Orienting of visual attention by subliminal central cues

Roman Vakhrushev, Igor S. Utochkin

Higher School of Economics, Psychology Dept.

Abstract

In several recent studies it was demonstrated that spatial shifts of attention may be directed by subliminal peripheral events [Mulckhuyse and Theeuwes, 2010, Acta Psychologica, 134, 299-309]. In three experiments based on Posner’s cue paradigm we investigated whether attention may be directed by subliminal central events (arrows at fixation point). In Experiment 1, participants had to detect asterisks from the right or left from fixation preceded by brief presentation of faint arrow cue concurrently with salient warning signal at 200- or 500-msec SOAs. 75% cues were valid and SOAs were randomly intermixed. The similar design was used in Experiment 2 but 200- and 500-msec SOA trials were blocked. In Experiment 3, 50% cues were valid and SOAs were blocked. No cue effects were found in Experiments 1 and 3. Small but significant acceleration of responses to valid cues was obtained in 500-msec but not in 200-msec SOAs in Experiment 2. Results of Experiments 2 and 3 are consistent with results documented for conscious orienting to central cues indicating that this process is relatively slow and informativeness-dependent. However, Experiment 1 and 2 together demonstrated that unconscious orienting is limited by temporal uncertainty factors, while conscious orienting is not.
Experimental researches of the past decades demonstrated that our perception, behavior and decision is partially influenced by subliminal stimuli (Marcel, 1983; Merikle & Daneman, 1998). Subliminal stimuli or events are those very faint or brief to be consciously perceived (detected, discriminated or identified). It is established that processing of supraliminal and subliminal events differ in several critical features such as predominant code, availability for strategic regulation and voluntary ignoring, etc (Merikle & Daneman, 1998).

In several recent studies it was found that although subliminal events go unaware they, nevertheless, may produce attentional shifts to a certain spatial location (see Mulckhuyse & Theeuwes, 2010, for review). They control attention in involuntary manner that is similar with stimulus-driven control of attention by supraliminal events such as abrupt onsets, offsets or motion. They are able to summon attention to a location by their occurrence at that very location. Such way to control attention is termed as exogenous attentional capture, or peripheral cue. It is established that exogenous attention operates fast (it can affect reaction times at cued location at 25-50 msec stimulus onset asynchronies (SOA)), automatically and irresistibly (Jonides, 1981). Hence, exogenous attention shares basic mentioned characteristics of subliminal processes. Hence, experimental results that demonstrate exogenous shifts of attention to subliminal peripheral events, appear rather consistent. However, endogenous processes can control spatial shifts of attention along with exogenous processes. Endogenous attentional shifts are regulated by goal, sets and expectations. They are considered as central by origin. Such attentional shifts are relatively slow (they occur at about 200 msec after the signal to move attention towards a certain location) and are consciously controlled. That is, a person may either attend or ignore central cues for attentional shifts. This deliberate decision depends on cue utility, or informativeness. Central cues may be presented in symbolic form (arrows or verbal commands). They may also vary in informativeness, that is, likelihood that critical event occurs at cued location. It is presumed that this information may be used consciously by reasonable strategy of
attentional control (Posner et al., 1980; Jonides, 1981) which is impossible in endogenous shifts of attention by peripheral cues.

We hypothesized that subliminal processes whose automatic is well documented in previous studies are sensitive to endogenous factors as well. In other words, our hypothesis was that subliminal central cues are able to control spatial shifts of attention.

General Design

In our experiments, we used a modified Posner cue paradigm with central arrows as informative cues. The subjects had to fixate a black dot at the center of gray field and to make speeded response to a target stimulus (a white flashing asterisk) to the left or to the right from the center. Asterisks were preceded by briefly presented (30 msec) white box around fixation point that served as a warning signal. Subliminal arrow cues to the right or to the left were presented concurrently with the warning signal. Arrows were placed inside the central box and located at fixation. Arrows and background were colored in similar shades of gray. Their poor contrast along with brief presentation provided failure to detect arrows consciously. No serial masking typical for subliminal experimental designs was used. It was made to avoid overlapping exogenous orienting back to the center that may interfere with endogenous shift of attention (if any) elicited by an arrow. Arrow cue could be either valid or invalid. Valid cues indicated a location where target is in fact to occur, while invalid cue indicated an opposite side. Catch trials were also introduced to procedure to control anticipatory responses. In catch trials, only warning signals with subliminal arrow cues were presented and no target asterisk followed it.

Stimulus onset asynchronies (SOAs) were equal to either 200 msec or 500 msec. These two SOA values were used to estimate time course of spatial orienting.
Awareness test was carried out by participants after they finished cue task. Stimulus display was identical with one used in cue task. However, no target asterisks were presented. Instead, participants had to discriminate between left and right directions of subliminal arrows presented with the white central box for 30 msec. Total amount of 25 right and 25 left arrows were presented in random order during the test. Chance level (no more than 50% correct responses) was considered as unawareness proof.

Experiment 1

Methods

In Experiment 1 (N=24), cues were valid in 75% trials and were invalid in 25% trials. Hence, arrows were informative. Participants passed through 75 valid and 25 invalid trials with 200 msec SOA, 75 valid and 25 valid trials with 500 msec SOA and 20 catch trials following in random order. Trials were divided into two serial blocks, including 110 trials per block. Two minutes break was made between the first and the second blocks. 12 practicing trials were added at the beginning of each block. Hence, each block included 122 trials in total.

Two within-subject factors were used in this experiment. The first one was Cue (valid cue vs. invalid cue) and the second one was SOA (200 msec vs. 500 ms.). Reaction time was considered as dependent variable.

Results

Trials with responses faster than 180 msec were excluded from data analysis.

Average percentage of correct responses in arrow discrimination test did not differ with chance level ($M = 48.3\%, \ SD = 7.6\%$). This may serve as evidence of unconscious nature of arrows effects on attentional shifts (if any).
Results of the asterisk detection performance are shown at Figure 1a.

ANOVA revealed significant main effect of SOA on reaction time ($F (1, 23) = 7.30, p < .05$). This effect is due to relative acceleration of responses in 500-msec SOA as compared to 200-msec SOA. Main effect of Cue as well as effect of interaction Cue $\times$ SOA failed to reach significance.

Discussion

In Experiment 1, we failed to obtain any evidence that subliminal arrow cues may induce spatial shifts of attention. The one possible interpretation is that central endogenous attention is not affected by unconscious subliminal events. This interpretation seems to be consistent with common opinion that centrally induced endogenous orienting is predominantly consciously controlled rather than automatic (Jonides, 1984; Posner, 1980). Nevertheless, several experimental results demonstrated that probabilistic endogenous processes are still able to modulate orienting of attention in purely automatic manner (e.g., Bartolomeo et al., 2007, Lambert et al., 1999, Experiment 1).

The second possible interpretation of our failure to obtain orienting pattern may lie in the nature of automatic probabilistic processes. As was demonstrated by Utochkin (unpublished data) effects of cue informativeness on purely automatic orienting to peripheral events is mediated by temporal uncertainty. Thus, informativeness has little effect on reaction times if short and long SOAs are randomly intermixed (as in typical cue experiments designs). In contrast, informativeness has rather significant effect if short and long SOAs are joined in blocks. In other words, it appears that endogenous factors of automatic spatial attention may be revealed if temporal uncertainty is removed. We supposed that this notion may be applied to subliminal processes as well. We are going to test this hypothesis in Experiment 2.
Although we failed to obtain any evidence for spatial orienting to central subliminal cues we found that SOA had significant effect on reaction time. We argue that this effect may be assigned to alerting general reaction to supraliminal warning signal rather than subliminal cue. Time course of this alerting effect is consistent with typical pattern described in literature (Niemi & Näätänen, 1981; Posner, 1978).

Experiment 2

Experiment 2 (N=23) had the similar design with Experiment 1. Again, cues were valid in 75% trials. The principal feature of this experiment was that trials with 200 msec and 500 msec SOAs were joined in two separate blocks. Half participants received 200-msec block first followed by 500-msec block. Another half participants received reversed block sequence. Two minutes break was made between the first and the second blocks.

Factors and dependent variable were identical with ones used in Experiment 1.

Results

Trials with responses faster than 180 msec were excluded from data analysis.

Average percentage of correct responses in arrow discrimination test did not differ with chance level (\(M = 49.5\%, SD = 5.7\%\)). This may serve as evidence of unconscious nature of arrows effects on attentional shifts (if any).

Results of the asterisk detection performance are shown at Figure 1b.

ANOVA revealed significant main effect of Cue on reaction time (\(F(1, 22) = 5.73, p < .05\)). This effect is provided by relative acceleration of responses in valid cue condition. Nevertheless, additional paired t-tests revealed that the difference is significant only for 500-
msec SOA ($t (22) = –2.75, p < .05$) while in 200-msec SOA it failed to reach significance. Main effect of SOA as well as effect of interaction Cue × SOA failed to reach significance.

Discussion

In the present experiment, we modified conditions to achieve temporal stability of SOAs. We presumed that cue effects (if any) could interfere with temporal uncertainty brought by intermixed design of Experiment 1.

Here, we found significant benefit in reaction time due to valid arrow cues. Consequently, our suggestion about interference with temporal uncertainty was correct. This is a critical conclusion since it revealed one important difference between orienting of attention carried out consciously and unconsciously. Thus, conscious orienting to central cues appears to be independent on temporal uncertainty. Cue effects are typically obtained in experiments where different SOAs intermixed in one block of trials (e.g., Posner et al., 1978).

The second notion concerns time course and magnitude of cue effect on reaction time. As can be seen from results (Fig. 2b), cue effect is insignificant at short 200-msec SOA and reaches significance at longer 500-msec SOA. This result indicates that effect develops relatively slow in time. This pattern is highly consistent with results obtained for conscious orienting to central cues (Posner et al., 1978). Yet, magnitude of this subliminal cue effect (about 11 msec) is smaller than one for supraliminal cue (about 30 msec as reported by Posner et al. (1978)). Similarity between time courses of unconscious and conscious shifts of central attention suggests that subliminal cue affects attention in endogenous rather than exogenous manner that is typically more rapid.
In Experiment 2, we obtained evidence that subliminal arrow cues do actually produce shifts of attention to a certain spatial position. Nevertheless, it is still not clear what feature make subliminal cue to affect attentional shifts. On the one hand, as was proposed by Posner, central cues are utilized as soon they are informative in respect with predicting future target location. On the other hand, arrows may produce shifts of attention by their own left-right orientation rather than their informativeness. Results by Eimer (1997) with supraliminal arrow cues suggest that such arrow orientation effect may be considered as probable interpretation for pattern obtained Experiment 2. To distinguish between probabilistic (informativeness related) and graphic (related arrow orientation) interpretation we conducted Experiment 3 with uninformative cues. If subliminal cue informativeness contributes to shift of attention then uninformative cue condition should eliminate cue effects. In contrast, if cue orientation contributes to shift of attention then effect from Experiment 2 should persist with uninformative cues. If both factors contribute to attentional shifts then effect should be attenuated by uninformative cues.

Methods

In Experiment 3 (N=24), the same blocked design was used with the same amount of trials. The only difference was that only 50% cues were valid.

Factors and dependent variable were identical with ones used in Experiment 1.

Results

Trials with responses faster than 180 msec were excluded from data analysis.

Average percentage of correct responses in arrow discrimination test did not differ with chance level (\(M = 52.0\%, SD = 5.1\%\)). This may serve as evidence of unconscious nature of arrows effects on attentional shifts (if any).

Results of the asterisk detection performance are shown at Figure 1c.
ANOVA revealed no significant factor effects on reaction time.

Discussion

In the present experiment central cues were uninformative in respect with target location. No cue effects were found in the result. According to our above reasoning, this result provides evidence that subliminal cue effects have probabilistic rather than graphic nature. In other words, implicit learning appears to underlie spatial shifts of attention by subliminal central cues. Again, this result is strongly consistent with what is described for conscious orienting (Jonides, 1981; Posner, 1980) indicating that unconscious orienting system is probably based on similar mechanisms.

Conclusion

In our three experiments, we found evidence that orienting of attention to subliminal central cues exist along with orienting to subliminal peripheral events as was demonstrated earlier (Mulckhuyse & Theeuwes, 2010). We found that this process shares some critical features with spatial orienting elicited by conscious orienting of attention. First, time course of these subliminal shifts of attention develops relatively slow and has its effects at relatively late SOAs. Second, cue effects of subliminal cues are sensitive to manipulations with informativeness. Nevertheless, magnitude of these unconscious effects is smaller than one of conscious effects. This indicates that conscious control over central attention is, no doubt, more powerful and efficient tool to deal with the central cues. However, an important limitation was revealed concerning extents to which subliminal central cues may be used. This limitation is associated with temporal factor. Thus, probabilistic effects of subliminal cues were found when temporal uncertainty brought by variable SOA was removed. In contrast, conscious orienting is insensitive to temporal uncertainty.


Figure captions

Figure 1. Effects of subliminal central cues on simple reaction times (a) in Experiment 1, (b) in Experiment 2 and (3) in Experiment 3.