplemental experiment with a more sensitive memory test. This experiment was similar to Experiment 2, except that now the subjects were required to estimate the frequency of pattern occurrence (some occurred four times, some eight) rather than to estimate element-location frequency and then to recall the patterns. We found that the subjects receiving the orienting task of the pattern memory condition could discriminate pattern frequency, but those receiving the orienting task of the present/absent condition could not. This supported our conclusion that pattern-level memory units could have little influence on the estimation of element-location frequency in the present/absent condition; they were minimally retrievable (an average of one per subject) for orienting tasks in which pattern learning was incidental. To be useful, *different* patterns must be retrieved while frequency is being estimated at different locations.[7]

EXPERIMENT 3

We have argued that a location's adjacent surround affected estimates of element frequency for the location because the subjects retrieved pattern elements with imprecise position codes: Estimates for a location would increase most when elements occurred with high frequency in surrounding locations, and least when elements occurred with low frequency in surrounding locations. Alternatively, it is possible that frequency estimates for a location were affected by frequencies of occurrence in surrounding locations as a function of the number of patterns recalled with elements in the surrounding locations.

Two orienting tasks were used to test for the possibility that the effects of the adjacent surround were due to the retrieval of pattern-level, rather than element-level, memory representations. One was an incidental, element-level counting task, the other an intentional learning task in which subjects were told to remember the number of times a pattern element appeared in each of 16 possible locations within the frame. If the intentional instructions reduced the effects of the adjacent surround while minimally affecting pattern recall, it would indicate that the effect of a location's adjacent surround on frequency estimates for the location depended on the imprecision of position coding for individual elements rather than the imprecision of pattern recall (i.e., recalling patterns with elements in the location being tested, but also recalling patterns with elements in surrounding locations).

Method

Subjects. Sixty-four undergraduate students at Florida Atlantic University participated in Experiment 3 for course credit in an undergraduate psychology class.

Procedure. The experimental procedure, with the exception of the orienting tasks introduced in Phase 1, was identical to that of Experiments 1 and 2. Although patterns used in Experiment 3 were also identical to those used in the preceding experiments, the dots presented inside the circles were arranged differently. On one occurrence of a pattern, a dot was presented in the center of two of the circles. On its other occurrence, a dot was presented in the center of the other three circles. The order of this assignment of dots (two vs. three per pattern) was randomized.

For one group of 32 subjects, the Phase 1 task for each pattern involved counting the number of circles with a dot inside it. The subjects in the *counting* condition were required to press one button if there were three circles with dots and the other button if there were two circles with dots. They were instructed to respond as quickly as possible while keeping their errors to a minimum and were given no indication that they would have to remember anything about the patterns. The 32 subjects in the *intentional* condition saw the same patterns (and dots inside the circles) as in the counting condition, but they did not have a discrimination task. They were shown an index card with a frame and grid lines defining 16 locations within the frame and were instructed to try to remember the number of times a circle appeared in each of the locations within the frame (recall that the grid lines were never actually presented during the first two phases of the experiment).

Results

Performance in orienting tasks. Mean RTs and error rates are presented in Table 1. RTs were faster for "2" responses than they were for "3" responses.

Accuracy of frequency estimation. Correlations between the actual and estimated frequencies again were relatively small, but they were positive for 81% of the subjects in the counting condition and 94% of the subjects in the intentional condition. The means of the actual/estimate correlations (see Table 2) were significantly greater than 0 [$r = 0.28$, $t(31) = 5.22$, $p < .001$; $r = 0.35$, $t(31) = 8.07$, $p < .001$; for the counting and intentional conditions, respectively]. The correlations obtained for the two conditions were not significantly different from each other [$t(62) = 1.14$, $p > .05$].

Effect of pattern retrieval on frequency estimation. The subjects correctly recalled 6.8% of the patterns in the intentional condition (70.2% of which were recalled in the correct quadrant) and 5.3% of the patterns in the counting condition (55.2% of which were recalled in the correct quadrant). Mean partial-correlation coefficients were only slightly reduced from the mean correlation coefficients observed without partialling out recall frequency. The correlations were positive for 75% of the subjects in the counting condition and 91% of the subjects in the intentional condition. The means of the actual/estimate correlations, with recall frequency partialled out, were significantly greater than 0 [$r = 0.33$, $t(31) = 7.33$, $p < .001$; $r = 0.25$, $t(31) = 4.83$, $p < .001$; for the intentional and counting conditions, respectively]. The partial correlations obtained for the two conditions were not significantly different from each other [$t(62) = 1.19$, $p > .05$]. The same analyses were repeated, but with a relaxed scoring criterion that counted a recalled pattern as correct if it was a rotated or mirror-image reversal of an original pattern. Percentage recall with the relaxed criterion increased to 21.3% and 18.6%, in the intentional and counting conditions, respectively. Although mean partial-correlation coefficients were slightly reduced, they remained reliably greater than 0 [$r = 0.27$, $t(31) = 6.44$, $p < .001$; $r = 0.23$, $t(31) = 5.11$, $p < .001$; for the intentional and counting conditions, respectively]. The difference between the conditions was not significant [$t(62) < 1.0$].

The significant actual/estimate correlations that were obtained after the contributions of pattern retrieval were partialled out were again consistent with the conclusion that the subjects' estimates of element-location frequency did not depend on pattern retrieval.

Encoding precision. For the counting condition (see Figure 4), the correlation between mean estimated frequency and effective frequency (based on the adjacent surround) increased from 0.73, when $k = 0$ (i.e., the surround frequencies were not included), to a maximum of 0.96, when $k = .6$. A smaller increase was obtained when effective frequency was based on the rectilinear surround: The correlation between mean estimated frequency and effective frequency increased from 0.73, when $k = 0$, to 0.81, when $k = .2$. Estimation accuracy appeared to be influenced by imprecise position coding in the counting condition.

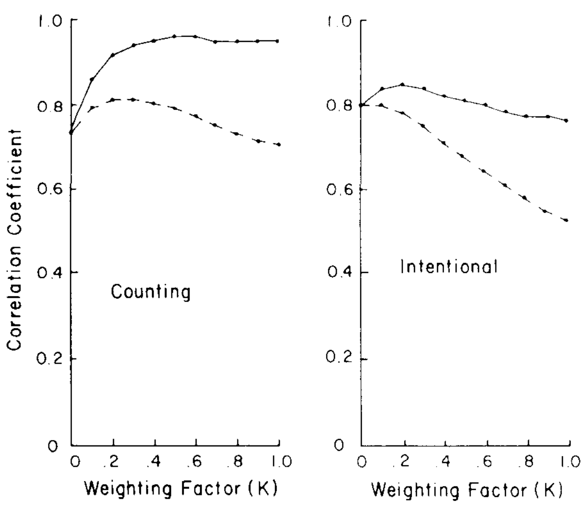

Figure 4. Experiment 3: For the counting and intentional conditions, correlations between mean estimated and effective frequency for the 16 locations within the frame. Each correlation was computed for a different value of *k*, which weights the contribution of occurrence frequencies at surrounding locations in relation to the location's actual occurrence frequency in determining the effective frequency of occurrence for the location. The solid lines represent correlations based on the adjacent surround, and the broken lines represent correlations based on the rectilinear surround.

In the intentional condition, our correlations on effective, rather than actual, frequency indicated a relatively small improvement in estimation accuracy when effective frequency was based on the adjacent surround (from $r = 0.80$, when $k = 0$, to $r = 0.85$, when $k = .2$) and a sharp decrease in estimation accuracy when effective frequency was based on the rectilinear surround. Imprecise position coding had a smaller effect on estimation accuracy in the intentional condition than it did in the counting condition.

Compositional constraints. The three correlations between mean estimated and actual frequency in the counting condition were all positive: 0.95, 0.75, and 0.31, for the corner, side, and middle locations, respectively. These correlations also were positive in the intentional condition: 0.82, 0.73, and 0.70, for the corner, side, and middle locations, respectively. We again could conclude that the observed correlations between actual and estimated frequency were not due to the subjects' awareness of compositional constraints in the location of the circles.

Discussion

In Experiment 3, as in Experiments 1 and 2, the subjects were able to estimate the frequency with which the component elements of patterns appeared at various locations in the frame, and they did not appear to derive their estimates from insight into the compositional constraints regarding the likely locations of elements within the frame. Recall accuracy was very similar in the intentional and counting conditions, and correlations between actual and estimated frequency remained significant after the effects of pattern retrieval were partialled out. Correlations with mean estimated frequency were increased by taking the frequency of surrounding locations into account in computing the effective frequency of each location, but the effect of the adjacent surround was considerably smaller in the intentional condition than it was in the counting condition. Thus, differential effects of the adjacent surround on estimation accuracy were obtained in the absence of recall differences. (Although the correctly recalled patterns were somewhat more likely to be recalled in the correct quadrant in the intentional condition, levels of recall were too low—an average of one pattern per subject— for this to be significant.) Intentional instructions appear to have facilitated the precision of position coding for individual pattern elements.

During the past several years, there have been a number of studies concerned with the effects of intentionality on the encoding of frequency-of-occurrence information (e.g., Greene, 1984, 1986; Naveh-Benjamin & Jonides, 1986; Sanders, Gonzalez, Murphy, Liddle, & Vitina, 1987). The reliable advantage of the intentional conditions in the above studies has been taken by the above investigators as evidence inconsistent with one of Hasher and Zacks's (1979) criteria for automatic encoding. The results of the present study are anomalous with regard to the automaticity issue. Our intentional condition facilitated the precision of element-position coding, but when the effects of each location's adjacent surround were taken into account, correlations were higher in the incidental, counting condition. The subjects in the counting condition might have encoded the position of all the pattern elements with a relatively low level of precision, whereas the subjects in the intentional condition might have encoded the positions of fewer pattern elements, but with greater precision.

GENERAL DISCUSSION

Despite their certainty that they lacked the knowledge to perform the estimation task, when coaxed to do so, the subjects were able to estimate the frequency with which the constituent elements of a series of patterns occurred in various locations within the frame. This result was consistent with other evidence indicative of a dissociation between what subjects know and what they think they know (see studies of amnesiac or amnesiac-like memory performance by Graf, Mandler, & Haden, 1982; Parkin, 1982; Schacter, 1987). As indicated earlier, it was possible for our subjects to have produced reasonably accurate estimates of element-location frequency without remembering anything about the patterns. They could have done so if they had realized that there were compositional constraints that influenced where the circles composing our patterns were most likely to be located; the circles were constrained to occur in the middle locations most often and the corner locations least often. However, awareness of these constraints was not sufficient for the subjects to have differentiated among frequencies of element occurrence at each of the four corner locations, at each of eight side locations, or at each of the four middle locations. In all three experiments, we obtained evidence from the subjects' mean estimates indicating that they could independently estimate frequency at the corner, side, and middle locations. We concluded, therefore, that the subjects' estimates were based, not on their awareness of compositional constraints in the location of the circles, but on what they remembered about the stimuli presented during Phase 1.

All three experiments were concerned with whether or not subjects could abstractively encode superficial characteristics of visual patterns. Testing for the encoding of the frame-relative location of individual pattern elements met our criteria for a proper test of the abstraction hypothesis. This information is superficial in that it is irrelevant to the semantic content of the patterns (which probably includes a description of the spatial relations among the elements), and it is unlikely that it would combine with the general experimental context to form an integrated episodic memory. Also, it is plausible for information concerning element-location frequency to be retained, because it could contribute to the efficient processing of spatial relations among the pattern elements.

The experimental results supported the abstraction hypothesis. Significant correlations between actual and estimated frequency were obtained after the effects of pattern retrieval were partialled out, indicating that superficial, element-level position information was abstractively encoded so that it could be retrieved independent of the retrieval of the patterns comprising the elements. Although conclusions drawn from the partial-correlation procedure were tempered by the low levels of recall obtained in most of the experimental conditions, all three experiments did in fact show that significant correlations between actual and estimated frequency could be obtained under conditions that severely limited the retrievability of pattern-level information. The pattern memory condition of Experiment 2 provided additional evidence that estimates of element-location frequency could not have been based on the retrieval of patterns with elements at the location being tested. Recall was significantly increased, but estimation accuracy was minimized in this condition. Estimation accuracy was best for incidental-learning orienting tasks in which pattern recall was very low (approximately one pattern per subject). Since pattern-level memory units cannot influence estimates of element-location frequency unless they are retrieved, we concluded from their low levels of retrieval that they were not responsible for the subjects' ability to estimate element-location frequency. The supplementary pattern-frequency experiment described in the discussion of Experiment 2 supported this conclusion with a more sensitive memory test.

Further support for the abstraction hypothesis came from a second analytic procedure in which correlations with estimated frequency were improved by taking the frequency of surrounding locations into account in computing an effective frequency for each location, providing evidence of confusion among imprecise element-level position codes. Imprecision in position coding has previously been characterized by probabilistic models that assume that the position code associated with an element specifies a spatial region in which the element probably was located (Kinchla, 1971; Kinchla & Allan, 1969; Wolford, 1975). Such models could readily account for the results obtained in this study if it is assumed that estimates for each location were produced by retrieving codes for individual elements from memory and incrementing estimates of occurrence frequency according to the probability that each of the retrieved elements was located at the location being tested. The results of Experiment 3 indicated that the precision of position coding was enhanced (without accompanying increases in pattern recall) when the subjects were told beforehand that they were to remember the location of individual elements.

Whether or not the subjects encoded information that could be used to estimate element-location frequency appeared to be task-dependent. It was obtained with orienting tasks that required the subjects to process location of individual elements (the vertical/horizontal and diagonal detection tasks of Experiment 1; the present/absent task of Experiment 2; the intentional and counting tasks of Experiment 3), but it was not obtaiined when the subjects were required to remember each pattern (the pattern memory condition of Experiment 3). Evidence of reduced estimation accuracy in the pattern memory condition was surprising from the point of view that remembering a pattern requires attention to all its elements. It was, however, consistent with the view that remembering a pattern involves coding spatial relations among the pattern elements rather than the relation of each pattern element to a surrounding reference frame.

Our evidence that relatively high levels of pattern recall were accompanied by relatively poor estimation of element location frequency does not mean that pattern- and element-level coding are incompatible. One possibility is that pattern-level codes involving spatial relations among the pattern's elements are formed from element-level units with frame-relative position codes, but the latter information is suppressed as a consequence of pattern-level coding. Were this the case, the element-level units would not be available to influence the subsequent processing of the pattern. Another possibility is that pattern-level units are formed by the direct coding of spatial relations among the pattern's elements, independent of the frame-relative position codes associated with element-level units; codes could develop simultaneously at the two levels, but coding efficiency would depend on the distribution of attentional resources between the levels (hence, the effect of the orienting task in Experiment 2). If codes developed simultaneously at both levels (although perhaps at different rates), element-level information would be available to facilitate pattern processing. As suggested in the introduction to this article, faster processing of spatial relations among the elements of a pattern could result from access to information regarding the likely location of individual pattern elements.

In conclusion, this article has focused on the abstractive encoding of superficial, frame-level position information for individual pattern elements. Although the mechanisms resulting in the abstraction of this information from a series of patterns may be similar to the mechanisms involved in category learning (e.g., see Posner & Keele, 1968), the function of the abstracted information is different. As implied by our referring to the frame-relative position of individual elements as "superficial" information, it is unlikely to be pertinent to the recognition or classification of the patterns (as might abstracted information associated with a prototypical representation of the category). Element-level position information would more likely characterize the constraints under which the patterns were produced. Some of the constraints were compositional; there were necessarily more pattern elements in the middle locations than in the corner locations of the 4×4 matrix of possible element locations. Other constraints reflected biases in the process (or individual) producing the patterns (e.g., a bias to have more elements in the lower left corner than in the upper left corner). Knowledge of such constraints would facilitate pattern processing in the same sense that knowledge of orthographic constraints facilitates the processing of printed words (e.g., McClelland, 1976).

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NOTES

1. The recall-frequency measure could also be thought of as a measure of the ease with which the subjects could recall a single pattern with an element at the location being tested. As a result, our method does not distinguish between two strategies in which pattern retrieval could be used as a basis for estimating element-location frequency. One strategy would base estimates on the ease of retrieving a single pattern, the other on the number of patterns that could be retrieved with elements at the location being tested.

2. Because continuous contours could not be displayed on the monitor, the elements constituting each pattern were approximations of circles.

3. Over all three experiments, 3 of the subjects were replaced because they repeated the same estimate for every location tested.

4. To be certain that the subjects' estimates of element-location frequency depended on the frequency of occurrence of circles rather than on the frequency of occurrence of the dots placed inside some of the circles, we computed partial-correlation coefficients in which the dot frequencies associated with each location in the frame were partialled out. Although there were some fluctuations in individual data, the overall pattern of data was unchanged. This result, which was obtained in all three experiments, indicated that the subjects' estimates of how often circles occurred at locations within the frame were based on circle frequency (as per our instructions) rather than on dot frequency.

5. The recall data were scored according to the first appearance of a pattern in each subject's recall. For example, if a pattern was recalled correctly, but in the wrong quadrant, it was scored as such, even if it was later recalled in the correct quadrant. Similarly, a pattern first recalled in the wrong orientation was scored as such, even if it was later recalled in the correct orientation.

The 17 patterns used in this study were classifiable according to the size of their equivalence set, which is determined by the number of patterns that can be generated by rotations and reflections of the pattern with respect to their horizontal and vertical axes (Garner & Clement, 1963). There were two patterns with equivalence sets of Size 1, eight with equivalence sets of Size 4, and seven with equivalence sets of Size 8. All three experiments reported in this study replicated Bell and Handel's (1976) evidence that the recall accuracy for a pattern was inversely related to the size of its equivalence set.

6. The results reported in Experiment 2 were replicated in a similar experiment in which the present/absent orienting task was replaced with an orienting task that required subjects to indicate whether a dot placed within one circle of each pattern was displaced to the left or right of center.

7. We also found, under the pattern memory instructions, that frequency estimation for the simpler, more symmetrical patterns tended to be more accurate when the patterns were always presented in the same quadrant of the 4×4 matrix than when they were presented in different quadrants. This provided further evidence that the pattern memory instructions tended to enhance, rather than detract from, attention to the location of the patterns.

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