Towards a Model of the Mind's Eye's Movement*

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ABSTRACT

Two experiments are described that investigate alternative models to account for shifts of attention to parts of the visual field without changes in fixation. Such shifts are diagnosed by a cost-benefit analysis of reaction times and errors in a forced-choice visual search task. The results cannot be accounted for by models that postulate sequential examination of array items. Rather, search through an array is better viewed as a process in which the items are examined simultaneously. A shift of attention, according to this view, is characterized as a modification in the processing resources that are allocated to the examination of each array item.

In 1894, Helmholtz described a series of experiments intended to examine shifts of attention in the visual field:

> I refer now to the experiments with a momentary illumination of a previously completely darkened field on which was spread a page with large printed letters. Prior to an electrical discharge [of light] the observer saw nothing but a slightly illuminated pinhole in the paper. He fixed his gaze rigidly upon it, and it served for an appropriate orientation of directions in the dark field. The electrical discharge illuminated the printed page for an indivisible instant during which its image became visible and remained for a very short while as a positive after-image. Thus, the duration of the perceptibility of the picture was limited to the duration of the after-image. Eye movements of a measurable magnitude could not be executed within the duration of the spark, and movements during the brief duration of the after-image could no longer change its position on the retina. Regardless of this, I found it possible to decide in advance which part of the dark field surrounding the continuously fixated pin-hole of light I wanted to perceive, and then actually recognized upon the electrical illumination single groups of letters in the region of the field ... the letters of by far the largest part of the field were not perceived, not even in the vicinity of the fixation point. With a subsequent electric discharge I could direct my perception to another section of the field, while always fixating on the pinhole, and then read a group of letters there (from Warren and Warren, 1968).

Helmholtz's observations led him to conclude that one can shift one's attention to various locations in the visual field without shifting one's eyes. Indeed, these observations have been confirmed by recent experiments. In these experiments, subjects are induced to shift their attention, but not their fixation, to specific loci in the visual field. Although several techniques have been used to induce attention shifts, perhaps the most successful method is modelled after the procedure developed by Sperling (1960) and Averbach and Coriell (1961) to study iconic storage. The procedure involves presenting a spatial cue either shortly before presenting a target display or simultaneously with it. Subjects are instructed to attend to the cued location and their performance in detecting or identifying a stimulus at this location is assessed. This performance can then be compared with that when no spatial cue is provided. Several experiments that have employed this design have demonstrated a facilitation in target identification with a spatial cue, in some cases even when the cue was presented simultaneously with the target array (e.g., Eriksen & Hoffman, 1974; Holmgren, 1974; Van der Heijden & Eerland, 1973).

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Posner, Nissen, and Ogden (1978) have extended this technique to include measurement of both processing facilitation and inhibition. They provided subjects with a visual cue before the onset of the target display that varied in its probability of correctly cueing the target's location. In one experiment they measured simple reaction time to a square of light that could appear to the left or right of a fixation mark. The cue, an arrow located at fixation and pointing to the left or right, correctly signalled the target's location on 80 per cent of the trials. On these trials, reaction time was faster than on trials in which only a neutral cue appeared (also placed in the centre of the display, but not locationally informative). Furthermore, reaction time for the 20 per cent of trials in which the arrow pointed in the wrong direction was longer than reaction time in the neutral condition. Thus, Posner et al. (1978) demonstrated both a benefit in processing for a valid cue, and a cost in processing for an invalid cue. These effects, moreover, could not be attributed to eye movements since eye position was monitored in this experiment, and trials on which subjects refixated the display were excluded from analysis.

Evidently, as Helmholtz supposed, subjects can improve their detection or discrimination performance for stimuli that appear at a non-foveal location without actually shifting their gaze to this location. How is this accomplished?

Assume that subjects generally allocate their processing resources in a nearly optimal fashion when viewing a visual display (as suggested by Shaw & Shaw, 1977). The fact that performance can be improved by attending to a cued location suggests that the total resources available for processing a multi-item visual array are not sufficient to permit optimal processing of each array item. That is, if there were sufficient resources to go around, then providing information in advance about the location of an impending target should produce no benefit in processing that target. We can view information about target position, then, as information about where processing resources should be selectively allocated. In order to characterize the mechanism mediating performance changes in these experiments, we must analyse the way in which resources are allocated to the processing of various items in the display.

Helmholtz's observations suggest that a mechanism based on an all-or-none principle of resource allocation best characterizes the attention-shifting process. According to this view, resources can be assigned to only one display location at a time, with the consequence that an array item at only that position will be processed. If an array requires further examination (as it might if the experiment employed the Posner et al., 1978, procedure), then resources would be reallocated to alternative display positions one at a time. Thus, according to this model, array items would be processed in a sequential manner as attention was devoted to alternative display positions in turn.

This account of attention shifts is certainly qualitatively consistent with the currently available data. For example, it accounts nicely for the faster detection of a target at a correctly cued location than for a target at a non-cued location. And it also explains the slower detection of an incorrectly cued target as compared with detection when no locationally informative cue is provided. Furthermore, this model is also consistent with the experiment reported by Shaw (Note 1) in which subjects' response time to discriminate a target was an inverse function of the probability of target occurrence at various locations. According to a sequential allocation model, in this context subjects would allocate resources to potential target locations in the order of their likelihood of containing a target.

These qualitative accounts of the data notwithstanding, there is reason to suspect that the all-or-none model is not the best view of attention allocation. First, Eriksen and his associates have found that increases in the number of items contained within a visual display slow down target processing, even if the target region is cued well in advance of the display presentation (Eriksen & Hoffman, 1972, 1973; Colegate, Hoffman, & Eriksen, 1973; Eriksen & Rohrbaugh, 1970). Furthermore, although much of the interference in processing is apparently caused by items that immediately flank the target, non-adjacent display items seem to have a disruptive effect as well. These results and others prompted Eriksen and Hoffman (1973) to propose a mechanism in which all non-attended array items receive some fairly gross processing, while items within the region of concentrated attention are processed to the point of recognition. Such a model assumes, contrary to the all-or-none position, that resource allocation can be graded.

Another uncomfortable aspect of the all-or-none allocation model is that it contradicts much of the available research concerning visual search processes. There are by now many experiments that suggest that resources can be applied to several display locations simultaneously, resulting in parallel processing of a visual array (e.g., Donderi & Zelnicker, 1969; Egeth, Jonides, & Wall, 1972). Insofar as the all-or-none model predicts sequential examination of array items, it contradicts the results of these experiments.

Thus, the available evidence is in conflict concerning an all-or-none resource allocation model of attention shifts. On the one hand, the model is qualitatively consistent with the results of experiments concerned with shifts of attention. On the other hand, it contradicts recent evidence concerning processing in visual search tasks. Experiment 1 provides further evidence concerning this model by testing certain quantitative predictions that it makes about the magnitudes of costs and benefits in an attention shifting task similar to that of Posner et al. (1978). In order to test these quantitative predictions, we replicated the basic cost-benefit effect using a forced-choice discrimination task.

EXPERIMENT 1

METHOD

General Design

The experiment was designed to measure the magnitudes of cost and benefit effects within the context of a task requiring search through multiple-item arrays. As such, it combined the experimental paradigm of Posner et al. (1978) with the kinds of stimulus arrays used by Eriksen and his associates.

The experimental task required subjects to examine briefly presented eight-letter arrays and to judge which of the two uppercase letters L or R was present in each array. All arrays contained one and only one of these target letters located randomly at one of eight possible display positions.

There were three types of trials interleaved in random order. On 'valid cue' trials (35 per cent of the total) subjects were presented with an arrowhead shortly before presentation of the letter display that pointed to the target's location. On 'invalid cue' trials (15 per cent of the total) subjects were also presented with an arrowhead before the letter display, but it pointed to a location containing a non-target item. Finally on 'neutral cue' trials (50 per cent of the total), a diamond-shaped cue that was locationally uninformative appeared before the letter display.

Subjects

Twelve undergraduates were paid for participation in a one-hour session. All subjects had normal or corrected-to-normal vision.

Apparatus and Stimuli

Stimuli were presented on a graphic display device (equipped with a high-speed P4 phosphor) which was driven by a digital computer. Subjects viewed the display at a distance of approximately 60 cm while they sat in a darkened room.

The stimulus arrays consisted of eight letters evenly spaced around the circumference of an imaginery circle of 7.5° diameter. Each letter was 1.2° in height, and .8° in width. Each stimulus array was constructed by first locating an uppercase L or an uppercase R at one of the eight array positions, and then randomly selecting uppercase letters from the remainder of the alphabet without replacement to fill the seven remaining display positions. On the neutral cue trials, each stimulus array was preceded by an outline diamond (.8° in height, .6° in width) located in the centre of the region where the upcoming letters would appear. On the valid and invalid cue trials, the stimulus arrays were preceded by an outline arrowhead (.8° in length) that pointed to one of the 8 array locations. The arrowhead was positioned in the display such that its tip was .7° from the closest portion of the letter to which it pointed. The arrowhead pointed from the centre to a display position.

Each experimental session consisted of three blocks of 160 trials each. In each block of trials, there were 80 neutral cue trials, 56 valid cue trials, and 24 invalid cue trials arranged in random order. For the valid trials, the arrowhead correctly pointed to the target seven times for each of the eight display positions. For the invalid cue trials, a target appeared at each of the eight positions three times, while the cue pointed to one of the non-target positions. The location signalled by the cue on these invalid trials was chosen such that, over all invalid trials, each location was signalled approximately an equal number of times. The two targets (L or R) were used equally often per block of trials.

Each of the three blocks of trials was preceded by a block of 40 practice trials constructed according to the same principles outlined above. Data from these practice trials, and from the first block of 160 test trials, were not included in the analyses presented below.

Procedure

Subjects were first instructed about the details of the experiment, including the identities of the targets, the nature of the conditions, the validity of the locational cue, and other aspects of the general procedure. They were cautioned to respond as accurately as possible, but within that limitation, as quickly as possible. Finally, they were told the procedure for each trial of the experiment: At the beginning of a block, they were told to initiate the first trial by depressing a response key on the right side of a panel on which they rested their hands. This resulted in a fixation dot appearing in the centre of the display screen; the dot remained in view for 1.5 sec. After it disappeared, .5 sec elapsed, and then a cue appeared. The cue was either the diamond on neutral trials, or the arrowhead on valid and invalid cue trials. In either case, the cue remained in view for 25 msec, after which the screen went blank for 50 msec. Following this interval, the letter display was presented for 25 msec. Subjects were then required to press a left or a right response key (with appropriate index fingers) according to whether an L or an R respectively had been presented as part of the display. This response then triggered the 1.5 sec presentation of the fixation dot that preceded the next trial. Each block of 160 trials was interrupted in the middle to provide subjects an opportunity to rest if they desired. In addition, rest periods were provided between blocks of trials.

Two precautions were exercised to prevent subjects from refixating the display during the valid and invalid cue trials. First, subjects were verbally exhorted to fixate the centre of the display on all trials, even if an arrow cue appeared. They were told to use the arrow cue to guide the locus of their *attention*, but they were also told not to shift *fixation*. The second precaution that was taken to prevent changes in fixation was to use a total duration of cue plus blank interval plus display of only 100 msec. Previous research using a paradigm of the sort used in the present experiment has demonstrated that the average latency of a saccade once a cue has been presented is 220 msec (Colegate, Hoffman, & Eriksen, 1973). Given this, it is reasonable to assume that the use of a 100 msec total stimulus duration in the present experiment should have rendered non-functional even the very fastest of saccades under these circumstances.

RESULTS

Overall RT and Error Effects

The mean reaction times (with standard deviations calculated across subjects presented in parentheses) for the valid cue trials, the invalid cue trials, and the neutral cue trials were 546 msec (77.0), 873 msec (206.5), and 703 msec (151.6) respectively. The corresponding mean error rates and their standard deviations for these three types of trials were 2.1% (2.3%), 12.9% (8.2%), and 6.0% (3.8%).

Analyses of these overall data were conducted by performing t-tests to assess separately whether the performance benefits (neutral cue minus valid cue) and costs (invalid cue minus neutral cue) were reliable for each dependent measure. The obtained t-values were all highly significant: $t = 4.59$, $df = 11$, $p < .005$ (reaction time benefit); $t = 8.12$, $df = 11$, $p < .001$ (reaction time cost); $t = 4.02$, $df = 11$, $p < .005$ (error benefit); $t = 3.36$, $df = 11$, $p < .005$ (error cost). It is apparent from these analyses that a valid cue enhances both the speed and accuracy of target discrimination, while an invalid cue depresses performance as measured by these two variables. Having thus demonstrated the effectiveness of the cue under these conditions, we sought to test various predictions of all-or-none allocation models of attention shifts.

All-or-None Resource Allocation

The key assumption of this class of models is that resources are allocated to the processing of array times one at a time. From this it follows directly that if a task calls for the examination of several array locations before a target decision can be made, several shifts of attention will be required. Below we enumerate and test several specific versions of this model all of which follow this allocation principle. The models differ from one another in the assumptions that they make concerning details of the item examination process.

(1) EXHAUSTIVE SEARCH OVER ALL ITEMS: According to this version, subjects terminate their examination of an array only after examining all items, regardless of whether the target has been located and identified early or late in the search process. Such an exhaustive scanning hypothesis cannot be an appropriate explanation of the present data. It predicts that reaction times for valid and invalid cue conditions should be identical with one another since an exhaustive analysis of the array would require the same number of item examinations in both of these conditions. Our results obviously do not support this prediction.

(2) EXHAUSTIVE SEARCH OVER NON-CUED ITEMS: This is a modification of the previous model that permits subjects to make use of the locational cue when it is valid to terminate their examination of an array. The claim is that, on valid cue trials, only the cued location is examined. On invalid cue trials, the cued location plus *all* non-cued locations are scanned before the array examination terminates. Likewise, according to this version, all array items must be examined when subjects are provided with no locational cue in the neutral condition.[1] The benefit of a valid cue should equal the time required to examine seven items (in the neutral condition all eight items must be examined; however, only the cued item must be examined when the cue is valid). Also, there should be no cost incurred with an invalid cue because eight items must be examined in this case compared to eight for a neutral cue. The overall results presented above disconfirm this model on the grounds that there are both substantial benefits and substantial costs for valid and invalid cues respectively in the present experiment.

(3) TERMINATING SEARCH OVER ARRAY ITEMS: The major alternative to an exhaustive search mechanism is one whose examination of array items ceases when a target is located and identified. There are two major ways of testing this model.

(a) According to a terminating model, the presentation of a locational cue should provide a starting place for search on some large proportion of the trials on which such a cue is presented (perhaps all). When the locational cue is valid and the cued location is examined first, only this cued location will be processed before a response is emitted. When the cue is invalid and the cued location is examined first, then, on the average, five locations will be examined before search is terminated (the cued location plus four of the remaining seven). When no locational cue is provided, then 4.5 locations will be examined on the average before the search can end. This version thus predicts the qualitative data pattern that we have reported above: a benefit in proces-

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[1] Although it is possible to assume that search is self-terminating in the neutral condition, this would certainly be an ad hoc assumption of this model. After all, if subjects could terminate their search after locating the target in the neutral condition, why couldn't they likewise terminate their search after finding a target on the invalid cue trials?

sing when the cue is valid and a cost when it is not.

The relative magnitudes of benefits and costs in Experiment 1 are not consistent with a terminating hypothesis, however. The hypothesis predicts that benefits should be greater than costs (note above the relative number of examinations involved when the cue is valid, invalid, or neutral). Furthermore, such a prediction is made regardless of the percentage of trials on which the cued location is actually examined first, assuming that this percentage is greater than chance. The actual magnitudes of the benefits and costs in reaction time for the present experiment were 157 msec and 170 msec respectively. These values are not reliably different ($t = 0.46$, $df = 11$, $p > .20$), and, in fact, their difference is in the opposite direction from the prediction. The same is true of the 3.9% benefit and the 6.9% cost in the error rates ($t = 1.24$, $df = 11$, $p > .05$).

(b) An alternative method for testing the terminating search model is based on analysis of serial position effects. Since search is assumed to terminate upon identification of the target, there should be a monotonic increase in RT with the number of array locations that must be examined before the search can terminate.

Perhaps the most reasonable hypothesis about the preponderant order in which array locations are examined is this: First the item at the cued location is identified – it has, after all, the highest probability of being a target. If this fails to be the target, items are examined roughly in the order of their distance from the cue. This hypothesis is plausible because it permits subjects to examine first items that are nearby the location to which they are currently attending. As Eriksen and Hoffman (1972) have shown, the resolution of attention concentration is such that when subjects are concentrating on one location, information from surrounding locations intrudes on their current processing. The present hypothesis makes use of this intrusion by having these very items that have already been partially processed receive the benefit of complete processing next in line. According to this hypothesis, then, response time ought to be a monotonic function of the distance between the cued location and the location of the target on invalid trials.

There are two ways of measuring distance to test this prediction. The first method assumes that subjects first turn attention alternately to the two locations that flank the cued position. If no target is found, they then examine the next nearest two locations in turn, and so on. According to this assumption, reaction time (and, perhaps, errors) should increase as the absolute, nondirectional distance between cue and target increases. In the present experiment, this prediction can be evaluated by examining reaction times and errors for an absolute distance between target and cue of 1, 2, 3, or 4 positions on either side of the cue. The reaction time values for the positions were 868 msec, 860 msec, 884 msec, and 884 msec ($F < 1$); the corresponding error rates were 14.6%, 13.4%, 12.2%, and 12.2% ($F < 1$). There is quite clearly no reliable effect here to support the prediction of distance effects.

The alternative way in which subjects could shift their attention from location to location is to move either clockwise or counterclockwise. The performance implications of such a directional scan depend upon whether there is any consistency in its direction from subject to subject, or within any one subject, from trial to trial. If there were uniform consistency, then a graph of reaction time and, perhaps, errors should be monotonically related to the clockwise position differences between cue and target. Table 1 shows that no such trend appears. However, if there were little consistency in scanning direction, one would *expect* this graph to show an independence of mean reaction time with position, which it does ($F < 1$).

One can further test whether a direction-

TABLE 1
Reaction times and errors for invalid trials for each clockwise distance between cue and target

	Clockwise distance between cue and target (expressed as number of array positions)						
	1	2	3	4	5	6	7
Reaction time	878	860	853	884	914	865	858
Per cent errors	18.2	13.4	10.9	13.4	10.9	10.9	9.7

al but inconsistent scan underlies these data by examining reaction time variability. If the direction of scan is haphazardly alternated, then reaction time to a target that is four locations from the cue should have the least variability of all, since a subject will always have to shift attention four times to reach this location regardless of the direction of the shift. Reaction time to targets located three or five clockwise positions from the cue should have the next lowest standard deviation, followed by reaction time to targets that are two or six clockwise positions away. Finally, targets at a distance of one or seven clockwise positions should have the greatest reaction time variability.

This prediction was tested by examining both between-subject and within-subject standard deviations by position. The between-subject values are 258 msec for a distance of 4,263 msec for the mean standard deviation of clockwise distances 3 and 5, 213 msec for the mean of 2 and 6, and 255 msec for the mean of 1 and 7. These data do not fit the predicted pattern.

Within-subject standard deviations likewise do not support the prediction. For each subject, the reaction time standard deviation for each clockwise distance of cue to target was calculated and average values were obtained for clockwise positions 1 and 7, 2 and 6, 3 and 5, and 4. These values, averaged over subjects, are: 270 msec, 255 msec, 264 msec, and 259 msec respectively. Analysis of variance of these standard deviations reveals no reliable effect ($F < 1$).

To sum up these analyses, then, we have tested various predictions of exhaustive and terminating versions of a sequential scanning hypothesis, and have found no support for either version. These analyses rule out the possibility that subjects first fix their attention on the cued location, then refixate it successively on other array locations to identify a target. We must find a theoretical alternative to these models.

One class of models consistent with the data reported above rests on the assumption of a simultaneous analysis of several (perhaps all) array items when a target is not identified at the cued location. Again, one can imagine several versions of this type of model, all of which share the central assumption of limited resources that are applied to multiple locations to permit simultaneous processing. One version of this model would posit that attention is always first concentrated on the cued location. If analysis of this position fails to identify a target, then processing resources are distributed over all other locations and analysis is carried out on these other loci simultaneously. This hypothesis would predict the overall pattern of costs and benefits in the following way: Benefits accrue because concentrating all or most resources on the cued location results in faster processing of this location than in the neutral condition in which the target receives only one-eighth of all processing resources (because there are eight equally likely target locations). Costs arise because of the two-stage nature of the analysis as compared with the single-stage simultaneous analysis in the neutral condition.

An alternative to this kind of hypothesis, but one that still retains the assumption of simultaneous array analysis, is based on the notion of a weighted resource allocation. On this hypothesis, resources are allocated to processing the array locations as a monotonic function of their likelihood of containing a target. The cued position has a high priority for resource allocation since it is much more likely to contain a target than other locations. By assumption, greater resource allocation will result in faster processing (Norman & Bobrow, 1975). This sort of hypothesis is quite similar in principle to that proposed by Shaw and Shaw (1977) although we here make no specific claims about the quantitative assignment of resources to locations.

The present experiment cannot distinguish between these alternative versions of a simultaneous processing hypothesis. Accordingly, a second experiment was designed to do so.

EXPERIMENT II

Consider the predictions of each of the two simultaneous processing hypotheses for an experiment in which the validity of the locational cue is systematically manipulated. According to the two-stage version, the performance benefits that arise in such an experiment ought to be independent of validity. This follows because, by hypothesis, no matter what the validity (within reason), the cued location will always be examined first, thus producing a constant time difference between valid cue trials and neutral trials. A straightforward reading of the weighted resource allocation hypothesis makes quite a different prediction for this case, however. As cue validity is lowered, ever fewer resources will be allocated to processing the cued location, thus producing a diminished benefit for valid cue trials compared to the neutral condition. This will be compensated, however, by a decreased cost for invalid cue trials since the non-cued locations will have more resources applied to their analysis. The present experiment pits these two predictions against each other.

METHOD

General Design

As in Experiment 1, there were three basic types of trials: valid cue, invalid cue, and neutral cue. In each session, the neutral cue trials constituted 50 per cent of the total. The percentage of valid cue trials in each session could be 35 per cent, 25 per cent, or 15 per cent, with the remaining trials being of the invalid cue type. The manipulation of cue validity was accomplished across experimental session, but within subject.

Subjects

Subjects were 12 undergraduates who were paid for participation in four experimental sessions each. The sessions were conducted on consecutive days.

Apparatus and Stimulus Materials

The apparatus and stimulus materials were identical with those of Experiment 1. Each session consisted of three blocks of 160 trials interspersed with three blocks of practice trials as before (only the last two blocks of 160 trials were included in the data analyses). Of the 160 trials in each major block, 80 were of the neutral cue variety. The remaining 80 used either 56 valid and 24 invalid cues, 40 valid and 40 invalid cues, or 24 valid and 56 invalid cues depending on the condition. Practice trial blocks were constructed with the same probabilities as the large blocks that they preceded.

Procedure

Subjects participated in one practice session followed by three test sessions. The practice session was identical with the experimental session of Experiment 1, with 70 per cent cue validity for all subjects. The cue validity assigned for each of the test sessions was determined by using a Latin Square principle balanced across subjects.

Subjects were given the same instructions as in Experiment 1 governing general experimental conditions and trial-to-trial procedures. Before each session, in addition, subjects were fully informed of the probability of occurrence of each type of cue and of the locational cue's validity.

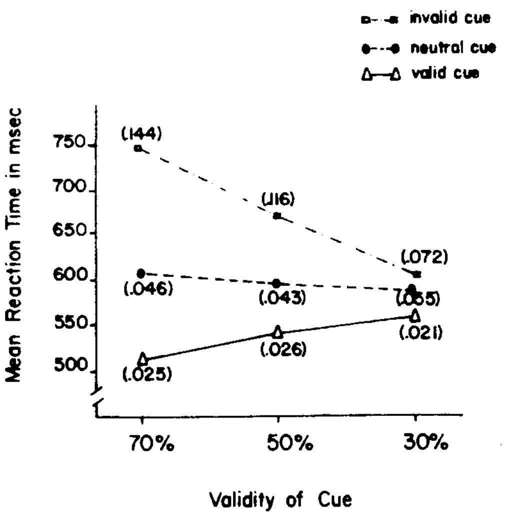

FIGURE 1 Reaction times and errors (in parentheses) as a function of cue validity in Experiment II.

RESULTS AND DISCUSSION

The major result is displayed in Figure 1 which graphs reaction time as a function of cue validity. The three points for the neutral condition arise by separately plotting neutral cue data for each of the cue validity blocks in which the neutral cues were embedded. It is obvious, even from casual inspection of the figure, that variations in validity produce large and systematic changes in costs and benefits. This observation was confirmed by an analysis of variance that included the factors of cue validity (with the neutral cue trials matched with the other trials by the blocks in which they appeared) and cue type. This analysis revealed a main effect of cue type ($F = 51.46$; $df = 2,22$; $P < .001$) which was analysed by Bonferroni post hoc tests. These tests demonstrated highly reliable ($p < .001$) costs and benefits in the 70% validity condition, reliable costs ($p < .01$) and marginally reliable benefits ($p < .06$) in the 50% validity condition, and no reliable differences ($p > .10$) in the 30% validity condition. The main analysis also revealed the obvious interaction of cue validity with cue type ($F = 7.84$, $df = 4,44$, $p < .001$). It is quite apparent, then, that the prediction of the two-stage model is not upheld: The benefit in performance due to a valid locational cue is not invariant with cue validity. This is further confirmed by analysis of error rates which also show an interaction of cue validity with cue type ($F = 4.76$; $df = 4,44$; $p < .005$).

Although this experiment has tested and rejected the version of a two-stage model in which the cued location is always examined first, it has not ruled out all versions of this model. In particular, one may claim that subjects go through a probability matching procedure in each validity condition, somehow matching the probability of first examining the cued location first with the probability of cue validity. This model, like the weighted resource model, would predict the systematic decrease in benefits and costs that we found with decreased cue validity.

While the present experiments cannot distinguish between these two alternatives, they have eliminated various other possibilities. The results of Experiment I rule out models in which resource allocation to the cued location conforms to an all-or-none principle and in which resources are shifted from one location to another in a sequential manner. Experiment II also demonstrates that the all-or-none principle of allocation to the cued position cannot explain performance, even if coupled with a parallel processing mechanism for uncued locations. Further tests are now required to determine whether resources are divided among all array locations simultaneously (with a larger amount applied to the cued location), or whether the benefit of the cued location is due to subjects mixing trials on which the cued location is examined first with those on which all locations are examined simultaneously.

RÉSUMÉ

Deux expériences visant à trouver de nouveaux modèles pour expliquer les changements dans

l'attention portée aux parties du champ visuel sans changements de fixation. Les changements d'attention sont identifiés par une analyse (en coûts et gains) des temps de réaction et des erreurs dans une tâche d'exploration visuelle à choix forcé. Les résultats ne peuvent s'expliquer par des modèles assumant un examen séquentiel des items présentés. L'examen visuel est plutôt conçu comme un processus en vertu duquel les items sont examinés simultanément. Suivant ce point de vue, un changement d'attention est considéré comme un changement dans les ressources de traitement visuel affectées à l'examen de chacun des items.

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