© Journal of the Indian Academy of Applied Psychology
September 2024, Special Issue,168-180

Exogenous - Endogenous Orienting, Time Course of Facilitation and Inhibition during Vigilance Task Performance

Anil Kumar Yadav, Shalini Dubey, Trayambak Tiwari, Shreshtha Yadav, Indramani L. Singh
Banaras Hindu University, Varanasi.

Anju L. Singh
Vasanta Kanya Mahavidyalaya, Varanasi

Two experiments were conducted to examine the effects of exogenous and endogenous modes of covert orienting and different SOAs (stimulus onset asynchrony) on vigilance task performance. In experiment one endogenous and exogenous orienting were compared to know which mode of orienting was more influential on vigilance task performance. The most influential and effective mode of orienting then were examined at three Stimulus onset asynchrony (SOA) levels in experiment two. Results revealed that exogenous cue elicited faster detection of target and produced more cue validity effect in comparison to endogenous cue. However, both the types of cues were able to prevent the decrement functions as performance decrement was not seen across the time period. The SOAs were tested with exogenous cue in experiment two. The inhibition of return (IOR) was not seen in exogenous orienting but cue validity effect decreased with increasing SOAs during vigilance task. This suggested that exogenous cue was beneficial for vigilance however the benefit was limited to the shorter SOA.

Keywords: Vigilance, Endogenous-Exogenous Orienting, Cue validity, Stimulus Onset Asynchrony, Inhibition of Return.

Spatial Covert Attention: Endogenous and Exogenous

In our daily lives we are presented with an overwhelming amount of information. Although we understand our surroundings effortlessly, but to make a sense out of the visual information we receive, we need to detect, localize, and identify relevant information. Attention is the capacity to focus on the relevant aspect while ignoring the unimportant ones. Since, our attentional resources are limited and performance diminishes when this pool is not replenished over time. Therefore, optimization of attentional resources is imperative for better performance (Carrasco & Barbot, 2014). Covert attention enables us monitor our surroundings and place subsequent eye movements to significant locations. We deploy covert attention in various situations. Attention affects performance and appearance in many tasks mediated by early visual dimensions (Anton-Erxleben & Carrasco 2013; Carrasco, 2014; Carrasco & Yeshurun 2009;). Two types of covert attention facilitate selective processing of information: endogenous attention (manipulated with a central cue), which enables observers to voluntarily allocate and monitor information at a given location. Its effects known to be sustained; observers deploy voluntary attention in 300 msec and can sustain it as needed (Jonides & Irwin, 1981; Muller & Findlay, 1987). Endogenous location cues initiate attention shifts in a fundamentally different way than exogenous cues. The former are meaningfully associated with a particular location and therefore must be interpreted by an observer (Posner, 1980). For this reason, the initiation of an attention shift by a symbolic cue is goal-driven. The observer processes the location information conveyed by the symbolic and, on this basis, develops a computational goal for carrying out the task (Wright & ward, 2008).

Exogenous attention (manipulated with a peripheral cue), which allows observers to involuntarily orient to a location where sudden stimulation has occurred. The involuntary deployment of attention is transient, peaks at 100–120 msec and decays quickly (Koenig-Robert & Vanrullen 2011; Liu et al. 2007; Müller & Rabbitt 1989). Whereas, observers can allocate resources according to cue validity when deploying endogenous attention, they cannot do so when deploying exogenous attention (Yantis & Jonides 1996; Giordano et al. 2009). Direct cues, on the other hand, produce their effect by virtue of being physically close to the target location. It appears the facilitative effect of direct cues on target detection response times arises, in part, from some form of sensory activation that occurs at the cued location and enhances responding to a target that appears shortly afterward at the same location (Posner, 1980). No cognitive interpretation of exogenous cue meaning is required and attention is captured by the onset of the cue. For this reason, the initiation of an attention shift by an exogenous cue is stimulus-driven (Wright & Ward, 2008). Exogenous cues cannot be ignored: Involuntary transient shifts of attention occur even when the cues are known to be uninformative and irrelevant (Barbot et al. 2011; Herrmann et al. 2010; Montagna et al. 2009; Pestilli & Carrasco, 2005; Pestilli et al. 2007; Yeshurun & Rashal, 2010) and even when they impair performance (Bocanegra & Zeelenberg, 2011; Dugué et al. 2020; Talgar & Carrasco, 2002; Yeshurun 2004; Yeshurun & Carrasco, 2008; Yeshurun & Levy 2003).

Time course of cue effectiveness is an essential difference between two kinds of orienting. Endogenous orienting developed gradually and the peak facilitation is found when SOA is about or greater than 300 ms (Jonides & Irwin, 1981; Muller & Findlay, 1987; Muller & Rabbit, 1989). On the contrary, orienting initiated by exogenous cue is rapid and transient. It is more effective when stimulus onset asynchrony (SOA) is short and about 100-150 ms (Jonides, 1981; Remington & Pierce, 1984; Muller & Rabbit, 1989; Yantis & Jonides, 1990). The facilitation effect observed with exogenous cues not only disappears after some time, but is reversed, so that after about 300 ms SOAs responses are slower and/or less accurate for valid cued target and responses to invalid cued target becomes faster. This phenomenon is termed by different names such as inhibitory aftereffect (Tassinnari et al. 1987), inhibitory tagging (Fuentes et al., 1999; Klein, 1988), or Inhibition of Return (IOR; Posner et al.,1985).

Sustained attention and orienting of attention

The ability to maintain attention for longer durations is imperative for several tasks. Various researches have showed that performance declined over time when observers were required to maintain attention in controlled settings (McLean et al. 2009). Recently, researches have used these two modes of orienting with vigilance task paradigm to know whether endogenous and exogenous orienting were able to prevent the decrement function as well as to enhance overall sustained attentional capacity. Researches (Bahri, 1990; Singh et al., 2006; Rai, 2009; Singh, 2011) suggested that facilitatory effect of valid cue as well as inhibitory effect of invalid cue, both were evident in vigilance task. Several studies have suggested that exogenous cue was more effective as its sudden onset produced alerting effect during vigilance while endogenous cue was less effective because it required more level of processing and developed gradually (Pattyn and Soetens, 2004; Pattyn et al., 2008; Sebestiani et al., 2009).

In sum, spatial cues facilitate the detection performance. Endogenous and exogenous spatial orienting improves the accuracy and speed with which stimuli are detected (e.g., Posner, 1980). Despite this, very few researchers have examined effects of exogenous and endogenous cuing using vigilance paradigm.

Overview of Present Study

Present study combined the covert orienting and vigilance paradigms and endeavored to examine whether spatial cue facilitate sustained attention performance. The major goal of present study was to explore how two modes of covert orienting affected sustained attention performance. The other objective of this study was to examine the role of various SOAs in sustained attention performance across time period. It was hypothesized that benefit of exogenous cue would be more than endogenous cue on vigilance task performance and the phenomenon of facilitation and inhibition would differ at different stimulus onset asynchrony (SOA) levels. Two experiments were conducted. In first experiment exogenous and endogenous orienting effect on vigilance task performance were examined and compared. On the basis of this comparison type of orienting (endogenous or exogenous) were finalized for the second experiment. In the second experiment phenomena of facilitation and inhibition were tested while manipulating three distinct SOAs.

Experiment 1

Participants

Twenty students of Banaras Hindu University, whose age ranged from 19 to 24 years with mean age of 21.5 years participated in this experiment. All the participants were having normal or corrected-to normal vision.

Experimental task

The experiment was designed on *SuperLab®* 4.0 (Cedrus, 2007) and was displayed on a 15’ colour monitor. Visual vigilance detection task with spatial location cue was used in which two squares of different sizes were used as target and non target. The target was 3.30 cm^2 and the non target was 3.00 $cm^{2.}$ In endogenous cue condition an arrow cue was used and in exogenous cue condition a star was used. Arrow cue was presented at central location and star cue was presented at both central and peripheral locations. The cue was manipulated as valid, invalid and neutral. Valid cue indicated the correct location of target where the target or non target would appear, invalid cue indicated the incorrect location of target whereas neutral cue didn’t show any location i.e. right or wrong. Cues were valid on 80% of the trial, invalid on 10% and neutral on 10%. The display of the task trial consisted of fixation (+ sign) displayed centrally on the screen for 500 ms followed by a cue on the screen for 250 ms and afterwards target or non target was displayed for 100 ms either in left or right periphery and then blank screen for 3150 ms. Each participant received 3150 ms for deciding about the appearance of target and to respond immediately for target by pressing a response key. The ratio of target and non target was 20:80. Four 10-min blocks with 150 events in each were used.

Experimental Design

A 2 (Cue type: endogenous & exogenous) x 3 (Cue validity: valid, invalid & neutral) x 4 (Time period: 4 blocks of 10 minutes each) mixed factorial design was employed with repeated measure on last two factors. Two types of cues, endogenous and exogenous were manipulated as between subject factor and cue validity (valid, invalid and neutral) and time (Four 10-min. blocks) were treated as within subject factors.

Procedure

Informed consent was obtained from all the participants in this study. Then participants were tested for their normal visual acuity using Snellen chart and biographical information regarding their age, gender, education, weight, knowledge of computer, etc. were taken from the participants. Participants were instructed about the experiment and task was imparted lucidly to all the participants. After the instruction, each participant first received a demonstration of 3 minutes then practice session of 10 minutes and participants who secured 70% or above accuracy were selected to participate in final session of 40 minutes. For half of the participants endogenous cue i.e. arrow cue was presented at the central location while remaining half was given exogenous cue i.e. star cue presented at both the location, central or peripheral. Target and non-target were presented randomly. Participants indicated the presence of target by pressing the response key.

Results

Correct detection of target (hit rates), incorrect detection (false alarm) and reaction time (RTs) were recorded for each participant as sustained attention task performance measures. Analysis of variance (ANOVA) was computed to examine the main and the interaction effects of independent variables.

Reaction Time

The effect of cue type on reaction time performance was significant $F(1, 18) = 6.76$, $p = 0.018$, partial $ç^2$) = .273). Exogenous cue improved RT performance (Exo: M= 224.55 ms; Endo: M = 319.43 ms). The nonsignificant effect of time period indicates that both the cues help to maintain the RT performance throughout time periods and prevent the classic vigilance decrement. The effect of cue validity was not significant though the separate t test analyses yielded different findings (see figure 1). For exogenous cue, t tests (t (9) = 3.39, p =.009) showed benefit of valid (M = 210.18ms) cues over invalid cues (M= 341.31 ms) and neutral cue (M= 316.65 ms; t (9) = 2.25, p =.05). In endogenous cue valid cues (M 258.02 ms) speeded performance than invalid (M = 341.68) cues (t (9) = 3.26, p =.01). none of the interaction was found significant.

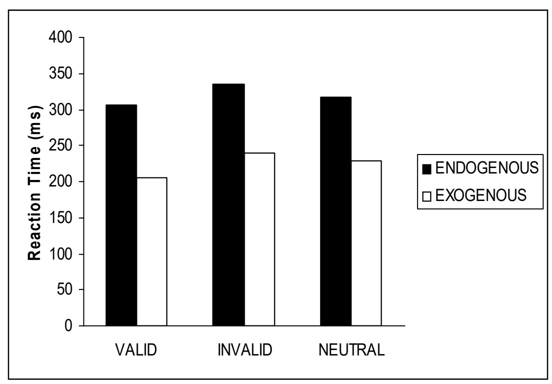

Figure 1. Reaction time as a function of cue type and cue validity. Valid, Invalid and Neutral depicts three cue validity.

Correct Detection

The effect of cue validity was significant, $F(2, 36) = 46.76$, $p < 0.01$, partial ç2= .722). In both the cue types, participants had highest accuracy with valid cue (Endo: M= 86.62%, Exo: M= 86.45%) in comparison to invalid (Endo: M= 74.65%, Exo: M= 77.03%) and neutral (Endo: M= 72.86% Exo: M= 69.23%) cues. Cue type has no effect on correct detection performance, F (1, 18) =.016 p=.901. Mean result also indicated that correct detection performance was almost similar in both the cue types (Endo: M= 78.04%, Exo: M=77.57%). Correct detection performance was maintained across time period (Fig 2) as time period failed to produce significant effect, F (3, 54) = .841, p=.477. None of the interactions were reported significant.

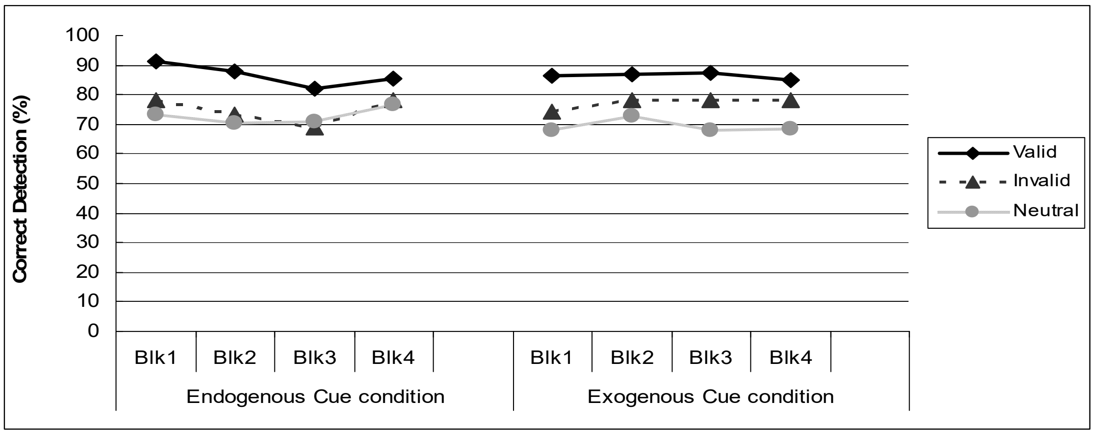

Figure 2: Correct detection as a function of cue type, cue validity and time period. Blk=Time Block of 10 min each.

Incorrect Detection

The mean of overall incorrect detection performance indicated that participants committed more error in exogenous cue type (M = 32.22 %) than endogenous cue type (M=26.89 %). Although the effect of cue type was not significant, $F_{(1, 18)}$ = .523, p=0.48. The ANOVA result shows that the effect of was cue validity was significant, F (2, 36) = 17.01, p<0.001 (partial $ç^2$ =.486). Participants committed less error in detecting targets in valid cue condition (Endo: M= 20.67% Exo: M= 23.19%,) whereas, False alarm was higher in invalid (Endo: M= 28.83%; Exo: M= 43.99%) and neutral cue condition (Endo: M= 31.19 %; Exo: M= 32.50 %). The interaction effect of cue validity and cue type was also significant, F (2, 36) = 4.57, p<0.017 (partial $ç^2$=.202). As in fig 3 we can see that neutral cues leads more errors with endogenous cues while with exogenous cues invalid cues resulted in most inaccurate responses. The effect of time period was not found significant.

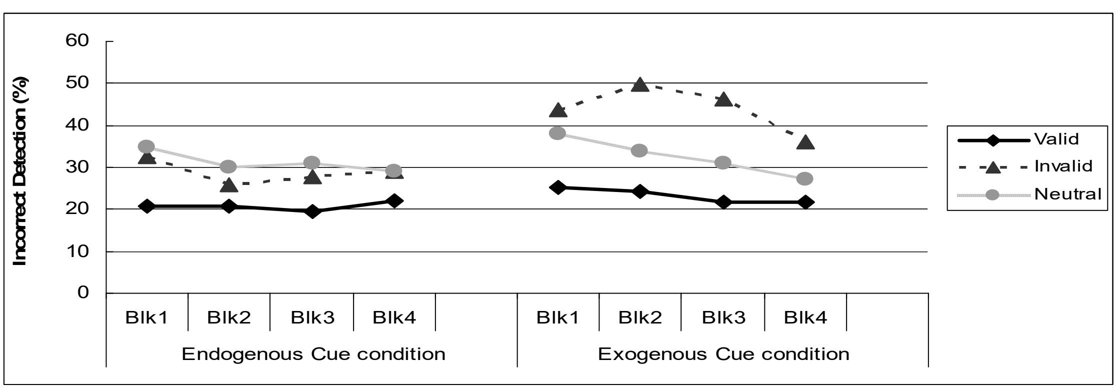

Figure 3. Incorrect detection as a function of cue type, cue validity and time period. Blk=Time Block of 10 min each.

Cost-benefit analysis

To study the cueing effect, combined RT cost + benefit (invalid cue RT- valid cue RT), separate RT benefit (neutral cue RT- valid cue RT) and separate RT cost (neutral cue RT – invalid cue RT) were computed. These data were further submitted to 2 (cue type: Endogenous & exogenous) x 4 (time period: 4 blocks of 10 min each) with repeated measure on last factor.

The obtained result demonstrated that participants got more benefit of valid cue under exogenous cue type (M=25.81) in comparison to endogenous cue type (M=10.8). However, the effect of cue type on separate RT benefit was not significant. Moreover, the effect of time period was significant, $F (3, 54) = 2.93$, $p = 0.042$, partial $ç^2 = 0.140$. The findings on RT costs also indicated that participants showed minimum amount of RT cost with invalid cue in exogenous cue type (M= 10.62) while maximum cost was seen in endogenous cue type (M= 19.15). However, the effect of cue type on RT cost was not found significant, while the interaction of cue type and time period was significant, $F (3, 54) = 3.32$, $p < 0.026$ (partial $ç^2 = 0.156$) which indicated more costs and less benefit with endogenous cue type across time periods than exogenous.

Thus, the obtained result on experiment 1 indicated that valid cue facilitated the performance whereas inhibitory effect of invalid cue was found. Result on RT performance measure supports our first hypothesis that benefit of exogenous cue would be more than endogenous cue on vigilance task performance as participants were faster in detecting target in exogenous cue type in comparison to endogenous cue type. Although the cue type had no effect on correct detection and incorrect detection performance measures. On the basis of result of experiment 1 exogenous cue was finalized for experiment 2 to examine facilitatory and inhibitory effect of stimulus onset asynchrony (SOA) on it.

Experiment 2

Experiment 2 was designed to study the effect of stimulus onset asynchrony on cued vigilance task performance. Exogenous orienting was used with the three different levels of SOA (250, 450, and 800ms) to find out how facilitation and inhibition would change when the time interval between the cue and target presentation (i.e., SOA level) was varied.

Participants

Total 30 students of Banaras Hindu University were randomly assigned into three SOA (200, 450 & 800 ms) conditions. Participants' age ranged from 19 to 25 years with the mean age of 21.37 years. All the participants had normal or corrected to normal visual acuity of 6/6.

Experimental design

A 3 (3 SOA levels: 200, 450, 800 ms) x 3 (Cue validity: valid, invalid and neutral) x 4 (time periods: 4 block 10 min. each) mixed factorial design was employed with repeated measure on last two factors. Three levels of stimulus onset asynchrony (SOA) were manipulated as between subject's factor. Cue validity and time period were manipulated as within subject factors.

Procedure

Method and procedure of experiment 2 were same as experiment 1 with difference that only exogenous orienting was used at three different levels of SOA (200, 450 and 800ms).

Results

Reaction Time

Participants were faster in detecting target in 200ms SOA level (M= 291.25 ms) while slower in 450ms (M=380.13 ms) and 800ms SOA levels (M= 441.81 ms). The ANOVA result also indicated that the significant effect of SOA level, F (2, 27) = 3.238, p<0.055 partial ç^2=.193. Although, the effect of cue validity was not significant, but mean result indicated that in 200ms and 450 ms SOA level valid cue (200ms: M= 264.02 ms; 450ms: M=375.81 ms) lead to faster detection of target in comparison to invalid (200ms: M= 333.629; 450ms: M=382.042) and neutral (200ms: M= 276.10 ms; 450ms: M=382.55 ms) cues. However, in 800ms SOA level participants were slightly faster in neutral cue (M=435.3 ms) in comparison to valid (M=439.031 ms) and invalid (M=451.09 ms) cue. The effect of time period was not significant indicated that performance decrement was not seen in any of SOA levels. None of the interactions were found significant.

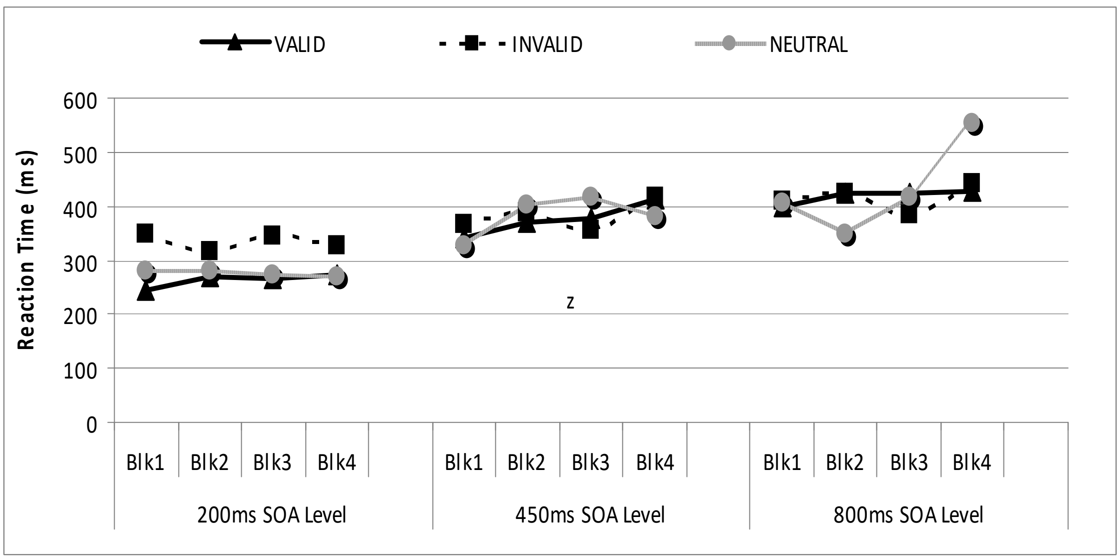

Figure 4. Reaction time (RT) as a function of SOA level, cue validity and time period. Blk=Time Block of 10 min each.

Correct Detection

The overall correct detection performance was maximum in 200 ms (M=80.93%) SOA level in 800 SOA (M=68.95%) level participants detected least no of target. The effect of SOAs on was significant, F (2, 27) = 4.570, p<0.02 (partial ç^2= 0.253). The effect of cue validity was also significant, F (2, 54) = 65.529, p= < 0.000 (partial ç^2=.708), indicated that in all SOA levels, correct detection performance was better in valid cue (200ms: M=93.03%; 450: M=83.46%; 800ms: M=81.49%) condition followed by neutral (200ms: M=77.47%; 450: M=71.79%; 800ms: M=65.28%) and invalid (200ms: M=72.31%; 450: M=59.33%; 800ms: M=60.28%) cue condition. The effect of time period and other interactions were not found significant.

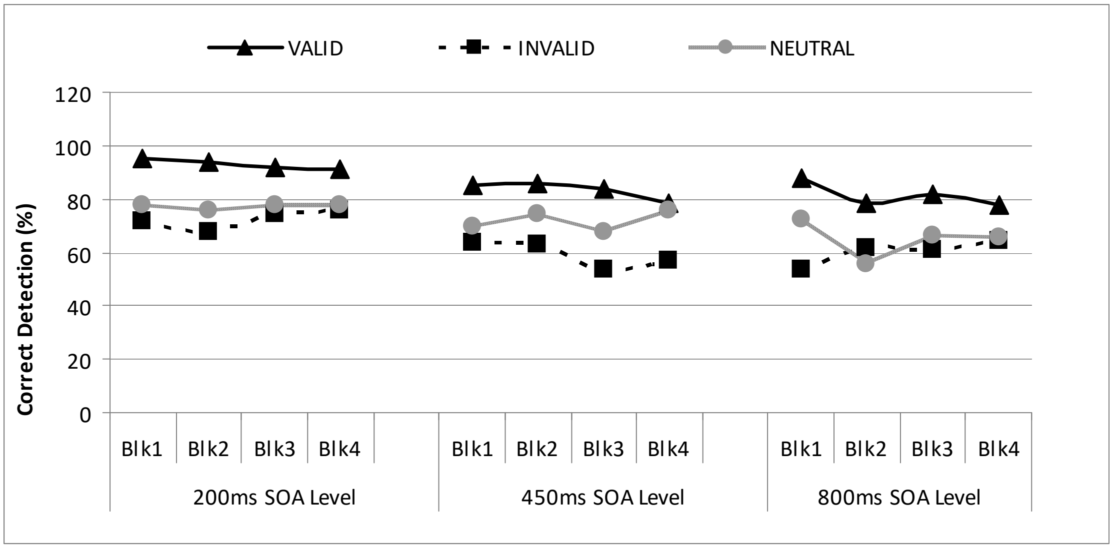

Figure 5. Correct detection as a function of SOA level, cue validity and time period. Blk=Time Block of 10 min each.

Incorrect Detection

The participants committed less error in 800ms (M=20.37%) SOA level followed by 450ms (M=21.61%) and 200ms (M=26.47%) SOA levels. The effect of SOA level was not significant, F (2, 27) = 0.387, p<0.682. The main effect of cue validity was marginally significant, F (2, 54) = 2.84, p<0.067 partial ç^2=0.095, indicated that participants committed fewer false alarm in valid cue (200ms: M=22.50%; 450: M=19.81%; 800ms: M=14.27%) as compared to invalid (200ms: M=27.24%;t450: M=22.93%; 800ms: M=23.77%) and neutral (200ms: M=29.67%; 450: M=22.09%; 800ms: M=23.06%) cues. The interaction of cue validity, block and SOA level was also significant, F (12, 162) = 1.83, p<0.047 partial ç^2=0.119, indicated that cue validity differently affected the incorrect detection performance across the time period in all the SOA level conditions.

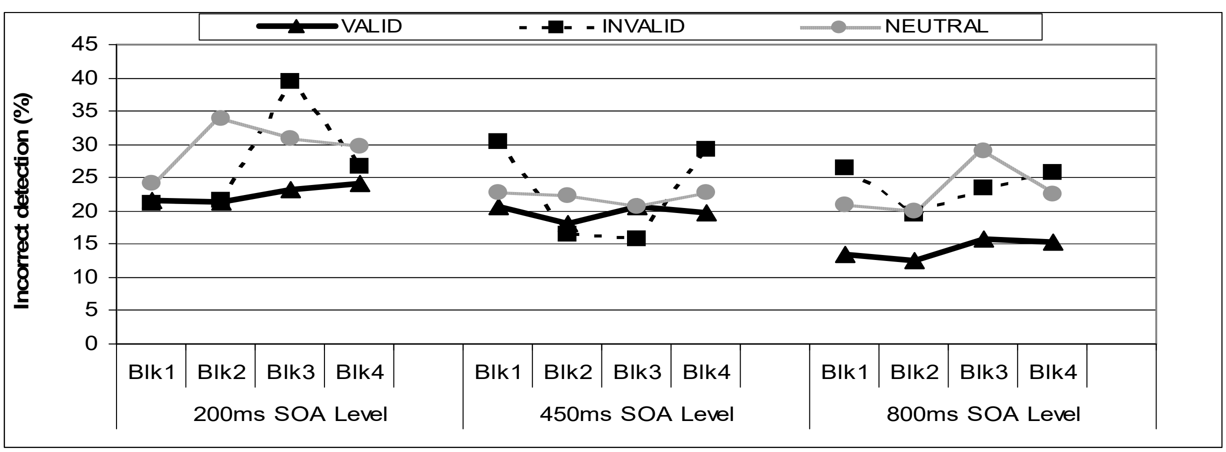

Figure 6. Incorrect detection as a function of SOA level and cue validity. Blk=Time Block of 10 min each.

Cost benefit analysis

Further combined RT cost and benefit and separate RT benefit and separate RT cost were computed to see the cuing effect. These data were further submitted to 3 (SOA: 200, 450 & 800 ms) x 4 (time period: 4 blocks of 10 min each) with repeated measure on last factor. None of the main and interaction effect was found significant. Although the maximum RT cost + benefit was found better with shorter SOA i.e. 200 ms (M= 50.63 ms) in comparison to longer SOAs (450 ms: M= 16.23ms; 800 ms: M=20.25 ms)

The results of experiment 2 indicated that on reaction time and correct detection performance measures, participants perform better in shorter SOA i.e. 200 ms in comparison to longer SOAs (450 and 800 ms). But incorrect detection performance measure indicated that in shorter SOA (200 ms) participants committed maximum number of error while false alarms was reported minimum in longer SOA (800 ms). But the overall results indicate that under shorter SOA (200 ms) maximum facilitation of exogenous cue was found while at longer SOA performance became poorer which supports our second hypothesis.

Discussion

Two experiments were conducted in this study to know how endogenous and exogenous cues were helpful in minimizing the vigilance decrement. Experiment one was done to explore the cue validity effect with two cue type i.e. endogenous and exogenous during vigilance task. Experiment two was conducted to examine the interactive effect of three SOA levels and cue validity (200ms, 450ms and 800ms) in exogenous orienting during vigilance task.

Findings of experiment one showed that detection of target was faster in exogenous cue than endogenous cue. Thus, the RT results support our first hypothesis and goes in accordance with the previous researches (Giordano et al., 2009; Posner, 1980; Jonides, 1981; Pattyn et al. 2008; Sebestiani et al. 2009). In exogenous orienting condition attention was captured by the sudden onset of the cue and cognitive interpretation of the cue was not required, thus it takes less time to initiate. Whereas, in endogenous cue an arrow directing either right or left location was presented and it was meaningfully associated with particular location therefore must be interpreted by an observer in order to be used thus, require sufficient time for initiation of shift. Although the correct detection and incorrect detection performance were similar in both endogenous and exogenous cue types. Cue validity effect found in present study was consistent with previous researches (Bashinski & Bacharach, 1980; Rai, 2009; Singh 2011; Singh et al., 2006; Posner et al., 1978; Posner et al., 1980). Cue validity effect has emerged as a facilitator for all vigilance performance measures. On valid cue trial participants not only detected maximum number of targets but also committed fewer false alarms and took less time to respond. Moreover, facilitation of cue validity in reaction time performance was found more evident in exogenous cue than endogenous cue.

In experiment 1 endogenous and exogenous cue were used to see whether they minimized the decrement function during 40-min vigilance task. In experiment 1 time period effect was not found significant for any of the performance measures. Although, block wise deviation was seen for some performance measures but this deviation was non-significant. This suggested that although the exogenous cue lead faster detection, but both, endogenous and exogenous cues were helpful in the maintenance of attention for prolonged period of time (Pattyn & Soetens, 2004).

Further, the phenomena of facilitation and inhibition were examined in experiment

2 while manipulating 3 SOAs (200, 400 & 800 ms) as between subject factor. It was hypothesized that the phenomenon of facilitation and inhibition would differ at different stimulus onset asynchrony (SOA) levels. Literature suggested that exogenous cues were more effective when the interval between the cue and the target (SOA) was short while endogenous cues being effective at longer stimulus onset asynchrony (Jonides, 1981; Muller & Findlay, 1987; Muller & Rabbit, 1989). Results of experiment 2 revealed that participants received more benefits at 200 ms SOA level than 450ms and 800ms SOA levels. Participants were faster in detecting target in 200 SOA level and slowest in 800 SOA. Similarly, correct detection rate was better in shorter SOA i.e. 200 than longer SOA levels. In all the SOAs under valid cue, participants committed lesser number of false alarms and detected more target than invalid and neutral cue conditions. Cue validity failed to yield significant effect on reaction time performance. Reaction time result supported the findings of Jonides (1981) that expectancies about cue validity and predictive value have minimal effect on exogenous orienting than endogenous.

The findings of experiment 2 indicated that exogenous cue facilitate performance when stimulus onset asynchrony was shorter and consistent with the previous researches which suggest orienting initiated by exogenous cue to be rapid and transient. Hence, the peak facilitation for cued location occurred within 150 ms after cue onset, was followed by a decline between 150-300ms stimulus onset asynchrony. In present study, shorter SOA i.e. 200 ms facilitated the reaction time and correct detection performance as detection of target was faster and detection rate was higher in 200 SOA. Whereas, in longer SOA i.e. 450 ms and 800 ms, participants were less accurate and slower in detecting target. Thus, in exogenous orienting the peak facilitation in performance was found at shorter SOA while inhibition was found at longer one. Although the phenomenon of inhibition of return (IOR) was not seen here, as at longer SOA i.e. 800 ms performance was better under valid cue than invalid. Hence, the results on experiment 2 support our second hypothesis that the phenomenon of facilitation and inhibition would differ at different stimulus onset asynchrony (SOA) levels.

Limitations and Future recommendations

In the present study eye movement was not monitored which leaves the question unanswered whether the participants shifted their attention covertly or was the orienting accompanied by eye movement. In future, studies may be conducted along with monitoring eye movement in cuing. Moreover, studies should explore SOA levels with various exogenous cues to establish which type of exogenous cue was more effective.

Implications

This ability to remain vigilant over longer period of time is critical for various everyday tasks involving vigilance. Thus, by providing cue and arousing the observers we can deal with the untoward consequences of the vigilance decrement to some extent. Task of driving also includes the use of attentional components of selection, vigilance and control. Navigation through traffic requires the selection and processing of critical cues such as change in traffic signals, shifting of attention among the various sources of information such as voluntary shifting to traffic signals or involuntary shifting to honking car and sustained attention is required for long stretches of driving. Cues can be used to design effective websites for young as well as older adults as computers have enhanced the lives of people enabling them to maintain functional independence. Thus, the ability to attend over a period of time and orient attention is not only central to enjoyment of various hobbies but also essential to safety of people.

Conclusion

The findings of present study support previous researches that exogenous orienting being more effective than endogenous orienting. The effect of exogenous cue was also found in vigilance task. However, both the cues were able to prevent the decrement function and maintained the attention for longer period of time. Though the exogenous cue was reported beneficial for vigilance task but its benefits have some limitations. As exogenous orienting had maximum effect on performance when interval between cue and target (stimulus onset asynchrony, SOA) was short. Whereas, in longer SOAs, exogenous cue slightly inhibited the performance. Furthermore, cue validity effect was more visible on shorter SOA than longer one for exogenous orienting. In sum exogenous cue was more effective and its effectiveness limited to the shorter SOA.

References

Anton-Erxleben, K., Herrmann, K., & Carrasco, M. (2013). Independent effects of adaptation and attention on perceived speed. *Psychological Science*, *24*(2), 150–159. https://doi.org/10.1177/0956797612449178

Bahri, T. (1990). *Orienting of attention and Vigilance* [Unpublished doctoral dissertation]. Department of Psychology, Catholic University of America, Washington, DC, USA.

Barbot, A., Landy, M. S., & Carrasco, M. (2011). Exogenous attention enhances 2nd-order contrast sensitivity. *Vision Resarch, 51*(9),1086-1098. https://doi.org/10.1016/j.visres.2011.02.022

Bashinski, H. S., & Bacharach, V. R. (1980). Enhancement of perceptual sensitivity as the result of selectively attending to spatial locations. *Perception & psychophysics*, *28*(3), 241–248. https://doi.org/10.3758/bf03204380

Bocanegra, B. R., & Zeelenberg, R. (2011). Emotional cues enhance the attentional effects on spatial and temporal resolution. *Psychonomic bulletin & review*, *18*(6), 1071–1076. https://doi.org/10.3758/s13423-011-0156-z

Carrasco M. (2011). Visual attention: the past 25 years. *Vision research*, *51*(13), 1484–1525. https://doi.org/10.1016/j.visres.2011.04.012

Carrasco, M., & Barbot, A. (2014). How Attention Affects Spatial Resolution. *Cold Spring Harbor symposia on quantitative biology*, *79*, 149–160. https://doi.org/10.1101/sqb.2014.79.024687

Carrasco, M., & Yeshurun, Y. (2009). Covert attention effects on spatial resolution. *Progress in brain research*, *176*, 65–86. https://doi.org/10.1016/S0079-6123(09)17605-7

Dugué, L., Merriam, E.P., Heeger, D.J, & Carrasco, M. (2020). Differential impact of endogenous and exogenous attention on activity in human visual cortex. *Scientific Reports 10*, 21274 (2020). https://doi.org/10.1038/s41598-020-78172-x

Fuentes, L.J., Vivas, A.B., & Humphreys, G. W. (1999). Inhibitory tagging of stimulus properties in inhibition of return: Effects on semantic priming and flanker interference. *Quarterly Journal of Experimental Psychology, 52*(1)*,* 149-164. https://doi.org/10.1080/713755797

Giordano, A. M., McElree, B., & Carrasco, M. (2009). On the automaticity and flexibility of covert attention: a speed-accuracy trade-off analysis. *Journal of vision*, *9*(3), 1–10. https://doi.org/10.1167/9.3.30

Herrmann, K., Montaser-Kouhsari, L., Carrasco, M., & Heeger, D. J. (2010). When size matters: attention affects performance by contrast or response gain. *Nature neuroscience*, *13*(12), 1554–1559. https://doi.org/10.1038/nn.2669

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and performance* (Vol. XI, pp. 187-203). Hillsdale, NJ: Erlbaum.

Jonides, J., & Irwin, D. E. (1981). Capturing attention. *Cognition, 10*(1-3), 145–150. https://doi.org/10.1016/0010-0277(81)90038-X

Klein R. (1988). Inhibitory tagging system facilitates visual search. *Nature*, *334*(6181), 430–431. https://doi.org/10.1038/334430a0

Koenig-Robert, R., & VanRullen, R. (2011). Spatiotemporal mapping of visual attention. *Journal of Vision, 11*(14), Article 12. https://doi.org/10.1167/11.14.12

MacLean, K. A., Aichele, S. R., Bridwell, D. A., Mangun, G. R., Wojciulik, E., & Saron, C. D. (2009). Interactions between endogenous and exogenous attention during vigilance. *Attention, Perception, & Psychophysics, 71*(5), 1042–1058. https://doi.org/10.3758/APP.71.5.1042

Montagna, B., Pestilli, F., & Carrasco, M. (2009). Attention trades off spatial acuity. *Vision research*, *49*(7), 735–745. https://doi.org/10.1016/j.visres.2009.02.001

Müller, H. J., & Findlay, J. M. (1987). Sensitivity and criterion effects in the spatial cuing of visual attention. *Perception & Psychophysics, 42*(4), 383–399. https://doi.org/10.3758/BF03203097

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*(2), 315–330 https://doi.org/10.1037/0096-1523.15.2.315

Pattyn, N. & Soetens, E. (2004). Endogenous and exogenous attention in vigilance tasks. In *46th Annual Conference of the International Military Testing Association Proceedings.*

Pattyn, N., Neyt, X., Henderickx, D., & Soetens, E. (2008). Psychophysiological investigation of vigilance decrement: boredom or cognitive fatigue?. *Physiology & behavior*, *93*(1-2), 369–378. https://doi.org/10.1016/j.physbeh.2007.09.016

Pestilli, F., & Carrasco, M. (2005). Attention enhances contrast sensitivity at cued and impairs it at uncued locations. *Vision research*, *45*(14), 1867–1875. https://doi.org/10.1016/j.visres.2005.01.019

Pestilli, F., Viera, G., & Carrasco, M. (2007). How do attention and adaptation affect contrast sensitivity?. *Journal of vision*, *7*(7), 1–12. https://doi.org/10.1167/7.7.9

Posner, M. I., Nissen, M. J., & Ogden, W. C. (1978). Attended and unattended processing modes: The role of set for spatial location. In H.L. Pick Jr., & E. Saltzman (Eds.), *Modes of perceiving and processing information*. Hillsdale: Lawrence Erlbaum Associates.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology, 2*(3), 211–228. https://doi.org/10.1080/02643298508252866

Posner, M. I., Snyder, C. R. R., & Davison, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109*(2), 160-174. https://doi.org/10.1037/0096-3445.109.2.160

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology, 32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Rai, U. (2009). *Effect of visuo-spatial cuing on sustained attention task performance* [Unpublished doctoral dissertation]. Department of Psychology, Banaras Hindu University, Varanasi, U.P., India.

Remington, R., & Pierce, L. (1984). Moving attention: evidence for time-invariant shifts of visual selective attention. *Perception & psychophysics*, *35*(4), 393–399. https://doi.org/10.3758/bf03206344

Sebastiani, M., Casagrande, M., Martella, D., & Raffone, A. (2009). The effects of endogenous and exogenous spatial cueing in a sustained attention task. *Cognitive processing*, *10 Suppl 2*, S302–S304. https://doi.org/10.1007/s10339-009-0316-5

Singh, I. L., Greenwood, P. M., Parasuraman, R. (2006). Cued vigilance performance in young and old adults. *Psychological Studies, 51,* 7-11.

Singh, R. (2011). *Effect of cuing on sustained attention task performance in young and old adults* [Unpublished doctoral dissertation]. Department of Psychology, Banaras Hindu University, Varanasi, U.P., India.

Talgar, C. P., & Carrasco, M. (2002). Vertical meridian asymmetry in spatial resolution: Visual and attentional factors. *Psychonomic Bulletin & Review, 9*(4), 714–722. https://doi.org/10.3758/BF03196326

Tassinari, G., Aglioti, S., Chelazzi, L., Peru, A., & Berlucchi, G. (1994). Do peripheral non-informative cues induce early facilitation of target detection? *Vision Research, 34*(2), 179–189. https://doi.org/10.1016/0042-6989(94)90330-1

Wright, R. D., & Ward, L. M. (2008). *Orienting of attention*. Oxford University Press.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance, 16*(1), 121–134. https://doi.org/10.1037/0096-1523.16.1.121

Yeshurun, Y., & Rashal, E. (2010). Precueing attention to the target location diminishes crowding and reduces the critical distance. *Journal of vision*, *10*(10), 16. https://doi.org/10.1167/10.10.16

Yeshurun Y. (2004). Isoluminant stimuli and red background attenuate the effects of transient spatial attention on temporal resolution. *Vision research*, *44*(12), 1375–1387. https://doi.org/10.1016/j.visres.2003.12.016

Yeshurun, Y., & Carrasco, M. (2008). The effects of transient attention on spatial resolution and the size of the attentional cue. *Perception & Psychophysics, 70*(1), 104–113. https://doi.org/10.3758/PP.70.1.104

Yeshurun, Y., & Levy, L. (2003). Transient Spatial Attention Degrades Temporal Resolution. *Psychological Science, 14*(3), 225-231. https://doi.org/10.1111/1467-9280.02436

Acknowledgement: Authors wish to acknowledge the research grant received from IoE, BHU vide Development Scheme No. 6031 and partial financial support received from Malviya Centre for Ethics and Human Value, BHU.

Anil Kumar Yadav, Assistant Professor and Corresponding Author, Cognitive Science Laboratory, Department of Psychology, Banaras Hindu University, Varanasi, India. Email: anilyadav@bhu.ac.in

Shalini Dubey, Ph.D., Corresponding Author, Cognitive Science Laboratory, Department of Psychology, Banaras Hindu University, Varanasi, India. Email: dubey.saii@gmail.com

Trayambak Tiwari, Assistant Professor and Corresponding Author, Cognitive Science Laboratory, Department of Psychology, Banaras Hindu University, Varanasi, India. Email: trayambak@bhu.ac.in

Shreshtha Yadav, Assistant Professor and Corresponding Author, Cognitive Science Laboratory, Department of Psychology, Banaras Hindu University, Varanasi, India. Email: shreshtha@bhu.ac.in

Indramani L. Singh, Professor Emeritus, Cognitive Science Laboratory, Department of Psychology, Banaras Hindu University, Varanasi, India. Email: ilsingh54@gmail.com

Anju L. Singh, Associate Professor and Corresponding Author, Department of Psychology, Vasanta Kanya Mahavidhyalaya, College admitted to the privileges of Banaras Hindu University, Kamachha, Varanasi, India. Email: anjubhu@gmail.com