Bulletin of the Psychonomic Society
1990, 28 (1), 37-40

Attentional selection of items and spatial locations

WILLIAM P. BANKS
Pomona College and Claremont Graduate School, Claremont, California

and

DAVID KRAJICEK
Claremont Graduate School, Claremont, California

The first experiment reported here shows that cuing subjects about the identity of items in advance of a visual display has approximately the same effect on attentional selection (as measured by costs and benefits in reaction time) as cuing the location at which they will appear. The second experiment shows that the "spotlight" of directed spatial attention can be content-specific so that it facilitates perception of some items more than others. Both of these findings challenge the spotlight metaphor of attention by which spatial selection is assumed to precede processing for item identity and in which the spotlight itself is content-neutral. Two alternate hypotheses are proposed.

It is well established that visual attention can be directed to a location in space, with the result that items appearing at that location are detected or processed more quickly than items appearing at other, unattended locations. Posner and his colleagues (Posner, 1980; Posner, Nissen, & Ogden, 1978; Posner, Snyder, & Davidson, 1980) have developed a paradigm in which the effect of cuing spatial attention can by analyzed in terms of the *benefit* in reaction time (RT) for items presented at the cued position and the *cost* in RT for items presented at a noncued location. In this paradigm, the attentional cue will typically give the correct location for the target approximately 80% of the time. On the remaining 20% of cued trials, the target will appear at a position that was not cued. On these trials, RT is typically longer than on the correctly cued trials, and this increase in RT is taken as the cost of allocating attention to the cued location. The benefit of cuing is found by comparing RT to targets on the cued trials with either processing of targets at a noncued location or processing of targets after a cue that tells the subject that a target is about to appear but does not indicate location.

In this article, we report some preliminary findings on the effect of preparing subjects for specific items that are to be presented rather than cuing the spatial location at which they are to be presented. The implicit model that many investigators seem to hold about the process of attentional selection is that spatial selection is a sort of "spotlight" that is neutral as far as content is concerned. It will, by the metaphor, "illuminate" equally any item in its beam. The cost of an item's being at a noncued location results from the time taken to redirect the attentional beam. Once an item is in the attentional spotlight, it can be processed.

The attentional spotlight has, therefore, two important properties. First, it is content-neutral. Any item that falls in the spotlight can be processed; the spotlight itself does not have selectional properties other than spatial ones. The second property of the spotlight model is that spatial selection comes before processing. This property implies that attentional selection based on any attribute other than spatial location will be less efficient and generally slower than selection based on spatial location.

In this article, we challenge both properties of the spotlight metaphor of selective attention, first by showing that cuing an item's identity results in approximately the same cost-benefit function as cuing its location, and second, by showing that the spotlight is not content-neutral, but can be prepared to process some items more quickly than others.

EXPERIMENT 1

Method

Subjects. Seven undergraduates from Pomona College participated in the experiment for partial fulfillment of a course requirement. Each subject was tested in a single session that lasted approximately 45 min.

Design. Two factors—cue type and cue validity—were independently manipulated as within-subject variables. The subject's reaction time was taken as the performance measure. Each experimental session was divided into two blocks, with a short rest period between blocks. Each of the blocks consisted of 376 trials. The first block was preceded by 15 warm-up trials, randomly chosen from the experimental trial types, and the second block was preceded by six warm-up trials. The order of trial presentation was randomly generated for each subject.

Apparatus and Stimuli. Stimuli were presented and response times recorded on Macintosh Plus microcomputers. The subjects viewed the display screen at a distance of approximately 55 cm. The target was a figure made of squares, each 0.9° in height and 0.9° in width. If either of the two boxes was filled, the target was positive (correct behavior

This project was supported by a Pomona College Faculty Research Grant. Address correspondence to William P. Banks, Psychology Department, Pomona College, Claremont, CA 91711.

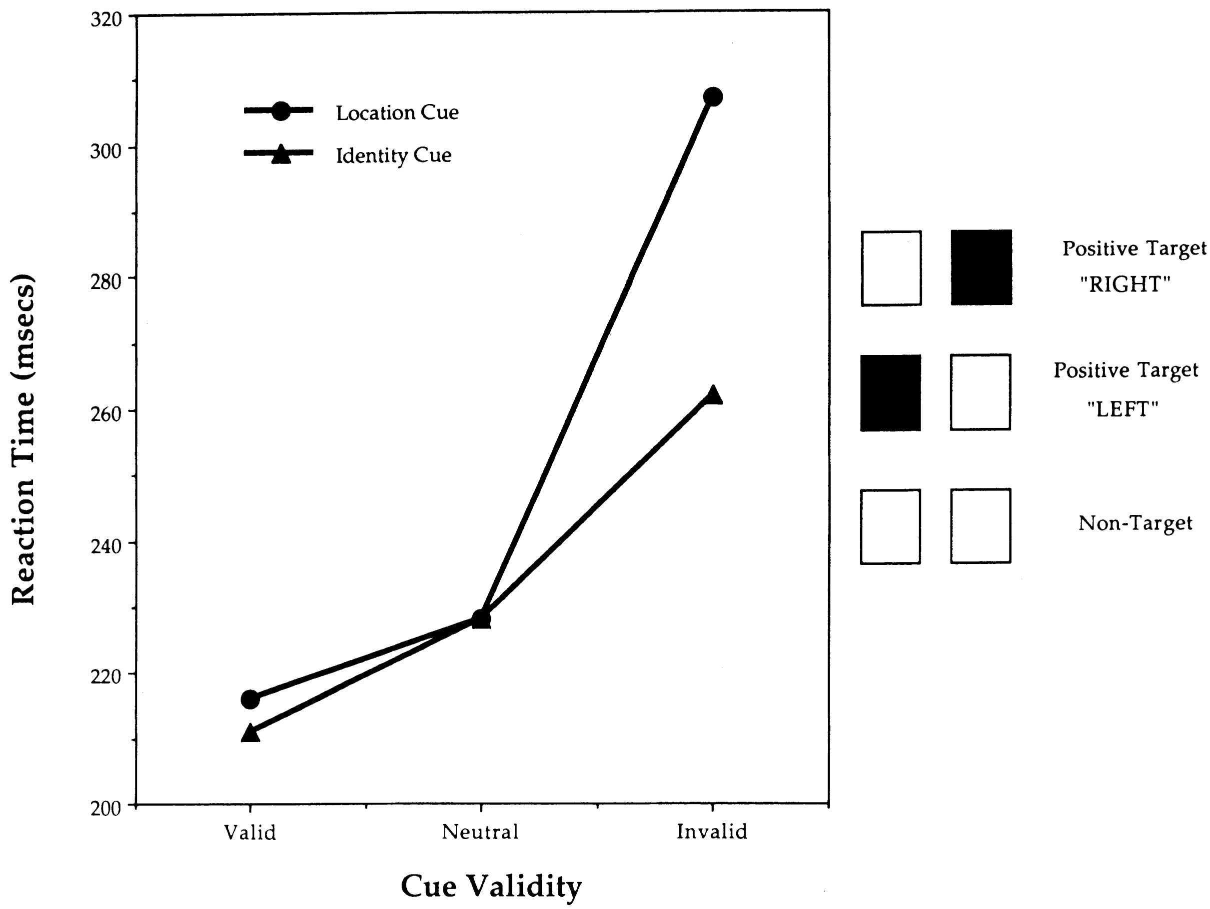

Figure 1. Reaction time to detect a target when its position was given before presentation (location cue) or when its identity was specified in advance of the presentation (identity cue), for both valid and invalid cues. The neutral cue alerted the subject that the stimulus was about to appear, but it gave no positional or identity information. The two positive targets, with their designations, and the nontarget are shown to the right of the figure.

was to respond); if neither was filled, the stimulus was negative (the subject was told to withhold responding). The stimuli are illustrated on the right side of Figure 1. A single box and a plus sign, serving as the spatial and neutral cues, respectively, were also 0.9° in height and 0.9° in width. The letters that made up the identity cues were each 0.9° in height and 0.6° in width. Both the neutral and the identity cues were centered with respect to a fixation point. The subjects responded to the positive target stimuli by pressing the computer's mouse button with either the right or the left index finger.

Procedure. The subjects were told that they would be presented with two adjacent boxes and to respond, as quickly as possible, if one of the boxes was filled. Three types of cue were presented to the subjects prior to the onset of a stimulus display. The subjects were instructed to use the information provided by the cues to aid in the identification task. One cue informed the subjects about the spatial location of the target stimulus. A single box would appear at the exact location on the CRT at which the filled box (i.e., the target stimulus) would most likely appear. A second cue gave the subjects only identity information about the stimulus display. The words "RIGHT" and "LEFT" would appear at the fixation point to inform the subjects which box of the two in the target—the right or the left—would most likely be filled. A third cue, a plus sign, gave the subjects no information about the target stimulus's location or identity. Cue validity, for both location and relative-position cues, was 80%.

An invalid spatial cue cued the subject to a location on the opposite side of the computer screen from where the actual target stimulus appeared. An invalid identity cue cued the subject to the wrong position within the stimulus display.

Each individual trial began with the presentation of an × at the center of the screen for 1 sec. The × served as a fixation point and as a warning that the trial had begun. Immediately following the offset of the fixation point, one of the three cues appeared on the screen for 125 msec. Following the offset of the cue, the × reappeared, along with a two-box display. Both the × and the two boxes stayed on the screen until a response was made or until 2 sec had elapsed since presentation. For an incorrect response, the subjects received immediate negative feedback in the form of a tone emitted from the computer for 250 msec. Succeeding trials began with the appearance of the × 0.5 sec after the completion of the previous trial.

Results and Discussion

The subjects' mean RTs to each trial are shown in Figure 1. The results show strong effects of cue validity [$F(1,6) = 91.3$, $p < .01$], indicating that attentional selection was effective, at least by the usual criterion. The positional cue showed more of a cost and less of a benefit than did the identity cue, resulting in an interaction between cue type and cue validity [$F(1,6) = 7.72, p < .05$]. Cue validity was reliable for both the position cue and the identity cue alone [Dunnett's $t(6) = 9.68$ and 5.5, respectively, both $ps < .05$].

These results show that preparing a subject for a particular target has the same sort of cost/benefit effect on processing as does preparing a subject for the place at which a target will appear. This finding suggests, among other things, that localization of the target is not a prerequisite for identifying it, or at least that localization and identification are somewhat independent and may be processed in parallel. The results also suggest that a similar mechanism may be involved in attentional cuing for location and identity.

The following experiment was designed to test more directly for priming of item identity. This experiment provides a test to determine whether items are more quickly detected at positions at which they occur more frequently. We assume that associative links between the location and the item will be stronger the more frequently the item appears there. Only positional cues were used in Experiment 2, but the frequency with which items appeared at different locations was varied. If cuing a location also primes the items that appear there, then the items that are more frequently presented there should be more strongly associated with the position, more highly activated, and therefore more quickly detected than items less frequently seen at that location.

EXPERIMENT 2

Method

Subjects. Nine subjects, drawn from the same subject pool as in Experiment 1, participated in the experiment.

Apparatus and Stimuli. Stimuli were presented and RTs were recorded on the same instruments used in the previous experiment. The target stimuli were three letters (Z, H, O), each 0.5° high and 0.3° wide. The targets were presented at one of four locations, each location 3° from the fixation point, directly above, below, to the right, or to the left of the fixation point. For convenience, we refer to these locations as north, south, east, and west, respectively. An arrow, 0.9° high and 1.7° wide, was used as the spatial location cue. A plus sign, identical to the one used in the first experiment, served as the neutral cue. The plus sign and the arrow cue were centrally presented, replacing the fixation point at the beginning of a trial. The subjects responded to target letters by pressing the computer's mouse button with either the right or the left index finger.

Procedure. The experimental task required the subjects to respond to the onset of one of three target letters (Z, H, O) that could appear at one of the four locations. They were to withhold responding to any other letter. The nontarget letters were chosen randomly, with replacement, from the remaining 23 letters of the alphabet. The experiment had two blocks of 400 trials. In the first block, which was designed to create associations between positions and letters, some target letters always appeared in particular locations. For half of the subjects, H was

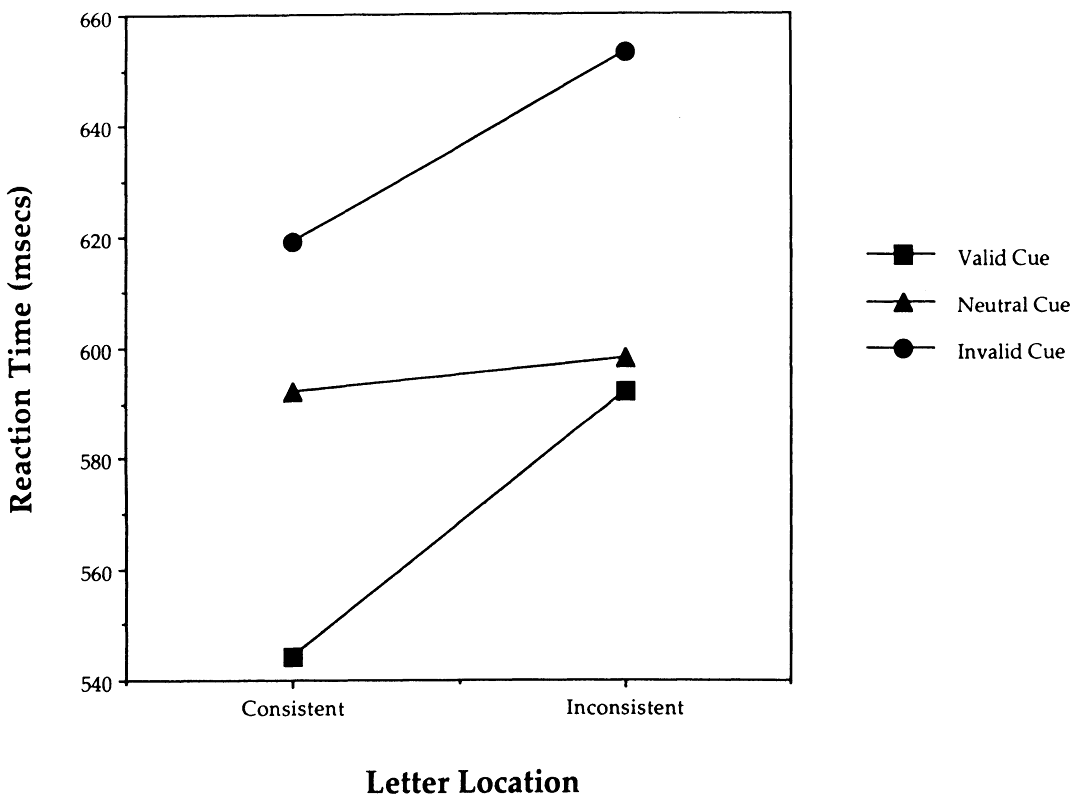

Figure 2. Time to detect a letter target when a valid spatial cue, an invalid spatial cue, or a neutral cue was presented in advance of display. Effects of these cues are plotted separately for cases in which the target letter was frequently associated with the cued location (Consistent letter location) and for when it was infrequently associated with the cued location (Inconsistent letter location).

always presented at north and east, and O at west and south in the first block. For the other half, O was presented at north and east, and H was presented at west and south. For all subjects, Z could occur with equal likelihood at any of the four locations in both blocks. In the second block, assignments were modified such that, for each subject, O and H were presented in their first-block location on 80% of correctly cued trials and in the other two positions on 20% of correct trials.

Each individual trial began with the presentation of an × in the center of the screen for 1 sec. Following the offset of the ×, either a spatial or a neutral cue (arrow or plus sign, respectively) appeared at the fixation point and was followed, 125 msec later, by the onset of a letter. The letter stayed on the screen until the subject made a response or until 2 sec had elapsed since letter presentation. Incorrect responses elicited feedback identical to that used in Experiment 1. The subjects were also given instructions similar to those in Experiment 1.

Design. The design consisted of two within-subjects experimental conditions: cue type and letter location. RT for each trial was the performance measure. Only the second block was analyzed, since the first block served only to create associations. The order of trial presentation was randomly generated for each subject.

Results and Discussion

Mean RTs are shown in Figure 2. The results clearly show the effect of cue validity, with a mean RT of 578 msec for the valid spatial cue, 598 msec for the neutral cue, and 634 msec for the invalid cue [$F(2,16) = 17.6$, $p < .001$]. Letters were detected 43 msec more quickly in their frequent than in their infrequent locations, and this effect was also reliable [$F(1,8) = 27.3$, $p < .001$].

We interpret the letter-location effect as a result of the priming of the letters associated with the cued locations. Priming takes place when the location is cued, and it happens as a result of the association between the cue and the letter. Lambert and Hockey (1986) found similar results with a similar paradigm, and suggested that the result comes from expectancy effects. Our results show that the effect is not from a generalized expectancy because the letter-position effect is seen only when spatial cues were used. It dropped to 4 msec for the neutral cue. The interaction between type of cue and location consistency was reliable [$F(2,16) = 8.27$, $p < .01$]. The consistency effect for the neutral cue alone did not approach reliability ($t < 1.0$).

GENERAL DISCUSSION

The results clearly imply that (1) selective attention can be prepared as efficiently for an item as for a location in space, and (2) the spatial spotlight can be made more ready for some objects than for others. Both of these findings challenge the traditional spotlight metaphor, in which spatial selection has to be made before other attributes can be processed and, furthermore, in which spatial selection of regions is indifferent to the nature of the objects in those regions.

We have considered two ways of explaining these results. The first, and we think the less fruitful, explanation is to challenge the cost-benefit paradigm itself. It is possible that the selective cues—whether for spatial location, items, or features of items—do not actually direct attentional or perceptual processing to the position or item in question. Rather, the cues set up expectations that operate postperceptually. When they are satisfied, the response is facilitated, resulting in a benefit in RT, and when they are violated, the response is slowed, resulting in a cost in RT. Banks and Root (1979) showed how a mechanism much like this could account postperceptually for RT effects in a different paradigm. If this account is correct, the cost-benefit function would reflect a kind of Stroop-like response interference rather than the effects of attentional selection, and of course the cost-benefit analysis would show as strong an effect for item cuing as for spatial cuing. We are currently testing this hypothesis but are not yet ready to report our results.

The second interpretation of these results assumes that (1) spatial location and item identity, and presumably other features as well, are processed in parallel, and (2) attentional selection operates by priming or activating representations or processors of the visual items or locations. By this account, spatial locations, items, and features of items can equally be primed and will show RT benefits when primed, and processing costs when not primed. We are currently developing this priming approach into a general model of attentional selection.

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(Manuscript received June 16, 1989.)