HOW STIMULUS DIMENSIONS AND TASK REQUIREMENTS AFFECT THE
FOCUSING OF ATTENTION

by

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The size of an attended area has been shown to impact processing efficiency (e.g., Castiello & Umilta, 1990); the larger the focus-area, the slower the reaction time (RT) to targets in that area. This study examined the pattern of focus-size effects through a wide range of cue sizes. Experiment 1 failed to find a focus-size effect with either a discrimination or detection task. To determine if a focus-size could be found, Experiment 2 replicated an earlier study (Maringelli & Umilta, 1998) that included more stimulus onset asynchronies (SOAs) and fewer cue sizes than the first experiment. An effect of focus-size was found with the short SOAs, however with half the strength as the original study. Experiment 3 was a modified version of the first experiment, with fewer cue sizes and shorter SOAs. As in the second experiment, a small focus-size effect was found for the middle range of the cue sizes. Overall, the focus-size effect was smaller and weaker than expected, suggesting that the methodological approach and current theorizing of the effect should be further examined.
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How Stimulus Dimensions and Task Requirements Affect the Focusing of Attention

Visual attention is comprised of two primary components, an orienting mechanism and a focusing mechanism. Whereas the orienting mechanism aligns visual attention with the stimulus (e.g., Posner, 1980), the focusing mechanism scales visual attention to the dimensions of the stimulus (Eriksen & St. James, 1986). Although the majority of visual attention research has explored orienting, the focusing of visual attention is equally important in determining what information in the visual field is selected for more detailed processing. This is because visual attention selectively focuses on stimuli, not broad areas of the visual field, such as a quadrant, in order to allow enhanced analysis of task-relevant items (Kanwisher & Wojciulik, 2000). Consequently, the focus of attention is a dynamic feature which fits to stimuli that may vary in size and shape. How the dimensions of the focused stimulus explicitly impact processing efficiency is the subject of this proposal.

Examinations of Focusing in Isolation of Orienting

A series of focusing studies begun by Castiello and Umilta in 1990 were prompted by several questions initially posed by Eriksen and St. James (1986). The original questions of Eriksen and St. James (1986) were as follows. First, can the focus area vary in size, continuously, from an area as small as one degree visual angle to an area as large as several degrees visual angle? Second, as the size of the focus area (focus-size) increases, is there a decrease in the attentional resources deployed to each object within the focus area? This question may also be stated accordingly when only one object is in the area of focus: Does processing efficiency drop as focus-size increases? Third, is the boundary of the focus area sharply bounded from the background (i.e., residual field), or is it marked by a gradual drop-off in processing resources? With regard to the first question, Eriksen and St. James have shown that the area of the attentional focus can vary in size. However, until Castiello and Umilta begun their examination of
focusing, it was unclear whether there was an inverse relation between focus-size and processing efficiency for objects within the focus area (2nd question) or if there is sharp demarcation between the boundary of the focus area and the residual field (3rd question).

Overall, the set of studies initiated by Castiello and Umilta can be catalogued according to five primary inquiries (the first and second of which are the unanswered questions from Eriksen and St. James). First, does the focus-size have an inverse relation with processing efficiency; are observers less efficient task processors with larger stimuli compared to smaller stimuli (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Eriksen & St. James, 1986; Maringelli & Umilta, 1998; & Turatto et al., 2000)? Second, can focusing shape itself tightly to the contours of an irregular polygon (Usai, Umilta, & Nicoletta, 1995)? More specifically, can the shape of the attentional focus manipulate itself to exclude areas that, although not part of the stimulus, are perceptually within the outermost contours of the stimulus? Third, can two areas of focus occur simultaneously (Castiello & Umilta; Castiello & Umilta)? Fourth, what is the time course for focus-size effects (Benso, Massimo, Gastone, Mascetti, & Umilta, 1998)? Fifth and finally, is focusing composed of both voluntarily and automatic mechanisms, similar to the orienting of attention (Turatto, Benso, Facetti, Galfano, Mascetti, & Umilta, 2000)? The experiments associated with these questions will now be examined more closely.

The initial study of Castiello and Umilta (1990) was conducted primarily to affirm that the size of the area under focus does indeed influence processing efficiency (as suggested by Eriksen & Yeh, 1985; Eriksen & St. James, 1986). Castiello and Umilta began with two key assumptions. First, focus-size reflects, roughly, the size of the object that requires focusing. Therefore, through the manipulation of stimuli size, focus-size can be indirectly measured. Second, the more densely that attentional resources are distributed, the quicker and more efficiently, information is processed (Egeth, 1977; Eriksen & St. James, 1986). Ultimately, task completion will then occur sooner with smaller, as
opposed to larger, distributions of attention. Their primary hypothesis reflected these assumptions. If attentional resources are finite and their distribution is reflected by subsequent processing efficiency, they hypothesized that processing efficiency should decrease as focus-size increases. If this hypothesis was true, then RTs would be inversely related to the focus-size (i.e., the smaller the focus-size, the faster the RT).

Castiello and Umilta (1990) used a modification of a simple cuing paradigm (Posner, 1980) to explore the relationship between focus-size and RT. At the start of each trial, two square placeholders were presented ten degrees in the periphery, along with a central fixation point. These remained visible throughout the duration of each trial. Five-hundred ms after presentation of the fixation, a peripheral cue (a brief brightening of a square placeholder's exterior) was then presented for 100 ms. After stimulus onset asynchronys (SOAs) of either 50 or 500 ms, a target could then be presented in one of the square placeholders. Critical to testing the impact of focus-size on RT, the square placeholders were three different sizes (1, 2, and 3 degrees visual angle diameter). The participants were required to simply detect the appearance of a target presented in one of the placeholders. The findings were analyzed in terms of the relationship between the cue location and the target location (i.e., cue-validity). A valid trial presented a target in the cued placeholder, whereas an invalid trial presented a target in the placeholder that was not cued. In neutral trials, both placeholders were cued. A reliable effect of focus-size was found for the valid condition at the 500 ms SOA but not at the 50 ms SOA. Although the effect of focus-size was not significant for the neutral condition, the neutral condition did have the same pattern of results as the valid condition. Invalid trials did not reveal an effect of focus-size. Since cue validity was explored further in a later experiment, these results will be left for now. Overall, the findings of Castiello and Umilta support the notion that processing efficiency is negatively affected by
the size of the area that attentional resources are spread over (focus-size). In other words, as the focus-size increases, processing efficiency decreases.

In addition to replicating their earlier findings, Castiello and Umilta (1992) further examined how cue validity interacted with focusing effects. Because their initial 1990 study was primarily conducted to examine the relationship between focus-size and processing efficiency, this experiment further explored the impact of validity on focus-size effect. Additionally, since the issue of splitting attention is a contentious issue in visual attention (e.g., both the zoom-lens and spotlight theories of visual attention contend that attention cannot be split: Eriksen & St. James, 1986; Eriksen & Yeh, 1985; Posner, 1980; while the gradient theory does not have a problem with this: Laberge & Brown, 1986), an individual study dedicated to the issue seemed well-advised. This study used methods similar to their earlier study (Castiello & Umilta, 1990). Each trial contained a display of two peripheral square placeholders (again, either 1, 2, and 3 degrees) flanking a central fixation point. Five-hundred ms after presentation of fixation, a brightening of one or both of the square placeholders (cuing) could occur for 150 ms. Following cue presentation, a target could appear in one of the square placeholders. This presentation only used a 500 ms cue-target SOA, based on their earlier finding that focus-size effects only happened in this SOA and not at the shorter 50 ms SOA (Castiello & Umilta, 1990). Cue-validity, or spatial relationship between cue and target, was again used to examine the association between focusing and processing efficiency. Overall, the results were in agreement with their earlier findings. Reaction times increased as focus-size increased, again suggesting that processing efficiency is inversely related to the size of the area over which the attentional resources are spread. The interpretation that focus-size affects processing efficiency is corroborated by the finding that neutral trials showed the same pattern and invalid trials did not. If neutral trials (i.e., both placeholders were cued) forced focal attention to split, then neutral trials should have mimicked the pattern of results for
valid trials, albeit with less strength. Since the resources were split between two locations, not one, the
effect of focus-size should have been diminished. Additional support for this focal phenomenon comes
from the lack of focus-size effect for invalid trials. If the focus of attention was incorrectly placed, then
the subsequent target should not benefit from the already dispatched and focused attention resources.
Attention would be required to re-orient and re-focus to the invalid target.

These previous experiments illustrated an effect of focus-size on performance, but they did not examine the shape of the focus itself for a single object. From the previous results it could be interpreted that attention is fit roughly to the size of the attended stimulus. Usai et al. (1995) posed a more specific question to get closer to the heart of the matter: Can the shape of the attentional focus fit tightly to the contours of the stimulus in order to exclude areas that, although not part of the stimulus, are perceptually within the outermost contours of the stimulus? The experiment of Usai et al. approached this problem by using polygons with missing pieces. If the target appeared in the area of the missing piece (i.e. not in the polygon itself) but RTs were similar for targets presented in the polygonal cue, then it could be argued that attention fitted roughly to the region of the stimuli, not tightly to the stimuli's contours. Each trial consisted of three centrally presented stimuli: fixation, cue, and target. Following fixation, a polygon cue was presented in the center of the screen, and the polygon could have missing pieces of varying size. For example, imagine a stop-sign shaped stimuli with a pie-shaped chunk taken out (see Figure 1). The area where the chunk was taken out would constitute the missing-piece area of the stimuli in these experiments. The cue remained on for the remainder of the trial, but after a cue SOA of 500 ms, a target could be briefly presented. There were multiple target locations inside and outside the cue (including the missing-piece area), and participants were required to detect the presence of the target. The critical comparison was of the mean RTs for targets inside and outside the polygon cue. Reaction times for targets appearing in the missing piece were similar to those for
targets presented in the polygon, and RTs to targets inside the missing piece area were statistically different from those outside of it, although there was a gradual increase in RT as the distance from the cue increased. This suggests that participants were unable to exclusively focus attention on the cue and avoid an irrelevant area between relevant areas, even though the probability of the target appearing in the missing piece was low (e.g., 10%). There was, therefore, a beneficial effect of focusing for the polygon as well as its missing piece. It appears that the shape of the focus of attention does not fit exclusively to the contours of an irregular stimulus, but fits roughly from the polygon's outermost contours inward. This is in accord with the gradual drop-off in RTs accompanying increasing distance from the cue’s outer edges; focus area illustrates a gradual boundary, not sharply demarcated.

All of the previous studies used SOA manipulations of either 50 or 500 ms (Castiello & Umilta, 1990; Castiello & Umilta, 1992; & Usai et al, 1995), and only the 500 ms SOA produced focus-size effects. However, Maringelli and Umilta (1998) found that SOAs of 100 ms, and to a lesser extent 700 ms, also evoked focus-size effects. Benso et al. (1998) decided to look more closely at focus-size effects with a thorough manipulation of SOA. With a different method from any previously discussed experiments, pre-cues were presented at random screen locations for 150 ms and then followed by a cue at the same location. The pre-cue oriented attention, thus allowing the cue to measure focusing. The cues were squares of either 2.5 or 7.5 degrees in width, with ten different SOAs varying from 33 to 704 ms. Two patterns of results were found, based on whether or not the stimuli appeared in foveal or peripheral vision. When in foveal vision, focus-size effects began between 33 and 66 ms SOAs and ended shortly after 500 ms SOA. Focus-size effects took place only between 300 and 400 ms SOA. Thus, the effect of focus-size in the periphery is severely limited in respect to its counterpart in the fovea. While the periphery has a window of only approximately 100 ms for focus-size effects to occur, the fovea displays focus-size effects in a window of approximately 400 ms. In addition to providing
support for the idea that focus-size affects processing efficiency, this study gave a more definitive timeline for these effects, as well as the effects of stimuli’s retinal location on attention.

The final studies of this series examined the automatic and voluntary aspects of focusing attention (Maringelli & Umilta, 1998; Turatto et al., 2000). Presumably, if orienting attention can be induced both automatically and voluntarily, then focusing might as well. Maringelli and Umilta first examined automatic focusing by adapting a theory that was based on the exogenous orienting of attention: If automaticity is stimulus driven, then reducing the salience of stimulus characteristics will reduce the impact of attention (Theeuwes, 1994). Each trial consisted of two centrally presented stimuli: a square outline (3 or 6 degrees), which remained on the screen until the end of the trial, and after varying SOAs (100, 500, or 700 ms), followed by a small red dot (0.4 degrees) for 100ms. Participants were required to detect the dot. The imperative condition affected the salience of the focused cue’s stimulus characteristics, specifically size; in separate conditions, the size of the outline was either presented randomly or fixed. If fixed presentations reduced the salience of the stimulus characteristics, then the effects of focus size would be reduced or eliminated in this condition. This is exactly what they found; in the random condition, the effects of focus-size were found, and in the fixed condition, there was no effect.

Turatto et al. (2000) supplemented Maringelli and Umilta (1998) by studying voluntary focusing in addition to automatic focusing. In Turatto et al., all trials consisted of centrally presented stimuli: 1) after a fixation of 500 ms, the first cue (2.5 or 7.5 degrees) was presented for 700 ms, 2) followed by a second cue (same size possibilities as the first cue) which remained on the screen until the end of the trial, and 3) after varying SOAs, a target stimulus was presented for 50 ms. This presentation sequence was constant with several variables manipulated throughout the experiments: the first and second cue presentations could overlap, and the SOA between second cue and target presentation was either short
(66 ms) or long (800 ms). Presuming focus-size effects are involved, subsequent RTs would then reflect the cue that determined the focus size. Participants were either required to detect the presence or discriminate the identity of the target, which was a between-experiments variable.

The findings of Turatto et al. (2000) supported the existence of both automatic and voluntary influences on focusing. For cues that did not overlap, RTs reflected the size of the second cue, not the first. The second cue was automatically focused on and remained so until target presentation; therefore, the focusing effect of the first stimulus was replaced by the effect of the second stimulus' size. Because focusing can only scale itself to current stimuli (Castiello & Umilta, 1992), these effects occur even though processing efficiency would benefit from a smaller area of focus. If the first and second cue did overlap, however, then RTs could reflect the size of the first cue. These results were mediated by the SOA between the second cue and the target's presentation. When the SOA was only 66 ms, the RT reflected the size of the second cue, but if the SOA was 700 ms, then RTs could reflect the size of the first cue. It seems that an adequate period of time must be present for the automatic focusing of the second cue to be overcome by the voluntary refocusing of the first cue. It should also be noted that, due to the spatial certainty of the target, the participants could have voluntarily chosen to reduce their focus to the target area. RTs did not reflect the size of the target, however, therefore indicating that focusing cannot occur to an empty spatial location. Overall, the automatic focusing of attention is strong but there is also has a weaker voluntary presence.

Present Experiments

This study continued the line of investigation started by Castiello, Umilta, and their colleagues (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995). Since these earlier experiments serve as the starting point for the present experiments, a recapitulation of their findings is in order. The two questions originally
posed by Eriksen and St. James (1986) were answered as follows: (a) the size of the focus area was inversely related to processing efficiency, as expressed in RT (Benso et al.; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta; Turatto et al.), and (b) there was a gradual drop-off in processing efficiency around the boundary between the focus area and the outer residual field (Castiello & Umilta, 1990; Castiello & Umilta, 1992; Usai et al.). Other findings from the previous experiments also gave additional insight into focusing. Focused attention can be split between two hemifields (Castiello & Umilta, 1992). When attention was focused on an object, irrelevant information not presented within the object but within the outermost contours was still processed (Usai et al.). Focused attention had both a strong automatic as well as a weaker voluntary component (Maringelli & Umilta; Turatto et al.). Lastly, depending on whether the stimuli were foveally or peripherally presented, there were two time courses for focus-size effects (Benso et al.).

The experiments presented here further examined the focusing of attention. The first of the present experiments attempted to determine more precisely the pattern of focus-size effects. This experiment also examined whether task difficulty altered the effect of focus-size on processing efficiency. The second experiment attempted an exact replication (Castiello & Umilta, 1990; Maringelli & Umilta, 1995), since the expected pattern between focus-size and processing efficiency was not found in the first experiment. After successfully finding the focus-size effect in the second experiment, the third experiment again attempted to analyze the focus-size effect pattern with a modified SOA and cue sizes.

Experiment 1

The goal of the first experiment was to gain a more complete understanding of the relationship between focus-size and RT. In earlier studies, cue size manipulations were limited to no more than three levels. For example, Castiello & Umilta (1990) used cues that were one, two, or three degrees,
whereas Benso et al. (1998) used cues 2.5 and 7.5 degrees. The main purpose of the present study was to determine if the focus-size effect on RT held across a wide range of placeholder sizes (ranging from very small to very large). Using a wide range of sizes also allows for a characterization of the focus-size effect (e.g., linear, logarithmic, etc.)

The secondary purpose of this experiment was to examine the effect of task difficulty on the focus-size. Most of the earlier studies used detection tasks to assess focus-size effects (e.g., Maringelli & Umilta, 1998), and even when a discrimination task was used (Turatto et al., 2000), it was manipulated as a between experiment variable. The same focus-size effect was found for both tasks, but the magnitudes were not compared because of the between-experiment design. Based on the logic of Eriksen and St. James' (1986) zoom-lens model, it may be useful to examine what differences, if any, occur from task manipulation. Eriksen and St. James view attention as coming from a resource “reservoir”, and the amount used varies according to the demands being placed on attention, i.e. optimal attention allocation. After a participant has sufficient experience with and knowledge of a task, extra attention resources will be applied to the task as it becomes more attention demanding. Ultimately, optimal attention judgments could occur until a task is met that requires all of the attentional resources or until other limitations, such as sensory or motor, are met. Once a participant has allocated all attentional resources to the visual field, then the prediction based on the zoom-lens that the density of processing resources decreases as the size of the attentional focus increases could be tested. The thinning of the attention resources should be more pronounced as the attentional demands increase, and therefore an interaction between task and cue size should be found as there are greater increases in RT with increasing cue size.

**Method**

**Participants**
Twelve University of Toronto undergraduates agreed to participate in exchange for partial course credit. They had either normal or corrected-to-normal vision.

Apparatus

Participants were seated approximately 40 cm in front of a computer monitor. Their heads were positioned on adjustable chin rests, and their orientation centered through adjustable chairs. With these devices, participants should have been comfortable throughout the duration of the experiment. Responses were indicated through key press.

Procedures

The experiment was conducted in a dimly lit room. The participants were instructed to maintain fixation on the center of the monitor, respond quickly and accurately to the appearance of the target stimulus, either indicate the color or detect the presence of the target, and avoid responding to catch trials. Each participant was then allowed ten practice trials, and the experimenter remained in the room in order to make sure everything was understood. All stimuli were centered on a black background: a small white dot for fixation (0.30 degrees, a light gray square (0.5, 1.0, 2.0, 4.0, 8.0, 12.0, 16.0, and 24.0 degrees), and another small red or blue (approximately equiluminant) dot for the target (0.2 degrees). The sequence of events for each trial was composed of three presentations: 1) the fixation stimulus was presented for 500 ms, 2) the square cue presented until a response was given, and 3) following a 350 ms SOA, the target was presented for 100 ms. In order to reduce anticipatory responses, 25% of trials did not present a target (i.e., catch trials). Errors were determined by whether the participant’s response was an extremely long or short RT (i.e., less than 150 ms or more than 1000 ms), or if a response was given to a catch trial. A blank screen then followed each response for 1000 ms.

Design
The detection and discrimination tasks (320 trials each) were completed in separate blocks, and the sequence of block presentation was determined using ABBA counterbalancing. Throughout the entire experiment's 640 trials, there were 80 trials for each of the eight cue sizes and 160 catch trials, both of which were randomly presented. Short breaks were given after every 160 trials.

Results & Discussion

Errors were seldom, less than five percent, and were not included in the analysis. For correct responses, a 2 (task difficulty: discrimination and detection task) X 8 (cue size: 0.5, 1.0, 2.0, 4.0, 8.0, 12.0, 16.0, and 24.0 degrees) analysis of variance (ANOVA) was conducted. The ANOVA revealed main effects for both variables. A main effect of task difficulty was found, F(1,10) = 137.02, p < .0001. As expected, RTs were overall slower by 94 ms for the discrimination task (418 ms) as compared to the simple detection task (324 ms). Cue size also displayed a significant main effect, F(7, 77) = 7.747, p < .0001. RTs tended to decrease as the cue size increased (from smallest to largest cue size: 382, 375, 367, 365, 366, 369, & 379 ms). Cue size and task difficulty did not significantly interact, F (7, 77) < 1.0, but visual examination of the data reveals a difference in focus-size trends for the two tasks (refer to Figure 1). There is no effect of cue size for the detection task, though there appears to be some effect for the discrimination task.

None of the a priori predictions that motivated the conduct of this experiment were fruitful; only the standard effect of task manipulation was congruent with a priori predictions. The main effect of cue size was unexpected, as it displayed an effect opposite to previous findings (Bensou et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995). The previous research repeatedly found that RTs increased as cue size increased, but here a trend was found for decreasing RTs with increasing cue size. This main effect does not conclusively indicate whether a predominant effect of cue size was present; the ANOVA only indicates that one cue
size was significantly different from the rest, but there were eight different cue sizes. Based on the findings illustrated in Figure 2, pairwise t-tests (alpha level set at .05) for the discrimination task were then conducted between several cue sizes that had visibly different effects on RT. A strong effect of cue size would (a) presumably display significant differences between most, if not all, of the cue sizes as well as (b) be present for both tasks (the previous studies repeatedly found an effect of cue size during detection tasks, though in the opposite direction). With only one significant t-test, the effect shows little strength in this study.

Contrary to the unexpected effect of cue size, the main effect of task was expected; in fact, the task manipulation was included solely to determine if the predicted focus-size effect would increase with a more difficult task. Yet, since this focus-size effect was not found, this prediction was consequently not supported. Furthermore, the lack of focus-size effect with these tasks is surprising since both the detection and discrimination task displayed the focus-size effect in a previous study (Turatto et al., 2000).

Experiment 2

In order to examine the striking differences between the findings from the previous experiment and those found in the literature (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995), a replication was conducted. The present experiment is a replication of the Maringelli and Umilta study.

Methods

Participants

Ten University of Toronto undergraduates agreed to participate in exchange for partial course credit. They had either normal or corrected-to-normal vision.

Apparatus
The apparatus was exactly the same as that used in Experiment 1.

**Procedures**

The experiment was conducted in a dimly lit room. The participants were instructed to maintain fixation on the center of the monitor, respond quickly and accurately to the appearance of the target stimulus, and avoid responding to catch trials. Each participant was allowed ten practice trials, and in order to make sure everything was understood, the experimenter remained in the room until the practice trials were over. All stimuli were centered on a black background: a square white outline (3 or 6 degrees) for the cue and a small red dot for the target stimulus (0.4 degrees). Each trial was composed of two presentations: the square cue was presented until a response was given, and the target was then presented for 100 ms after a varying SOA, depending on the block. In order to reduce anticipatory responses, 20% of trials did not present a target (i.e., catch trials). Errors were determined by whether the participant’s response was an artificially long or short RT (i.e., less than 150 ms or more than 1000 ms), or if a response was made during a catch trial. A blank screen followed each trial for 1000 ms.

**Design**

The 240 trials for each of the two cue sizes and 96 catch trials were randomly presented throughout the entire experiment, but the 160 trials per SOA were presented in separate blocks. A Latin-square design was used to determine the sequence of blocks. Three short breaks were given, one after every block.

**Replication Difficulties**

There was only one hindrance to exact replication. In Maringelli and Umiltä’s (1998) study, the levels of SOA were done between-experiment, and each experiment included 480 trials. Because the effects of focus-size could be found with fewer trials, and to economize experimentation time, this experiment manipulated SOA within subject.
Results & Discussion

Errors were high (about 10% of trials) so the number of correct trials per condition was subjected to a 3 (SOA: 100, 500, or 500 ms) x 2 (cue size: 3.0 or 6.0 degrees) ANOVA. No main effects or interaction effects (all Fs < 1.0) were found; error rates were similar for all variable manipulations. For correct responses, another 3 (SOA: 100, 500, or 700 ms) x 2 (cue size: 3.0 or 6.0 degrees) ANOVA was conducted for the RTs. Only cue size revealed a main effect, F(1, 9) = 9.80, p = .012; RTs were faster for the small cue (309 ms) than for the large cue (318 ms). SOA, however, lacked a significant main effect, F(2, 18) < 1.0; RTs were constant throughout the different SOAs (310 ms at 100 ms SOA, 314 ms at 500 ms SOA, and 316 ms at 700 ms SOA). Furthermore, little of the overall variance was explained by the interaction between cue size and SOA, F(2, 18) = 1.22, p = .319 (see Table 1).

Due to Experiment 1’s unexpected lack of focus-size effect, the results of this replication were not predicted a priori. However, in Experiment 2 the main discrepancy between the first experiment and the focus-size effect literature did not occur again; the inverse relationship between processing efficiency and cue size was reestablished, i.e. the focus-size effect (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995). In other words, as cue size increased, RTs also increased.

Contrary to the confirmation of focus-size effects, the other effects of SOA and its interaction with cue size were again surprisingly incongruent with the previous literature (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; & Maringelli & Umilta, 1998). Cue-target SOA did not impact RT; the ability to respond was not impacted by the amount of time focused on the cue. The previous literature, however, consistently reported effects of SOA, although the evidence differs between studies. This replication’s between-experiment manipulation (Maringelli & Umilta) originally revealed a continual decrease in RTs for 100, 500, and 700 ms SOAs (from short to long SOA: RTs of
320, 302, and 263 ms). In another experiment that examined a wider range of within-subjects SOAs, a U-shaped RT trend was found for SOAs between 33 and 700 ms, with a resulting range of RTs from 350 to 305 ms (Benso et al.). Therefore, if a solid pattern has not been discriminated for SOA, then the lack of effect in this experiment may not be so disturbing.

Equally surprising was the lack of interaction between cue size and SOA; the length of time the focus was held did not significantly change the magnitude of the focus-size effects. Because attention is a dynamic process, it was expected that the strength of this attention effect would vary depending on the length of focusing. Attention continually changes to meet the environmental demands, as well as going through residual decay that occurs after peak focusing. However, there does appear to be a trend (refer to Table 1), so pairwise t-tests were performed between the cue sizes at each SOA. The small and large cue RTs differed significantly at both the 100 (p = .001) and the 500 ms SOA (p = .05), but they were not significantly different from one another at the 700 ms SOA (p = .197). The magnitude of the focus-size effect (from short to long SOA) was 12, 10, and 6 ms; therefore, the effect does display a weakening for longer SOAs, although initially insignificant. Previous studies also displayed this interaction between SOA and cue size. In the Maringelli and Umilta (1998) experiment that this replication was based on illustrated (between experiments) an increased weakening of focus-size effect for 500 and 700 ms SOA (difference in focus-size effects, from short to long SOA: 21, 15, and 12 ms). Additionally, in the Benso et al. experiment focus-size effects were not seen at the 33 ms SOA, remained stable between 66 and 469 ms SOA, and then decreased until the focus-size effect disappeared at 700 ms SOA. Overall, this experiment provides support for the focus-size effect, but only weak support for the interaction between cue-size and SOA.

Experiment 3
Although the previous experiment only revealed a partial replication, a focus-size effect was found, as would be expected from the literature (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995). Therefore, Experiment 3 will reexamine the range of the focus-size effect. This experiment will be similar to the first, but with shorter SOA manipulations. In Experiment 1 an SOA of 350 ms did not produce the focus-size effect, and Experiment 2’s 100 ms SOA produced a stronger focus-size effect than the other available SOAs. As in Experiment 1, a range of cue sizes will be used, this time including the two sizes used in Experiment 2.

Methods

Participants

Ten University of Toronto undergraduates agreed to participate in exchange for partial course credit. They had either normal or corrected-to-normal vision.

Apparatus

The apparatus was exactly the same as that used in Experiment 1.

Procedures

The experiment was conducted in a dimly lit room. The participants were instructed to maintain fixation on the center of the monitor, respond quickly and accurately to the appearance of the target stimulus, and avoid responding to catch trials. Each participant was allowed ten practice trials, and in order to make sure everything was understood, the experimenter remained in the room until the practice trials were over. All stimuli were centered on a black background: a light gray square (1, 3, 6, 9, 12, & 15 degrees) for the cue, and a small red dot for the target stimulus (0.4 degrees). Each trial was composed of two presentations: the square cue was presented until a response was given, and after a varying cue-target SOA (66 or 100 ms), the target was presented for 100 ms. In order to reduce
anticipatory responses, 25% of trials did not present a target (i.e., catch trials). Errors were determined by whether the participant’s response was an extremely long or short RT (i.e., less than 150 ms or more than 1000 ms), or if a response was made during a catch trial. A blank screen followed each trial for 1000 ms.

Design

The 96 trials for each of the six cue sizes and 144 catch trials were randomly presented throughout the entire experiment, with the 288 trials per SOA presented in separate blocks. An ABBA counterbalance was used to determine the sequence of blocks. Two breaks were given during every block, and a break was also allowed after the first block was completed.

Results & Discussion

Error rates were high (about 7% of trials), so the number of correct trials was subjected to a 2 (SOA: 66 or 100ms) X 6 (cue size: 1, 3, 6, 9, 12 or 15 degrees) ANOVA. No main effects or interactions were found (all Fs < 1.0); error rates were similar for all variable manipulations. For correct responses, another 2 (SOA: 66 or 100ms) X 6 (cue size: 1, 3, 6, 9, 12 or 15 degrees) ANOVA was conducted for the RTs. Only cue size revealed a main effect, $F(5, 40) = 2.88, p = .025$; besides the smallest cue, which displayed a longer RT than most of the cues (329 ms), RTs increased as cue size increased between 3 and 15 degrees (317, 321, 327, 332, and 336 ms). Another ANOVA was conducted without the smallest cue, and a clear effect of cue size emerged, $F(4,32) = 4.48, p = .006$. SOA, on the other hand, did not show a main effect, $F(1, 8) < 1.0$; RTs were similar for both the 66 (325 ms) and the 100 (329 ms) ms SOAs. Additionally, the interaction between SOA and cue size was not significant, $F(5, 40) = 1.45, p = .226$.

Based on the literature (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995), the effect of cue size was expected,
whereas the lack of significance for SOA and its interaction with cue size was unexpected; yet, the results are in accord with the previous experiment’s findings. Increasing cue size again adversely affected processing efficiency; as cue size increased, so did RT, i.e. the focus-size effect. Additionally, the focus-size effect is not limited to smaller sizes since this experiment found the focus-size effect for five cues whose range is greater than the smaller sizes that have been used to study focus-size effects. The lack of effect for the smallest cue, which has been used successfully in the previous focus-size effect studies (Castiello & Umilta, 1990; Castiello & Umilta, 1992), was surprising; a predominant focus-size effect would be expected at all cues.

On the other hand, SOA (the length of time allowed for focusing) did not affect processing efficiency. This is contrary to the literature which found that SOA impacts RT (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992 &; Maringelli & Umilta, 1998). Specifically, one study found a significant difference between the same SOAs as those used in Experiment 3 (Benso et al.). Furthermore, the length of time available for focusing (SOA) did not alter the effect of cue size on processing efficiency in Experiment 3 (refer to Figure 3); similar magnitude focus-size effects were seen for both SOAs. In previous studies, the length of time available for focusing did affect whether focus-size effects would be present, and if they were, the strength of these effects.

General Discussion

Before considering the difficulties encountered in these focus-size experiments and their theoretical implications, a brief highlight of each experiment’s aim and main findings is in order. In the first experiment, the foremost interest was the pattern (linear, logarithmic, etc.) of the focus-size effect (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli et al., 1998; Turatto et al., 2000; & Usai et al, 1995). The secondary aim of this experiment examined
how task difficulty would affect the magnitude of the focus-size effect. Surprisingly, the
discrimination task illustrated an effect contradictory to the original focus-size effect for the smaller
cues and no effect for the larger cues, while the detection task produced no discernable pattern for
any of the cues. The second experiment then examined whether the focus-size effect could indeed
be found, so an exact replication of the Maringelli and Umlita (1998) study was conducted.
Although this attempt did provide the focus-size effect, the replication was only partially successful
for the main effect of SOA, and its interaction with cue size, were not significant. Lastly, using the
successful manipulations from the previous experiment, Experiment 3 returned to the original
intention of the study. Again an effect of focus-size was found, albeit smaller than the replication (an
average of 6 ms while the replication had a 12 ms effect), and it was not constant throughout all of
the cue sizes; the smallest and the largest cue sizes had longer and shorter RTs than predicted by
the focus-size effect. As before, there was no effect of SOA.

An examination of the focus-size effect literature's between-study (Benso et al., 1998;
Castiello & Umlita, 1990; Castiello & Umlita, 1992; Maringelli et al., 1998; Turatto et al., 2000; &
Usai et al., 1995) and this study's between-experiment manipulations may help to illuminate the
root of this study's replication difficulties. Before continuing, it should be emphasized that the
present experiments were very similar to the previous literature's successful manipulations, so the
focus-size effect seems particularly sensitive; indeed, the only novelty in this study, as compared to
the previous literature, was the number and range of cue sizes available. In the initial experiment
of this study there were eight cue sizes and the last experiment had six sizes, while the previous
literature only included two or three different cue sizes per experiment. The largest cue in the
previous literature was eight degrees, while this study had 24 and 15 degree cues in the first and
last experiment, respectively.
Within this study, there were several manipulation differences between the experiments; number (either 2, 6, or 8 available) and range (largest cue size: either 8, 15, or 24 degrees) of cue sizes, SOA (66, 100, & 350 ms), task (detection and discrimination), and fixation stimuli (either included or not included in the cue). Each if these factors will be discussed in term.

1) Cue sizes: The number and range of cue sizes was greater in the first and last experiments. Their effects were confounded with one another, but both experiments that included more and greater cue sizes yielded either a weaker or absent focus-size effect.

2) SOA: In the first experiment, a 350 ms SOA did not yield the focus-size effect, while the subsequent replications’ 100 ms SOA did yield the effect. It is also noteworthy that the 500 and 700 ms SOA used in this experiment also yielded much smaller focus-size effects than the original study found; in fact, there was not a significant difference between the large and small cue size at the 700 ms SOA. Therefore, this study had a difficult time uncovering the focus-size effect at longer SOAs.

3) Task type: In the first experiment, both the detection and discrimination task evaded the focus-size effect, while the latter two experiments, which both used detection, did find the effect. With mixed results, task is the only noted manipulation that did not appear to impact the results.

4) Fixation: For the first experiment, a fixation point, which was the initial presentation of each trial, lasted until the target appeared. The latter two experiments did not include a fixation stimulus, only a cue and a target, and were successful in finding the focus-size effect.

The weakening of the focus-size effect seems related to the previously expounded differences, and their impact may be most appropriately described in relation to the automaticity of focusing. To begin, SOA seemed a likely contributor to the lack of focus-size effect in the first experiment, which relied on focusing to occur automatically. This research and other focus-size
effect literature (Benso et al., 1998; Castiello & Umilta, 1990; Castiello & Umilta, 1992; Maringelli et al., 1998; Turatto et al., 2000; & Usai et al., 1995) were conceived of and supported by the literature which has found abrupt onsets and new objects to reliably capture attention (Yantis & Jonides, 1984; Yantis & Hillstrom, 1994). Subsequently, the previous focus-size research concretely established that focusing will indeed occur automatically to abrupt onsets, and that this automaticity is strong enough to defy commands to maintain focus of another stimuli (Turatto et al., 2000). However, it is known that the automatic orienting of attention has effects that occur and dissipate quickly (e.g., Yantis, 1998). Thus, the effects of automatic focusing may have disappeared at the 350 ms SOA. In the latter experiments, the automatic focusing of attention was still engaged at the shorter SOAs, rendering the focus-size effect available for measurement.

The presence of the fixation point may have also contributed to the negation of the focus-size effect in the first experiment. Given adequate time and multiple stimuli choices, participants will refocus on the smaller object (Turatto et al., 2000), so participants may have had enough time to simply refocus on the smaller fixation object. In the latter two experiments, the lack of fixation stimuli may have made it more likely that the automatic focusing of the cue was measurable since there was only one stimulus available for focusing.

Additionally, the number and range of available cue sizes most likely contributed to the current weakening of the focus-size effect. The focus-size effect did weaken in the last experiment, while the number and range of cues were the primary difference from the replication. Unfortunately, why this weakens the focus-size effect is ambiguous since varying the cues would not weaken the exogenous component of attention; in fact it would make the cues more salient, therefore increasing the likelihood of attention (Maringelli & Umilta; 1998; Theeuwes, 1994). Ultimately, the incongruencies between these findings and the previous focus-size effect literature
will be best approached by further experimentation of exactly those previously noted manipulations.

This study's replication difficulties lead to a crucial question regarding the original zoom lens theory that served as the original explanation for the focus-size effect (e.g., Eriksen & St. James, 1986). This theory assumes that, due to limited resources, the attentional scope enlarges or contracts, consequently benefiting task efficiency as the resources become denser. However, subsequent literature (e.g., Kramer & Hahn, 1995) has left the zoom-lens and like models with more questions than answers. For example, a primary assumption of the model was that attention could not be split, but this has since been proven possible, even substantiated by some of the focus-size literature itself (Castiello & Umilta, 1990; Castiello & Umilta, 1992). Consequently, the replication difficulties encountered in this study may be linked to a faulty theoretical base. Until further supporting research concerning these models is found, it may be best to abandon these models while exploring focus-size effects.

With tenuous theoretical support for the focus-size effect and the replication problems experienced in this study, where can the focus-size examinations go? Foremost, it should be addressed whether the weakness of the focus-size effect in this study simply indicates the weakness of the current methodology. Two aspects of this study and the previous literature may weaken the attentional affects. These are that blank visual fields (Shiu & Pashler, 1994) are not suited to illustrate the effects of attention nor is spatial certainty of the stimuli (Folk et al., 1992). Both of these elements are predominant in not only this study, but most of the previous focus-size literature as well (Benso et al., 1998; Maringelli & Umilta, 1998; Turatto et al., 2000; & Usai et al, 1995). The use of visual search would address both of these concerns, which has preliminary support from one study that combined both cue-size and visual search (Greenwood & Parasuraman, 1999). In
addition, the investigation of the automatic and voluntary components of focusing begun by Turatto et al. (2000) should be continued. The true likelihood of focusing is imperative knowledge if researchers truly wish to investigate its parameters, i.e. focus-size effects. In conclusion, the focus-size effect was elusive throughout the entire set of experiments in this study; many questions have been raised, a few explanations have been attempted, but until more studies are done, the focus-size effect is deemed at best very sensitive.
References


### Table 1
Mean Millisecond RTs for Experiment 2

<table>
<thead>
<tr>
<th>Cue Size</th>
<th>100 ms</th>
<th>500 ms</th>
<th>700 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 deg</td>
<td>304</td>
<td>309</td>
<td>313</td>
</tr>
<tr>
<td>6 deg</td>
<td>316</td>
<td>319</td>
<td>319</td>
</tr>
</tbody>
</table>

Note: Cue size is expressed in the diameter degrees visual angle.
Figure Captions

**Figure 1.** Example of a polygon with a missing piece used in Usai et al. (1995); the missing piece is the area that renders the hexagon incomplete.

**Figure 2.** Experiment 1: Reaction times and standard errors for the eight cue sizes according to detection and discrimination task.

**Figure 3.** Experiment 3: Reaction times and standard errors for the six cue sizes according to 66 and 100 ms stimulus onset asynchrony.
Figure 2

Experiment 1

Reaction Time (ms)

Cue Size (Degrees)

- Detection
- Discrimination
Figure 3

Experiment 3

Reaction Time (ms)

Cue Size (Degrees)

- - 66ms SOA
- - 100 ms SOA