© Journal of the Indian Academy of Applied Psychology
July 2013, Vol.39, No.2, 174-181.

Top-down and Stimulus Driven Control over Visual Orienting during Vigilance

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Endogenous and exogenous orienting affect vigilance performance differently. Symbolically-presented endogenous cue is said to fabricate top-down control, whereas stimulus cue presented in exogenous orienting produces automatic and stimulus driven control on visual orienting. Present study examines the effect of these two modes of orienting on vigilance performance. Twenty students of Banaras Hindu University, with mean age of 21.5 years (age ranged from 19-24 years) participated in sensory visual detection task. An arrow was used as a cue in endogenous condition while a star was used as a stimulus cue in exogenous condition. These cues had high predictive value. Participants were required to detect randomly presented peripheral target (i.e., square of 3.3cm) over non-target (i.e., square of 3 cm) in 40-minute vigilance task. Results revealed that exogenous cue type elicited faster detection of target than endogenous cue. Furthermore, participants in both the cue types showed facilitatory effect of valid cues and inhibitory effect of invalid cues on vigilance performance.

Keywords: Top-down control, Stimulus-driven control, Orienting, Endogenous, Exogenous, Vigilance

In day-to-day life, we usually receive a variety of stimulation from our visual world. Few of them are relevant to our purpose and few are irrelevant. Thus, in our everyday life, it becomes essential to select visual information that is important for us in accomplishing the goals we want to achieve (Mulckhuyse & Theeuwes, 2010). Attention, a cognitive mechanism does perform this activity for us. It focusses on relevant aspects of the environment at the expense of others. Thus, it reduces the inputs we received from an environment full of stimuli (Vogt, Houwer, Moors, Damme, & Crombez, 2010).

Shifting or orienting attention in visual space enriches the selection capacity of attention. Orienting attention toward the target location at which a target stimulus is about to appear not merely facilitates detection of target but also enhances discriminative decision about the perceptual property of target (Lupiáñez, Decaix, Siéroff, Chokron, Milliken, & Bartolomeo, 2004). Directing or orienting attention to an object in space may be automatic (e.g. when honking car attracts our attention) or it may be in more controlled way for example, when we are waiting for traffic light to appear green from the red or yellow (Bartolomeo, Decaix & Sieìroff, 2007).

Endogenous and Exogenous Orienting

When shift of attention occurs voluntary in accordance with our goals and intentions, it is called endogenous orienting or top-down orienting. When attention is captured involuntarily by external sensory stimulation, it is known as exogenous or stimulus-driven orienting. Endogenous orienting was considered as part of the "intellectual domain" while, exogenous orienting as part of the "sensory domain" by James in 19th century (as cited in Wright & Ward, 2008).

These two modes of control over covert visual orienting have been studied by using various location cues. In endogenous orienting, symbolic cues such as an arrow either pointing toward left or right, or any stimulus indicating the expected target location, are usually presented at the central location (Posner. 1980). Symbolic cues are meaningfully associated with a particular location

and therefore, must be interpreted by an observer in order to be used, e.g. observer has to process whether the direction of cue is right or left. Thus, the initiation of an attention shift by an endogenous cue is goal–driven (Wright & Ward, 2008). On the contrary, exogenous orienting usually consists of direct cues; these are underlines, outline boxes, or novel stimuli that are presented in close proximity to the expected target location (Posner, 1980; Yantis & Hillstorm, 1994; Oonk & Abrams, 1998). Direct cues produce their effect by virtue of being physically close to the target location. In exogenous orienting, attention is captured by the sudden onset of the cue and cognitive interpretation of the cue is not required (Jonides, 1981; Wright & Ward, 2008). Due to the onset of the cue, some form of sensory activation occurs at the cued location and produces facilitatory effect on target detection that appear shortly afterward at the same location (Wright & Ward, 2008). This is why initiation of attention shift by an exogenous cue is said to be stimulus-driven and automatic.

Despite this, four other differences have been observed by Jonides (1981) between these two kinds of cues. First, processing of endogenous cue requires more cognitive resources than exogenous cue. Second, it has been generally reported that participants might ignore endogenous cues but are unable to ignore exogenous cues. Third, experimental differences usually observed are that exogenous cues had bigger effects than endogenous cues. Fourth, expectancies about cue validity and predictive value have minimal effect on exogenous orienting than endogenous orienting. Time course of cue effectiveness is another essential difference between two kinds of orienting. 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). On the contrary 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).

Posner location cueing paradigm is commonly used to study covert visual orienting. Validity is an imperative aspect that affects performance in this paradigm. It has been found that facilitation in performance is only found on valid cued trial in which cue correctly indicated the location of target in comparison to those invalid cued trial in which target appeared elsewhere to the cued location (Posner, 1980; Posner & Cohen, 1984; Posner, Nissen & Ogden, 1978; Posner, Snyder, & Davidson, 1980). Frequency of valid cues is also an important factor to determine especially the effectiveness of endogenous orienting. When cue predict 70-80% target location correctly, endogenous cue produce its maximum facilitatory effect whereas exogenous orienting is less affected by frequency of valid cues (Jonides, 1981; Muller & Humphreys, 1991; Mayer, Dorflinger, Rao, & Seidenberg, 2004).

Orienting of Attention and Vigilance

Deterioration in the ability to remain vigilant for critical signals with time is a fundamental problem of vigilance (Davis & Parsuraman, 1982; Warm, 1984; Parasuraman, 1986). Various attempts have been made to overcome this decrement problem such as by manipulating event rate, by providing feedback, by giving caffeine intake or any other drugs, or by providing supplementary information about target onset, and so on. Orienting is also used in the same context by researchers (Bahri, 1990; Singh, Greenwood & Parasuraman, 2006) using vigilance paradigm. Their results showed that valid cue facilitated, whereas invalid cue inhibited detection performance. But, this benefit of valid cue was limited to the low event rate condition during vigilance task.

Sebestani, Casagrande, Martella, & Raffone (2009) reported 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. However, Rai (2009) and Singh (2011) have found that participants performed better with central cue in comparison to peripheral cue in sustained attention task. Moreover, the benefit of valid cue

evident in their study was consistent with previous researches.

In sum, it can be concluded that exogenous cue have greater effect on performance in comparison to endogenous cue but the effect of exogenous cue is transient. Orienting in response to exogenous cue not only begins quickly but also weakens rapidly. Endogenous orienting developed gradually as it requires processing of cue. Thus, it can be said that which type of orienting will be effective it depends on time of cue presentation or delay between cue presentation and target onset (Stimulus onset asynchrony, SOA). Moreover, these two types of orienting is largely studied with selective attention task but very few studies have attempted to explore its effect on sustained attention task performance.

In the present study, an attempt has been made to examine how top-down control produced by endogenous orienting and stimulus-driven control produced by exogenous orienting improve performance during vigilance task. It is also studied that how cue validity effect interact with these two modes of orienting and to affect vigilance performance. It was hypothesized that exogenous cue would have greater effect on vigilance performance and under valid cue performance would be better than invalid or neutral cue.

Method

Participants:

Twenty undergraduate and postgraduate students of Banaras Hindu University were participated in this experiment. They were randomly assigned into two experimental conditions (10 in endogenous cue type and 10 in exogenous cue type). Participants' age ranged from 19 to 24 years with the mean age of 21.5 years. All the participants had normal or corrected-to-normal visual acuity of 6/6.

Experimental Task:

The experiment was planned on *SuperLab*® 4.0 (Cedrus, 2007) and was displayed on a 15' colour monitor. Visual vigilance detection task with spatial location cues 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. Two types of cues were used. In endogenous cue condition, an arrow cue was used, and in exogenous cue condition, a star was used. Arrow cue was presented at the 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 did not 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. Then, a cue appeared on the screen for 250 ms. after cue, target or non target was displayed for 100 ms either in left or right periphery and then followed by blank screen which remained for 3150 ms (see figure 1). Each participant received 3150 ms. for taking decision 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 was used.

Design:

A 2 (Cue type: endogenous and exogenous) x 3 (Cue validity: valid, invalid and neutral) x 4 (Time period: 10 minutes block) mixed factorial design was used with repeated measure on the last two factors. A low event rate, i.e. 15 events per minute, was used. Cues were manipulated as valid, invalid, and neutral. Two types of cues, endogenous and exogenous, were manipulated as between subject factor and cue validity (valid, invalid and neutral) and time period (Four 10-min. blocks) were treated as within subject factors.

Procedure:

All the participants were required to give their written consent before participating in this study. Then, participants were tested for their normal visual acuity in the lab and biographical information regarding their age, gender, education, weight, knowledge of computer, medical practice etc. were taken from the participants. The instruction

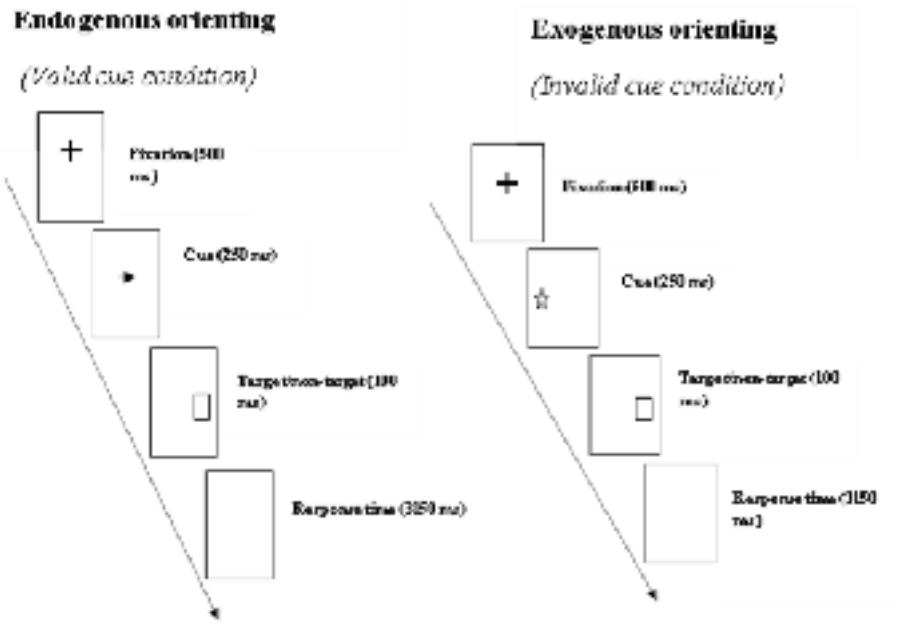

Figure 1. Sequence of events in task in endogenous and exogenous orienting.

with brief introduction about the task was imparted lucidly to all the participants. After the instruction, each participant first received a demonstration of 3 minutes to become familiar with the task. The practice session of 10 minutes was given and only those participants who secured 70% or more on correct detection (hit rates) during their practice session were allowed 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 the 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. The entire session lasted about 60 minutes

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. Perceptual sensitivity (d') was derived from the percentages of correct detection and incorrect detection for each experimental condition. Analysis of variance (ANOVA) was computed to examine the main and the interaction effects of independent variables.

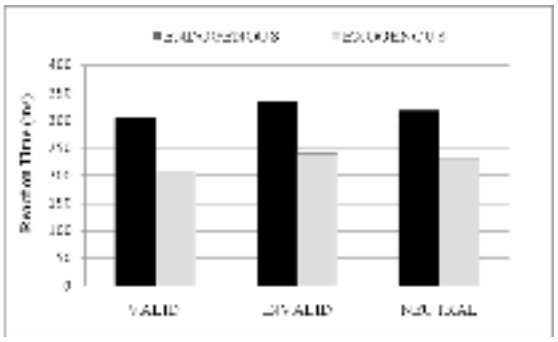

Figure 2: Reaction time as a function of cue type and cue validity.

Reaction Time (RT):

Reaction time (RT) data was analysed in 2 (Cue type: Endogenous and exogenous) x 3 (cue validity: Valid, invalid and neutral) x 4 (Time period: 4 blocks of 10 min. each) analysis of variance (ANOVA) with repeated measure on last two factors. The main effect of cue type was significant, $F_{(1, 18)} = 6.76$, $p<0.018$, (partial $eta^2 = .273$) indicated that participants were faster in detecting targets with exogenous cue (M= 224.55

ms, SD= 61.52) than endogenous cue (M= 319.43 ms, SD= 108.65). The separate ANOVA showed significant main effect of cue validity in exogenous cue type, $F_{(2, 18)} = 5.55$, $p < 0.013$ (partial $eta^2 = .382$) and but this effects was not found significant in endogenous cue type, $F_{(2, 18)} = 0.72$, $p = 0.501$. Although in both the condition participants were faster in detecting targets in valid cue condition than invalid and neutral cue condition (see Figure 2). Interaction effect of cue validity and time period, $F_{(6, 108)} = 2.59$, $p < 0.028$ (partial $eta^2 = .223$) was also found significant in exogenous cue type. The main effect of time period was not significant, $F_{(3, 54)} = .154$, $p = .926$ indicated that RT performance was maintained across time periods.

Correct Detection (Hit rates):

The data of correct detection were also analyzed in a same way as RT data. The main effect of cue validity was significant, $F_{(2, 36)} = 46.76$, $p < 0.001$, (partial $eta^2 = .722$) indicated that in both the cue type participants had highest correct detection in valid cue condition (Endo: M= 86.62%, SD= 10.34; Exo: M= 86.45%, SD= 9.50) in comparison to invalid (Endo: M= 74.65%, SD= 6.68; Exo: M= 77.03%, SD= 5.58) and neutral cue condition (Endo: M= 72.86%, SD= 12.23; Exo: M= 69.23%, SD= 10.26). The effect of cue type was not significant, $F_{(1, 18)} = 0.02$ $p = .901$. The main effect of time period was also not found significant, $F_{(3, 54)} = .841$, $p = .477$. Thus the correct detection performance was stable across time periods under both cue types (Figure 3).

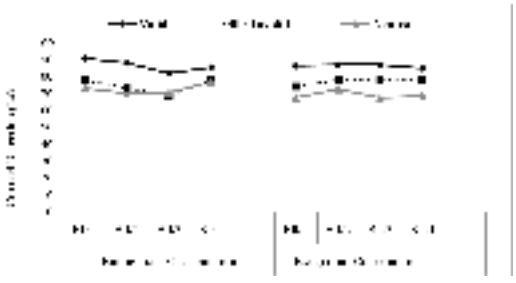

Figure 3: Correct detection as a function of cue type, cue validity and time period.

Incorrect Detection (False alarms)

The ANOVA result showed that the main effect of cue validity was significant, $F_{(2, 36)} = 17.01$, $p < 0.001$ (partial $eta^2 = .486$). Result indicated that participants committed less error in detecting targets under valid cue condition whereas, false alarms was also found higher under invalid as well as in neutral cue condition (as in figure 4). The effect of cue type was not significant, $F_{(1, 18)} = 0.52$, $p = 0.479$. However, the commission of error was higher in exogenous cue type (M= 32.22%, SD=21.8) than endogenous cue type (M=26.89, SD=19.22). The main effect of time period on incorrect detection performance was not significant, $F_{(3, 54)} = 0.84$, $p = 0.47$. The interaction effect of cue validity and cue type was significant, $F_{(2, 36)} = 4.57$, $p < 0.017$ (partial $eta^2 = .202$) which indicated that cue validity differently affected the performance in both the cue type.

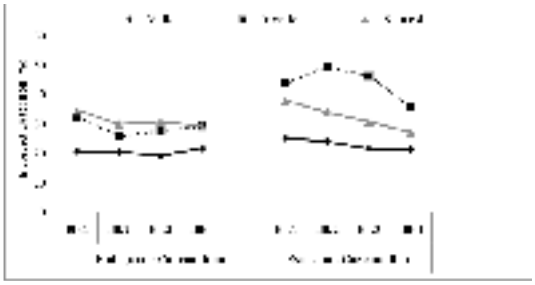

Figure 4: Incorrect detection as a function of cue type, cue validity and time period.

Sensitivity index (d')

The main effect of cue type on sensitivity index was not significant, $F_{(1, 18)} = .637$, $p = 0.435$ (partial $eta^2 = .034$). Sensitivity index of participants was found similar in both endogenous (M=1.63, SD= 0.61) and exogenous (M=1.42, SD= 0.81) cue types. The effect of cue validity was significant, $F_{(2, 36)} = 27.676$, $p < 0.001$ (partial $eta^2 = .606$). Mean result and Figure 5 also indicated that sensitivity was better reported under valid cue condition, in both endogenous (M=2.26, SD= 0.60) and exogenous cue type (M=2.21, SD= 0.81) in comparison to invalid cue (Endogenous: M=1.37, SD= 0.63, Exogenous: M=2.26, SD= 0.60) and neutral cue condition (Endogenous: M=1.25, SD= 0.61, Exogenous: M=0.87, SD= 0.65). Non significant main effect of time period indicated that sensitivity was not affected by time period as cue maintained the alertness of participants over time.

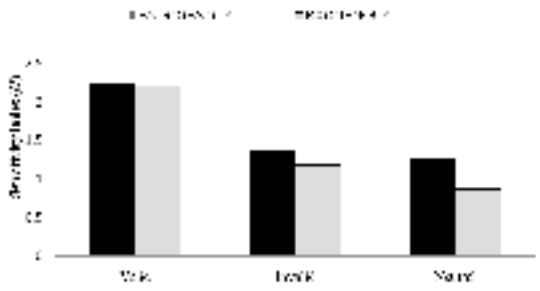

Figure 5: Sensitivity index as a function of cue type and cue validity.

Cost Benefit Analysis

In addition, a cost-benefit analysis was also done on the basis of obtained reaction time score to find out the cue validity effects. Separate RT benefit (neutral cue RT – valid cue RT) and separate RT cost (invalid cue RT – neutral cue RT) were computed. These data on separate RT cost and separate benefit analysis was further subjected to a 2 (Cue type: Endogenous and Exogenous) x 4 (Time period: 4 blocks of 10 min each) analysis of variance. 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 main effect of cue type on separate RT benefit was not significant, $F_{(1, 18)} = 0.26$, p=0.617. Moreover, the main effect of time period was found significant, $F_{(3, 54)} = 2.93$, $p<0.042$, partial $eta^2 = 0.140$. 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 main effect of cue type on RT cost was not found significant, $F_{(1, 18)} = 0.065$, p=0.801 while the interaction of cue type and time period was significant, $F_{(3, 54)} = 3.32$, $p<0.026$ (partial $eta^2 = 0.156$) which indicated more costs and less benefit with endogenous cue type across time periods than exogenous.

Discussion

Voluntary effect of endogenous orienting and reflexive effect of exogenous orienting have been examined in this study. The result clearly showed the benefit of sudden onset of peripheral cue i.e. exogenous cue over voluntary cue i.e. endogenous cue on reaction time performance. Exogenous cue elicited faster detection of target than endogenous cue. Thus, the reaction time result goes in accordance with the previous researches (Posner, 1980; Jonides, 1981; Jonides & Yantis, 1988; Yantis & Jonides, 1990; Sebestani, Casagrande, Martella & Raffone, 2009). The reason behind late response in endogenous cue condition is an arrow cue. Arrow cue require interpretation by observer in order to be used hence, it take sufficient time for initiation of response. In exogenous orienting, a star was presented at the location of target just prior to the target onset; hence, attention is captured by the sudden onset of star cue and cognitive interpretation of the cue is not required which has taken less time to initiate response. Cost benefit analysis of the finding also shows that maximum benefit of valid cue as well as minimum cost of invalid cue, both are found in exogenous orienting condition. However, the differential effect of these two types of orienting is not seen on correct detection and incorrect detection performance. However, the exogenous orienting has greater impact on performance but non significant effect of time period on all performance measures clearly reveal that both the cue types i.e. exogenous and endogenous maintained the alertness of participants thus prevent from decrement function across time period on vigilance performance.

Cue validity further affected vigilance performance. In both endogenous and exogenous orienting, cues were highly predictive, as 80% trials were validly cued, 10% invalid and 10% neutral cued trials. Cue validity effect has emerged as a facilitator for all vigilance performance measures. On valid cued trial, participants not only detected maximum number of target while committed fewer false alarms and also took less time to respond. Moreover, facilitation in reaction time performance was found to be more evident in exogenous cue than endogenous cue. Perceptual sensitivity of participants also reported better under valid cue than invalid and neutral cues. The benefit of valid cue obtained in the present study is consistent with the previous

findings (Posner, 1980; Singh, Greenwood & Parasuraman, 2006; Rai & Singh, 2007; Singh, Upadhayay & Singh, 2010). These findings suggest that the benefit of valid cues occurs because the focus of attention is shifting to the cued location, thereby facilitating sensory processing of the target at that location (Downing, 1998; Singh et al., 2010).

Conclusion

Thus, the findings of the present study confirm our hypotheses that exogenous cue would have greater effect on vigil performance and valid cue, in general, would facilitate vigilance performance. Endogenous cue requires top-down processing in terms of interpreting direction of cue and then shifting attention on the basis of this interpretation. This is why endogenous orienting slows down the performance, whereas, exogenous orienting works on sensory basis and it produces its effect by appearing suddenly in close proximity to the target or nontarget locations. Thus, exogenous orienting is governed by stimulus-driven control. In sum, both cue types, i.e. endogenous and exogenous, maintain vigil performance over time period and, hence, reduce vigilance decrement function. Predictive value of cues also affected the performance and this is why facilitation of valid cue can be seen on all performance measures.

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Received: February 20, 2013
Revised: March 27, 2013
Accepted: April 30, 2013

Acknowledgement: This research was supported by the Indian Council of Social Science Research (ICSSR) to the first author.

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ISSN 1028-9097

Journal of Behavioural Sciences

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University of the Punjab
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