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Time Course of Visual Attention Across Perceptual Levels and Objects

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Abstract

Theories of shifts of visual attention based on attentional blink or dwell time do not directly address shifts of attention across different levels (global or local) involving multiple objects. Two experiments were conducted employing the attentional dwell time paradigm to investigate the shifts of visual attention between objects selected at same or different levels. Participants were instructed to identify two successive compound stimuli at a pre-specified level (global or local) presented at two different locations with variable SOA. The initial pair of locations in which the stimulus was presented was fixed in Experiment 1 but not in Experiment 2. Experiment 1 results showed very little impairment for second target identification when both the targets were at the global level. Attentional shift was better with both targets at the same level compared to different levels. Experiment 2 results showed that local followed by global target identification is difficult at short SOAs compared to other conditions. The results indicate that scope of attention affects the time course of visual attention. Global processing could be performed with very little capacity limitation simultaneously with distributed attention. The default mode of attention might be distributed and attention becomes focused for target identification. Different mechanisms may underlie shifts in focused attention between different locations and changes in attentional set required by changes in perceptual levels.

Key words: scope of attention; distributed attention; time course; global-local processing; shifts of attention; attentional resource

PsycINFO classification codes: 2346, 2323

Complex objects like faces or scenes are perceptually organized in terms of parts and wholes resulting in a hierarchical structure. An object is considered a hierarchical object when its small patterns or objects are subsumed within large patterns or objects. A face, for example, might be considered a global or whole object and nose or lip can be considered a local part of that whole object. Global-local is a relative term and it depends on the spatial scale that is used as the reference frame (Navon, 2003). Studies on global-local processing using hierarchical stimuli have shown better performance for target identification at the global level compared to the local level (Navon, 1977; Navon, 2003).

Information at different levels can be obtained by attending to a particular level of an object (Robertson, Egly, Lamb, & Kerth, 1993). For example, one can attend to an object at the global level (face) and shift to another object at either the local (nose, eye etc) or the global level (another face). Using a double identification task, Ward (1982) showed faster identification time for the target appearing at the same level compared to different levels as the preceding target across trials. The effect was obtained for both the global and local levels and this effect has been called the level repetition effect (Hübner, 2000; Ward, 1982). The level repetition effect suggests that perceptual levels play a key role in shifting attention between objects in space over time. The level repetition effect addresses identification of targets appearing at the same compared to different level across trials and does not provide a direct estimate of shifts of attention between objects identified at the same or different perceptual levels.

Studies investigating the time course of shifts of visual attention employing rapid serial visual presentation (RSVP) or the attentional dwell time paradigm have shown that the identification of the first target impairs the identification of the second

target when they appear in close temporal proximity (Duncan, Ward, & Shapiro, 1994; Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1994; Ward, Duncan, & Shapiro, 1996). The phenomenon is called the attentional blink (AB). The impaired identification of the second target suggests that visual attention might be a slow system with a rate of 200-500 ms per item (Duncan et al., 1994; Logan, 2005; Raymond et al., 1992; Shapiro et al., 1994; Ward et al., 1996).

It has been argued that the impaired performance of the second target (T2) is due to the limited capacity of attentional resources required to encode the first target (T1) in visual short term memory (VSTM) (Chun & Potter, 1995; Duncan et al., 1994; Shapiro et al., 1994; Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2005; Ward et al., 1996). Shapiro and colleagues have argued that the blink is due to the interference due to distractors (Shapiro et al., 1994). In contrast to the limited capacity accounts of AB, Di Lollo and his colleagues (2005) have proposed a temporary loss of control theory in which AB is due to the participant's inability to maintain the appropriate levels of control when targets are separated by distractors (Di Lollo et al., 2005). Moreover, Olivers and Nieuwenhuis (2006) have argued that AB is due to the overinvestment of the central resources to the first target and showed an attenuated AB in the distributed compared to the more focused attention condition. This suggests that shifts of visual attention depend on the scope of attentional allocation to the objects.

Majority of the AB studies have overlooked the importance of distributed attention in shifting attention and emphasized focused attentional processing. A change in the scope of attention has been linked to other differences in visual processing (Srinivasan, Srivastava, Lohani, & Baijal, 2009; Treisman, 2006). Distributed attention has been shown to play a critical role in obtaining global

information or gist of a visual scene and computing statistical representations of objects in a visual display (Treisman, 2006). Studies investigating the scope of attention have used compound stimuli and global-local processing has been associated with differences in the scope of attention (Lamb & Robertson, 1988; Robertson et al., 1993). These studies have shown faster global target detection with high compared to low locational uncertainty indicating increase in the scope of attention with increase in location uncertainty (Lamb & Robertson, 1988). Based on these findings, global processing has been linked to a broad scope of attention and local processing has been linked to a narrow scope of attention (Lamb & Robertson, 1988; Robertson et al., 1993). Given the putative links between scope of attention and global-local processing, the time course of attention might be different for different perceptual levels associated with differences in the scope of attention.

Recently, many studies have investigated the changes in the spatial extent of focal attention over time by typically requiring the identification of targets in two different streams and investigating lag-1 sparing (Jefferies & Di Lollo, 2009; Jefferies, Ghorashi, Kawahara, & Di Lollo, 2007; Shih, 2000; Visser, Zuvic, Bischof, & Di Lollo, 1999; Yamada & Kawahara, 2007). While Visser et al. (1999) found lag-1 sparing only when both the targets were presented in the same stream, Shih (2000) found lag-1 sparing when the second target was presented in a different stream. More recently, Jefferies and her colleagues (2007) have shown lag-1 sparing with targets in separated streams, but only when observers had no advance information of the location of the first target. They have argued that when the first target's location is known in advance, then attention is more focused on that stream and therefore the second target identification is impaired when it appears in the different stream. When

the first target location is not known, attention is more distributed over space, encompassing both the streams resulting in lag-1 sparing.

While the studies by Jeffries and colleagues have investigated the scope of attention over time, they have focused mostly on lag 1 sparing. They have not directly manipulated the scope of attention using stimuli that would require changes in the scope of attention. Other AB studies manipulating the scope of attention indirectly have shown improved second target performance in more distributed attention conditions compared to more focused attention conditions (Olivers & Nieuwenhuis, 2006). These findings indicate that the magnitude of AB reduces in the distributed compared to the more focused attentional condition.

Furthermore, studies examining the temporal limitations of scope of attention have shown an attenuated AB for a second target appearing at the global level compared to the local level (Crewther, Lawson, & Crewther, 2007; Lawson, Crewther, & Crewther, 1999; Lawson et al., 1998). In these studies, participants were asked to identify a first target at a pre-specified level and then a second target that could appear either at the global or local level. In addition, there were distractor compound stimuli between first and second targets. The AB was approximately 1-2 seconds substantially larger than the standard AB of 200-500 ms (Duncan et al., 1994; Raymond et al., 1992; Shapiro et al., 1994; Ward et al., 1996). Interestingly, no level repetition effect was found, that is the magnitude of AB was not dependent on the level at which the first target appeared (Crewther et al., 2007). In addition, the perceptual uncertainty of the second target may have led to better global compared to local second target identification irrespective of the first target perceptual level (Jefferies et al., 2007; Lamb & Robertson, 1988; Olivers & Nieuwenhuis, 2006). The findings from previous studies indicate that perceptual or location uncertainty changes

the scope of attention that in turn affects the shifts of visual attention across objects in space (Crewther et al., 2007; Jefferies et al., 2007).

Previous studies have investigated the relationship between shifts of visual attention and scope of attention by manipulating perceptual levels (Crewther et al., 2007) or target locations (Lamb & Robertson, 1988; Jeffries et al., 2007). The main purpose of the study was to investigate the role of the scope of attention in shifting attention from one object to another object by manipulating both perceptual level and locational uncertainty. So far, no study has been done involving shifts in perceptual levels as well as shifts in attention between objects/locations to measure the time course of shifts of visual attention. Two experiments were conducted employing the attentional dwell time paradigm, in which two targets are presented in sequence at two different locations with variable SOAs. Both the experiments had four conditions based on the levels in which a target appeared and shifts of attention across same (no-switch: global to global and local to local) and different (switch: local to global and global to local) levels. In Experiment 1, participants were informed about the order of the perceptual scale (to which the participant attend and identify the target) and the order of the location pairs (left/right or top/bottom) of the target. However, in Experiment 2, the location pair in which the first target would appear was unknown to the participants.

In both experiments, we expected the global target identification to be better than the local target identification and performance to improve with SOAs. Given that there is no uncertainty in the perceptual level of the second target, in contrast to Crewther et al. (2007), we expected a more typical AB and a level repetition effect. However, we expected differences in scope of attention to affect AB and the level repetition effects. Similar to Jefferies et al. (2007), we expected that in the first

experiment the scope of attention would be less distributed or more focused compared to the second experiment. In Experiment 1, this would mean attention would tend to be more focused and any need for local target detection would keep attention focused except for the global-global condition in which the task would demand that attention is distributed. In contrast, in Experiment 2, the larger location uncertainty would result in attention being more distributed to start with and if the default nature of scope of attention is to go from distributed to focused depending on the task requirement, then there should be a cost for the non-default strategy of going from focused to distributed attention (local-global condition).

EXPERIMENT 1

Attention to a global cue facilitates target identification at both the perceptual levels. However, attending to a local cue facilitates only local target detection (Robertson et al., 1993). In addition, Ward (1982) showed response advantage for target presented at the same level compared to different level as the previous target. Lamb and Robertson (1988) have argued that the facilitation is due to the mechanisms activated for a particular perceptual level from the previous trial. Consistent with the mechanism activation hypothesis, Di Lollo and colleagues (2005) have argued that the configuration of the attentional system plays a critical role in AB. Hence, we expected that shifting attention across objects attended at the same perceptual level might take less time than objects attended at different perceptual levels. In addition, we expected a global advantage especially when both targets had to be identified at the global level which may result in participants using a large scope of attention especially at very short SOAs.

Method

Participants

Forty five student volunteers (global-global = 11, global-local = 12, local-local = 10, local-global = 12) from University of Allahabad participated in the experiment. All of them had normal or corrected-to-normal vision and were naive to the purpose of the study.

Apparatus and Stimuli

Compound letters and digits were used as stimuli in the experiment. Global stimuli were constructed from local stimuli arranged in a 4x5 matrix. Global stimuli subtended a visual angle of $3.21^\circ \times 4.72^\circ$ and local stimuli subtended a visual angle of $0.40^\circ \times 0.56^\circ$. The letters “S” and H” were used as targets with the letter “E” as a distractor with compound letter stimuli. The digits “4” and “6” were used as targets with the digit “0” as a distractor with compound digit stimuli. The total number of stimuli used in the experiment was eight (four of which are shown in Figure 1). The targets were presented 4.76° from the central fixation. The size of the fixation sign was $0.95^\circ \times 0.95^\circ$. All the stimuli were white presented on a black background. The stimuli were presented using DirectRT (Empirisoft Corp, USA) on 19” CRT monitor with a resolution of 1024x768 and refresh rate of 100 Hz. Observers sat a distance of 80 cm from the computer monitor.

Insert figure 1 about here

Procedure

Each trial began with a fixation plus sign at the centre of the screen (Figure 2). Participants initiated the trial by pressing the space bar key. After 500 ms, both the targets were presented at two different locations with a variable SOA (0, 200, 400, 600, 900 ms). The targets were presented at four different locations (right, left, up, down). Participants were instructed to identify the target at a pre-specified possible locations and order of levels for the first and second targets resulting in four different between-subject conditions (global-global, global-local, local-global, local-local). For a given participant, a digit or letter appeared as the first target and correspondingly a letter or digit appeared as the second target. Similarly, a given compound stimulus appeared at the horizontal position as the first target and vertical positions as the second target as target or vice versa.

Insert figure 2 about here

Each target was immediately followed by a visual mask (made of random lines) for 200 ms to limit visual persistence. After the presentation of both the targets, the fixation display appeared on the screen to cue the participants for the response. Participants' task was to identify both the targets and report in the order of target presentation at the end of the trial. They were instructed to fixate at the fixation cross during the target display. The response keys were "left shift key" and "Z key" (using left hand) for T1 "/" and "right shift key" (using right hand) for T2. Participants were informed that their responses were not being timed and to be as accurate as possible. Exposure durations were determined individually for each subject through a series of practice trials given before the main experimental session. An informal staircasing procedure was used to find the exposure duration (60 to 120 ms) limiting the

participant to around 85% accuracy in identifying only one target at a time using a single target identification condition. The staircasing procedure was blocked and performed separately for targets at the global and local levels. The order of the blocks was counterbalanced across participants. The average exposure time for the stimuli was around 110 ms (SD = 9.98 ms) and the exposure durations were the same for both global and local targets. The experimental session consisted of a total of 140 practice trials followed by a main session of 144 trials. Compared to main trials, the number of trials during practice session was considerably more as the participants were introduced to seven exposure durations varying from 60 to 120 ms at an interval of 10ms. A large range of exposure durations was used in practice session to get the optimal identification accuracy of both the targets employing single target identification task.

Results

Identification accuracy of both the targets was computed (see Figure 3) and only trials in which the first targets were identified accurately were considered for analysis. A three factorial mixed analysis of variance with perceptual level (global, local) and level switch (same: no switch, different: switch) as between subjects variables and SOA (0, 200, 400, 600, and 900 ms) as within subjects variable was performed separately for both the targets. Post-hoc analysis was performed with Tukey's HSD.

Insert figure 3 about here

T1 Identification

There was a significant main effect of perceptual levels, $F(1, 41) = 10.867$, $MSE = 38.337$, $p < .01$. T1 at the global level was identified better (96.70 %) than at the local level (93.86%). The main effect of level switch was also significant $F(1, 41) = 7.991$, $MSE = 38.337$, $p < .01$. T1 was identified better when both the targets appeared at the same level (96.59%) compared to different levels (94.20%). The effect of SOA was also significant $F(4, 164) = 9.583$, $MSE = 13.291$, $p < .001$. First target identification improved with SOA (from 92.59% at 0 ms to 96.9% at 900 ms).

The interaction between perceptual level and SOA was significant $F(4, 164) = 2.401$, $MSE = 13.291$, $p = .05$. Post-hoc comparisons showed a significant difference between global and local first targets at 0 ms, $t(43) = 5.495$, $p < .05$ and 200 ms, $t(43) = 5.815$, $p < .05$. T1 identification was significantly better at the global level (94.56% and 97.47%) than the local level (90.34% and 92.99%) at 0 and 200 ms SOAs.

T2 Identification

There was a significant main effect of level-switch $F(1, 41) = 32.070$, $MSE = 125.337$, $p < .001$. Second targets were identified better during the no switch condition (89.3%) compared to switch condition (80.7%). The main effect of perceptual levels was close to significance, $F(1, 41) = 3.067$, $p = .087$. Global target identification accuracy was 86% compared to the local target accuracy of 83.3%. The main effect of SOA was significant, $F(4, 164) = 69.957$, $MSE = 47.407$, $p < .001$. Results showed that performance improved with SOA (from 74.72% at 0 ms to 94.46% at 900 ms) across all conditions.

The interaction between perceptual level and level switch condition was significant $F(1, 41) = 4.615$, $MSE = 125.337$, $p < .05$. Post-hoc analysis showed that target identification accuracy was better for the second target when both targets

appeared at the global level (92.06%) compared to when both targets appeared at the local level (86.22%), $t(20) = 3.899, p < .05$. The interaction between perceptual level and SOA was significant $F(4, 164) = 3.466, p < .05$. Post-hoc comparisons showed that there was a significant difference between global (79.3%) and local (70.2%) levels at 0 ms SOA, $t(43) = 6.129, p < .01$.

The interaction between perceptual level, level switch and SOA was also significant $F(4, 164) = 3.705, MSE = 47.407, p < .01$. The pattern of performance was different for different conditions especially at shorter SOAs (up to 400 ms). Post-hoc analysis with short SOAs showed that global targets preceded by a global target (88.8%) was identified better than global target preceded by a local target (70.6%), $t(21) = 8.829, p < .001$, local targets preceded by global (70.2%), $t(21) = 9.045, p < .001$ as well as local targets (69.6%), $t(19) = 9.298, p < .001$ at 0 ms SOA. At 200 ms SOA global target preceded by a global target (83.93%) was identified better than global target preceded by a local target (73.24%), $t(21) = 5.187, p = .05$. However, there was no difference between a global target and a local target preceded by a target at the same level at 200 ms SOA ($p = ns$). At 400 ms SOA, global target preceded by a global target (92.98 %) was identified better than global target preceded by a local target (80.8%), $t(21) = 5.905, p < 0.05$. Also, local target preceded by a local target (92.2%) was performed better than local target preceded by a global target (80.82%), $t(20) = 5.526, p < 0.05$. Other differences between conditions at a particular SOA were not significant.

Discussion

For both the first and second targets, identification accuracy was better for global compared to local targets indicating a global over local advantage. The

performance improved with SOA but the pattern was different for the different scale-switch combinations. There was very little blink for a global target preceded by a global target and performance was better in this condition compared to all other conditions at 0 ms SOA. The requirement of global identification may have resulted in attention being more distributed making it easier to identify both the global targets presented at the same time. The identification of a local target preceded by a local target showed typical AB.

There was a level repetition effect with successive targets appearing at the same level compared to different levels suggesting that it takes longer time to shift attention across objects attended at different perceptual levels compared to same perceptual levels. There was no difference between shifting from a global target to a local target and local target to a global target. The results are consistent with the level activation mechanism (Lamb & Yund, 1996) and temporary loss of control hypothesis (Di Lollo et al., 2005). The presence of level repetition effect contradicts previous finding by Crewther et al. (2007). Both the shorter AB and presence of level repetition effect might be due to the lack of uncertainty in the perceptual level of the second target and the absence of distractors with relevant information at both levels (Jeffries et al., 2007).

EXPERIMENT 2

Studies investigating the relationship between predictability of target's location and scope of attention have shown that attention gets constricted with highly predictable targets, whereas, low predictability increases the scope of attention (Jefferies et al., 2007; Lamb & Robertson, 1988). Lamb and Robertson (1988) showed slower reaction time (RT) for central target, especially for the local patterns, with high

uncertainty of target's location. The result indicated that uncertainty increases the scope of attention over a wide range and more certainty decreases the scope that might be compatible with local target detection. In addition, Jefferies et al. (2007) showed lag-1 sparing with targets presented in separate AB streams, when the location of the first target was unknown, indicating that attention is more distributed over space, encompassing both the streams and result in lag-1 sparing. In this experiment, we increased location uncertainty (the pair of locations in which the first target could appear was not fixed) resulting in a need to have a broad scope of attention. We expected that the need for global processing consistent with broad scope of attention would be benefited. In addition, we expected the experiment to answer possible asymmetries in changes in scope of attention (global-local vs local-global) assuming that broad to narrow or zooming in is the default mode of change in scope of attention. We used only SOAs from 0 to 400 since most of the differences between conditions were at the shorter SOAs in Experiment 1.

Method

Participants

Sixty one student volunteers (global-global = 14, global-local = 15, local-local = 14, local-global = 18) from University of Allahabad participated in the experiment. All of them had normal or corrected-to-normal vision and were naive to the purpose of the study.

Apparatus and Stimuli

The stimuli and the apparatus were the same as in Experiment 1.

Procedure

The locations of the first target were uncertain, whereas the locations of the second target were determined by the location of the first target. For instance, if the first target appears at one of the two horizontal locations, then the second target appeared at one of the two vertical locations in a particular trial. The participants were informed about the perceptual levels of the to-be-identified targets. The optimal exposure duration was determined using an informal stair-casing procedure, with exposure duration varying from 60 to 140 ms with an interval of 10 ms. Furthermore, the optimal exposure duration resulting in around 85% accuracy for both the targets using single target identification condition was determined and used in the main experimental session. The experimental session consisted of a total of 180 practice trials followed by a main session with 192 trials. The average exposure duration for the stimuli was approximately 91.18 ms (SD = 16.69 ms) which was consistent for both global and local targets across all the conditions. The rest of the experimental conditions were the same as in Experiment 1.

Results

Identification accuracy of both the targets was computed (see Figure 4) and only those trials were considered for analysis in which the first targets were identified accurately. A three factorial mixed ANOVA with 2 (perceptual levels: global, local) X 2 (Switch: same, different) as between X 3 (SOA: 0, 200, 400 ms) as within subject variables was performed separately for both the targets. Post-hoc analysis was performed with Tukey's HSD. Eight participants (global-global: 0, local-local: 1, global-local: 2, local-global: 5) were excluded from the main experiment due to less than 80% accuracy for the first target in the experiment. The local-global condition in

which the local target had to be identified first and the global target had to be identified second (local-global) turned out to be the most difficult condition for participants.

Insert figure 4 about here

T1 Identification

A 2 (perceptual levels: global, local) X 2 (level switch: same, different) X 3 (SOA: 0, 200, 400 ms) mixed ANOVA showed significant main effect of perceptual levels, $F(1, 49) = 7.912$, $MSE = 67.132$, $p = .05$. First target at the global level was identified better (94.621%) than at the local level (90.97%). The effect of switching was close to significance, $F(1, 49) = 3.566$, $p = .065$. The effect of SOA was also significant $F(2, 98) = 18.126$, $MSE = 10.884$, $p < .001$. First target identification accuracy improved with SOA (from 90.625% at 0 ms to 93.573 at 400 ms).

The interaction between perceptual levels and level switch was significant $F(1, 49) = 4.353$, $MSE = 67.132$, $p < .05$. Post-hoc analysis showed the local target followed by a global target (88.06%) was identified worse than the local target followed by a local target (93.55%), $t(25) = 3.975$, $p < .05$. The local followed by global target identification was also worse than both the global first target conditions ($p < .05$). The switching did not have an effect the identification of the global first target ($p = ns$).

T2 Identification

A 2 (perceptual level: global, local) X 2 (level switch: same, different) X 3 (SOA: 0, 200, 400 ms) mixed ANOVA showed a significant main effect of SOA, $F(2,$

98) = 66.771, $MSE = 27.990$, $p < .001$. Results showed that identification accuracy improved with SOA (from 80.06% at 0 ms to 91.566% at 400 ms).

The interaction between perceptual level and level switch was significant $F(1,49) = 4.464$, $MSE = 171.204$, $p < .05$. More importantly, the interaction between perceptual level, level switch and SOA was also significant $F(2, 98) = 4.676$, $MSE = 27.990$, $p < .05$. Performance for the second target for all the conditions was the same at 400 ms SOA and showed differences at the shorter SOAs (0 and 200 ms SOAs). Post-hoc analysis at 0 ms showed better accuracy for a global target preceded by a global target (84.11%), $t(25) = 6.444$, $p < .01$ compared to a global target preceded by a local target (74.74%). Similarly at 200 ms SOA performance for a global target preceded by a global target (86.96%) was better compared to a global target preceded by a local target (78.76%). $t(25) = 5.639$, $p < .05$. The identification of a local target preceded by a global target was better compared to a global target preceded by a local target at both 0 ms $t(24) = 5.302$, $p < .05$ and 200 ms SOAs, $t(24) = 4.724$, $p < .05$.

Discussion

In general, the performance for the second target improved with SOA with similar performance in all the conditions at 400 ms. Consistent with Experiment 1, the magnitude of AB was short, unlike the findings of the Crewther et al. (2007) study. There was a global identification advantage but only for the first target. The performance for the local first target when the second target was global was poor for all SOAs. With the same condition, the performance of the global second target did improve with SOA. These results indicate changes in the scope of attention (local to global) results in a different time course when attention has to be shifted from the local aspect of one object to global aspect of another object. The better performance

with the global to local condition compared to the local to global condition indicates that it might be easier to zoom in (broad-to-narrow) than (narrow-to-broad) than zoom out when attention shifts from one object to another object. It is to be noted that this effects is present only at 0 and 200 ms SOAs. Second target identification results also show that while the global-global condition did have larger second target accuracy, they were not significantly different from the local-local and the global-local conditions. This can be due to the more generic broader scope of attention induced by the presence of large location uncertainty in Experiment 2.

GENERAL DISCUSSION

Two experiments were conducted to investigate the time course of attentional processing across objects (at different locations) attended at either same or different perceptual levels. An important aspect of the study is the combination of two different aspects of attention: global-local attention and shifts of attention from one object/location to another object/location. Not all the conditions produced AB and the magnitude of AB was different across different perceptual levels and switching conditions in both the experiments. Novel findings include the lack of AB with the global-global condition in Experiment 1 and the difficulty with the local-global condition in Experiment 2. The results indicate that the blink effect is not a fixed cost or amount but varies based on the nature of attentional processes (focused vs distributed) involved in performing a given task (Crewther et al., 2007; Jefferies et al., 2007; Srivastava & Srinivasan, 2010).

In general, results showed a global advantage for the first target at shorter SOAs. While there was a global advantage for the second target in Experiment 1, there was no general global advantage for the second target in Experiment 2. In

comparison, global advantage was present for second target identification in studies on the time course of global-local attention (Crewther et al., 2007; Lawson et al., 1999). The lack of global advantage in Experiment 2 for a global second target is mainly due to the difficulties in shifting from local to global levels and its implications are discussed later.

Both the targets were identified better when they appeared at the same level compared to when they appeared at different levels in Experiment 1 indicating the presence of the level repetition effect (Hübner, 2000; Lamb & Robertson, 1998, Ward, 1982). The results are different from those obtained with previous AB studies (Crewther et al., 2007) on global-local attention who did not find any level repetition effect. There are many methodological differences between our study and the AB studies on global-local attention (Crewther et al., 2007). They used a single location to present the stimuli (no location uncertainty) and an inter-stimulus interval of zero ms. In addition, they used a cue to indicate the first target level and, more importantly, there was uncertainty with respect to the level in which the second target appeared. This uncertainty means that participants had to monitor both the levels as well as the object identity, whereas in our experiments participants had advanced knowledge of the perceptual levels in which both the targets appeared. Due to the level uncertainty, participants would need to monitor both the levels and this may have resulted in the longer AB in their study. In addition, the AB paradigm used by Crewther et al. (2007) contained distractor stimuli between the two targets unlike the dwell time paradigm used in the current study.

Explanations of AB like interference theory (Shapiro et al., 1994) or temporary loss of control theory (Di Lollo et al., 2005) would argue that the presence of distractors would make the identification of the second target difficult. In the

paradigm used by Crewther and colleagues (Crewther et al., 2007; Lawson et al., 1999; Lawson et al., 1998), distractor information from both levels would be processed which could be more than the distractor processing or loss of control in typical AB studies. This may have resulted in the larger than one second AB. Given the absence of distractors and the fact perceptual levels to be attended are pre-specified (only one level need to be processed for a given compound stimulus), our results show a more typical AB in those conditions that show a blink effect. A direct comparison of our study with the Crewther et al. (2007) study is not possible given the differences in the paradigms but future experiments on global-local attention using AB paradigms can be performed in which the levels are pre-specified and distractors play a lesser role in hindering the second target identification.

Experiment 1 indicates that the difference between switch and no-switch conditions is significantly different at 0 and 400 ms indicating that the cost involved in shifting between different levels results in a longer dwell time. The difference between switch and no-switch conditions was not significant at 600 and 900 ms SOAs. There was also no asymmetry in shifting between different levels in Experiment 1. Shifting across levels showed a larger AB effect but still less than that obtained with other AB studies using global-local stimuli (Crewther et al., 2007; Lawson et al., 1999; Lawson et al., 1998). Shifting attention between levels may require a change in filter settings or changes in the mechanisms employed to detect targets at a specific level.

The difficulty in shifting across different levels is consistent with other theories of AB (Di Lollo et al., 2005; Olivers & Meeter, 2008). This difficulty in shifting across levels can be explained by the temporary loss of control hypothesis (Di Lollo et al., 2005), which argues that AB is not due to T1 processing but changes in

attentional set due to the targets that follow the first target. While the current study employed the attentional dwell time paradigm with no distractors in between the two targets, the attentional set (in terms of the level or scope) need to be changed when two successive targets with each at a different perceptual level have to be identified showing larger AB, i.e. shifting cost. The resource theories (Shapiro et al., 1994; Shapiro et al., 2005) could explain the difficulty in switching levels by postulating that it requires additional resources over and above those required in identifying a second target in AB or dwell time tasks. These results indicate that separate mechanisms exist with one mechanism responsible for the opening of attentional windows at different locations and another mechanism associated with shifting from one level to another level.

The general advantage for the shift over no-switch condition was not present in Experiment 2 and there was an asymmetrical effect with the switch from global to local producing better performance than the switch between local to global for both the first and second target conditions. How do we explain the differences in the switching effect between the two experiments? The main difference between the two experiments is the larger location uncertainty in Experiment 2 resulting in a broader scope of attention. The spatial shift of attention with location uncertainty over multiple locations requires distribution of attention over a larger space encompassing all the potential locations (Jeffries et al., 2007). The increase in location uncertainty results in the increase in scope of attention providing a significant advantage to global processing (Lamb & Robertson, 1988). Scope of attention increases both as a function of location uncertainty as well the perceptual level of the target. The results of the study indicate that the changes in scope of attention produced by both these factors affect perception and further studies would be needed to explore the similarities and

differences in the way scope of attention is affected by location- and object-based properties.

It is possible that distributed attention is the default mode of attention (Raffone & Srinivasan, 2009; Srinivasan et al., 2009). When a task is to be performed or some response-relevant information needs to be consciously accessed, top-down attention becomes focused or selective. Distributed attention enables us to perceive gist and computing statistical information from visual scenes (Srinivasan et al., 2009; Treisman, 2006). Processes associated with distributed attention differ with focused attention in terms of awareness (Bajjal & Srinivasan, 2009). Global processing associated with distributed attention results in larger afterimage durations than local processing associated with focused attention. The time course of consolidation of information in visual short term memory in a distributed attention task indicate earlier consolidation when compared to that in a focused attention task with the same set of stimuli (Bajjal & Srinivasan, submitted).

The results from Experiment 2 in which the global to local switch is much easier than local to global to local switch is consistent with the notion of the default mode of distributed attention and then focusing for object identification. The possibility of such a default mode explains the presence of asymmetry in switch effects in Experiment 2 in which the scope of attention is broad. It is to be noted that this effect is present only at short SOAs. With a narrower scope of attention in Experiment 1, the switching between takes a longer time and is probably performed through more voluntary or controlled selection mechanisms.

Strikingly almost no AB was found in Experiment 1 for the second target appearing at the global level compared to the local level at 0 ms, indicating the efficiency of distributing attention across both targets appearing at the global level

compared to when any one of the targets appeared at the local level. This indicates that global processing with multiple targets can be performed with very little capacity limitations. Further, no difference was found for the identification accuracy between global and local targets preceded by targets at the same level from 200 ms to 900 SOAs. This indicates that the advantage for processing two global targets presented simultaneously at 0 ms SOA is not present at higher SOAs due to sufficient time being available for shifting attention from one object to another object. It is to be noted that Crewther et al. (2007) found AB on all the conditions and our results of lack of AB with the global-global condition and standard AB with the local-local condition are completely different from their results.

The lack of attentional blink in the global-global condition can be explained with the link between global processing and a large scope of attention or distributed attention. Distributed attention conditions are better suited for statistical processing and in our study aided global processing over a large attentional window covering both target locations. In contrast, local processing for any one object needed more focused attentional processing (narrow scope of attention or smaller attentional window) resulting poor performance in the other three conditions at 0 ms SOA in Experiment 1.

The lack of AB for the global second target preceded by a global target in Experiment 1 poses problems for theories of AB (Di Lollo et al., 2005; Olivers & Meeter 2008; Shapiro et al., 1994; Visser et al., 1999). If a pre-fixed attentional window is assumed that fits a given first target, then there should be AB for the second global target even if it is preceded by another global target. The resource theories in their present form would not be able to explain the lack of AB with the global-global condition. However, attentional resources could be linked to the scope

of attention with distributed attention linked to lesser resources and focused attention linked to greater resources. This is consistent with studies on distributed attention indicating that performance in a distributed attention task is independent of set size (Treisman, 2006). In addition, the current finding is also consistent with better performance under conditions of distributed attention in an AB task (Olivers & Nieuwenhuis, 2006).

The results from the current study indicate that distributed attention facilitate global processing across the visual space spread over multiple objects. The results also indicate a default mode of shift in attention from distributed to focused (zooming in) that enables us to easily process global information followed by local information. Focused attention has capacity limitations that impair the identification of a subsequent target at shorter SOAs. Shifting between perceptual levels results imposes an additional cost, especially with focused attention, due to the limitations imposed by the need to change processing mechanisms or attentional set. Further studies would be needed to identify the exact mechanisms involved in different modes of attention and differences in shifts of attention between locations and levels.

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Figure 4: Performance in Experiment 2 as a function of SOA for (a) the first target and (b) the second target with the attentional dwell time paradigm.

4	4	4	4	E		E	E	E	E	E	6	6	6	6
4			4	E		E	E				6			6
4			4	E	E	E	E	E	E	E	6			6
4			4	E		E				E	6			6
4	4	4	4	E		E	E	E	E	E	6	6	6	6

Figure 1

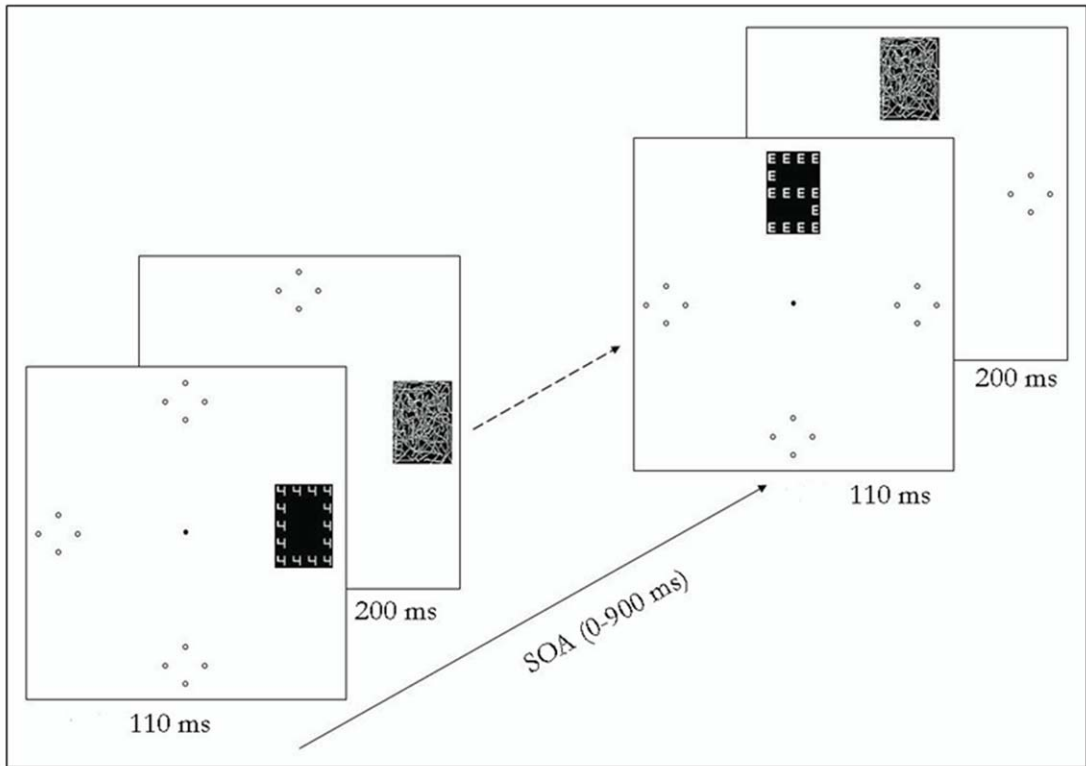


Figure 2

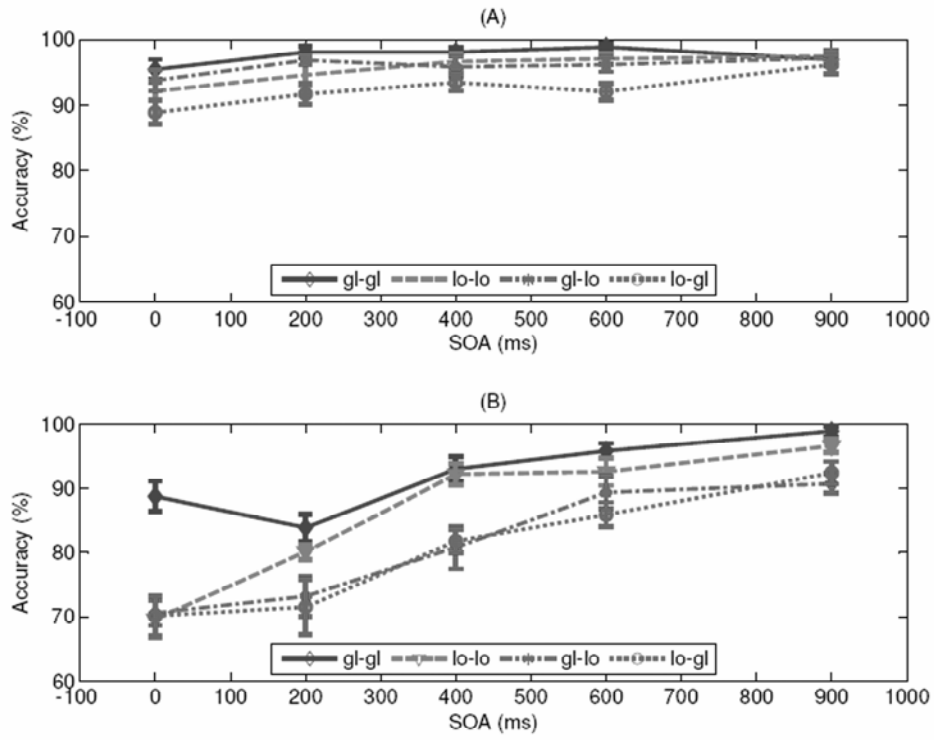


Figure 3

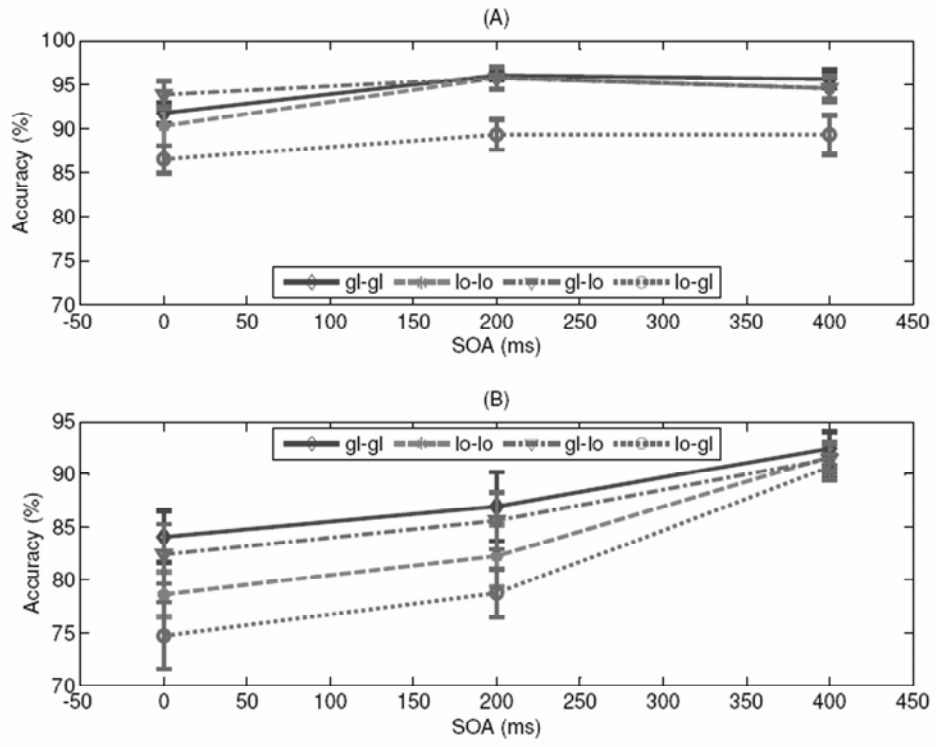


Figure 4