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LUMINANCE CHANGE DOES NOT AFFECT THE ATTENTIONAL ORIENTING TO AN EXOGENOUS CUE

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Abstract

This study aimed to examine whether the abrupt-onset feature or luminance of an exogenous cue was responsible for triggering the orienting response. The luminance level of an abrupt-onset cue was manipulated. A dim peripheral flash was made of luminance of 18.9 fL. A bright peripheral flash was made of luminance of 33.7 fL. Both types of peripheral cues were against a display background of 9.2 fL. Using EOG electrodes to monitor eye movements, the allocation of spatial attention was measured with response times to recognition of the targets that are presented at different locations following a cue. The results showed that the reaction time costs of the uncued locations for the bright cue was about the same as for the dim cue. The findings suggest that the dynamic changes of a peripheral flash, rather than luminance of the flash, may trigger the attentional orienting system.

Keywords: attentional orienting, exogenous cue, abrupt-onset, luminance

1. Introduction

In the location-precuing paradigm, two sources of spatial selection—exogenous and endogenous cues—are used to direct covert orienting which refers to the allocating of attention to a peripheral location without concomitant eye movements. The differences between exogenous and endogenous orienting lie in the selective mechanism and time courses (Posner, 1980; Chica, Bartolomeo, & Lupiáñez, 2013). An endogenous cue is a symbolic indicator (e.g., an arrowhead or a line) presented at the center of the display (also referred to as a central cue), indicating the very likely location of the forthcoming target in the periphery. The facilitation effect of the valid cue on the target detection must be ascribed to the perceptual goal generated endogenously because the target never appears at the center of the stimulus display. In contrast, an exogenous cue is an abrupt brightening (like a flash) of the outline of one location in the periphery (also referred to as a peripheral cue), which is randomly associated with the target location. The shift of attention and processing benefits for the cued location may be initiated by the sudden stimulus onset because participants are given no reason to expect the target at the cued location.

The exogenous cue used in the location-precuing paradigm has two properties. One is the abrupt onset of the flash; the other is brightness of the flash, namely, a brightness feature singleton. These two properties may together determine the salience of the flash. The degrees of stimulus salience in contrast to the surrounding background may, however, only be determined by the brightness level of the flash; the brighter (contrasted with the background), the more salient. The abrupt-onset feature activates a transient subsystem in the visual processing system, which in turn orients observers' attention to the onset locations in the space (Todd and Van Gelder, 1979). This dynamic change of the stimuli, as opposed to the static stimulation, has been claimed to be the main determinant of attentional capture (Yantis and Jonides, 1984). In addition, in visual search, stimulus salience, such as a feather singleton, is said to trigger a preattentive system, making the stimulus with a distinctive feature be detected quickly without any interference of the surrounding distractors (Treisman and Gelade, 1980). Theeuwes (1992) found that attention was distracted by an irrelevant color diamond (e.g., red) first when searching for a target located in a green circle that was embedded in the other green diamonds. This suggested that a color singleton could capture attention even it was irrelevant to the target.

However, Bacon and Egeth (1994) argued that the reason for Theeuwes's (1992) results was that subjects adopted a singleton detection strategy which would guide attention by a feature discontinuity because the target instance was a unique circle embedded in the other diamonds. Therefore, sometimes attention was attracted to the uniquely colored object without the target inside. Bacon and Egeth (1994) included two or three target instances (e.g., more green circles) in the display so that the target was not in a unique shape in the entire display anymore. This change made the singleton detection strategy ineffective. The results suggested that an irrelevant color singleton did not delay the search time any longer. Similarly, Mounts (2000) suggested that a color singleton irrelevant to the target could not capture attention. Therefore, whether a bight feature singleton within a bright abrupt-onset cue is able to capture attention seems to be inconclusive. A question worthy of exploring is whether the brightness level of a peripheral flash play a role in capturing attention?

On the other hand, the results of Hsieh (2023) and others (Müller et al., 2005) showed that an exogenous cue-induced weaker inhibition of the uncued locations than did an endogenous cue. The exogenous cue, such as a sudden movement or an abrupt flash, usually has a survival value, either signifying a potential danger (predator) or food (prey), so it would be worthwhile to focus attention fully on it, while to inhibit the other possible distractors (Cutzu & Tsotsos, 2003). The question of interest is whether the size of this inhibition can be modified. If the inhibitory mechanism is initiated by detection of the abrupt-onset feature, then the manipulation of stimulus luminance will not modify the size of inhibition. If inhibition is initiated by another system that is related to detection of stimulus energy, it is speculated that the less energetic stimulus may induce more inhibition of the uncued locations because attentional resources need to be more focused on that stimulus location and thus will be hardly distracted to the other uncued locations (Forster & Lavie, 2008). This study aims to examine whether the abrupt-onset feature or luminance of an exogenous cue is responsible for triggering the orienting response.

2. Method

The stimulus display (see Figure 1 in Hsieh, 2023) included six boxes arranged along a semicircle in peripheral vision, 5.7° distant from the fixation center so that each box had the same visual acuity. The outline of one of the six boxes was brightened abruptly to serve as an exogenous cue. Each box (display location) was referenced to location 1 through 6 from the rightmost to the leftmost. Those numbers were not included in the actual experimental display. The distance was measured as the shortest line between the center of any two locations. The longest distance between cued and target locations could be 9.3°. To ensure that covert attention shift, not overt movements of eyes, was responsible for performance, eye movements were monitored using EOGs (electro-oculograms) electrodes. EOGs were recorded from three sites, i.e., a horizontal EOG recorded from the left outer canthus and a vertical EOG recorded from the sites inferior and superior to the left eye. All electrodes were referenced to the right outer canthus.

2.1 Participants

Twenty-nine undergraduates participated in a single 1 $^{1}/2$-hour session, in partial fulfillment of an introductory psychology class requirement. All had normal or corrected-to-normal visual acuity. Four participants were discarded from the analysis because of frequent eye movements or very low accuracy (below 50%).

2.2 Stimuli

The stimulus display included six boxes outlined in black color against a gray screen background (9.2 fL). Each box was 1.1° tall x 1.14° wide. The outline of one box (either location 1 or location 4) was brightened for 100 ms, serving as a peripheral cue. The luminance of the flash could be either 33.7 fL or 18.9 fL. The target was either the letter "P" or "B" in black (0.62° long x 0.35° wide), placed in the center of a box. The possible farthest target location was 9.3° away from the cued location.

2.3 Design

A 2 x 2 x 6 design was used. Three within-subjects variables were brightness of the cue (dim/bright), cueing locations (location 1 and location 4), and target locations (0°, 2.6°, 4.9°, 6.5°, 8.1°, and 9.3° distant from the cued location). The trials with different brightness of the cue were blocked. A total of 480 trials was divided into 4 blocks of 120 trials each. Two blocks were bright-cue trials. Another two blocks were dim-cue trials. Each block was randomly assigned to the observers. On 80% of the trials, the peripheral cue appeared with 16.7% predictive validity. On 20% of the trials, all boxes were brightened simultaneously, serving as a neutral cue. The peripheral cue appeared in two possible locations equally often. Subjects were told that the peripheral brightening had nothing to do with the upcoming target location.

2.4 Data analysis

Reaction times (RT) slower than 1500 ms or faster than 300 ms were considered errors and discarded from the analysis. The low cutoff value of 300 ms was on average more than 2.5 standard deviations below the mean RT for each subject. 4.1% of the trials were truncated overall for this reason. There were three types of trials in this experiment. A valid trial is one in which the flashed and target locations are matched. An invalid trial is one in which the flashed and target locations are not matched. Neutral trials are those in which every location is flashed. Although the peripheral cue does not have any predictive validity, we still use the terms—valid and invalid—to describe the spatial relationship between the cue and the target. Because there were only eight trials for each target location in the neutral condition, I decided not to calculate the RT costs and benefits based on a reference to the mean RT in neutral trials. Instead, I simply calculated the RT cost for each uncued location with a reference to the mean RT in the valid cue trials.

3. Results

The results are graphed in Figure 1. Reaction times were analyzed in a repeated measures ANOVA with cue brightness and target locations as two factors. The main effect of target locations was significant, F(5, 120) = 7.25, p < .01, indicating that responses to identification targets in the valid location were quicker than in the invalid location. The effect of cue brightness was not significant, F(l, 24) = 1.2, p = .28. The interaction of cue brightness and target locations was not significant either, F (5,120) < 1. The overall error rates were 15.3% and 14.3% for the bright-cue and dim-cue condition, respectively. Accuracy was analyzed in a repeated measures ANOVA with cue brightness and target locations as two factors. The main effect of target locations was significant, F(5, 120) = 3.4, p < .01, indicating that a target in the cued or 2.6° distant location was responded to more accurately than targets in other locations. The main effect of cue brightness was not significant, F(l, 24) < 1. The interaction of cue brightness and target location was not significant either, F(5, 120) = 1.1, p = .35. The results suggest that there is no difference between bright-cue and dim-cue conditions in terms of error rates. The RT costs in terms of invalid RTs minus valid RTs were analyzed in a repeated measures ANOVA with cue brightness and target locations as two factors. None was significant. The effect of target locations was close to a significant level, F(4, 96) = 2.17, p = .08. The reason was that the RT cost of 2.6° distant location was slightly lower than other target locations. The results suggest that the RT costs are not significantly different between bright and dim cues. However, it is worth noting that reaction times for the dim cue were slightly longer than for the bright cue. For instance, the mean RT of valid trials for the dim cue was slightly longer than for the bright cue (559 vs. 547 ms).

4. Discussion

The peripheral flash not only directs observers' attention to a particular location in the space but also alerts observers. The bright cue was more salient than the dim cue and hence induced more alerting effects. As a result, reaction times in the bright-cue trials were slightly quicker than in the dim-cue trials.

However, the dim cue did not induce a larger cost for the target identification in invalid trials than did the bright cue. The possible reason is that the attention system for orienting is in response to the abrupt-onset feature of the stimuli, but not to the luminance values of the stimuli. In other words, what matters to the orienting system is the dynamic change of the stimulus, but not its static contrast. It has been argued that the visual system is composed of two subsystems: a transient system that only responds to dynamic changes in visual stimulation, such as onset, offset, or movement, and a sustained system that responds to static visual stimulation, such as visual patterns (Todd and Van Gelder, 1979; Livingston and Hubel, 1988). It is very likely that in one route, the abrupt-onset feature of the peripheral cue is detected by the transient system automatically, which in tum triggers the orienting system (possibly in the parietal lobe). In the other route, the luminance value is analyzed by the sustained system, which in tum activates the alerting system. On the one hand, those two routes seem to be independent of each other because the experimental results show that the luminance values (i.e., the degrees of salience) do not have any impact on attentional orienting. On the other hand, it is also very likely that those two systems will interact in a certain way because obviously, the most salient stimulus has a higher likelihood of capturing attention. For instance, the brightest dot in a display of gray dots will pop out and be detected at first.

On the other hand, the evidence from the simulation of the connectionist model (Tsotsos, 1993) suggests that luminance of various degrees in a peripheral flash may have no effect on the allocation of spatial attention. In the simulation, the input units corresponding to a brighter cue was assigned a strength value of 100 as used in the simulation. Relatively, the input units were assigned a strength value of 60, serving as a dimmer cue. The ratio of 100 over 60 resembled the ratio of 33.7 fL over 18.9 fL used in the experiment. The simulation process was identical to that for exogenous orienting in Hsieh's study (2023). Both cues of different brightness produced a very similar result in terms of the distribution of activation of the output units.

In conclusion, the peripheral flash provides two types of visual information: the dynamic change of stimulation and the static luminance contrast. The orienting of attention is mainly determined by information of dynamic changes.

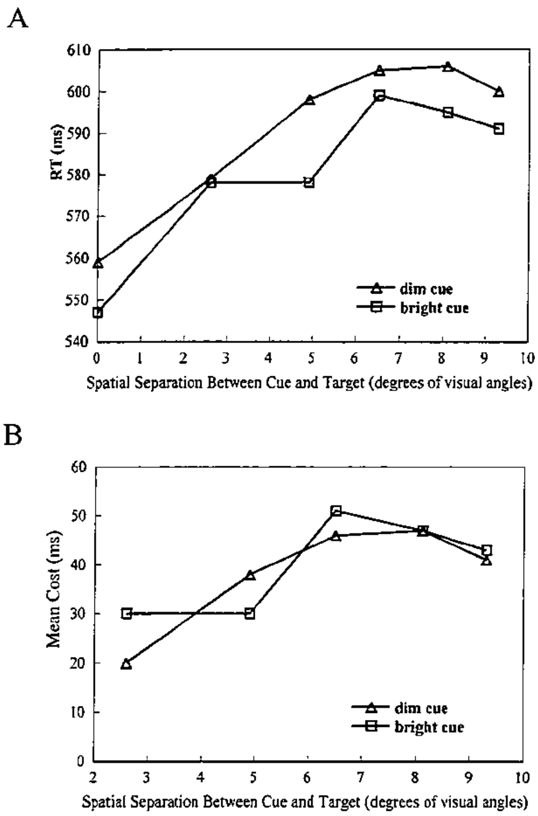

Figure 1. The results of this study in which luminance of a peripheral flash was manipulated. A: The validly cued location is

represented by a visual angle of 0°. Reaction times (RT) are plotted as a function of the distance between the flash and target locations. B: The dependent measure is RTs of invalid locations minus RTs of valid locations.

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