2011

The Effect of Cognitive Load on Distraction During Visual Search

Katryne Michaud

ABSTRACT

Salient visual features have been known to capture attention, but there is disagreement regarding why these features capture attention (because of their bottom-up salience/uniqueness or the goals of the observer). To explore whether attention capture is truly a bottom-up, stimulus-driven, and automatic effect, Boot, Brockmole, & Simons (2005) added an auditory task to a traditional attention capture paradigm. In single task conditions, they found that onsets (objects that appear suddenly) and color singletons (items of a unique color compared to the items around them) captured attention. However, when participants also had to listen to the auditory task, the degree to which these distractors captured attention changed (onsets capture was eliminated while color singleton capture increased). These findings challenge the notion that capture is stimulus-driven and automatic; the search display was exactly the same in single and dual-task situations. However, it was puzzling why onsets decreased in their ability to capture attention while color singletons increased under the same dual-task conditions. Boot, Brockmole, & Simons (2005) proposed a transience hypothesis: transient singletons like an onset require cognitive resources to be recognized as being unique, while sustained distractors such as color-singletons required cognitive resources to suppress. We tested this hypothesis with onset distractors that were either the same as the other distractors in the display, or onset distractors that also had a unique shape. Contrary to predictions, neither had the ability to capture attention under dual-task load. Results do not support stimulus-driven accounts of attention capture. Theoretical and practical significance is discussed.

Keywords: Visual Search, Attention Capture, Multi-tasking

THE FLORIDA STATE UNIVERSITY

DEPARTMENT OF PSYCHOLOGY

THE EFFECT OF COGNITIVE LOAD ON DISTRACTION DURING VISUAL SEARCH

By

KATRYNE MICHAUD

A Thesis submitted to the
Department of Psychology
in partial fulfillment of the requirements for graduation with
Honors in the Major

Degree Awarded:
Summer, 2011

The members of the Defense Committee approve the thesis of Katryne Michaud defended on April 20, 2011.

Dr. Walter R. Boot
Thesis Director

Dr. Murray Krantz
Outside Committee Member

Dr. Ralph R. Radach
Committee Member

ACKNOWLEDGEMENTS

It is a pleasure to thank the many people who have helped make this thesis possible. This includes Dr. Walter R. Boot for serving as my thesis advisor, and Drs. Ralph Radach and Murray Krantz for serving as thesis committee members. I would like to thank the FSU Honors Office for their invaluable assistance and for the funding to complete this project through the Bess H. Ward Honors Thesis award. Finally, I would like to thank allof the faculty at FSU and within the psychology department for their help throughout my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Salient visual features have been known to capture attention, but there is disagreement regarding why these features capture attention (because of their bottom-up salience/uniqueness or the goals of the observer). To explore whether attention capture is truly a bottom-up, stimulus-driven, and automatic effect, Boot, Brockmole, & Simons (2005) added an auditory task to a traditional attention capture paradigm. In single task conditions, they found that onsets (objects that appear suddenly) and color singletons (items of a unique color compared to the items around them) captured attention. However, when participants also had to listen to the auditory task, the degree to which these distractors captured attention changed (onsets capture was eliminated while color singleton capture increased). These findings challenge the notion that capture is stimulus-driven and automatic; the search display was exactly the same in single and dual-task situations. However, it was puzzling why onsets decreased in their ability to capture attention while color singletons increased under the same dual-task conditions. Boot, Brockmole, & Simons (2005) proposed a transience hypothesis: transient singletons like an onset require cognitive resources to be recognized as being unique, while sustained distractors such as color-singletons required cognitive resources to suppress. We tested this hypothesis with onset distractors that were either the same as the other distractors in the display, or onset distractors that also had a unique shape. Contrary to predictions, neither had the ability to capture attention under dual-task load. Results do not support stimulus-driven accounts of attention capture. Theoretical and practical significance is discussed.

Keywords: Visual Search, Attention Capture, Multi-tasking

INTRODUCTION

The scenes we view every day are far too cluttered and complex to process and understand all at once. Attention research describes how the visual system copes with the overwhelming details of the world around us. Visual attention has been conceptualized as a spot-light or zoom lens, enhancing the visibility of objects within a scene (Eriksen & St-James, 1986; Eriksen & Yeh, 1985). Objects falling outside of this spotlight or outside the focus of the zoom lens are ignored or processed to a lesser extent. In this way, the cognitive processes responsible for the allocation of attention determine what visual information in the environment is processed and what is ignored. There are several factors that have been investigated by scientists that influence where attention will go and what will capture attention. Some researchers have postulated that unique or distinct objects and events can capture attention automatically, but attention can also be directed based on our own ability to control attention (Yantis & Jonides, 1990).

Theories of attention are crucial to understanding human cognition and behavior, but an understanding of attention also has important practical implications. While driving, we are faced with distraction continuously. Attention research has implications for predicting how attention will act in different situations such as driving in a school zone. Talking on a cell phone is a large distraction and makes it difficult to pay attention to relevant visual information while driving. Another instance in which attention is crucial is air traffic control. When viewing a radar screen, an air traffic controller is faced with several distractors (irrelevant aircraft) that can overwhelm the visual system. Mechanisms of attention help the controller to restrict his or her processing to only the aircraft that they are responsible for. Hence, a better understanding of how attention is controlled has important implications for our understanding of performance in complex environments with important consequences. The inappropriate allocation of attention during driving or air traffic control has potentially disastrous consequences.

It is generally agreed that there are two ways to control attention: top-down attentional control and bottom-up attention forces. Top-down mechanisms of attention can rapidly shift visual resources to objects and visual features relevant to our goals while inhibiting distraction. For instance, a person's goal might be to find her car in a parking lot. The person remembers where she parked, so therefore, will direct her attention to a specific location that is relevant to this goal (where she remembers parking). In contrast, bottom-up, irrelevant visual properties can capture attention in the absence of a goal to attend to them. For example, a driver could send his attention to a billboard that has bright colors. The billboard is not relevant to the driver's goal (driving the car and avoiding obstacles), yet, it captures attention. This is why this type of attentional allocation is often referred to as stimulus-driven attention capture. Even though these seem to be clear in definition (goal-driven versus stimulus driven attention shifts), researchers disagree which has the largest influence on visual processing. One group of researchers believe that certain objects and events have the ability to capture our attention automatically, while another group of researchers suggest that all shifts of attention are the result of top-down goals and intentions. This debate has been investigated in several paradigms to understand attention and the degree to which unique but irrelevant features can be ignored (see Figure 1 for an example).

The way researchers study top-down and bottom-up visual attention (and their interaction) is to look at situations of attention capture. Researchers create situations in which top-down goals compete with bottom-up visual uniqueness. In these attention capture paradigms, observers are given a clearly defined goal (find a certain target). This goal allows observers to shift their attention in a top-down manner to visual features consistent with their goals. Sometimes, in addition to the search target observers are presented with a unique distractor in displays that is never relevant. Since this item is never relevant, if it influences performance, it must have done so in a bottom-up manner based purely on its uniqueness and not the goals of the observer. Theeuwes (1992) used such a paradigm to study the interactions between the top-down and bottom-up vision. Participants had to identify the orientation of the line in a target. For instance, the target could be a green circle (among squares) with a horizontal or vertical line in it. The circle was always the target and therefore shape could be used to guide attention to the target. However, an item of a unique color (referred to as a color singleton), which is a unique bottom-up property, was used to distract attention away from the object that was relevant. In the case of Theeuwes (1992), on some of the trials one of the squares was a unique color (red). This uniquely colored item was absent in control conditions. Results demonstrated that when the color singleton was absent, reaction times were faster. When the color singleton was present, reaction times were slower (attention was captured). This was presented as evidence that salient and unique objects that are not relevant can interfere with goal-directed top-down attention. Onsets, or abruptly appearing objects in the display, have also been found to strongly capture attention (Yantis, & Jonides, 1984). It has been proposed that the visual system may have evolved to give automatic priority to the processing of new objects because of their potential biological relevance (Boot, Kramer, & Peterson, 2005).

Theeuwes (1992) and Yantis & Jonides (1984) proposed that attention capture is purely bottom-up, occurring based on properties of objects in the environment and not the goals or intentions of the observer. Their findings suggest that an irrelevant abrupt onset or salient object such as a color singleton (that are not goal-oriented or expected by the observer) automatically capture attention despite selective goal-oriented attention to a different feature that defined the target (e.g., shape). Their attention capture paradigms revealed that even though the participants were given a target defined by a specific feature trial after trial, the abrupt appearance of a new object in the display captured attention. Participants were slower to identify the target. This implies that regardless of instructions to direct attention to a specific target and ignore all other events, observers were not able to do so; implying attention to onsets was automatic and stimulus-driven. According to this view, if attention was purely top-down, abrupt onsets and singleton objects not relevant to the task of the participant should not influence attention (Jonides & Yantis, 1988; Schreij, Owens, & Theeuwes, 2008; Theeuwes, 1994; Yantis & Jonides, 1984). Furthermore, there is more convincing evidence that bottom-up forces dominate the control for attention during visual search. Christ & Abrams (2006) found that during visual search, onsets still captured attention even when participants were informed before every trial where their search target would appear. If participants could override bottom-up attention capture, they should have easily been able to shift attention only to the target location based on their top-down knowledge of where the target was going to be. However, this was not the case. Thus, this experiment strongly supports the idea that certain visual features cannot be ignored, and that in some certain situations the top-down control of attention is impossible.

There are further supporting ideas that top-down attentional control cannot eliminate bottom-up shifts of attention to unique items; Theeuwes (1992, 1994) investigated the effect of irrelevant color singletons during visual search. Participants were told the red color singleton was never the target, and completed hundreds of trials of practice. However, even after being informed of the irrelevance of the color singleton distractor and trying to ignore it for hundreds of trials, the color singleton still captured attention, almost as well as it did initially. The results of other experiments have led to same similar conclusions that attentional control is bottom-up (Atchley, Kramer, & Hillstrom, 2000; Boot, Kramer, & Peterson, 2005; Enns, Austen, DiLollo, Rauschenberger, & Yantis, 2001; Franconeri & Simons, 2003; Jonides & Yantis, 1988; Theeuwes, Kramer, Hahn, & Irwin, 1998).

In contrast, other researchers suggest that attentional allocation is purely top-down and that there is no existing evidence for purely bottom-up stimulus shifts (Folk, Leber, & Egeth, 2008; Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994). They maintain that that the allocation of attention (including all attention capture effects) is dependent upon the goals and expectations of the observers. Folk, Remington, & Johnston (1992) investigated top-down control of attention by looking at a cuing paradigm. Before the search display appeared, an irrelevant cue could appear around one of the four locations the target could be presented later. Since this cue only appeared around the target with a probability of chance (25% of the time), participants had no particular reason to attend to the cue. Folk and colleagues specifically measured attention capture by looking at cuing effects. If the irrelevant cue was capable of pulling attention to a location, participants should be very fast at identifying the target when the cue happened to appear where the target was about to appear. When the same cue appeared at a location other than where the target was about to appear, participants should be slow (they must reallocate attention to the correct target location). In one condition, the target symbol that participants had to identify (X or =) was defined as the only symbol to onset in the display. When this was true, the onset of four circles around one of the potential target locations strongly captured attention (a large cue validity effect). However, when the target was defined as being a color singleton (the one red symbol among three white symbols), onsets no longer captured attention. In this and other experiments, it was demonstrated that a cue only captured attention if it shared the same feature that defined the target. In another condition, a color singleton cue only captured attention when participants were searching for a color singleton. If participants were searching for a target defined by being an onset, color singletons failed to capture attention. A number of other studies have questioned the position that certain visual features capture attention in a way that is automatic and stimulus-driven (Bacon & Egeth, 1994; Gibson & Kelsey, 1998; Leber & Egeth, 2006).

To further investigate whether or not attention capture has a top-down component, or whether attention capture is stimulus-driven, Boot, Brockmole, & Simons (2005) added an auditory secondary task to a standard attention capture paradigm. The logic being that the auditory task would take away top-down resources. However, if attention capture is a purely stimulus-driven effect, the addition of an auditory task to the search task shouldn't matter. Whether or not participants are engaged in an auditory task does not change the visual display they are observing. In terms of understanding how attention operates in complex real-world situations, this manipulation may be informative as well. Attention research has typically studied attention and attention capture in single-task situations, and relatively little is known about how attention operates when multiple cognitive tasks must be performed at once. The general finding obtained was that cognitive resources seem to play a crucial factor in attention capture; despite some researchers claiming attention capture is a purely bottom-up effect. These results are described in detail next.

Boot, Brockmole, & Simons (2005) incorporated a dual task paradigm into a traditional attention capture paradigm. This was done by adding an auditory task in addition to the search visual task. For example, participants could hear a string of numbers like 1 2 5 9 9 5 8 7 2 2.

The task was to identify the number of times two numbers repeated sequentially in the auditory stream. When participants paid attention to the auditory task, onsets, (which have been assumed to capture attention automatically) failed to capture attention. However; surprisingly, uniquely colored items (color singletons) INCREASED in their ability to capture attention. Hence, these findings by Boot, Brockmole, & Simons (2005) challenges previous theories that attention capture is largely stimulus driven. The stimulus was the same in both conditions (single vs. dual), yet whether or not participants attended to the auditory task either eliminated or increased capture. These results also suggest that how we understand attention capture is incomplete since attention is typically studied in single-task situation (participants only complete a visual search task). Outside of the laboratory we often perform multiple tasks at the same time. For example, in addition to looking for airplanes in conflict on radar displays, the air traffic controller must also listen to and communicate with pilots and other air traffic controllers. The driver who chooses to use a cell phone while driving may not be able to direct visual attention correctly to the driving scene. There is additional evidence that shows that when working memory is overloaded by a verbal short-term task, attention capture is modulated (Lavie, & Fockert, 2005). These have implications for theories of attentional control and human factors (the study of information processing in real-world settings) implications as well.

One puzzling aspect of the results reported by Boot, Brockmole, & Simons (2005) is how the same secondary task has different effects on attention capture by different types of distractors, which is the main focus of the current research. A color singleton distractor increased in its ability to capture attention when participants attended to the auditory task. However, an onset (abruptly appearing distractor) decreased in its ability to capture attention. This is interesting because according to biological relevance/evolutionary perspectives of attention capture, onsets capture would be predicted to be more robust. These theories posit that the visual system evolved to give automatic priority to new objects in the environment, because new objects may require immediate response (e.g., the sudden appearance of a predator). To explain diverging effects of auditory distraction on onset and color singleton capture, Boot, Brockmole, & Simons (2005) proposed a transience hypothesis. An object that is unique for a long time period (like a color singleton) is a sustained distractor and an object that is unique for a short period of time (like an onset) is transient distractor. They hypothesized that cognitive resources might be needed to detect briefly unique items. For onsets, if cognitive resources are diverted, new objects might become old objects before they can be recognized as new. This could explain decreased capture when cognitive resources are tied up with an auditory secondary task. In contrast, a color singleton is always distinct (a sustained distractor). A sustained and unique item is unlikely not to be noticed as unique. In fact, cognitive resources might be necessary to prevent attention from going to and returning to this item during search. This was their explanation for why color singletons increased in their ability to capture attention under dual-task load.

The primary aim of the current investigation was to investigate and further explore this transience hypothesis. We investigated how the same cognitive dual-task used by Boot, Brockmole, & Simons (2005) might influence the ability of other transient and sustained distractors to capture attention in a similar attention capture paradigm. We specifically investigated the ability of an onset to capture attention, and also an onset that was also a unique shape. In other words, we looked at a transiently unique onset and an onset that remained unique even after the visual system might no longer consider it a new object. If the transience hypothesis is correct, under dual-task condition the onset should lose its ability to capture attention. However, the onset that is also a unique shape should either still capture attention or increase in its ability to capture attention. This is because it was predicted that cognitive resources may be needed to inhibit attention to items that are a sustained distraction. Figure 2 depicts these predicted results.

SIGNIFICANCE

The results we predicted are relevant for theoretical and practical reasons. Another demonstration of the effect of cognitive resources on attention capture supports a view that attention capture effects are based on goals and intentions (top-down) instead of automatic responses to certain visual properties (bottom-up). From a practical perspective, knowing the types of visual properties that capture attention, even under dual-task situations, can help designers create displays in which important information can be signaled for immediate processing. The tasks we complete in the real world are often complex with both visual and auditory components. Our experiment studies attention capture in situations more analogous to these situations compared to single task attention capture experiments.

METHOD

Participants.

Forty-four students from Florida State University were recruited (29 females, 15 males, M = 19.95 years, age range: 18-23 years). Participants were compensated 10 dollars for a half hour of participation. All participants reported normal or corrected to normal vision.

Material and Design.

The visual and auditory tasks were programmed using the E-Prime software package, and search stimuli were presented on a 20 inch color computer monitor. Participants sat in a dimly lit room in front of a computer and used the keyboard of the computer to identify the target on each trial. Each trial was initiated when the participant pushed the space bar. At the start of each trial, participants viewed a black screen with a fixation cross in the middle for 2000ms. After 2000ms, a premask screen appeared which hid the identity and location of the target (Figure 3). This screen consisted of a number of red circles in the periphery, with each circle containing a cross. The premask screen was presented for 1000 milliseconds. Then, all peripheral red circles changed to green except for one (the target). Simultaneously, line segments were removed from each cross to reveal vertical and horizontal search stimuli. Participants had to respond to the orientation of the line within the red circle as quickly as possible (but accurately as well), and had 2000ms to do so. On some trials, the premask screen had 7 items, and the search display had 7 items (baseline, or no onset condition). On other trials, the premask screen had 6 items, and a 7^{th} item onset as the search display was revealed. On half of these trials, the onset was a circle (non-unique onset). On the other half, the onset item was a diamond (unique onset). All shapes measured approximately 2.5 degrees in diameter. At the same moment the trial started, participants heard a voice reading a string of numbers such as: 3 5 5 7 4 9 2 2 1 6 for a total of 5 second each trial (at a rate of one digit every 500 ms). On half of the trials this number sequence had 2 sequential repeating numbers, and on the other half of trials this number sequence had 3 instances of a number repeating sequentially.

Procedure.

Half of all participants were instructed that they would need to listen to the string of numbers presented on each trial and report the number of times two numbers repeated sequentially. They indicated their response using the 1-4 number keys at the top of the keyboard. The other half of participants were told they could ignore these numbers, and were instead asked to press the number 2 at the end of each trial. Regardless of what participants were told about the auditory task, all participants were instructed to respond to the visual search target as quickly as possible as soon as it appeared (and accurately as well). Participants pressed the Z key on the keyboard if the target (the remaining red circle) contained a horizontal line, and the / key on the keyboard if it contained a vertical line. Participants were informed that new objects could appear in the search display, but that these onset items could never be the target. Participants in the dual task were told that the search task was their primary task. They were informed that responses to the auditory task were not timed, and only accuracy mattered.

In both single and dual-task versions, participants began by learning the dual auditory task alone and completed 6 trials of practice. Then, both groups of participants received 10 practice trials of only the visual search task without the auditory stimulus present. Then, both groups completed 10 practice trials in which the search and auditory tasks were presented simultaneously. In the single-task group participants were told to ignore the numbers, which the dual-task group counted the number of sequential repetitions. Finally, participants completed one real block of 108 trials. One third of these trials had no onset, one third had a non-unique onset (circle), and one third had a unique onset (diamond). The location of the target and identity of the target was determined from trial to trial. Participants were encouraged to take a break every 48 trials.

RESULTS

Of a total of 46 participants, one participant in the dual-task condition had abnormally long reaction times (> 2.5 *SD* from the mean), and one participant had abnormally low accuracies (< 2.5 *SD* from the mean). Thus, these participants were identified as outliers and were not included in the reported analyses. Table 1 depicts mean correct response times and accuracies for each condition and each group. Since capture effects can appear in both response time (RT) and accuracy data, and to control for possible speed-accuracy trade-offs, we computed search ''inefficiency'' scores to analyze capture effects (Smilek et al., 2006; Townsend & Ashby, 1983). Inefficiency scores are a form of corrected RT that penalizes participants for fast but inaccurate responses by dividing RTs for each condition by proportion correct. Mathematically, this inflates RTs for participants with low accuracies and allows for a single measure of capture that takes into account a distractor's effect on both speed and accuracy of response. In the dual-task condition, mean accuracy of reporting the number of repetitions in the stream was 65% (*SD* = 13). Participants were instructed that 1-4 repetitions could occur in the auditory task even though only 2 or 3 repetitions actually occurred. Accuracy was well above subjective chance (25%), indicating that participants in the dual-task condition were indeed attending to the auditory task.

Inefficiency scores were entered into a two-way ANOVA with distractor type (no onset, non-unique, and unique onsets) as within participant factor and task load (single versus dual) as a between factor design. As predicted, there was an interaction between distractor type and task load (F (2, 80) = 2.90, p = .06).

Figure 4 depicts capture effects (efficiency of the no distractor condition subtracted from each condition). Positive values indicate more capture. It appears that both unique and non-unique onsets capture attention in the single-task condition, but not in the dual-task condition shown in Figure 5. Individual t-tests determined whether capture effects under single and dual task load significantly differed from zero. In the single-task condition, the non-unique onset captured attention (t (21) = 2.41, p < .05), and the unique onset also captured attention (t (21) =

2.41, p <.05). In the dual-task condition, neither the unique nor the non-unique onset captured attention (t (19) = -.86, p = .40, t (19) =-.10 p = .92 respectively).

DISCUSSION

According to the bottom-up attentional control perspective, the abrupt onset of an object captures attention automatically. Certain salient visual stimuli, even though they are irrelevant to the task of the participant, capture attention effortlessly based purely on their visual stimulation and not on the goals and intentions of the observer (Atchley, Kramer, & Hillstrom, 2000; Bacon & Egeth, 1994; Boot, Kramer, & Peterson, 2005; Enns, Austen, DiLollo, Rauschenberger, & Yantis, 2001; Franconeri & Simons, 2003; Gibson & Kelsey, 1998; Leber & Egeth, 2006; Jonides & Yantis, 1988; Theeuwes, Kramer, Hahn, & Irwin, 1998; Yantis, & Jonides, 1984). In contrast, others believe that when something captures attention, it is because the attention-capturing stimulus is consistent with the goals and intentions of the observer (Folk, Remington, & Johnston, 1992; Folk & Remington, 1998; Folk, Leber, & Egeth, 2008; Folk, Remington, & Wu, 2009; Folk, Remington, & Wright, 1994). This perspective posits that attention capture is top-down, and that attentional allocation in general is dominated by cognition rather than purely based on stimulus-properties.

Boot, Brockmole, & Simons (2005), and our series of experiments found that attention capture effects were modulated when participants had to listen to and perform a simultaneous auditory task. If attention was controlled primarily by bottom-up factors, then we would not see a modulation between the two different conditions (single versus dual-task). Bottom-up visual properties of the display are not affected by reduced cognitive resources. However, we found that attention capture by both onsets, and onsets that had a unique shape as well, failed to capture attention under dual-task load. This suggests that attention capture involves top-down control mechanisms which were interfered with by the auditory task.

When Boot, Brockmole, & Simons (2005) presented observers with a color singleton, attention capture performance increased when given a task-load. On the other hand, when presented with onsets, attention capture performance decreased in the same condition. They suggested that an onset is a transient distraction: it is only new for a short period of time. Cognitive resources may be required to recognize it as new. A color singleton is always clearly different from the items around it. In this case, cognitive resources may instead be required to suppress reaction to the color singleton. We attempted to extend this finding by taking an onset, which is traditionally a transient distractor, and making it into a sustained distractor by also having it is as a unique shape. We predicted that an onset that was also a unique shape should maintain, or even increase in its ability to capture attention under dual-task load.

Based on the evidence obtained, the transience hypothesis was challenged. An abruptly appearing object, even if it was constantly unique from the items around it, did not capture attention when participants were listening and responding to an auditory task. A real-world example, a cell phone conversation might disrupt a driver's attention to a pedestrian suddenly stepping into the road, regardless of whether this pedestrian was dressed normally or uniquely (e.g., dressed as a clown). However, one might argue that the unique shape was not sufficiently salient enough to be recognized as being unique. A color singleton is easy to detect as unique, even when it is far in the periphery of vision. A shape singleton is probably more difficult to recognize as unique in the visual periphery. In future studies, using a more salient sustained distractor such as a luminance, size, or blinking singleton might be tested under single and dual-task load. Additionally, we tried to make a transient distractor sustained by associating it with another unique property (in this case a unique shape). We can also test the transience hypothesis by making a typically sustained distractor transient. For example, a color singleton distractor that changes after a brief period of time to the same color as the other items in the display is a transient distraction. Under the transience hypothesis, this item should fail to capture attention under dual-task conditions.

Fully understanding capture by different visual properties under single and dual-task load is critical for predicting performance in safety-critical real-world tasks. In real-world settings, we often wish to alert the operator to new and important information (e.g., an alarm). It is important to know which visual properties would be most effective in drawing attention both when the operator is solely performing one task, or when he or she is performing multiple tasks. In other instances pulling attention away from the primary task (using a cell phone while driving) can have disastrous consequences. Understanding how multi-tasking influences primary task performance can help predict and prevent distraction.

In conclusion, data may suggest a new way to think about attention and attention capture all together. A large distinction is typically made between top-down and bottom-up forces that influence attention. However, it is likely that both influence most attention shifts and attention shifts cannot easily or often be classified as being the result of only bottom-up or top-down influences. The particular situation or context (in this case paying attention or not to a dual task) can make attention appear to be either strongly influenced by bottom-up properties or top-down goals. Thinking only about bottom-up shifts of attention ignores that an observer with thoughts and goals and a long history of interacting with the world must be present to view the stimulus. Thinking about top-down shifts of attention ignores that an external world exists that must have some influence on how the observer allocated their attention. To move forward from the bottom-up and top-down capture debate, we propose that all attention shifts fall along a continuum, with these two extremes falling at either end of this continuum.

REFERENCES

Atchley, P., Kramer, A. F., & Hillstrom, A. P. (2000). Contingent capture for onsets and offsets: Attentional set for perceptual transients. *Journal of Experimental Psychology: Human Perception & Performance*, 26, 594-606.

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. Perception and Psychophysics, 55, 485-496.

Boot, W.R., & Brockmole, J.R., & Simons, D.J. (2005). Attention capture is modulated in dual-task situations. *Psychonomic Bulletin & Review, 12* (4), 662-668.

Boot, W. R., Kramer, A.F., & Peterson, M.S. (2005). Oculomotor consequences of abrupt object onsets and offsets: Onsets dominate oculomotor capture. *Perception and Psychophysics*, 67, 910-928.

Christ, E. S., & Abrams, A. R. (2006). Abrupt onsets cannot be ignored. *Psychonomic Bulletin & Review, 13* (5), 875-880.

Enns, J. T., Austen, E. L., Di Lollo, V., Rauschenberger, R., & Yantis, S. (2001). New objects dominate luminance transients in setting attentional priority. *Journal of Experimental Psychology: Human Perception & Performance, 27*, 1287-1302.

Erikson, W. C., & St-James, D J. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception and Psychophysics*, *40* (4), 225-240.

Eriksen, W. C., & Yeh, Y. (1985). Allocation of Attention in the Visual Field. *Journal of Experimental Psychology*, *11* (5), 583-597.

Folk, C. L., Leber, A. B., Egeth, H. E. (2008). Top-down control settings and the attentional blink: Evidence for nonspatial contingent capture. *Visual Cognition, 16* (5), 616-642.

Folk, C. L., Remington, R., & Johnston, J. C. (1992). Involuntary Covert Orienting is Contingent on Attentional Control Settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030-1044.

Folk, C. L., & Remington, R. W. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. Journal of ExperimentalPsychology: Human Perception and Performance, 24, 847-858.

Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: Contingent attentional capture by apparent motion, abrupt onset, and color. Journal of Experimental Psychology: Human Perception and Performance, 20, 317-329.

Folk, C. L., Remington, R. W., & Wu, S. C. (2009). Additivity of abrupt onset effects supports nonspatial distraction, not the capture of spatial attention. *Attention Perception & Psychophysics, 71*(2), 308-313.

Franconeri, S. L., & Simons, D. J. (2003). Moving and looming stimuli capture attention. *Perception & Psychophysics*, 65, 999-1010.

Gibson, B. S., & Kelsey, E. M. (1998). Stimulus-driven attentional capture is contingent on attentional set for displaywide visual features. Journal of Experimental Psychology: Human Perception and Performance, 24, 699-706.

Jonides, J., Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception A Phychophysic, 43,* (4), 346-354.

Lavie, N., Fockert, D. (2005). The role of working memory in attentional capture. *Psychonomic Bulletin and Review, 12* (4), 669-674.

Leber, A. B., & Egeth, H. E. (2006). It's under control: Top-down search strategies can override attentional capture. Psychonomic Bulletin and Review, 13, 132-138.

Schreij, D., Owens, C., Theeuwes, J. (2008). Abrupt onsets capture attention independent of top-down control settings. *Perception & Psychophysics, 70* (2), 208-218.

Smilek, D., Enns, J. T., Eastwood, J. D. & Merikle, P. M. (2006). Relax! Cognitive strategy influences visual search. Visual Cognition, *14*, 543-564.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception and Psychophysics, 51* (6), 599-606.

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: Selective

search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception & Performance*, 20, 799-806.

Theeuwes, J., Kramer, A. E, Hahn, S., & Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science, 9,* 379-385.

Townsend, J. T., & Ashby, F. G. (1983). Stochastic modeling of elementary psychological processes. Cambridge, UK: Cambridge University Press.

Yantis, S., & Jonides, J. (1990). Abrupt Visual Onsets and Selective Attention: Voluntary Versus Automatic Allocation. *Journal of Experimental Psychology: Human Perception and Performance*, *16* (1), 121-134.

Yantis, S., & Jonides, J. (1984). Abrupt Visual Onsets and Selective Attention: Evidence From Visual Search. *Journal of Experimental Psychology: Human Perception and Performance, 10* (5), 601-621.

Table 1

		Control	Non-Unique	Unique
Single				
	RT (ms)	754 (28)	787 (29)	785 (29)
	Accuracy	.93 (.02)	.94 (.01)	.94 (.01)
	Inefficiency	813 (34)	846 (36)	841 (33)
Dual				
	RT (ms)	804 (141)	811 (155)	820 (149)
	Accuracy	.94 (.06)	.96 (.03)	.95 (.04)
	Inefficiency	861 (146)	843 (148)	859 (142)

Note: RT = Response Time. Standard deviations are within parenthesis. Inefficiency scores were calculated by dividing mean response times by mean proportion correct for each condition (Smilek et al., 2006; Townsend & Ashby, 1983).

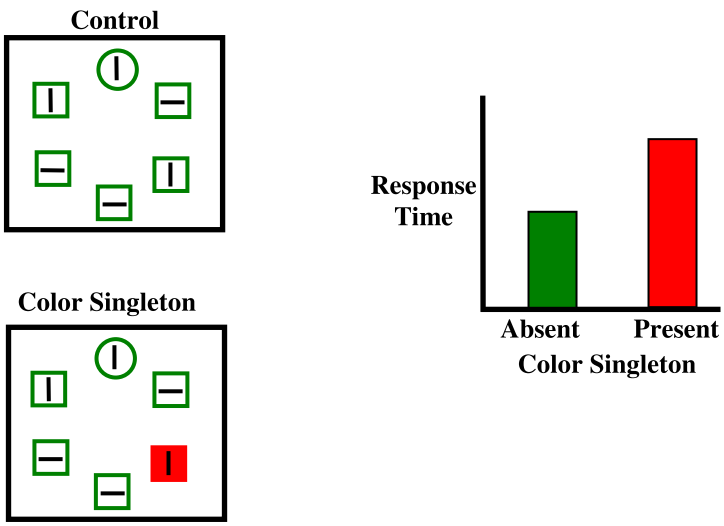

Figure 1. Prototypical attention capture paradigm. Participants must report the orientation of the line within the circle, and are slower to do so when another unique item (e.g., a uniquely colored item) is present.

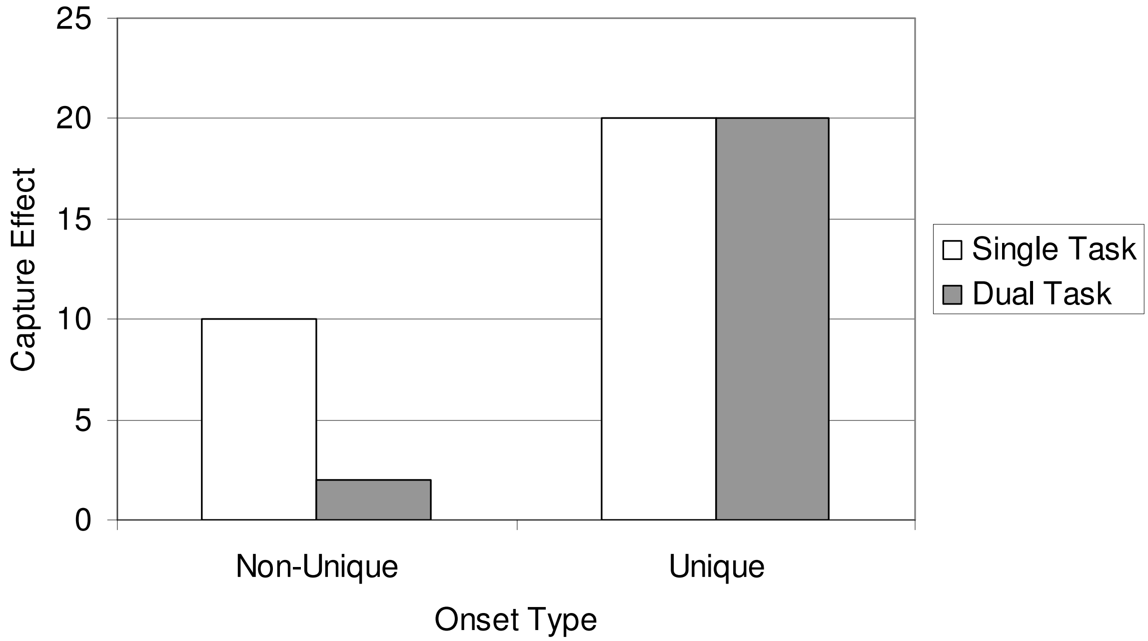

Figure 2. Predicted pattern of results. Although the dual-task should eliminate the power of a non-unique (transient) onset to capture attention, when the onset is a unique shape (sustained), we predict capture should remain robust (or potentially increase).

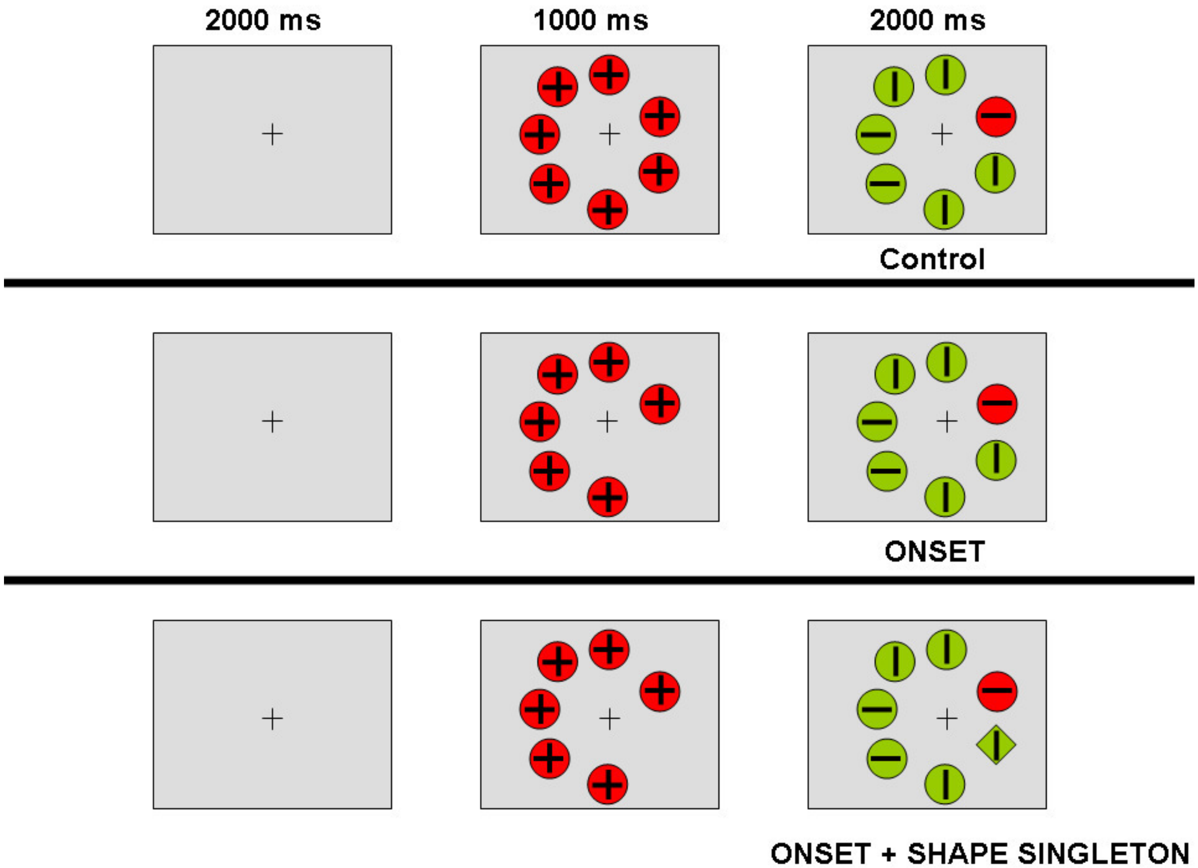

Figure 3. Different types of distractors in the experiment which were tested under single and dual-task load.

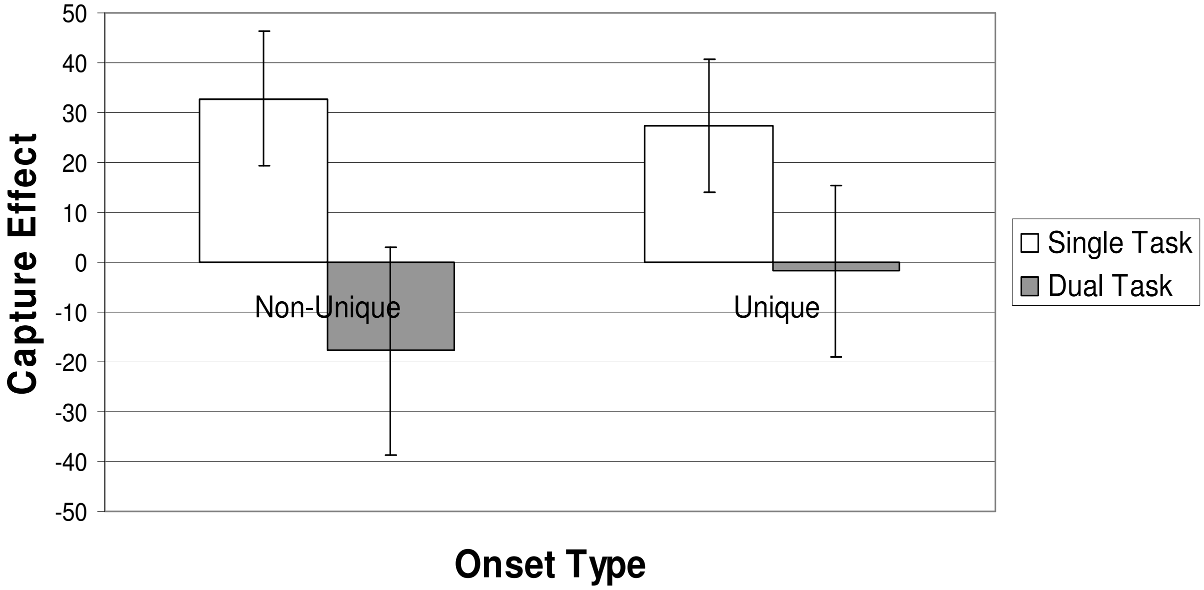

Figure 4. Contrary to predictions, the dual-task eliminated capture by both types of onset distractor.