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19. words in an array had been presented many times in a prior familiarization phase. However, these words had either always or never before appeared together. That is, familiar fields were either unitized or nonunitized. Novel words popped out only from unitized familiar fields. Experiments 5-8 manipulated duration of array exposure and found novel popout to remain relatively intact over the full range of durations examined (33-200 ms). Finally, Experiment 9 showed novel popout to be relatively unaffected by array-probe onset asynchrony. We attribute novel popout to the rapid, automatic orientation of attention to a local pertubation of an otherwise unitized perceptual field.

Novel Popout: Effects of Field Unitization and Exposure Duration

William A. Johnston, Kevin J. Hawley, & James M. Farnham

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Running Head: Novel Popout

Abstract

Observers received glimpses of 4-word arrays and were probed for the locations of particular words. Some words, called familiar, appeared in many arrays and others, called novel, appeared in only one. Studies conducted in the first year of the grant showed that familiar words are more localizable than novel words when they are not mixed together in the same array but that this difference is diminished, and often reversed, when a single novel word is arrayed with three familiar words. Thus, familiar arrays are more perceptible than novel arrays, but novel words popout from familiar fields. Nine new studies were conducted in the second year. Experiments 1-4 examined properties of the familiar fields from which novel words popout. Experiments 1 and 2 showed that a single prior presentation of either the individual words comprising the familiar field or the field as a whole does not suffice to produce robust novel popout. Experiment 3 demonstrated that whereas relatively few repetitions of an array are necessary to render it more perceptible than a novel array, relatively many repetitions are necessary to yield novel popout. In Experiment 4, all of the familiar words in an array had been presented many times in a prior familiarization phase. However, these words had either always or never before appeared together. That is, familiar fields were either unitized or nonunitized. Novel words popped out only from unitized familiar fields. Experiments 5-8 manipulated duration of array exposure and found novel popout to remain relatively intact over the full range of durations examined (33-200 ms). Finally, Experiment 9 showed novel popout to be relatively unaffected by array-probe onset asynchrony. We attribute novel popout to the rapid, automatic orientation of attention to a local pertubation of an otherwise unitized perceptual field.

Novel Popout: Effects of Field Unitization and Exposure Duration

The mind may be viewed as an adaptive, self-organizing system that comes to represent and anticipate the regularities in its environment. Experience with a relatively stable environment yields a network of mental representations of high ecological validity which, in turn, effects a dramatic change in the nature of perceptual processing. The observer shifts from a relatively inefficient, aschematic, bottom-up processor of the environment to a relatively proficient, schematic, top-down processor (e.g., Friedman, 1979; Rumelhart, Smolensky, McClelland, & Hinton 1986; Shiffrin & Schneider, 1977). This shift is highly beneficial; as long as the environment remains predictable, the observer can represent and navigate through it without exhausting mental resources. However, because expectations infiltrate perceptual experience, an occasional cost of schematic perception is that subtle changes in the environment go unnoticed. Fortunately, schematic perception appears to be offset by another process, one that keeps the organism at least somewhat vigilant to environmental change and, therefore, guards against an excessive entrenchment of obsolete schemata. We refer to this process as novel popout. Thus, schematic perception and novel popout may operate as opponent processes to achieve a balance between processing efficiency and sensitivity to change. Unfortunately, although a considerable volume of research and theory has addressed schematic perception, relatively little is known about novel popout. The present research is a continuation of the exploration of novel popout that was initiated in the first year of the current grant and reported in last year's technical report and elsewhere (e.g., Johnston & Hawley, 1990; Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990).

In their Experiment 4, Johnston et al. (1990) gave observers 200-ms glimpses of backward-masked 4-word arrays. Some of the words, called familiar, appeared many times across the series of arrays; others, called novel, appeared only once. Some arrays, called all-familiar, were comprised only of familiar words; others, called all-novel, were comprised only of novel words; and the rest, called one-novel, were comprised of one novel word and three familiar words. The locations of both novel and familiar words varied randomly across arrays and, therefore, could not be predicted in advance. Accuracy of word localization, assessed after each array, was higher for all-familiar arrays than for all-novel arrays. This finding was taken as evidence that familiar scenes are more perceptible than novel scenes. It illustrates the efficiency of schematic perception. Yet, novel words in one-novel arrays tended to be localized more accurately than the familiar words with which they appeared. This finding, called within-array novel popout, was accompanied by two between-arrays effects. Specifically, accuracy of localization was higher for novel words in one-novel arrays than for those in all-novel arrays, defining between-arrays novel popout, and was lower for familiar words in one-novel arrays than for those in all-familiar arrays, defining between-arrays familiar sink-in.

Johnston et al. (1990) offered a two-part account of their findings. First, a one-novel array yields a region of low perceptual fluency, the location of the novel word, in an otherwise fluently unfolding perceptual field. Second, attention moves covertly, automatically, and rapidly to the low-fluency region. The withdrawal of attention from the familiar field accounts for between-arrays familiar sink-in, and the focusing of attention on the location of the novel word accounts for between-arrays novel popout. Within-array novel popout is a natural by-product of sufficiently strong between-arrays effects.

The effects summarized above were observed under conditions in which a number of potentially crucial factors covaried. The present research attempted to isolate some of these factors and determine their contributions to novel popout. Experiments 1-4 investigated properties of the familiar fields from which novel words popout, and Experiments 5-9 examined the effects of duration of array exposure and array-probe onset asynchrony.

Experiments 1-4

The first two studies examined whether a novel word would popout from a field comprised of words that had been presented just once previously, either individually (Experiment 1) or as a group (Experiment 2). Experiment 3 investigated the relative rates of emergence of the various within- and between-array effects associated with novel popout. Experiment 4 examined the role of field integrity or "unitization" in producing novel popout.

Experiment 1

Several studies have shown that _old_ words, those seen previously in the context of an experiment, are more perceptible than _new_ words, those seen for the first time. This perceptual-memory effect is robust and durable, it is evident even for words that are presented for just 200 ms in a series of several hundred other words, and it is observed even in the absence of explicit memory for the old words (e.g., Hawley & Johnston, in press; Jacoby, 1983; Jacoby & Dallas, 1981). There is mounting evidence that perceptual memory for old items contributes to the "feeling of familiarity" on which observers sometimes rely in tests of recognition memory (e.g., Johnston, Dark, & Jacoby, 1985; Johnston, Hawley, & Elliott, in press; Kelley, Jacoby, & Hollingshead, 1989; Mandler, Nakamura, & Van Zandt, 1987). Johnston et al. (in press) proposed that the feeling of familiarity engendered by perceptual memory might be the basis novel popout.

> We suggest that perceptual memory, through perceptual fluency, yields a rapid if somewhat crude segmentation of the environment into familiar and unfamiliar components. Inasmuch as most organisms grow accustomed to their habitats...fluent perception accompanied by a general sense of familiarity may be the rule. Any novel intrusion...may be manifested as a region of low perceptual fluency in an otherwise fluently unfolding perceptual field. In short, perceptual memory may serve as a crude, but quick, novelty detector and thereby make it possible for the organism to be constantly vigilant to environmental change...(p. 13)

In an effort to test this proposal, we adopted a study-test procedure in which perceptual memory for "old" or "familiar" words was established in the study phase and the popout of "new" or "novel" words was examined in a test phase. We used study procedures that have yielded a strong perceptual-memory effect in our laboratory in some 12 successive experiments (Hawley & Johnston, in press; Johnston et al., 1985; Johnston et al., in press). Thus, they ensure a high level of perceptual memory for old words. Our test procedures were patterned after the methodology used by Johnston et al. (1990) to explore novel popout. In particular, the test phase consisted of 4-word arrays of three kinds: those composed of old words (i.e., all-old), those composed of new words (i.e., all-new), and those composed of one new and three old words (i.e., one-new). If perceptual memory for individual words is the basis of novel popout, then the various between- and within-array effects observed by Johnston et al. (1990, Experiment 4) should be replicated with new and old words serving the novel and familiar functions, respectively.

Method

Observers and design. Observers were 48 students from an introductory psychology course at the University of Utah. They participated in return for credit toward a higher grade. Array composition (all-new, all-old, and one-new) was manipulated within-observers in the test phase. Word type (new vs. old) was an additional factor nested within the one-new arrays.

Apparatus and stimuli. Observers served individually in a small room equipped with an IBM-XT compatible microcomputer, a keyboard, and a Samsung color monitor (Model MM-1464W) with a P22 phosphor. Observers wore headphones over which a low level of white noise was continuously broadcast in order to minimize external distractions. They sat facing the monitor from a viewing distance of about 60 cm. The monitor provided most of the light in the room.

The words were 656 singular nouns, 3-7 letters in length, and with Kucera and Francis (1967) frequencies of 18-33 per million. A single character, etched white against a dark background, subtended approximate visual angles of 0.38 degrees vertically and 0.24 degrees horizontally. In order to avoid item effects, four different random assignments of words to study and test trials were made, and each was administered to 12 observers.

Procedures. The study phase consisted of a series of 352 individually presented words. Words appeared inside a rectangular frame in the center of screen. Each was exposed for 1 s and was followed by the next word after a 500 ms interval. The observer's task was merely to read each word aloud. The first and last 8 words served as primacy and recency buffers, and the remaining 336 words served as old words in the test phase.

The test phase consisted of a sequence 150 trials. An array of four rectangular boxes, hereafter called locations, arranged in the form of a horizontally elongated cross, was centered on the monitor at all times. The entire array subtended approximate visual angles of 2.28 degrees vertically and 5.04 degrees horizontally. A stimulus could appear, center-adjusted, in any of the four locations. As Figure 1 illustrates, each trial consisted of a sequence of five arrays: warning, attention, masking, probe, and feedback. A row of three asterisks was presented for 200 ms in each location of a warning array. After a blank interval of 500 ms, an attention array appeared for 183 ms and was followed, 17 ms later, by a masking array. Thus, the virtual duration of an attention array was

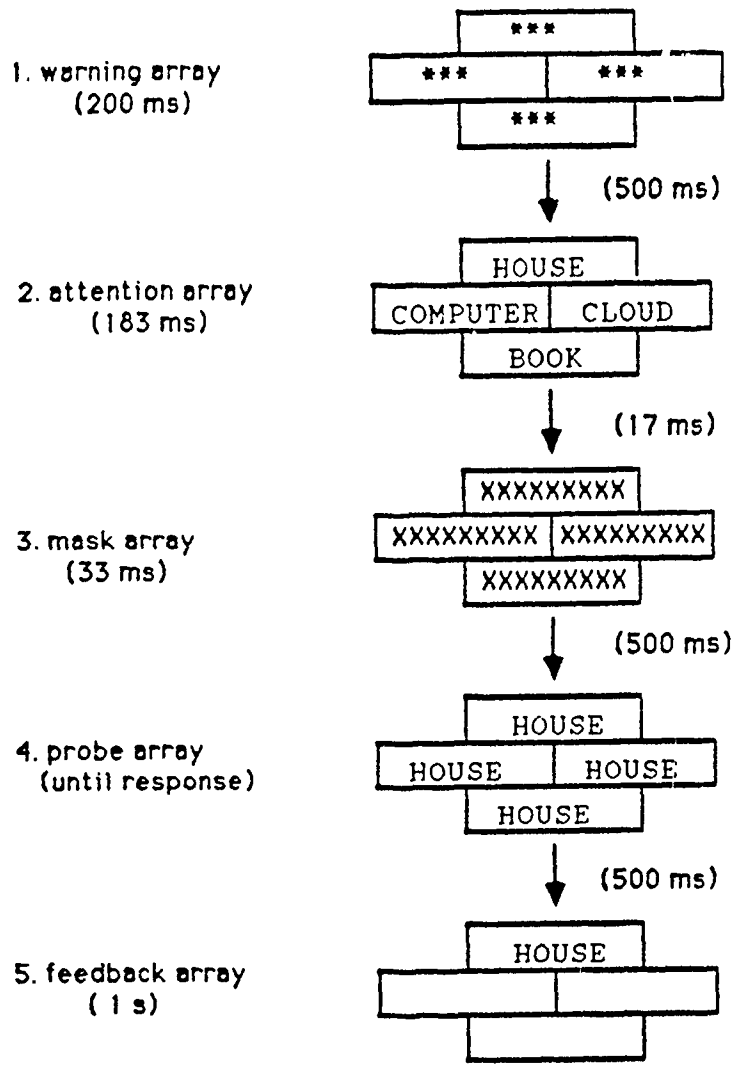

Figure 1. The sequence of arrays defining a single test trial.

200 ms. Each location contained a word in an attention array and a row of 9 *X*s in the ensuing masking array. A masking array was exposed for 33 ms and was followed, 500 ms later, by a probe array. One of the words from the attention array was presented in all four locations of the probe array. The observers' task was to indicate the location in which the probe word had appeared in the attention array by pressing the appropriate one of four keys on the numeric keypad of the keyboard. The spatial configuration of the keys corresponded to that of the four array locations. Observers were instructed to be as accurate as possible in responding. A response terminated the probe array and was followed, 500 ms later, by a feedback array in which the probe word reappeared for 1 s in the correct location. The intertrial interval was 500 ms. After every block of 30 test trials, the percentage correct localizations for that block was displayed for 5 s.

The test phase commenced with computer-presented instructions and 16 all-new practice trials. After a short break in which the experimenter provided any clarification needed of the task, 144 experimental trials were presented. All-new, all-old, and one-new trials were equally represented and randomly sequenced. In all, the 336 old words from the study phase and 240 new words were needed to compose the attention arrays of the experimental trials. New and old words were assigned to array locations randomly with the restrictions that each type of word appear equally often in each array location and be probed for equally often from each location. The experiment was prepared and executed using the PsyExper software developed by Hawley (in press).

Results and Discussion

Accuracy of word report in the study phase exceeded 98%. For the test phase, only the data for the experimental trials were analyzed. The main unit of analysis, computed for each observer under each experimental condition, was mean accuracy of localization (percentage correct). Throughout this report, effects are considered statistically reliable at $p < .05$.

The main findings are summarized in Table 1. Four a-priori t tests, each based on N = 48, tested for the enhanced perceptibility of all-old arrays compared to all-new arrays, between-arrays sink-in of old words (all-old arrays vs. old words from one-new arrays), between-arrays popout of new words (all-new arrays vs. new words from one-new arrays), and within-array popout of new words (new words from one-new arrays vs. old words from one-new arrays). None of the comparisons was reliable: all ts < 1.45. Thus, the familiarity of the field from which novel words popout is not attributable to perceptual memory for individual words.

Table 1

Percent Correct Localization for Novel and Familiar Words in the Three Array Compositions in the Test Phase of Experiment 1

	Word Type	
Array Composition	Novel	Familiar
All Novel	56.40	-----
One Novel	57.40	-----
All Familiar	-----	56.40

Experiment 2

Perhaps a single familiarization trial would suffice to yield a strong novel popout effect if the words were arrayed together rather than presented one-at-a-time and if the trial were administered just moments before the test for novel popout rather than many minutes earlier in a prior study phase. This possibility was assessed in Experiment 2. Observers viewed a mixed series of just all-novel and one-novel arrays. The familiar words in a one-novel array had appeared together in a prior, all-novel array. Repetition lag, the number of other arrays separating the two presentations of the familiar words, was either 0, 3, or 7.

Method

Observers and design. The observers were 21 students recruited in the same manner as described for Experiment 1. The design was a 2 (array composition) X 3 (repetition lag) factorial with repeated measures on both factors. Word type was an additional factor nested in the one-novel arrays.

Procedure. The basic procedure was the same as that described for the test phase of Experiment 1, the main exception being that the dark display background was replaced by a light blue one. There were 664 trials altogether. The first 24 were deemed practice trials, and the remaining 640 experimental trials. Duration of array exposure started out at 1 s and stablized at 200 ms by the twelfth practice trial. The experimental trials consisted of 120 pairs of critical trials and 400 all-novel filler trials. Each critical pair consisted of an all-novel trial followed at one of the three lags by a corresponding one-novel trial. A one-novel array contained a random three of the words from its all-novel mate, the "familiar" words, and a new word, the "novel" word. There were 40 of these critical pairs for each of the three lags, and the entire set of 120 critical pairs were randomly sequenced. The 400 filler trials were needed to separate the mated trials for lags 3 and 7.

Array composition. A total of 2,200 words were drawn from the Kucera and Francis (1967) norms. The first 1600 were drawn randomly and were used to compose the practice and filler trials. The remaining 600 were used to compose the critical trials. They were drawn randomly with the restriction that they be singular nouns, 4-7 letters in length, and with normative frequencies of 18-32 per million.

The assignment of words to trials and array locations was random with the restriction that both novel and familiar words appear equally often at each of the four locations in the one-novel arrays. For the all-novel trials, the probed locations were selected randomly with the restriction that each location be probed equally often. For the one-novel trials, the probed locations were selected randomly with the restrictions that the novel word be probed on half (i.e., 20) of the trials, that the familiar word probed never be the same as that probed previously on the corresponding all-novel trial, and that each array location be probed equally often (i.e., 5 times) for both novel and familiar words. Three different versions of the experiment were generated, within the constraints noted above, and each was administered to 7 observers.

Results and Discussion

Localization accuracy was computed only for the critical all-novel and one-novel trials. The data are summarized in Table 2. Two ANOVAs were carried out. Each was a 2 X 3 (lags 0, 3, and 7) with repeated measures on both factors. The first tested for, and failed to detect, a within-array novel popout effect in one-novel arrays. Neither Word Type (novel vs. familiar), $\underline{F}(1, 20) < 1.00$, Lag, $\underline{F}(2, 40) = 1.30$, nor the interaction, $\underline{F}(2, 40) < 1.00$, was reliable. The second tested for, and also failed to detect, a between-arrays novel popout effect. Although localization accuracy for novel words varied reliably as a function of lag, being relatively high for Lag 3, $\underline{F}(2, 40) = 3.74$, neither array composition (all-novel vs. one-novel) nor its interaction with lag approached statistical reliability (both $\underline{F}$s < 1.00).

Table 2

Mean Accuracy of Localization for Novel and Familiar Words in All-Novel and One-Novel Arrays at Each Repetition Lag in Experiment 2

		Word Type	
Array Composition	Lag	Novel	Familiar
All Novel	0	58.52	-----
	3	62.50	-----
	7	59.52	-----
One Novel	0	56.33	58.62
	3	63.20	60.24
	7	59.88	60.45

Somewhat surprisingly, novel popout was not observed, neither within the one-three arrays nor between the all-novel and one-three arrays, even when the familiarization trials immediately preceded the one-three arrays. Clearly, the level of field familiarity needed to generate novel popout requires more than a single familiarization trial. The development of novel popout as a function of number of familiarization trials was examined in Experiment 3.

Experiment 3

Novel words do not popout from a field comprised of words that had been presented just once before, either individually or as a group. Perhaps arrays of words must be presented several times before they become familiar enough to produce novel popout. In Experiment 3, localization performance for all-familiar and one-novel arrays was assessed after varying numbers of repetitions of the all-familiar arrays. The first presentations of these arrays provided an all-novel baseline. We anticipated that the fluency with which an array is perceived would increase with repetition frequency and that this would show up as a steady increase above the all-novel baseline in the accuracy of localization. We reasoned that if novel popout is a consequence of the fluent perception of familiar fields, then novel popout should likewise increase with the repetition frequency of familiar arrays.

Method

Observers and design. Observers were 36 students recruited from the same pool and in the same manner as was done in Experiments 1 and 2. The variables of interest, all of which were manipulated within observers, were array composition (all-novel, all-familiar, and one-novel), repetition frequency of all-familiar arrays (3, 6, 9, 12, and 15), and, for one-novel arrays, word type (novel and familiar). Only two of the array compositions, all-familiar and one-novel, were factorially crossed with repetition frequency; all-novel arrays were defined by the first presentations of what would become the all-familiar arrays.

Procedures. The basic procedures were the same as those described for the Experiment 2. Observers were administered, in succession, a 32-trial practice phase and a 384-trial experimental phase. Only all-novel arrays were presented in the practice phase. Duration of exposure of these arrays again was gradually reduced across the first 12 practice trials from 1000 ms down to the standard 200 ms. Observers again were admonished to emphasize accuracy over speed of responding.

Array composition. The words were 344 singular nouns, 4-7 letters in length, with Kucera and Francis (1967) frequencies of 18-33 per million. Of these words, 128 were used to construct the practice trials, and 216 were used to construct the experimental trials. All of the practice words and 120 of the experimental words served as novel words. The remaining 96 experimental words were grouped randomly into 24 sets of four words. These 24 sets comprised the all-familiar arrays; they were presented 16 times each in a random order. The first presentation of one of these arrays defined an all-novel array. Thus, there were 24 all-novel arrays in the experimental phase. After varying numbers of prior presentations of a familiar array, a random one of the four words was replaced by a novel word to form a one-novel trial. A one-novel trial was inserted after an average (range) of 3 (2-4), 6 (5-7), 9 (8-10), 12 (11-13), and 15 (14-16) prior presentations of each of the 24 all-familiar arrays. Thus, there were 24 one-novel trials at each repetition frequency. Of these, the novel word was probed 12 times, and a random one of the familiar words was probed the other 12 times. The all-familiar arrays were also represented at each of the average numbers of prior presentations.

The four words in an attention array were assigned randomly to the four array locations. Thus, whereas the four words in an all-familiar array always appeared together, they appeared in different spatial arrangements. The location probed on each trial also was selected randomly with the restriction that across trials each location be probed equally often for each combination of word type, array composition, and repetition frequency. There were three independent constructions of the experimental trials, entailing different familiar words and different probings of cells and word types. Each construction was administered to 12 observers.

Results and Discussion

The basic unit of the accuracy analyses was the percentage of the probes correctly localized by a given observer in a given experimental condition.

Preliminary analyses. Accuracy of localization averaged 50.87% for the last 20 trials of the practice phase, on which duration of exposure of the attention arrays had stablized at 200 ms, and 51.56% for the 24 first presentations of the repeated word sets ˈhe experimental phase. These means were statistically equivalent, t < ˈ 00. Since localization accuracy for all-novel arrays appears to have reached asymptote by the beginning of the experimental phase, the 51.56% mean accuracy of localization for the 24 first presentations of the repeated word sets was considered to have provided a reasonable estimate of an all-novel baseline.

The major findings for the experimental phase are summarized in Figure 2. After only 3 repetitions of the familiar arrays, none of the effects of interest was statistically reliable. However, localization accuracy for all-familiar arrays rose sharply from 3 to 6 repetitions, $\underline{t}(35) = 3.28$, to a point reliably above the all-novel baseline, $\underline{t}(35) = 5.17$. From 6 to 15 repetitions, the all-familiar baseline remained stable at about 60%, $\underline{F}(3, 105) = 1.01$. Given the lack of any effects after just 3 repetitions and the apparent stability of both baselines after 6 repetitions, we confine our attention below to the popout and sink-in effects that emerged between 6 and 15 repetitions of the familiar arrays.

Within-array effects. A 2 X 4 (Word Type X Repetition Frequency) repeated-measures analysis of variance of localization accuracy for one-novel arrays confirmed what is evident in Figure 2. Only the interaction was statistically reliable, $\underline{F}(3, 105) = 3.15$ ($\underline{F} < 1.00$ for both main effects). The basis of this interaction was diagnosed using Newman-Keuls post-hoc comparisons. After an average of only 6 repetitions of the familiar words, localization accuracy was higher for the familiar words in one-novel arrays than for the novel words. However, from 6 to 15 repetitions, localization accuracy steadily decreased for the familiar words but increased for the novel words. As a result, within-array novel

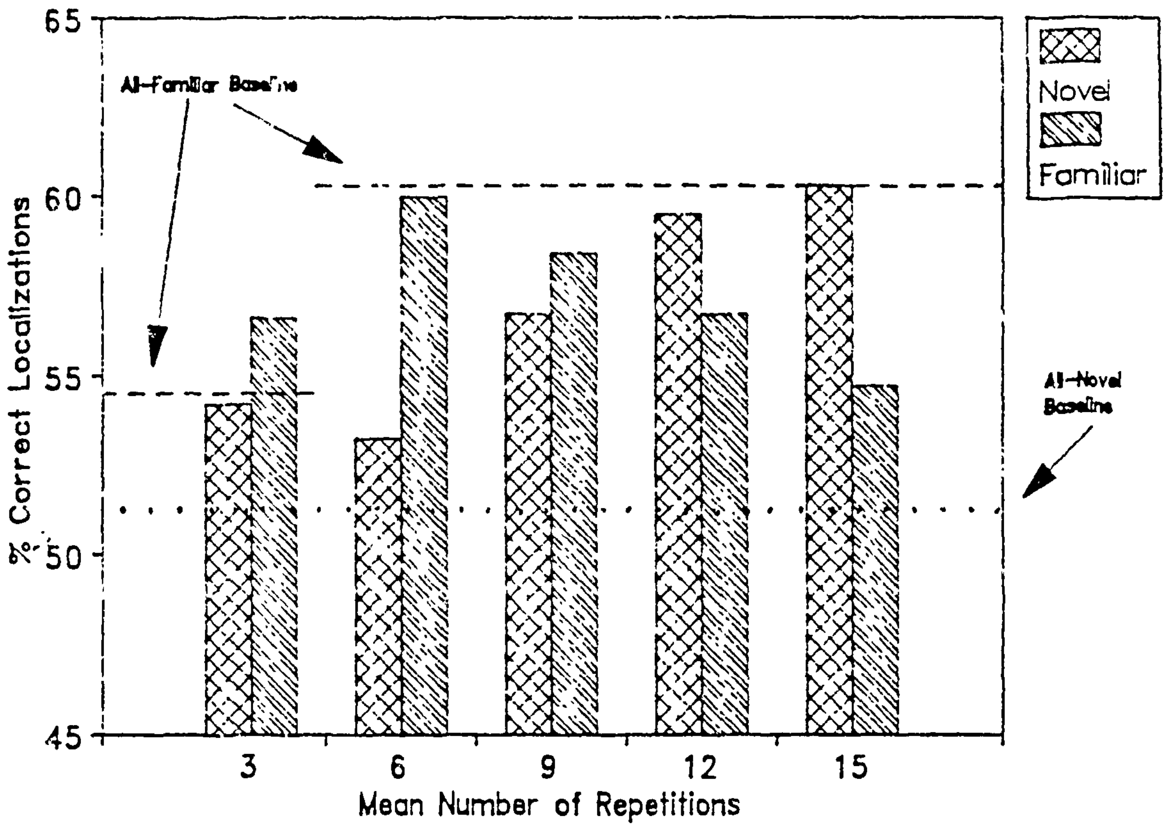

Figure 2. Mean accuracy of localization in Experiment 3 for novel and familiar words in one-novel arrays and for the all-novel and all-familiar baselines as a function of number of repetitions of all-familiar arrays.

popout did not begin to emerge until 12 repetitions of the familiar words and did not attain reliability until 15 repetitions.

Between-arrays effects. These within-array effects were mirrored in the between-arrays effects. Localization accuracy for the familiar words in one-novel arrays was statistically indistinguishable from the all-familiar baseline after 6 repetitions, $t(35) < 1.00$, but fell progressively below this baseline thereafter. However, between-arrays familiar sink-in did not attain statistical significance until 15 all-familiar repetitions, $t(35) = 2.32$. Likewise, localization accuracy for the novel words in one-novel arrays was statistically indistinguishable from the all-novel baseline after 6 repetitions of the familiar arrays, $t < 1.00$, but rose progressively above this baseline thereafter, attaining statistical reliablity after 9 repetitions, $t(35) = 2.09$, and approaching the all-familiar baseline after 12 repetitions, $t < 1.00$.

The findings are important in at least three respects. First, they show that the various between- and within-arrays effects reported by Johnston et al. (1990, Experiment 4) are replicable. The apparent fluent perception of all-familiar arrays relative to all-novel arrays, between-arrays familiar sink-in, between-arrays novel popout, and within-arrays novel popout were all replicated despite several methodological differences between the two studies. For example, whereas each observer experienced only one set of four familiar words in the Johnston et al. research, each experienced 24 different sets in the present study. Thus, novel popout does not require that observers be thoroughly familiarized with just one familiar field.

Second, the present findings demonstrate that the familiar sink-in and novel popout effects develop gradually as a function of the frequency with which the familiar arrays have been repeated. Third, and perhaps most importantly, the various effects did not bear precisely the same relationship to repetition frequency. Although an average of only 6 repetitions was needed to elevate the all-familiar baseline above the all-novel baseline, an average of 9 repetitions was needed to yield reliable between-arrays novel popout, and an average of 15 repetitions was needed to yield reliable levels of both between-arrays familiar sink-in and within-array novel popout. Thus, the various effects appear to be at least partially dissociable.

Putting aside until later the different rates of development of between-arrays familiar sink-in and between-arrays novel popout, let us consider the relatively early elevation of the all-familiar baseline above the all-novel baseline. If the magnitude of this elevation can be taken as an index of the perceptual fluency of the all-familiar arrays, then its relatively early onset casts doubt on the account of novel popout tendered by Johnston et al. (1990). The familiar fields appear to have unfolded perceptually just as fluently after 6 repetitions as after 15. Yet between-arrays novel popout did not even begin to develop until the familiar arrays had been repeated an average of 9 times.

Experiment 4

Neither perceptual memory for individual items nor perceptual fluency of whole arrays provides a full account of novel popout. What might it be about the continued repetitions of familiar arrays, beyond the point at which localization accuracy asymptotes, that is responsible for between-arrays novel popout? One possibility is that novel popout depends on the integrity, or unitization, of the familiar field. Owing to the continued strengthening of interword associations, the unitization the familiar field as a whole may continue to increase long after the perceptual fluency of individual words has leveled off. Thus, novel words may popout, not so much from a fluently unfolding perceptual field as from a unitized one. The role of field unitization in the production of novel popout was examined in Experiment 4.

A transfer of training procedure, summarized below in Figure 3, was used in which the arrays presented in the transfer phase bore variable relationships to those presented in the training phase. In particular, familiar words from different training sets could be intermixed in the same transfer array. The transfer phase consisted of two kinds of all-familiar array (same-set vs. different-sets), two kinds of one-novel array (also same-set vs. different-sets), and a hybrid array. The familiar words in a same-set array had always appeared together in the training phase; those in a different-sets array had never appeared together in the training phase. Thus, field unitization was considered to be high in same-set arrays and low in different-sets arrays. If novel popout requires a high degree of field unitization, then it should be observed only in one-novel same-set arrays.

The hybrid arrays allowed a test of the possibility that the novel popout effect observed in previous studies is a variant of a more general phenomenon in which odd objects popout from unitized perceptual fields. Thus novel words may sometimes popout, not because they are novel per se, but rather because they are not associated with the particular, otherwise unitized field in which they are imbedded. Hybrid arrays were comprised of four familiar words. However, three of the words were from the same training set and one, the "odd" one, was from a different training set. If novel popout is due to odd objects popping out from unitized perceptual fields, then the odd familiar words should popout from hybrid arrays.

Methodology

Observers and design. A new sample of 36 observers was recruited in the same way as described for the earlier studies. Array composition was manipulated within observers at six levels in the transfer phase: all-novel, all-familiar same-set, all-familiar different-sets, one-novel same-set, one-novel different-sets, and hybrid. Item type (novel vs. familiar and odd vs. field) was an additional factor nested within the one-novel and hybrid arrays. The design is summarized in Figure 3.

Procedure. An experimental session consisted of three successive phases: A 16-trial practice phase consisting of all-novel arrays, a 120-trial training phase, and a 288-trial transfer phase. The training phase comprised a random ordering of 24 all-novel trials and 96 all-familiar trials. Four different sets of four words were presented 24 times each across the all-familiar trials. These 24 presentations of a given all-familiar array should have produced at least as much field unitization as that produced by the maximum average of 15 presentations in Experiment 3. Randomly intermixed in the transfer phase were 32 all-novel

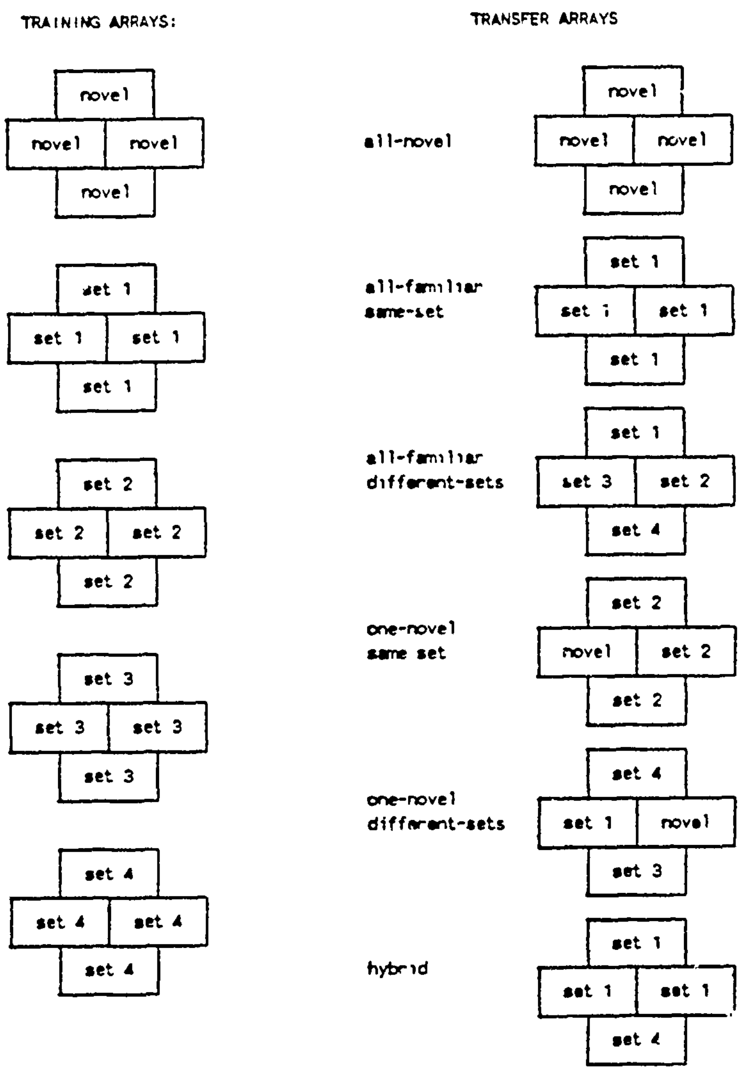

Figure 3. Design logic of Experiment 4.

trials, 32 all-familiar same-set trials, 32 all-familiar different-sets trials, 64 one-novel same-set trials, 64 one-novel different-sets trials, and 64 hybrid trials. More trials were administered for the array compositions involving different types of item (viz., novel vs. familiar and odd vs. field) so that each type of item could be probed 32 times from each array composition. Thus, the same number of observations (viz.,32) was made of each combination of array composition and item type.

Array composition. The words were 368 singular nouns with the same characteristics as those used in Experiment 3. Of these, 64 were needed for the 16 practice trials, 96 for the all-novel training trials, 16 (4 sets of 4 words) for the all-familiar training trials and for the various transfer trials involving familiar words, and another 192 for the all-novel and one-novel transfer trials. Words were partitioned randomly into these sets and were assigned randomly to trials and array locations with the restriction that each location be probed equally often in each phase of the experiment and each combination of word type and array composition. To prevent effects of the accidental unitization of particular recombinations of familiar words in different-sets arrays, an additional restriction was that the same recombination never be repeated. Two independent constructions of the experimental session were generated, and each one was administered to half of the observers.

Results and Discussion

Training. In a comparison of the data from the last two-thirds of training with those from the first half of transfer, accuracy of localization was reliably higher for all-familiar same-set arrays (60.57%)

than for all-novel arrays (55.07%), $F(1, 35) = 9.16$, but neither phase (training vs. transfer) nor the interaction between phase and array composition approached statistical reliability, both Fs < 1.00. We conclude that the usual perceptual advantage of all-familiar arrays over all-novel arrays was established relatively early in the training phase and carried over into the transfer phase.

Transfer. The transfer data are depicted in Figure 4. The within- and between-array comparisons were examined separately for the same-set, different-sets, and hybrid arrays.

The same-set arrays were basically the same as those examined in the prior studies. Of the four effects reported by Johnston et al. (1990) and replicated in Experiment 3, two were again observed in the same-set arrays of the present study. Specifically, accuracy of localization was lower for all-novel arrays than it was either for all-familiar same-set arrays, $t(35) = 2.78$, or for novel words in one-novel same-set arrays, $t(35) = 3.48$. The former effect illustrates the typical perceptual superiority of familiar arrays, and the latter effect defines between-arrays novel popout. The other two effects observed previously, within-array novel popout and between-arrays familiar sink-in, were not replicated, both ts < 1.00.

In contrast to the familiar fields of same-set arrays, those of different-sets arrays were assumed to be nonunitized. Localization accuracy was lower for all-novel arrays than for all-familiar different-sets arrays, $t(35) = 3.07$, indicating a relatively high level of perceptual fluency even for nonunitized familiar arrays. Indeed,

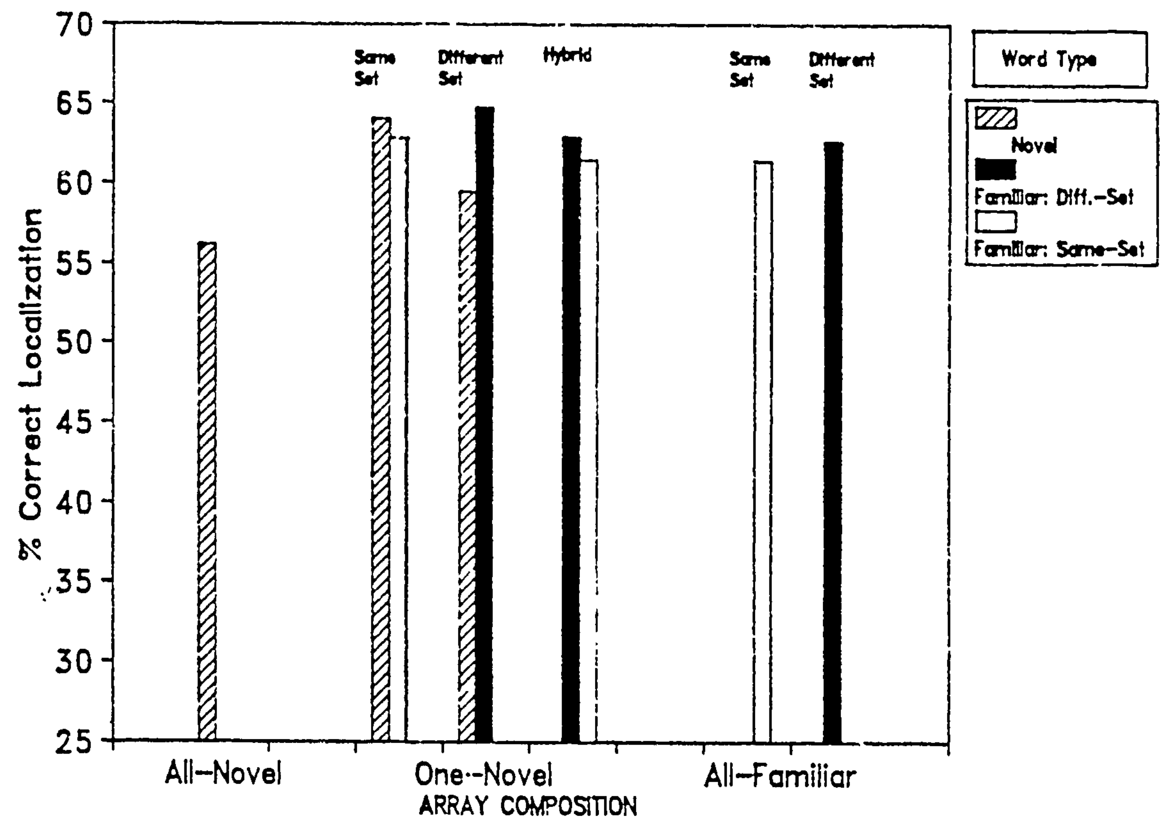

Figure 4. Mean accuracy of localization in the transfer phase of Experiment 4 for each type of word in each array composition.

localization accuracy was as high for all-familiar different-sets arrays as it was for all-familiar same-set arrays, $t < 1.00$. However, neither between-arrays novel popout nor between-arrays familiar sink-in approached statistical reliability for the different-sets arrays, both ts < 1.00. Moreover, the novel words in one-novel different-sets arrays were less, rather than more, localizable than the familiar words in these arrays, $t(35) = 2.80$.

The hybrid arrays featured an odd familiar word in a new, but unitized, familiar field. None of the effects approached statistical reliability in the hybrid arrays, all ts < 1.00. That is, localization accuracy for the odd familiar words in the hybrid arrays was comparable (a) to that for the same-set familiar words in those arrays, indicating the absence of within-array popout of the odd words, (b) to that for the all-familiar different-sets baseline, indicating the absence of between-arrays popout of the odd words, and (c) to that for the all-familiar same-set baseline, indicating the absence of between-arrays sink-in of the same-set familiar words.

We draw three main conclusions from the results of Experiment 4. First, novel popout can occur in the absence of familiar sink-in. This dissociability of the two effects in same-set arrays was also observed in Experiment 3 in which novel popout emerged after fewer repetitions of the familiar fields, and we address it further in the general discussion. Second, novel popout requires unitized familiar fields, not just fluently perceived ones. Accuracy of localization was as high for fields comprised of familiar words from different training sets as for those comprised of familiar words from the same training sets; yet novel popout was limited to the latter, presumably unitized, fields. Third, novel popout is not attributable to possible effects of object oddity or belongingness. Popout was not observed for odd familiar words presented in unitized fields.

Summary of Experiments 1-4

The present findings shed light on the figure-ground characteristics associated with novel popout. The figure must be novel and the ground must be unitized. Popout does not occur if the figure is just odd or the ground is just fluently perceived. These findings call for revisions in the perceptual-fluency account of novel popout tendered by Johnston et al. (1990). Attention does not appear to be drawn automatically to any local trouble spot in a field of fluently unfolding items. Otherwise, new words in Experiments 1 and 2 would have popped out from fields comprised of perceptually remembered old words, novel popout in Experiment 3 would have coincided with the perceptual advantage of all-familiar arrays over all-novel arrays that emerged after only 6 repetitions of the all-familiar arrays, and novel words in Experiment 4 would have popped out from the perceptually fluent, but nonunitized, fields comprised of familiar words from different training sets.

We offer a revised conceptualization of novel popout in the general discussion section. In the meantime, we turn our attention to Experiments 5-9. Whatever the processes may be that produce novel popout, they must take time to operate. Thus, if duration of array exposure is made sufficiently brief, then these processes may not have time to run their course and novel popout should be reduced. This line of thought led to the experiments reported below.

Experiments 5-9

Duration of array exposure was examined in Experiments 5-8, and the onset asynchrony between the attention arrays and the location probes was examined in Experiment 9.

Experiment 5

The three basic array compositions (all-novel, one-novel, and all-familiar) were crossed with three durations of array exposure (67, 100, and 200 ms.) and all nine of the resulting conditions were randomly intermixed across a long sequence of trials. Our primary expectation was that novel popout would again be evident at the 200 ms. duration of array exposure but would decline, perhaps disappear completely, at the shorter durations.

Method

Observers and design. A new group of 48 students was recruited to serve as the observers. The basic design was a 3 (Exposure Duration) X 3 (Array Composition) factorial with repeated measures on both factors. Word type (novel vs. familiar) was a nested factor in one-novel arrays.

Procedures. The entire session consisted of 424 trials. The first 40 served as practice and familiarization trials, and the remaining 384 as experimental trials. The same four words, the familiar words, were presented on all of the practice trials. Duration of exposure of the attention arrays started out at 1 s but was reduced to 200 ms by the sixteenth practice trial. From the seventeenth to the twenty-fourth practice trial, exposure durations of 67, 100, and 200 ms were represented equally often and in random order.

For the experimental trials, the ordering of conditions, assignments of words to trials and array locations, and selection of probe locations were determined randomly within the following restrictions. For each duration of exposure of one-novel arrays, both novel and familiar words appeared equally often in each location. In each of the nine basic conditions, each array location was probed equally often. For each exposure duration, the novel and familiar words in one-novel arrays were probed in proportion to their relative frequencies of presentation, that is, on 25% and 75% of the trials, respectively. In order to ensure an adequate number of probings of novel words, there were many more one-novel trials (80 for each exposure duration) as there were either all-novel or all-familiar trials (24 for each exposure duration). Thus, the number of observations for a given observer in a given condition ranged from 20 (novel words for each duration of exposure of one-novel arrays) to 60 (familiar words for each duration of exposure of familiar arrays).

A total of 532 words, similar to those used in the prior studies, was drawn from the Kucera and Francis (1967) corpus. Of these, a randomly chosen 528 served as novel words and the remaining 4 as familiar words. Six different constructions of the experiment were prepared, and each was administered to eight observers.

Results and Discussion

The main findings are summarized in Figure 5. Different ANOVAs tested for within-array novel popout, between-arrays familiar sink-in, between-arrays novel popout, and the typical superiority of the all-familiar over the all-novel baseline, all as a function of exposure duration. Although exposure duration consistently attained reliability as a main effect, all Fs > 47.00, it entered into no significant interactions, all Fs < 1.28. Neither between-arrays familiar sink-in nor within-array novel popout was observed. Indeed, novel words were reliably less accurately localized than familiar words in one-novel arrays, $F(1, 47) = 8.64$. However, both between-arrays novel popout, $F(1, 47) = 12.41$, and the expected baseline difference, $F(1, 47) = 16.51$, were replicated.

We consider in the general discussion the failure to observe either within-array novel popout or between-arrays familiar sink-in. In the meantime, we focus on the fact that a robust between-arrays novel-popout effect was observed and remained intact over all three durations of array exposure. This was confirmed by a separate analysis of the data for the 67 ms duration in which between-fields novel popout was indicated, $F(1, 47) = 4.76$. The observation of novel popout at such a brief duration of array exposure begs the question of how much further the duration might be reduced before novel popout disappears. Experiments 6-8 attempted to answer this question.

Experiments 6-8

Experiments 6-8 conformed to the same basic design and are best described together. Each experiment was a 2 (Exposure Duration) X 3 (Array Composition) factorial with repeated measures on both factors. In order to provide a benchmark for comparison, one of the exposure durations in each study was 200 ms. The other was 67 ms in Experiment 6, 50 ms in

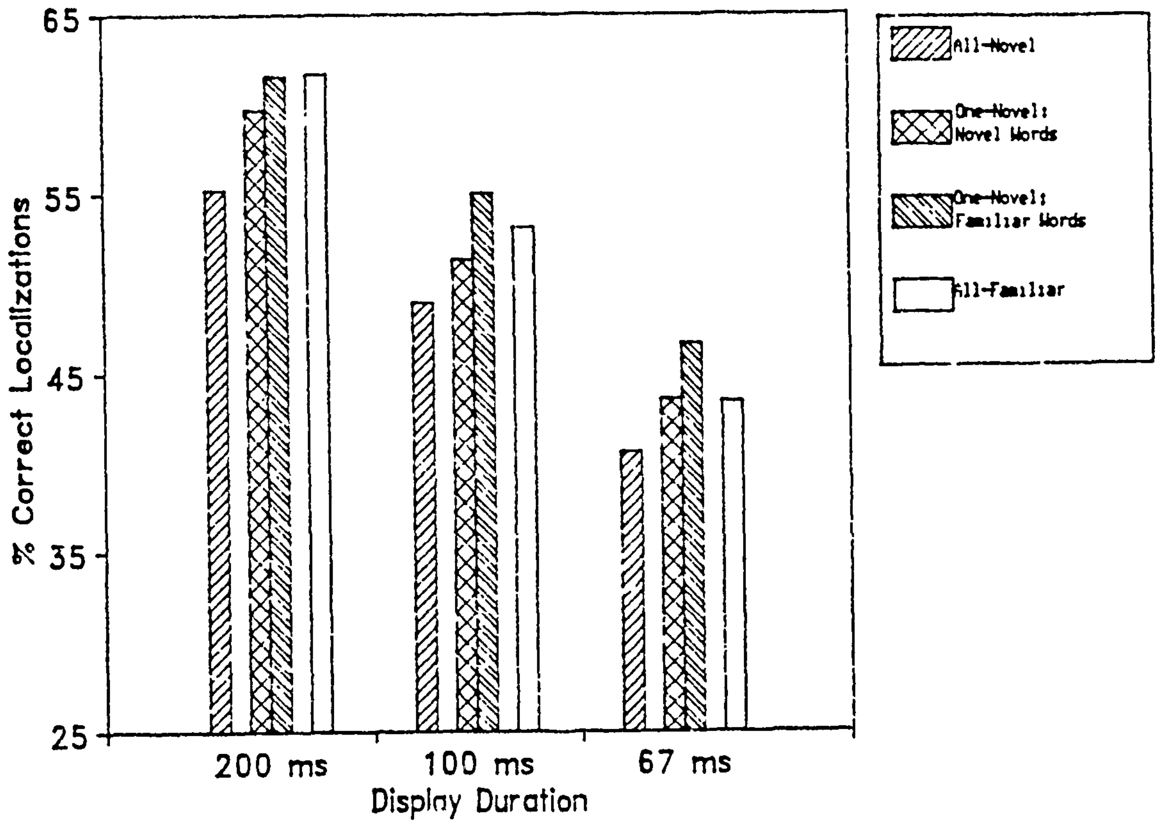

Figure 5. Mean accuracy of localization in Experiment 5 for novel and familiar words in the three array compositions at each duration of array exposure.

Experiment 7, and 33 ms in Experiment 8. It may be noted that 33 ms is the briefest duration permitted by our computer system.

Method

The sequence of trials for each study was derived from that used in Experiment 5. In particular, all of the 100 ms trials were converted to 200 ms, and the remaining trials were used for the shorter duration. We opted to have two-thirds of the trials at the longer duration because we were concerned that observers, particularly in Experiment 8, might give up if there were too many short-duration trials. In all other respects, the experiments were identical to Experiment 5.

Results and Discussion

As in Experiment 5, neither within-array novel popout nor between-arrays familiar sink-in was observed at any of the four durations represented across the experiments. Again, however, both the baseline difference (all-familiar > all-novel) and between-arrays novel popout was observed at all durations. The latter effect is shown in Figure 6. These data were submitted to an Experiment (6-8) X Array Composition (all-novel vs. one-novel) X Duration (long vs. short) ANOVA with repeated measures on the last two factors. Accuracy of localization decreased across the three experiments, $F(2, 117) = 9.15$, and from the longer to the shorter durations, $F(1, 117) = 509.71$. However, these effects were qualified by a reliable Experiment X Duration interaction, $F(2, 117) = 15.92$. The effect of experiment was restricted entirely to the shorter durations and merely reflects a decline in localization accuracy as the shorter duration dropped from 67 ms in Experiment 6 to 33 ms in Experiment 8. Likewise,

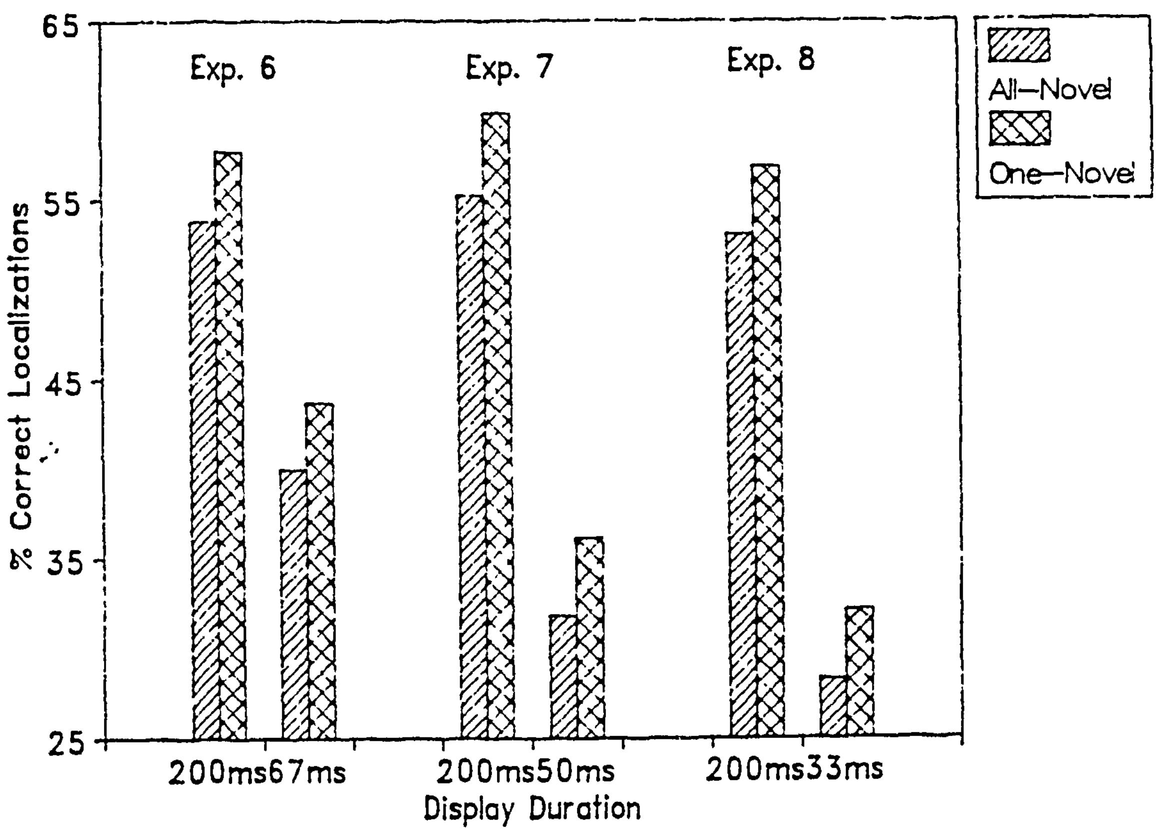

Figure 6. Between-arrays novel popout for the shorter and longer durations of Experiments 6-8.

the effect of duration increased across the three experiments owing to the increase in the difference between the longer and shorter durations.

Of most importance, array composition again attained statistical significance as a main effect, $F(1, 117) = 27.06$, and entered into no significant interactions, all Fs < 1.00. Thus, a robust between-arrays novel popout effect was again observed, and it remained intact even at the shortest duration of exposure examined, namely, 33 ms. These results, together with those of Experiment 5, reveal the remarkable robustness of between-arrays novel popout. Whatever may be the processes that produce novel popout, they appear to be completed within the first 33 ms of array exposure. If these processes extended beyond the first 33 ms, then the magnitude of novel popout should have been larger at longer durations of array exposure.

Experiment 9

As duration of array exposure was reduced from 200 ms to 33 ms in Experiments 5-8, the onset asynchrony between an array and the location probe, henceforth called SOA, was likewise reduced from 733 ms to 583 ms. It is possible that these covariations in exposure duration and SOA had offsetting effects on novel popout. Thus, a reduction in duration of array exposure might have eliminated novel popout if SOA had not also been reduced. This possibility was examined in our final study.

Method

Experiment 6 was precisely replicated except that the SOAs for the two durations were just the reverse of what they were in Experiment 6, namely, 733 ms for 50 ms duration and 583 ms for the 200 ms duration. Thus, comparisons across experiments could be made to assess the effects of duration holding SOA constant and of SOA holding duration constant.

Results and Discussion

Again, neither between-arrays familiar sink-in nor within-array novel popout was observed in any of the cross-experiment comparisons. However, both the baseline effect (all-familiar > all-novel) and between-arrays novel popout continued to be observed, all ts > 1.85. What is important is that neither of these effects interacted with either duration, when SOA was held constant, or SOA, when duration was held constant, all ts < 1.00. Thus, we may conclude that failure for novel popout to dissipate at the shorter durations of array exposure in Experiments 5-8 is not attributable to any offsetting effects of SOA.

General Conclusions and Discussion

How might the entire spectrum of present and prior findings be explained? We suggest that the perceptual processing of individual words in an array can proceed in two ways, one that is primarily bottom-up and one that is primarily top-down. Bottom-up processing specifies both the identity of the word and its spatial location. Prior repetitions of a word in the array establish and strengthen links between the representations of the word and the array. The spreading of bottom-up activation across these links promotes the identification and localization of the word. Thus, the fluency of bottom-up processing up increases with the frequency with which a word has been perceived previously in the array, especially in the same location. Top-down processing commences when the bottom-up activation of the representation of one word begins to spread to the representations of other words in the array. The fluency of top-down processing increases with the strength of the associative connections between the words, that is, with field unitization. Top-down processing can help to specify the identities of the interrelated familiar words but it does not specify their spatial locations. Thus, both nonunitized and unitized familiar arrays benefit from fluent bottom-up processing, but only unitized arrays benefit from top-down processing.

We suggest that novel popout is a consequence of the top-down processing that characterizes unitized familiar fields. In particular, we suggest that a mismatch between the top-down processing generated by a unitized perceptual field and the bottom-up processing generated by a novel intrusion into that field leads automatically to an immediate focusing of attention on the intrusion (for a similar idea, see Naatanen, 1990). This focusing of attention may take the form of an adjustment in the mutual inhibitory connections between locations in the visual field such that the location of the novel word receives less inhibition from neighboring locations but sends more inhibition to them. Attention would not be oriented to a novel word in a nonunitized field owing to the lack of any top-down processing by which mismatches could be detected and localized. Although this mismatch process accounts for the restriction of novel popout to unitized familiar fields, two phenomena remain to be explained: the occurrence of novel popout in the absence of familiar sink-in the failure to observe the popout of odd words from unitized fields.

Why is novel popout only sometimes accompanied by familiar sink-in?

According to the disinhibition account of spatially focused attention outlined above, the direction of attention to a a novel word is accompanied by its withdrawal from the contiguous familiar words. Whether or not familiar sink-in results from this withdrawal of attention may depend on the level of bottom-up processing already attained by the familiar words by the time that attention is withdrawn from them. The more highly unitized a familiar field, the more rapidly a mismatching novel intrusion could be detected and cause attention to be focused on its location. Thus, a highly unitized perceptual field may cause attention to be concentrated on a novel word even before the relatively fluent bottom-up processing of the familiar words nears completion. This early withdrawal of attention from the familiar words would retard their bottom-up processing and yield between-fields familiar sink-in. Thus, whereas relatively low levels of field unitization could produce novel popout, relatively high levels might be needed to produce familiar sink-in. This interpretation of familiar sink-in is consistent with the observation in Experiment 3 that the development of familiar sink-in lagged behind novel popout.

Why was familiar sink-in not observed in the one-novel same-set arrays of Experiment 4? We suggest that the unitization of the same-set arrays achieved during the training phase was to some extent dissipated during the transfer phase. In the transfer phase, words from the same training set were as often intermixed with words from different training sets as with those from the same training set. Moreover, since there were twice as many one-novel arrays in the transfer phase as there were all-familiar arrays, a same-set array was more often than not perturbed by a novel intrusion. Indeed, familiar words appeared in new or perturbed arrays three times more often than they appeared in intact, nonperturbed arrays. Thus, the level of unitization of the same-set arrays may well have decreased across transfer trials in Experiment 4. A similar explanation is applicable to the absence of familiar sink-in in Experiments 5-9. By contrast, in Experiment 3, all-familiar arrays were never intermixed, and they were relatively infrequently perturbed by novel intrusions. Indeed, the familiar words in Experiment 3 appeared three times more often in intact arrays than in perturbed ones. Thus, the level of unitization of these arrays was likely to increase across trials in Experiment 3.

Finally, we address the failure for odd familiar words to popout from hybrid arrays in Experiment 4. An odd familiar word in a unitized field also should generate a perceptual mismatch with top-down processing and, therefore, receive extra attention. However, as noted above with respect to familiar sink-in, the effects of attentional shifts may depend on how rapidly they are generated which, in turn, may depend on the level of field unitization. Because the level of field unitization may have been relatively low in the transfer phase of Experiment 3, the fluent bottom-up processing of odd familiar words may have approached completion by the time the extra attention, or disinhibition, arrived at their locations. Thus, popout of odd words might be observed only in when they appear in highly unitized fields.

Experiments 5-9 indicate that whatever may be the processes underlying novel popout, they commence, and possibly terminate, within 33 ms. Thus, if there is a detection of a mismatch and a consequent adjustment of the inhibitory connections among the array locations, all of this occurs within 33 ms. Moreover, if familiar words are sometimes perceived so fluently that they run their bottom-up course before the inhibitory connections are adjusted, then we must conclude that this fluent perception also is completed well within 33 ms.

Research planned for the final year of the grant will pursue some the suggestions made above as well as examine other factors that may modulate novel popout, including the spatial stability of all-familiar array configurations, array load, preexperimental associations among the words comprising the field, the use of objects rather than words as stimuli, transitory priming of perceptual fields, and others.

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