IMPLICIT AND EXPLICIT CAPTURE OF ATTENTION:

WHAT IT TAKES TO BE NOTICED

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Abstract

Two Inattentional Blindness type experiments involving 446 participants were performed in order to examine how unexpected objects are noticed. Perception of these unexpected objects was measured using explicit and implicit measurements. Despite initial difficulty in determining implicit perception, results showed a dissociation between implicit measurements and explicit measurements, providing strong evidence for unconscious processing. Research into attention capture often emphasizes the role of either expectations or stimulus properties in attention capture; the current research examines both. Critical objects presented were either of a colour that participants were familiar with, or of a new colour. The different patterns of results for these two categories of objects provide evidence for two separate mechanisms of attention capture: a parallel process driven by the features of objects, and a serial process, driven by the intentions of the observer. Predications of the recent theoretical work produced by Most, Scholl, Clifford & Simons, (2005) are examined, and support is obtained for their theoretical formulation.

Unexpected events occur in our everyday lives. You will probably encounter something that you did not expect over the new few minutes, perhaps even while reading this. When this event occurs, you may notice it, but you may miss it completely. This thesis looks at how unexpected events do – or do not – capture your attention.

Inattentional Blindness

It is sometimes assumed that if something is visible, people will report seeing it. However, recent findings have indicated that this is not always the case. Inattentional Blindness is one of several methods where otherwise visible objects have been made perceptually invisible (for a review of other methods, see Kim & Blake, 2005). Inattentional Blindness is produced when attention is focused on one object or task, which causes other objects or events to go unnoticed. There is some indication that Inattentional Blindness is produced by magicians to prevent people from noticing how they make objects ‘disappear’ (Kuhn & Tatler, 2005).

An early demonstration (Neisser & Becklen, 1975) of Inattentional Blindness involved participants watching a video of a ball game and a hand game superimposed on top of each other. Participants attending to one game did not notice odd events in the other game, a handshake, or players losing the ball. In a similar experiment, Simons & Chabris (1999) also demonstrated Inattentional Blindness by engaging participants in a primary task; counting passes made between basketball players in a video, during which an unexpected event occurred; a man in a gorilla suit or a woman with a large umbrella walked through the game.

After the video, the participants were asked if they had seen anything unexpected. In some conditions, only 8% of the participants were able to report the unexpected event.

The phenomenon of Inattentional Blindness provides insight into how people process sensory information, and how things are noticed. While Inattentional Blindness has been shown to occur visually, auditory, and cross-modally (Sinnett, Costa, & Soto-Faraco, 2006), a large proportion of research has been devoted the visual aspect of this phenomenon, and the current research focuses on this. Surprisingly, eye-tracking studies have shown that Inattentional Blindness can occur even when the focus of gaze is directed at the unexpected object (Koivisto, Hyona, & Revonsuo, 2004). In fact, in one study, children who were inattentionally blind still had as much eye contact with the unexpected object as those who saw the object (Memmert, 2006).

Mack & Rock (1998) designed the Inattentional Blindness paradigm to measure the relationship between attention and perception. Participants were instructed to direct their attention to a point on a screen (the point of fixation). Participants were informed that a cross will appear on the screen at a different location, and they were instructed to report which arm of the cross was longer. This process was repeated for three or four trials; on the last trial, an unexpected object (the critical stimulus) was presented on the display. After this last trial, the participants were asked if they saw anything apart from the cross. Participants who did not see the critical stimulus were described as inattententionally blind. Research using this paradigm has traditionally analyzed the effects of different stimuli to produce Inattentional Blindness, or conversely to decrease its occurrence.

One advantage of the Inattentional Blindness paradigm is the strict control over the expectations of participants, because it does not involve multiple presentations of critical objects. If a participant notices one critical object, they will have reason to expect other critical objects on future trials. For this reason, participants are only presented with a critical object once, eliminating any expectation of unexpected events.

Psychologists have used this paradigm to investigate attention and awareness. Various factors related to groups of individuals have been found to affect Inattentional Blindness; for example, individuals who have suffered a traumatic brain injury (Summers, 2005), and individuals who are intoxicated (Clifasefi, Takarangi, & Bergman, 2006), have both been shown to have higher rates of Inattentional Blindness. Various experimental manipulations have affected Inattentional Blindness; for example, Inattentional Blindness is increased when the unexpected object is further away from the cross, the focus of attention (Newby & Rock, 1998). Additionally, Inattentional Blindness also increases when the unexpected object appears at the location where participants had directed their attention, prior to presentation of the cross (Mack & Rock, 1998).

The present research uses the Inattentional Blindness paradigm to continue investigation of attention and awareness. Before further discussion, a distinction needs to be made between awareness and attention: Awareness refers to our subjective experience, our consciousness, and implies that we have knowledge of an event or object, and that we have conscious access to this knowledge. Attention implies a process, where we concentrate on some things, and ignore others. Attention and awareness are related; attentional processes can produce awareness, however, there is indication that attention does not always produce awareness, and awareness can occur in the absence of attention. The present research examines this relationship.

Inattentional Blindness and Perceptual Load

There are indications that visual short term memory is small, sometimes able to hold only one item (Olsson & Poom, 2005), and that to remember multiple items a comparatively long time (e.g. 15s) is needed for encoding into long term storage (Liu & Jiang, 2005). These results indicate that the human perceptual system has limited resources; we are unable to attend to, or be aware of everything that we see. Inattentional Blindness may be the product of such limitations (Olsson & Poom, 2005). If Inattentional Blindness is the product of limited resources, it follows that the amount of load placed on these limited resources by the primary task is an important consideration in Inattentional Blindness.

Early selective looking experiments have indicated that practice can affect rates of noticing; the more trials participants have undertaken, the more likely they are to notice something expected (Neisser, 1979). Recently it has been shown that participants who have broad expertise in area of the primary task are less likely to display Inattentional Blindness (Memmert, 2006). One possible explanation for this is that practice and expertise decrease the perceptual load, thus decreasing Inattentional Blindness.

The neural account suggests that a high load can render observers blind to external inputs. Using computer modeling of neuron activity in the cortex and thalamus, Dehaene and Changeux (2005) produced a simulation where high activation of cortical neurons blocked out external sensory input. This is consistent with fMRI data that has indicated that activity in the right temporal-parietal junction, important for stimulus-driven capture of attention and awareness, is suppressed by high visual short term memory load (Todd, Fougnie, & Marois, 2005).

Simons and Chabris (1999) included two levels of task difficulty; keeping a single count of all passes (easy), and keeping a count of passes for each team (hard). They found participants in the easy condition were more likely to notice someone walking through a ball passing game. A similar finding has been demonstrated using a variant of the Inattentional Blindness paradigm, where the difficulty of the primary task was manipulated to be either deciding the colour the cross (easy), or deciding which cross arm was longer (hard). In the harder, cross length task, Inattentional Blindness was higher (Cartwright-Finch & Lavie, 2007). Other studies of selective attention have also found similar results (Lavie, 1995), providing evidence that perceptual load is a requirement for Inattentional Blindness.

Capturing Attention

The Inattentional Blindness paradigm is one of many paradigms to examine how stimuli can capture attention. In this case, attention capture refers to observers becoming aware of an unexpected object; this can be referred to as explicit attention capture (Most, Scholl, Clifford, & Simons, 2005; Simons, 2000). However, there is evidence that attention can be captured by objects independent of whether observers are consciously aware of the object; this is referred to as implicit attentional capture. Implicit capture is measured using implicit measures; a change in performance (e.g. increase in reaction time, or a decrease in errors) is observed when an unexpected object is presented, even in cases when participants are unaware of the object.

One measure of implicit perception, a word stem completion task, was added to the initial Inattentional Blindness experiments (Mack & Rock, 1998). This task involves participants being presented with the first few letters of a word, and being asked to complete the rest of the word. In this task, implicit perception is inferred if participants produce the same word that was presented as the unexpected object. It is debatable whether this measure is a measure of attention capture – if meaning can be processed prior to the capture of attention (see the later section ‘Meaning and the Capture of Attention’), then this measure is a measure of preattentive, implicit processes. On the other hand, if meaning is not processed prior to the capture of attention, this measure is a measure of implicit attention capture.

Research into implicit attention capture often involves other paradigms, including the additional singleton, oculomotor capture, irrelevant feature searches and pre-cuing paradigms (See Most, Scholl, Clifford, & Simons, 2005; Simons, 2000 for a summary of these paradigms). In these examples, some change in performance of the primary task is observed, even when participants report being unaware of the critical stimulus. The pre-cuing paradigm involves a misleading cue appearing before a visual search. When a distracter appears at the cued location, performance on the primary task decreases. Experiments involving oculomotor capture track the eye, and attention capture is inferred when the eye moves to the unexpected object. The additional singleton task involves the addition of an object to a search display, which results in a slower response time hypothesized to be the result of having to filter out the distracter.

Capturing Attention without Awareness

Implicit attention capture refers to the idea that objects can capture people’s attention without their knowledge, a product of unconscious processes. However, there has been debate over unconscious perception, where psychologists have attempted to determine whether perception can occur in the absence of awareness. Early experimentation (e.g. Peirce & Jastrow, 1884) indicated that even when participants have zero certainty in their own judgement; they still are able to make above chance judgements regarding properties of objects. The classic dissociation paradigm (See Reingold & Merikle, 1988, 1990) became the common method of determining unconscious perception. In this paradigm, implicit perception is demonstrated when an explicit measure is zero, and an implicit measure is non-zero. In an early example of the dissociation paradigm, Marcel (1983) used a pattern mask to prevent participants being aware of words, but found that the presentation of these words sped up subsequent decisions about them.

There is debate over whether the explicit measures should be objective or subjective. An objective measure is one in which a participant demonstrates through some task that she has seen the unexpected object; a forced choice recognition task is one common objective measure of explicit perception. On the other hand, a subjective measure relies on participants indicating whether they were aware of the unexpected object. Holender argued that subjective measures are unreliable, and that to be sure of zero explicit perception, a participant "…must be unable to give direct evidence of identification…" (1986, p. 23). On the other hand Merikle (1992) argued that objective measures are likely to be influenced by both conscious and unconscious processes, so zero perception on an objective measure will indicate zero conscious and zero unconscious perception. Therefore, it is expected that the use of objective measures of explicit perception will decrease the sensitivity of the measures of implicit perception.

Dienes (2004), using higher order thought theory, argued that various sources of bias are possible in subjective measures. In higher order thought theory, a distinction is made between perceivers' actual conscious perceptions, and their second order thoughts about their conscious perceptions. Reports of being consciously aware might be perceivers' reports of whether they think they were aware. As an example, participants may not have been aware of something, but due to implicit processes, they may have a feeling that they know what was presented, and thus if they know what was presented, conclude they have seen it. However, Dienes argues that this is no different to situations encountered in other areas of research – experimenters' make predictions, and see if certain measurements of constructs align with predictions. These measures of constructs are invariably not direct measures of constructs, so there is always some degree of bias.

Merikle, Smilek and Eastwood (2001) defend subjective measures, pointing out that experiments involving objective and subjective measures have led to similar conclusions, so both are appropriate in investigating unconscious processing. Additionally, they argue that objective measures are ultimately established by using subjective measures – to find out whether a measure is a measure of awareness, experimenters need to compare it against subjective reports – so objective measures are only as unreliable as subjective measures. However, they suggest that the primary difference between objective measures and subjective measures of awareness is that objective measures present a more conservative estimate of awareness. Consequently, it is preferable to use objective measures when demonstrating unconscious processing.

One way to demonstrate zero objective conscious perception is to use Signal Detection Theory (see Hannula, Simons, & Cohen, 2005; Snodgrass, Bernat, & Shevrin, 2004). Signal Detection Theory involves comparisons of sensitivity (in terms of hits and misses) of one stimulus against another to produce a measure of detection, d′. This measure of detection is a more rigorous measure of detection, because it allows a way to measure and account for a participant's reporting bias, producing a measure of explicit perception that is independent of bias. If an implicit measure is found to be non-zero, when explicit measures produce a d′ of zero, there is strong evidence for unconscious perception (Macmillan, 1986; Snodgrass, Bernat, & Shevrin, 2004). Unfortunately, in order to determine d′, multiple measurements need to be made for each observer. Because of the strict control the Inattentional Blindness paradigm employs on expectations, Inattentional Blindness experiments must involve only one measurement of awareness, so Signal Detection Theory is of little use with Inattentional Blindness experiments.

Another issue relating to unconscious perception is the idea of exhaustiveness. In order to be sure of zero explicit perception, we would need to be sure that the measure encompasses all conscious processes (Reingold & Merikle, 1988, 1990). For example, a forced choice recognition task would not be sensitive to all conscious processes if a participant were aware of something being there, but was unable to work out what it was. This example demonstrates that while a forced choice recognition task may be sensitive to detect awareness of what the object was, it may not be sensitive enough to detect awareness whether an object appeared. An interesting result (Merikle & Reingold, 1990) provided some evidence that detection may be an exhaustive measure of awareness. They found that accuracy in a forced choice recognition task was largely dependent on whether the participant had detected the word; those who had not detected the word performed around chance, and those who detected the word performed well above chance on the forced choice recognition task. This provides evidence that detection is an exhaustive measure of conscious perception, exhaustive enough to include forced choice recognition.

A promising new direction involves the use of neuroimaging to determine when participants are aware of objects. This method may be able to conclusively demonstrate unconscious processing, but so far, imaging studies have not employed the rigorous measures of explicit perception necessary to establish when an observer is not aware of objects (Hannula, Simons, & Cohen, 2005). Imaging studies are able to provide important information about the operation of unconscious processes. Tsushima, Sasaki and Watanabe (2006) used fMRI to examine processes when dealing with irrelevant motion. In their experiments, they found that performance in a primary task was affected by the movement of irrelevant objects nearby. Interestingly, they found that this disruption to performance was lower when participants were unaware of the motion. Additionally, this disruption in performance corresponded with lower activity in the lateral prefrontal cortex and higher activity in the visual cortex. Due to the prefrontal cortex's role in inhibition, they concluded that inhibitory control does not operate on unconscious processes.

As an alternative to the dissociation paradigm, Reingold and Merikle (1988) suggested that unconscious perception can be shown if implicit measures and explicit measures are qualitatively different. If an indirect measure is more sensitive to an aspect of stimuli than a direct measure, this implies unconscious perception (assuming the direct measure is more sensitive to conscious processes than the indirect measure). This was demonstrated in a later experiment, where participants were shown one word, then a second word within a mask. The participant reports whether a word within the mask was the same as the word presented earlier (direct measure), or reports how similar the pattern mask was to the word presented earlier (indirect measure). With non-cued words, the indirect measure was initially more sensitive than the direct word, which provides evidence for implicit perception (Merikle & Reingold, 1991).

Snodgrass et al. (2004) proposed a similar framework to demonstrate unconscious perception. They argue that a single process conscious perception model predicts that implicit measures will be positively correlated with explicit measures of perception. On the other hand, if implicit measures are non-monotonic; following a U shaped pattern, decreasing as explicit measures decrease, but increasing when explicit measures reach zero, this provides evidence for unconscious processes. This non-monotonic pattern of implicit perception could be the result of multiple explicit processes, so two more conditions need to be met to demonstrate unconscious perception; the change(s) from a positive relationship need to occur at thresholds determined through some other means, and while the explicit perception is non-zero, the relationship between implicit and explicit measures must be unambiguously positive.

Results conforming to these predictions have been demonstrated, such as the word stem exclusion paradigm, where participants are told not to fill out the stem with a previously presented word. In this paradigm, implicit perception was demonstrated by an increase in word stem completions, which occurred for those viewing words for 43 and 57 ms, whereas conscious perception is demonstrated by a decrease in word stem completion, which occurred for those viewing words after 214 ms (Merikle, Joordens, & Stolz, 1995). Greenwald, Schuh and Klinger (1995) has also produced other examples of non-monotonic relationships.

Snodgrass, Bernat, and Shevrin's (2004) framework extended to the measurement of implicit and explicit perception over one dimension. If measurements were made across different dimensions, evidence for unconscious processing might be uncovered. If two different conditions produce similar rates of explicit perception, but qualitatively different rates of implicit perception, this result would be very difficult to explain using a single process conscious perception model. On the other hand, this bidirectional pattern of results would be parsimonious with unconscious processing (Snodgrass, 2004).

While many (e.g. Dienes, 2004; Merikle, Smilek, & Eastwood, 2001; Snodgrass, Bernat, & Shevrin, 2004) are certain of the existence of unconscious processes, some (Holender & Duscherer, 2004) still argue for single processes conscious perception models. Hopefully the present research will be able to contribute to this debate. The Inattentional Blindness paradigm presents some difficulty in this area, as there is only one measurement of awareness per participant; consequently these measures of awareness cannot easily be shown to be exhaustive, so participants' subjective reports may not be enough to provide evidence for unconscious perception using the classic dissociation paradigm. However, it is a goal of the present research to produce strong evidence for unconscious perception by showing qualitative differences between explicit and implicit measures in different conditions across two dimensions.

How to Capture Attention

Having addressed issues related to measuring implicit attention capture, we return to the question; what captures attention? Research has identified various factors which capture implicit and explicit attention, for example, dynamic stimuli tend to capture implicit attention more than static stimuli (Chastain, Cheal, & Kuskova, 2002), and moving and looming objects capture implicit attention, while retreating objects do not (Franconeri & Simons, 2003).

Similarly, the onset of a new object can cause implicit attention capture (Yantis & Hillstrom, 1994) and explicit attention capture (Cole, Kentridge, & Heywood, 2004). However, this could be due to a change in stimulation that accompanies an objects onset, such as a change in luminance. Gellatly, Cole, and Blurton (1999) produced an experiment where the onset of a new object coincided with a similar change in luminance in the other objects in the display. In this new condition, the implicit capture of attention resulting from onset was decreased.

The ability of object onset to capture attention has been shown to have other limitations; attention is not captured if the onset (or change in luminance) is gradual, (Irwin, Colcombe, Kramer, & Hahn, 2000), if the onset occurs amongst a large array of other objects (Patel & Sathian, 2000), or if the object appears while obscured by some other object (Franconeri, Hollingworth, & Simons, 2005). Conversely, it has been shown that attention capture can occur when changes to the display do not create an additional object (Chastain & Cheal, 2001).

There also is some indication that attention is attracted to features, rather than objects. Patel and Sathian (2000) performed an experiment exploring the interference produced by distracters. Target features (e.g. length, orientation) appeared on a single distracter (e.g. a long object at 45°), or on two separate distracters (e.g. a long object, and an object at 45°). In both of these cases, the interference produced was comparable, indicating that in their experiment, features, as opposed to objects, capture attention., however, this claim may just be the product of their experimental methods.

These results indicate that the formation of a new perceptual object is not necessary for attention capture, and in some cases is not even sufficient for attention capture. The features of objects may be more reliable in attracting attention. However, what happens in a situation such as the Inattentional Blindness paradigm, where people are focusing attention on a group of objects, while ignoring other objects? Some experiments provide evidence for stimuli capturing attention independently of the observers' intentions, but there is also evidence that attention capture depends on the demands of the task, and the intentions of the observer.

Some have argued that attention is captured by the physical properties of stimuli independent of an attention set: In Theeuwes' (1993) model of attention, attention is captured primarily by the basic physical properties of objects. His model allows some attention to be consciously directed at a particular location, but even then, the most salient stimulus within this area is processed. In support of this view Theeuwes (1994) reported that even when participants pay attention to colour, a sudden onset can cause implicit attention capture. Conversely, when participants pay attention to onset, a change in colour can also cause implicit attention capture. Other results have indicated that colour captures attention, even when participants are not attending to the colour (Horstmann, 2002; Turatto & Galfano, 2001).

In the case of Inattentional Blindness, attention plays an important role. In Simons and Chabris's (1999) experiment, participants were more likely to notice the unexpected (black) gorilla when they were paying attention to a black team and ignoring the white team. Other experimentation has shown that when an observer has been attending to a black object, while ignoring white distracters, Inattentional Blindness is highest (explicit attention capture is lowest) for white critical stimuli, followed by grey, then black, When attending white but ignoring black the reverse is true (Most et al., 2001). In this case, observers have formed an attentional set and this influences the rates of explicit attention capture.

As mentioned previously, (the change in stimulation accompanying) abrupt onsets can capture attention; however, this effect can be modified by factors relating to the task which observers are involved in. In a singleton finding experiment where one set of distracters are present prior to presentation of the target and a second set of distracters, the first set of distracters have little effect on performance. However, if the first set of distracters share features with the target, detection of the target is slowed, demonstrating the effects of task factors (Olivers & Humphreys, 2003). Similarly, distracters appearing concurrently with the target cause interference in searching for the target, when they are similar to the target (Patel & Sathian, 2000). Additionally, former targets have been shown to be very distracting in visual search tasks (Kyllingsbaek, Schneider, & Bundesen, 2001). Interestingly, while similarity with the target attracts attention, it has been shown that a deviation from what the observer expects is also effective at capturing attention (Horstmann, 2005).

One experiment (Richard, Wright, & Ward, 2003) suggested there might be two separate mechanisms involved in attention capture. In this experiment, participants were cued with multiple cues, one of which was the focus of attention. Implicit attention capture was demonstrated when responses were faster when the target appeared at one of the cued locations as opposed to the non-cued location. Surprisingly, both the attended cue, and the unattended cues produced implicit attention capture. This result was not the product of additional attention being distributed across the multiple cues, as the effect was independent of the numbers of cues. Richard et al. suggested this might be the result of two separate processes: a top-down process, driven by the attentional set, and a parallel, stimuli-driven process, unaffected by the attentional set.

Separate mechanisms of attention are consistent with the studies previously mentioned on colour, where the colour captures attention, despite an irrelevant attention set, and at the same time, attentional effects are still possible on top of this. A further study found that searching is faster when the target is coloured, but that searching is even faster when the participants are made aware that the target is coloured, demonstrating the effects of an individuals attention set. On the other hand, searching is slower when distracters are of the same colour as the target, demonstrating the effects of task factors (Braithwaite & Humphreys, 2003). Importantly, while the previous studies demonstrate the capture of attention by a colour outside of a relevant attention set, they did not demonstrate the capture of attention by a colour that is ignored. If attention was captured solely because of the features of objects, attention capture would be unaffected by set, so ignored features would still capture attention. On the other hand, if attention were captured solely because of attention set, attention capture would never occur without a relevant attention set.

Separate mechanisms of attention are consistent with fMRI data, where different regions of the brain are activated under different search conditions depending on the relevance of top-down or bottom-up processing. For instance, the suppression of stimuli driven processing might be linked to the right primary visual cortex, while stimuli driven processing in the presence of attention may be associated with activity in the right superior temporal gyrus / insular cortex (Patel & Sathian, 2000).

Measuring implicit perception and explicit attention capture allows us to test the idea of separate attention mechanisms. The present research involves presenting participants with unexpected objects, of colours that are being ignored, that are being attended to, and a new (novel) colour. The attended and ignored conditions allow examination of attention capture by attention set, while the novel condition allows examination of attention capture outside of the attention set. To discover whether there are separate processes for attention capture by attention set, and outside of the attention set, we can compare implicit and explicit measures of perception. If novel stimuli behave in a categorically different manner to stimuli within the attention set (attended or ignored), this would provide evidence for two separate mechanisms for capturing attention.

Meaning and the Capture of Attention

There is some debate over whether meaning is processed before or after attention is captured. This is not possible under early selection theories (e.g. Broadbent, 1958), where the filter of attention is applied at an early level, before meaning is processed. On the other hand, late selection theories (e.g. Deutsch & Deutsch, 1963) assert that the filter of attention is applied at a later level, after the stimulus has been processed for meaning. In early selection theories, objects without attention are processed only at the level of basic features (e.g. colour, location), whereas in late selection theories, they can be processed to a meaningful level.

If meaning is not processed prior to attention capture, it is expected that there would be no difference in attention capture between meaningless and meaningful words. However, when participants are presented their own names, Inattentional Blindness decreases markedly (Mack, Pappas, Silverman, & Gay, 2002). The same researchers also demonstrated that a happy face produces a decrease in Inattentional Blindness, while a sad face did not. Similar results occur with bodies (Downing, Bray, Rogers, & Childs, 2004). There is additional support for late theories of selection from experiments involving perceptual grouping. Participants judgements of the lengths of lines have been shown to be affected by visual illusions (e.g. Ponzo, Muller-Lyer), even when the illusions were not attended to, or consciously perceived (Moore & Egeth, 1997).

While some studies have shown the explicit capture of attention by meaning, this could be the result of slippage (Lachter, Forster, & Ruthruff, 2004); the participants attention is accidentally allocated to the unexpected object, which causes it to be processed semantically, causing more attention capture if it is meaningful. This is contrasted against objects being processed meaningfully prior to attention, and thus capturing attention.

Another experiment (Rees, Russell, Frith, & Driver, 1999) employed fMRI to measure the activation of the brain when participants paid attention to pictures while ignoring a letter stream. Interestingly, they found no difference in activation level for letter stimuli when the letter stream formed meaningful words or nonsense strings of consonants. From this, they concluded that words were not processed to a meaningful level prior to attention. However, Russell and Neumann (2006) report two experiments that incorporate a negative priming manipulation into the procedure of Rees et al. They found that ignored picture names impaired subsequent judgements of the pictures they named. Additionally, in a similar experiment performed by Ruz, Worden, Tudela and McCandliss (2005), Event Related Potential (ERP) responses indicated that ignored meaningful words caused higher activation than ignored meaningless words. Ruz et al. suggested that stimuli are processed semantically without attention, but that fMRI is insensitive to these changes. So there is some indication that meaning is processed prior to attention capture.

In order to investigate whether meaning is processed prior to attention capture, the current research examines the effect of words and non-words. By contrasting the measures of implicit and explicit capture of attention by words against the capture of attention by non-words, we can learn something of the effect of meaning on attention capture. Previous research indicates a higher rate of explicit attention capture by words than non-words is likely, which would provide evidence for the idea that attention can be captured by meaning. If implicit attention capture is also higher for words than non-words, there is additional support for the capture of attention by meaning. However, if the rates of implicit attention capture are equal for words and non-words, then it would appear that implicit attention capture depends on the features of objects, rather than their meaning, and that the difference in explicit attention between words and non-words occurs because words are more likely to reach awareness than non-words.

The Perceptual Cycle

Most et al. (2005) proposed a framework based on Neisser's (1976b) perceptual cycle, in an attempt to reconcile implicit attention capture and explicit attention capture. In Neisser's (1976b) theory, an image does not just appear in consciousness, instead the image is constructed, in a cyclic, iterative fashion. Perception is represented as a cycle involving the object, the perceiver's anticipations and explorations. The perceiver explores the object, and information about the object then causes revision of anticipations, which directs further exploration. After successive iterations, deeper processing occurs.

Neisser argues that selection is a positive process whereby perceivers select what they attended to, and consequently, nothing happens to unattended information (1976a), so "visual stimuli that do not become part of a cycle of expectation, exploration and reinterpretation may never be noticed at all" (Most, Scholl, Clifford, & Simons, 2005 p. 224). However, stimuli can cause the capture of attention; preattentive processes are attracted to basic cues, causing them to enter into a perceptual cycle (Neisser, 1976a). Conscious awareness is only produced after successive iterations, so awareness of unexpected objects is the result of sustained attention (Most, Scholl, Clifford, & Simons, 2005).

Crucial to this theory is the idea of re-interpretive processing, which is thought to play a role in object substitution masking: Di Lollo, Enns, and Rensink (2000) presented participants with two slightly overlapping patterns, and observed what participants saw. When the two patterns were presented concurrently for 100msec, participants perceived both patterns, but when one of the patterns was presented for a longer period, participants perceived only that pattern. This indicates that the participant's earlier perceptions can been overwritten by later perceptions, providing evidence for the reinterpretation of stimuli.

This model highly emphasizes that perception is dependent on the intentions of participants. In the context of completing a task, information will be perceived when perceivers need the information to complete a task, but not when it is unnecessary. This has been demonstrated in virtual reality experiment (Triesch, Ballard, Hayhoe, & Sullivan, 2003), in which participants were sorting blocks, and at some point during the task, a block attribute changed. Participants were more likely to notice the change if the sorting task required attention to the attribute.

Most et al. (2005) made four predictions based upon a reformulation of this model. Firstly, sustained attention is required for awareness. Secondly, sustained attention must be preceded by a transient shift of attention. Thirdly, while participating in an attentional task, the attentional set will be an important factor in shaping an individual's intentions, and thus will be significant in determining attentional shifts. Fourthly and lastly, while implicit measures of attention can exist without explicit attention, explicit attention must be accompanied by these implicit measures.

Most et al. performed several experiments to assess these predictions. In their experiments, participants were instructed to count the number of times specific objects bounced against the edge of a screen (amongst various other distracters). On the last trial, an unexpected object appeared and moved across the screen, and shortly after this, participants were asked if they had noticed an unexpected object. Experiments 1 - 3 examined the effects of attentional sets, and found evidence that attentional sets for luminance, shape, and an even more complex feature – ethnicity of faces, can all play an important role in noticing the unexpected object, replicating the previous results (Most et al., 2001). Experiments 4-7 examined factors that capture attention independent of attentional sets, focusing on sudden onset stimuli. Experiment 8 demonstrated implicit attention capture: increased errors when the unexpected critical item appeared. The authors noted that errors were not designed to measure attention capture, presenting for a rational for replication of their work. Additionally, it is surprising that the authors did not design their experimentation to include implicit measures, given that they aimed to "…relate and contrast … Inattentional Blindness and attention capture" (Most, Scholl, Clifford, & Simons, 2005 p. 217).

Aims of the Research

The current research expands upon the experimental results of Most et al. (2005), incorporating aspects of the Inattentional Blindness paradigm of Mack and Rock (1998) into a visual search task. Participants search for a cross amongst distracters, and on certain trials will be presented with an unexpected object. To determine whether participants were aware of the critical object, participants will be asked to indicate their certainty of seeing the object. A forced-choice recognition task will be used to verify this measurement, as previous research has indicated these two measures are interrelated (Haase & Fisk, 2001; Merikle & Reingold, 1990).

Similar to Most et al.'s experiments, in one condition the unexpected object will be the same colour as the cross (the attended condition), and in another, the unexpected object will be the same colour as the background (the ignored condition). A further condition occurs when the unexpected object is a new colour, not that of the background, and not of the cross (the novel condition). This is included to investigate the effects of attention set by contrasting objects that are ignored or attended with objects that are unexpected. The first hypothesis is that Inattentional Blindness will depend on the attentional set that is produced by the experimental procedure; Inattentional Blindness will be higher in the ignored condition, and lower in the attended and novel conditions.

Two measures of implicit perception are used: change in response time and a word stem completion task. These two measures of implicit attention capture will be used to expand upon the results of Most et al. (2005). Firstly, they are of use in evaluating Most et al.'s first prediction; that awareness is the product of sustained attention. Secondly, they are of use in determining whether separate mechanisms exist for attention capture of expected and unexpected objects. Thirdly, they are used in demonstrating unconscious perception.

The first measure of implicit perception concerns response time when the unexpected stimulus is presented. It is expected with successive trials response time will decrease due to practice effects, but will increase on presentation of the unexpected stimulus. The second hypothesis is that this increase will occur both when the participants see the critical stimuli, and when they claim not to have seen the critical stimulus. However, in accordance with the predictions made by Most et al. (2005), the increase in response time will be greater when participants are aware of the object.

The second measure of implicit perception concerns the word stem task. It is expected that in conditions where the critical stimulus is presented, more words will be produced that correspond to the critical stimulus (target completions), than the control condition, where no words are presented. The third hypothesis is that participants in the attended and novel conditions who are unaware of the critical stimulus will produce a higher rate of target completions than participants in the control condition, who were not presented with an unexpected object.

Alternatively, it is hoped qualitatively different patterns of implicit perception for the novel and attended conditions will be produced. The fourth hypothesis is that novel and attended conditions will not differ in terms of explicit attention capture, but will differ in terms of implicit perception. This would provide strong evidence for unconscious processing, and would also provide evidence for two separate processes of attention capture: one driven by the features of objects, and one driven by the intentions of the observer.

Contingent on these results, further comparisons will be made. The intention is to compare the effects of meaning on implicit measures of attention. The fifth hypothesis is that a word will produce greater implicit and explicit perception than a non-word, measured by a bigger increase in response time when the word is presented.

Experiment 1

Method

Participants

Participants were 446 students of the University of Canterbury who were recruited and participated voluntarily during the laboratory component of their introductory psychology course. Participants were in lab classes containing up to 35 students, participants were individually assigned into an experimental group at the beginning of the experiment.

Apparatus

The experiment was run on Computers (Compaq Evo), running windows XP professional. SuperLab Pro (Version 2.0) was used to present stimuli and record response times.

Stimuli and Design

During the cross finding task, the display contained a cross in one colour, a background pattern of another colour, and on the final trial the critical word/non-word (See Figure 1 for an example). Each word was scrambled to produce a corresponding non-word. The three different words used were 'help', 'crap' and 'idiot', with three corresponding non-words; 'pelh', 'racp' and 'odtii'. The displays were produced using the Gnu Image Manipulation Program (version 2.2).

Participants were randomly assigned into 12 groups by computer. Two groups were the result of the final task: either a word stem completion task, or a recognition task. A third group was added to measure the effects of meaning, where the critical stimulus was a non-word instead of a word (and the final task was a recognition task). These three groups had three attention conditions (attended, ignored or novel), and a control condition, where the critical stimulus was not presented. This produced a total of three control conditions and nine experimental conditions.

The background colour was randomly assigned for each participant to be red green or blue, and the cross colour was randomly assigned to be one of the remaining colours. The critical manipulation in this experiment was the presentation of an unexpected word or non-word letter string. In the control condition, no critical object was presented, while in the other conditions the colour of the critical stimulus depended on the attention condition. The attended condition occurred when the critical object was the same colour as the cross, while the ignored condition occurred when the critical object was the same colour as the background. In the novel condition, the critical object differed in colour from both the cross and the background. The conditions were all between groups conditions.

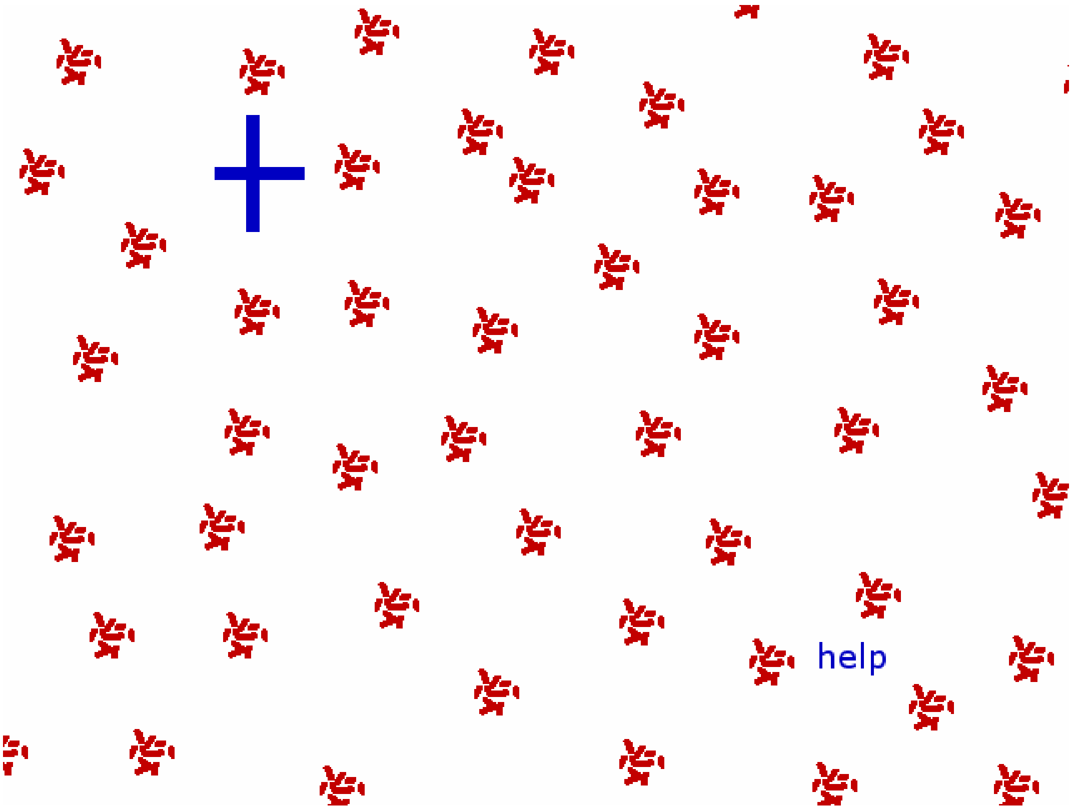

Figure 1: An example of the stimuli presented. Note that colouration would depend on the attention condition: In the attended condition the critical object was the same colour as the cross, in the ignored condition the critical object was the same colour as the background, while in the novel condition, the critical object was a new colour.

Procedure

There were two parts to the experiment. First, after the instructions and a practice trial, six computer controlled cross finding trials were completed. Second, a word stem test, or a recognition test, and a certainty rating task were administered, with instructions displayed on computer, and responses recorded on paper.

For the cross finding task, participants were instructed to look for a cross of a designated colour in a background pattern of a different colour (See Figure 1). Participants were instructed to indicate which arm of the cross was longer, responding with the left mouse button if the horizontal arm was longer and with the right mouse button if the vertical arm was longer. Participants indicated their readiness to commence each trial by pressing a mouse button that caused the immediate presentation of a display. The display remained visible until a response was made. Following the practice trial participants completed six cross finding trials. Response time and accuracy were recorded for each trial. These provided the primary measures of implicit perception.

The sixth trial was the critical trial. In the experimental conditions, this trial was identical to the previous five, except that the critical object (a word or non-word, coloured depending on the attention condition) was presented along with the cross and background. In the experimental conditions, this trial was identical to the previous five.

Following the critical trial participants either completed a word stem completion task or word recognition task and indicated their certainty of seeing something apart from the cross and background in any of the previous displays. Participants completing the word stem completion task were asked to complete a set of six word stems, one of which corresponded to the critical word presented in the final trial. This provided an additional measure of implicit perception. Non-words did not have an appropriate word stem, and those presented non-words did not perform the word stem task. Those assigned to the recognition task were required to select, which of ‘tree’, ‘help’ ‘crap’ and ‘idiot’, they thought most likely to have been presented on the previous display. This provides a measure of explicit perception. Finally, participants numerically indicated how certain they were that the last display had contained something other than a cross and background, on a scale of zero to ten where zero represented certainty that nothing had appeared, and ten represented certainty that something had appeared. This provided another measure of explicit perception.

Results

Data

Data from 376 of the original 446 participants were analyzed. Participants were excluded from analysis because: data was missing (40 participants); more than one error was made during the first five trials (17); two responses of 3000 ms or greater occurred during the first five trials (13). A further 57 participants had at least one response time greater than 6000ms on trials 1 to 5, this was considered the result of a lapse, which would affect response time analyses, so these data were excluded from the analysis of response time. However, their data were retained for the rest of the analyses.

Explicit Perception

The certainty rating task was used to determine which participants had conscious perception of the critical object. A certainty rating of six or above was chosen to indicate that the participants had ‘seen’ the object. This was confirmed by results from participants in the recognition condition, where those with ratings of five or less had recognition accuracy of

18.75%, well below chance (25%). Additionally, in the control condition, where no word was presented, no one recorded a certainty higher than five. These results provide a high degree of certainty that all those who had conscious perception of the unexpected object were detected.

Using these criteria, the overall Inattentional Blindness rate was 73% (only 23% of participants saw the unexpected object when it was presented) and no control participants met the criteria for conscious perception of a critical object. Similar rates of Inattentional Blindness occurred to words (72%) and non-words (75%), χ^2 (1, N = 264) = 0.25, *n.s*. Inattentional Blindness for the attentional conditions was calculated pooling words and non-words. Inattentional Blindness of 88% was observed in the ignored condition, which was significantly higher than 62% observed in the attended condition, χ^2 (1,181) = 16.06, $p <$ 0.001, and 69% observed in the novel condition, χ^2 (1, N = 172) = 9.37, $p < 0.01$. There was no significant difference between the novel and attended conditions, χ^2 (1, N = 174) = 0.87, *n.s*. These data are shown in Figure 2. These results support the first hypothesis that there will be higher rates of Inattentional Blindness in the ignored condition than the attended and novel conditions, and are consistent with the results of Most et al (2005).

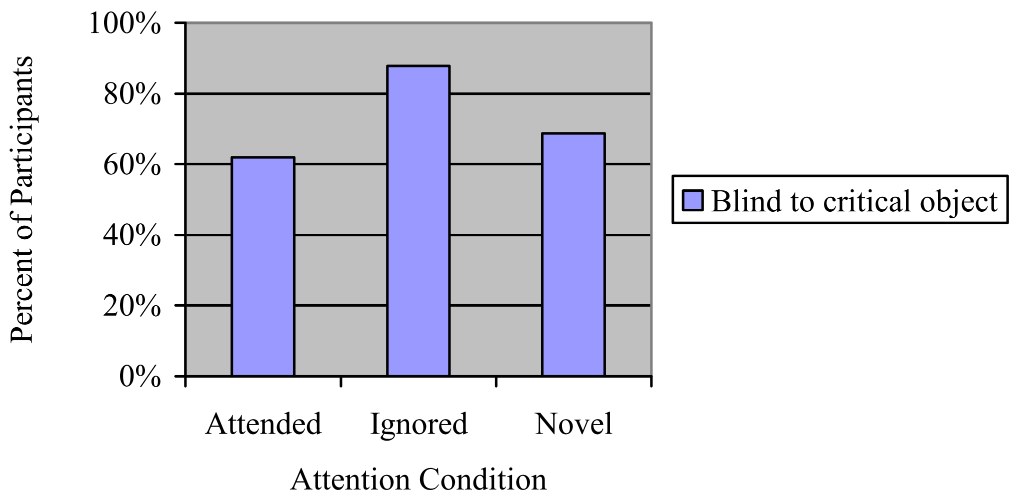

Figure 2: Rates of Inattentional Blindness in the three attentional conditions.

Implicit Perception

Response time

The primary measure of implicit perception was an increase in response time with the appearance of the critical object. To determine this, the attentional conditions, where a critical object appears, are contrasted against the control condition, where no critical objects appear. This was determined for participants who saw the critical object, and those who did not see the critical object. The analysis of the effects of meaning can occur once the response time measurement has been demonstrated as a measure of implicit perception for both words and non-words.

To ensure all groups are equal prior to the presentation of the critical object, the response times for the three trials prior to the presentation of the critical object were analyzed using a repeated measures ANOVA. There were no significant main effects, or interaction effects on response time for condition, trial, or participant seeing the critical object. These results demonstrate that in the trials prior to the presentation of the critical object, the participants who had seen, and had not seen the object had similar performance. Additionally, for these trials, performance was the same across all attention conditions, which is to be expected, as prior to the presentation of the critical object these conditions are identical. Surprisingly, there was no effect of trial, which implies there was no practice.

Having demonstrated all groups were equal prior to the presentation of the critical object, the change in response time was analyzed for the participants who saw the critical object.

Figure 3 shows the response times for the last four trials, for both words and non-words, and for the participants who saw the critical object. To determine the effect of presentation of the critical stimulus, repeated measures ANOVAs were performed using response times for the critical trial, and the preceding trial (including word and non-word conditions), contrasting the attention conditions where participants saw the unexpected object with the control condition. Two conditions were significantly different to the control condition; the attended condition had a significant interaction effect with trial, $F\ (1,109) = 23.7$, $p < 0.001$, and the novel condition also had a significant interaction effect with trial, $F\ (1,100) = 22.70$, $p < 0.001$. However, the ignored condition was no different to the control condition, with no significant interaction effect $F\ (1, 89) = 0.02$, *n.s*. This indicates that the presentation of the critical stimulus had an effect on response times, in the attended and novel conditions.

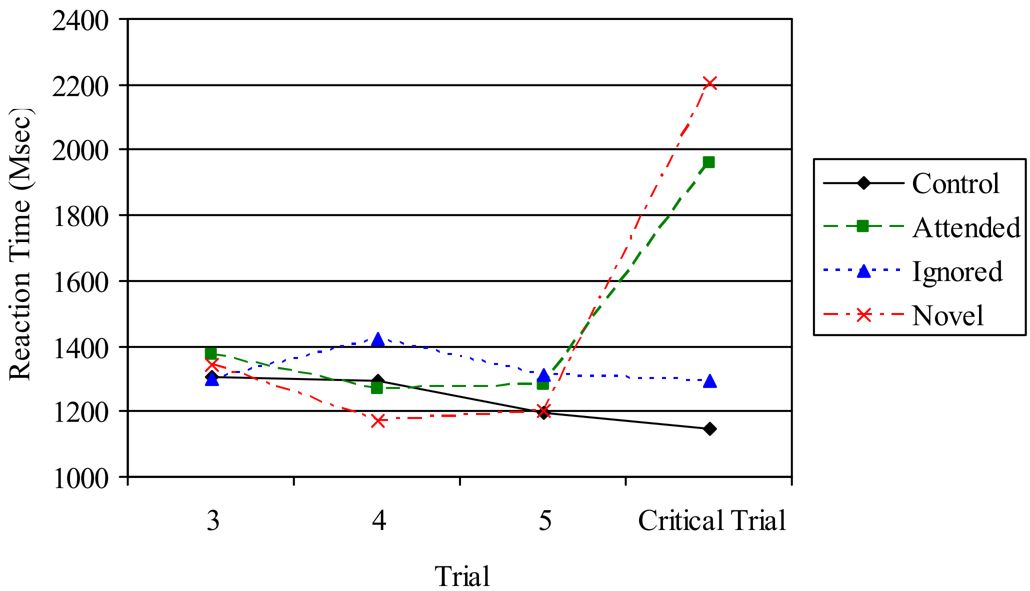

Figure 3: Response time for the last four trials, for participants who were aware of the critical object (in the case of the control condition, for all participants). These data show a decrease in response time for trials 3-5, due to practice effect, and an increase in response time on the sixth and critical trial in the attended and novel conditions, due to the appearance of the critical stimulus.

In order to establish whether the increased response time is due to the implicit perception of the target stimulus, it is necessary to show that this increase in response occurs among participants who did not report seeing the critical word. Figure 4 shows the response time data excluding those who indicated they had seen the critical object. To determine the effect of presentation of the critical stimulus, a repeated measures ANOVA was performed using response times for the critical trial and the preceding trial (including word and non-word conditions), contrasting the attention conditions where participants did not see the unexpected object with the control condition. Unfortunately, no attention condition was significantly different to the control condition (Interaction effects: attended, F (1,126) = 0.19, *n.s.*; novel, *F* (1,132) = 0.25, *n.s.*; ignored, *F* (1,149) = 0.50, *n.s.*). This indicates that in this experiment the increase in RT on the sixth trial in the attended and novel conditions is due to relatively infrequent explicit perception of the critical object, and that there is no increase in RT to a critical object when it is not explicitly reported, which does not support our second hypothesis.

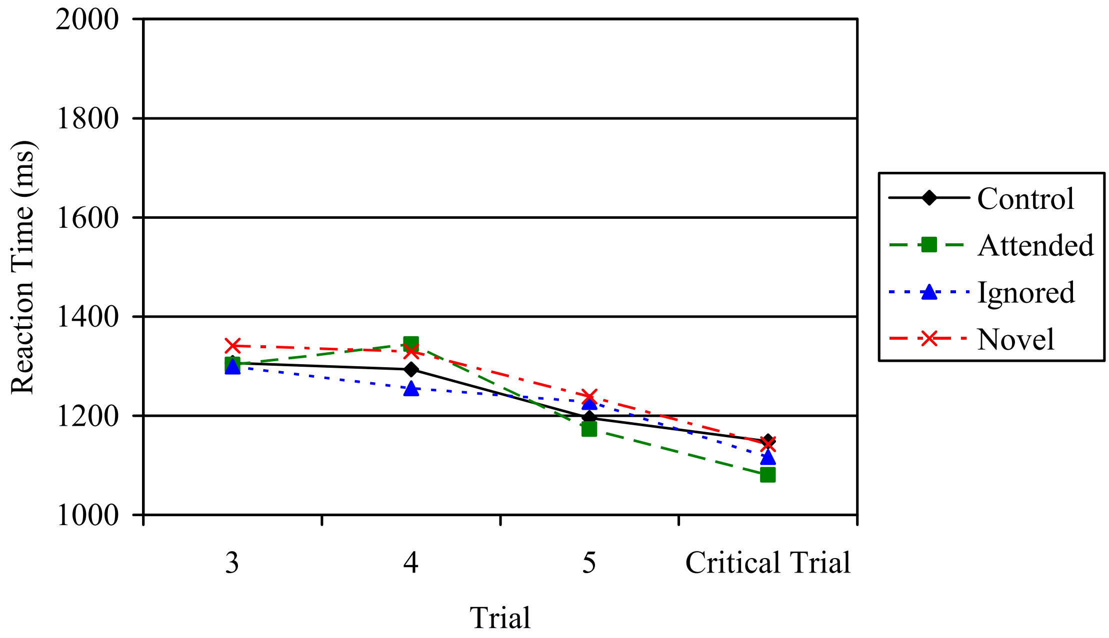

Figure 4: Response time for the last four trials, excluding data from those who reported seeing the critical object. These data show a decrease in response time for the four trials due to a practice effect, but no increase in reaction when the critical stimulus is presented in the sixth and critical trial.

As the response time measurement has not been demonstrated as a measure of implicit perception, the analysis of the effects of meaning on this measure cannot be performed. As the word stem task also cannot be used, this prevents investigation of hypothesis five, that implicit measures of attention capture will be greater when unexpected objects are words, as opposed to non-words.

Word Stem Completion

The secondary measure of implicit perception was the word stem task, which is measured as the number of participants who produced target word stems, that is, completing the word stem using the same word as the critical word presented. In the experimental condition, 16% of participants produced target word stems. (For individual words, the rates were; 'help' 17%, 'crap' 6%, 'idiot' 25%. No data exist for non-words). Target word stems were produced by 33% of the attended condition, 12% of the ignored condition, and 16% of the novel Condition.

Word stem completion can be regarded as a measure of implicit perception only when the completed stem forms the target word among participants who did not report seeing the critical word. Additionally, when participants are aware of the critical word, data from the word stem task are likely to be unreliable, because of how participants completed the task. Because the instructions could not have specific instructions for participants who saw the critical word, participants can think they are meant to fill out the word stem with the critical word, or that they are not meant to fill out the word stem with the critical word. Because of these two separate ways of completing the task, performance for participants aware of the critical object will be a measure of individual strategy, rather than perception. Therefore, word stem data are not analyzed for participants who were aware of the critical object.

Considering only those participants who did not report seeing the critical word, the rates of word stem target completions were; attended 21%, ignored 14% and novel 5%. These rates of target completion need to be compared against the control condition, where target word stems were produced by 13% of the participants. Chi-Squared tests showed that the attended condition, χ^2 (1, N = 129) = 0.96, *n.s*., the ignored condition, χ^2 (1, N = 139) = 0.03, *n.s*., and the novel condition, χ^2 (1, N = 131) = 0.97, *n.s*. did not produce significantly higher levels of implicit perception than the control condition. These results indicate that the word stem completion task did not produce significant implicit perception, which does not support the third hypothesis; more word stem target completions did not occur when the unexpected object was presented.

Attention now focuses on the rates of word completion among the various attention conditions. The rate of target word stem production for the novel condition was far lower than the attended and ignored conditions. In other words, participants who did not see the critical object were less likely to produce a target word stem if the critical object differed in colour from both the target colour and the background colour. The attended and novel conditions produced comparable levels of Inattentional Blindness (69% vs. 62%), but the rate of target word stem production for the novel condition (5%) was lower than the attended condition (21%), χ^2 (1, 38) = 2.25, *n.s.*, in accordance with hypothesis four. This result does not reach significance, so further experimentation is required to substantiate the results. If further experimentation produced significant differences between the novel and attended conditions, this would provide evidence for implicit perception.

Discussion

Experiment 1 produced significant Inattentional Blindness. In accordance with the first hypothesis, the rates were lower in the attended and novel conditions than in the ignored condition, indicating the attended and novel conditions produce more attention capture than the ignored condition. Unfortunately, response time did not prove to be a useful measure of implicit of perception; there was no increase in reaction time when participants were unaware of the critical object, which does not support the second hypothesis. This result indicates that, in our experiment, either no implicit processing has occurred, or that response time is not sensitive to implicit processing. Additionally, this result limited the analysis of meaning, preventing an investigation of the fifth hypothesis regarding attention and meaning.

Unfortunately, the word stem completion task also did not produce the predicted results. The third hypothesis predicted more word stem target completions would occur when the unexpected object was presented. However, no attention condition produced significantly more target completions than the control conditions (where no word was presented). There was a trend for word stem completions to be greater in the attended and ignored conditions relative to the novel conditions, which, while not significant, is as predicted in hypothesis four. The small number of participants remaining after excluding those who saw the word (the two conditions had the lowest numbers of participants who were inattentionally blind to the critical words) mean power to detect differences is low. Experiment 2 was designed to increase this power, and investigate hypothesis four; that novel and attended stimuli will produce different rates of implicit perception, despite similar rates of explicit perception.

Experiment 2 is a partial replication of Experiment 1; the manipulation of meaning and the recognition task have not been included in Experiment 2. Additionally while response time and errors were recorded, these were used merely as checks to ensure participants followed instructions. They are not used as a measure of implicit perception.

In Experiment 2, the goal is to produce significant word stem results to investigate hypothesis four. To achieve this goal, Experiment 2 uses multiple presentations of critical objects, resulting in more word stem data from each participant. To ensure expectations are not changed by this change in methodology, participants are asked only once if they have seen an unexpected object, which creates difficulty in identifying when a participant has seen an unexpected object. Consequently, any participants who report seeing any of the critical objects are excluded from analysis of word stems.

In Experiment 2, it is hypothesized that the rate of Inattentional Blindness will be slightly lower than Experiment 1, due to the repeated presentation of critical objects, but will follow the same pattern (The attended and novel conditions will have lower Inattentional Blindness than the ignored condition). It is also hypothesized that the same pattern of word stem completions will occur, but the differences between conditions will be significant, most importantly between novel and attended conditions. If the novel and attended conditions were significantly different, this would provide evidence for unconscious processing, and would provide evidence for separate processes for attention capture by the features of objects, and by the intentions of the observer.

Experiment 2

Method

Participants

126 females and 49 males were recruited using e-mails within the University of Canterbury, and other referrals. Participation was voluntary, but as an incentive, participants were given a chance to win one of four $50 petrol or grocery vouchers.

Apparatus

The experiment was conducted over the internet, using computers of different specifications. A Shockwave Flash applet of resolution 640x480 was used to standardize the display and the timing of the experiment. Because participants would adjust their viewing distance to read instructions, the visual angle for the experiment should be similar between participants.

Stimuli and Design

During the cross finding task, the display contained a cross of one colour, a background pattern of another colour, and on some trials, a critical word. The cross colour was randomly selected to be red, green, or blue, the background colour was randomly selected to be one of the two remaining colours, and the colour of the critical word was defined by the condition which participants were in.

Participants were randomly assigned into four groups by computer. Each group followed the same procedure, but received different combinations of colours for target, background, and critical stimuli. Four groups were formed by four conditions: a control condition and three attention conditions (attended, ignored or novel). In the control condition, no critical word was presented. In the attended condition, the critical word was the same colour as the cross. In the ignored condition, the critical word was the same colour as the background. In the novel condition, the critical word was a new colour, which participants had previously not seen.

Crosses and words were the same size as the previous experiment. The words presented were ‘help’ ‘crap’ ‘idiot’ and ‘tree’. Non-words were not used in Experiment 2. All these items were similar (in some cases identical) to those used in Experiment 1 and were produced using the Gnu Image Manipulation Program (version 2.2) and presented using Shockwave Flash.

Procedure

This experiment also consists of two parts, which are both similar to the two parts of Experiment 1. First, after the instructions and a practice trial, 25 cross finding trials were performed on the computer. At the end of this, participants were asked if they had seen the critical word on any trial.

The cross finding task was very similar, where participants searched for a cross amongst distracters, and made a decision about the nature of the cross. Here, however, participants were instructed to respond by pressing the 'l' key if any arms of the cross were shorter, and pressing the 'a' key if the arms of the cross were all of equal length. The keys were selected because they were on opposite positions on standard QWERTY keyboards. In order to ensure proper participation, performance was monitored. Response times and errors were recorded for each of these trials.

In the experimental conditions, trials 10, 15, 20 and 25 contained critical words. In the control conditions, these trials were like any other trial, containing no words. The critical object was one of three colours, corresponding to the three conditions: attended, ignored, and novel (as outlined in Experiment 1). After every fifth trial, participants were prompted to complete a single word stem, corresponding to the critical word that had been presented (prior to beginning to this, participants had been instructed to read a story, in order to decrease participants wondering at the use of a verbal test in a spatial task).

Unlike Experiment 1, participants experienced multiple trials where the critical object was present, in order to increase the amount of word stem data per participant. Prior to each trial, participants waited 1700 milliseconds, and then the stimuli appeared for 300 milliseconds (in Experiment 1 the stimuli were present until the participants responded), which was followed by a 500 millisecond pattern mask.

After the final word stem task a screen appeared, informing participants, "In the previous trials, an unexpected object may have appeared, (e.g. a word, a jumble of letters, a shape), in addition to the distracters and the cross. This unexpected object may have occurred in any of the previous trials". Participants were then asked, "Were you aware of anything aside from the distracters and the cross?", and if they responded positively, they were asked, "At any point, were you aware what the unexpected object was?" Responses were gathered using an html-style form on their computer. Additionally, they were then asked if they had participated in any previous experiment involving unexpected objects, if their attention was not fully devoted to the experiment, or if there was any reason why their data should not be included in the analysis. Positive responses to any of these questions led to the exclusion of that participant's data from the analysis.

Results

Data

While data from 175 participants were recorded, only the data from 133 participants were included in final analysis. Data from 35 participants were discarded because they reported prior participation in similar research. Data from a further 7 participants were removed because they made more than six errors in the cross-arm task or took over 2000ms to respond on at least 6 occasions for trials 6-25.

Explicit Perception

The overall Inattentional Blindness rate was 62% (only 38% of participants saw the unexpected object when it was presented). There were few false positives; in the control condition, where no unexpected object appeared, only 3% of participants claimed to have seen the object. Inattentional Blindness of 87% was observed in the ignored condition, which was significantly higher than 46% observed in the attended condition χ^2 (1, N = 64) = 12.69, $p < 0.05$, and 45% observed in the novel condition, χ^2 (1, N = 71) = 14.31, $p < 0.05$. There was no significant difference between the novel and attended conditions, χ^2 (1, 58) = 0.00, *n.s.* in their rates of Inattentional Blindness. These data are shown in Figure 5.

These results are comparable with Experiment 1, and indicate this Experiment is a valid replication of the previous one, despite the methodological differences.

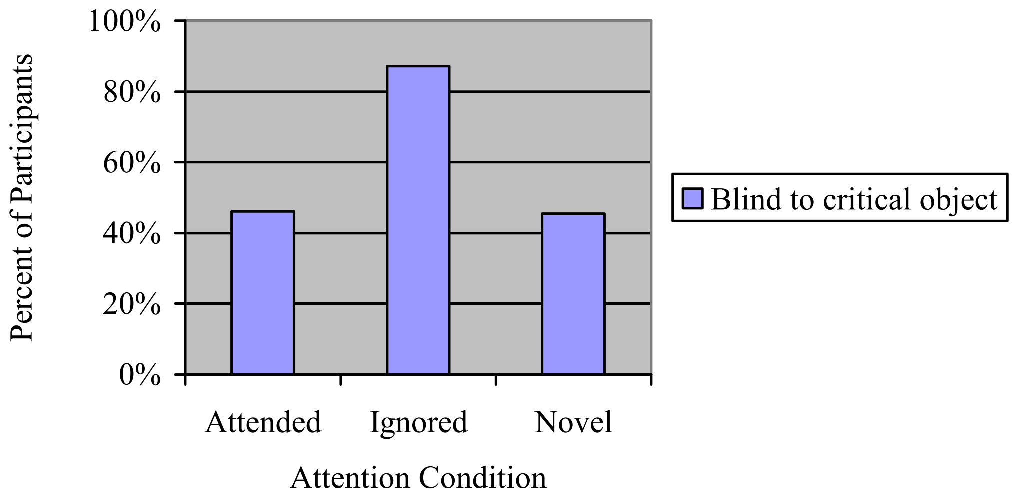

Figure 5: Rates of Inattentional Blindness in the three attentional conditions.

Implicit Perception

The measure of implicit perception for this experiment was the word stem task. The number of occasions where a completed stem was identical to the word presented on the previous display was found. In the three conditions where unexpected words appeared, participants produced target word stems 19% of the time. (For individual words, the rates were; 'help' 33%, 'crap' 5%, 'idiot' 26%, and 'tree' 10%). The average rate of target word stem production was 20% in the Attended condition, 21% in the ignored condition, and 16% in the Novel Condition.

Word stem completion can be regarded as a measure of implicit perception only when the completed stem forms the target word among participants who did not report seeing the critical word. Considering only those participants who reported not seeing the critical word, the average rates of target word stem production were; Attended 29%, Ignored 18%, and Novel 13%. These rates of target completion need to be compared against the control condition, where target word stems were produced at a rate of 18%. An ANOVA showed that the attended condition F (1, 59) = 0.23, *n.s*., the ignored condition F (3, 198) = 9.93, *n.s*.), and the novel condition F (1, 47) = 1.2203, *n.s*. did not produce significantly higher levels of implicit perception than the control conditions. These results seem to indicate that the word stem completion task did not produce significant implicit perception. This does not support the third hypothesis, that higher levels of implicit perception will be demonstrated with the presentation of the critical object.

However, the ANOVA showed that the Attended condition was significantly different to the Novel condition (F (1, 25) = 4.3410, $p<.05$). This indicates that those who were not aware of any unexpected objects had significantly higher rates of target completion if the unexpected object was the same colour as the colour they were attending to, rather than a new colour, which supports the fourth hypothesis.

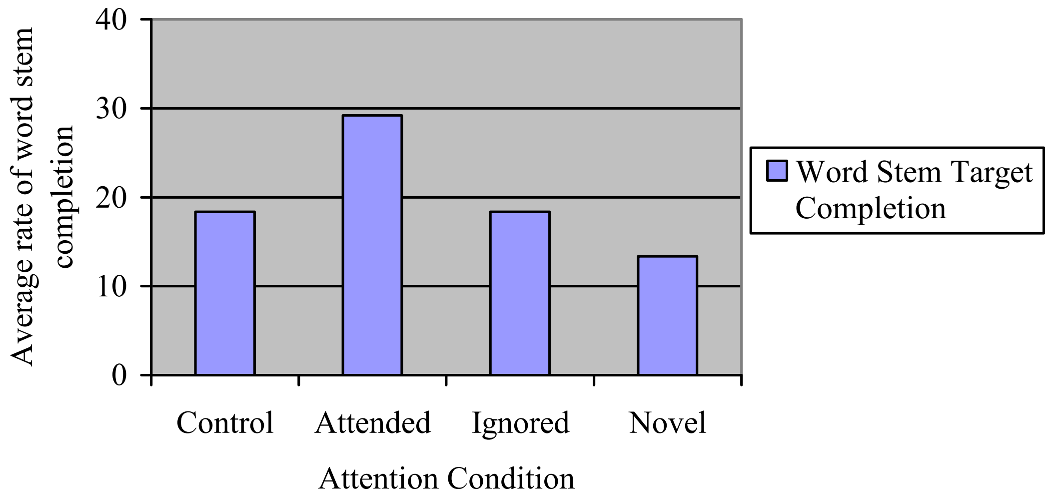

Figure 6: Rates of word stem target completion for the three attentional conditions, and the control condition, for participants who did not report seeing any of the four critical words.

The rates of target completion were compared for individual words. Notably, the difference between the novel and attended condition was lessened for the first word; ‘help’, and the last word; ‘tree’. An ANOVA produced no significant interactions between the effects of word, and the effects of condition; however, these data are included in the Appendix.

Discussion

The results for this experiment replicate experiment one, producing similar rates of Inattentional Blindness for the attended, ignored novel and control conditions. While the overall rate of Inattentional Blindness was lower (62%, in Experiment 2, compared with

72%, in Experiment 1 in the word conditions), this was to be expected for two reasons: Firstly, there were multiple opportunities to observe the critical stimulus, which would increase individual's chances of seeing an unexpected object, decreasing the overall rate of Inattentional Blindness. Secondly, the experiment was longer, so participants would become more practiced, which could decrease Inattentional Blindness, as has been demonstrated in similar situations by increasing the participants' expertise (Memmert, 2006) and lowering the perceptual load (Cartwright-Finch & Lavie, 2007; Lavie, 1995, 2006; Todd, Fougnie, & Marois, 2005).

Word stem results are also comparable with Experiment 1. Unfortunately, in the absence of awareness, no attentional condition produced significantly more or less target completions than the control conditions. In a classic dissociation paradigm, this would not provide evidence for unconscious perception. However, participants for whom the unexpected critical words matched the attended colour produced significantly more target completions than those whose words were a new colour, which implies implicit perception. These results are discussed in more detail in the next section.

General Discussion

Both Experiments 1 and 2 displayed evidence of Inattentional Blindness. This occurred when participants who were making judgments of cross arm length amongst distracters failed to notice the presentation of an unexpected object. Levels of Inattentional Blindness were lower and explicit attention capture was higher where the object was the same colour as the cross, while explicit attention capture was lower in conditions where the object was the same colour as the distracters, consistent with previous results (e.g. Most, Scholl, Clifford, &

Simons, 2005; Most et al., 2001). This demonstrates that under conditions of selective attention, explicit attention capture depends on attention set. Additionally, a higher rate of explicit attention capture occurred when the object was a new colour, demonstrating the ability of novel objects to capture attention.

The relatively high rates of Inattentional Blindness create an experimental environment that is favourable towards the exploration of implicit perception. It was hoped that the word stem task would provide a useful index of implicit perception. When participants were unaware of the critical object, the unexpected object did not cause significantly more target completions than trials without the unexpected object. However when the unexpected object was the same colour as the cross, more target completions were produced than when the unexpected object was displayed in a colour that the participant had not previously encountered in the experiment. Therefore, while objects of an attended colour and a novel colour appear to explicitly capture attention at the same rate, their rates of implicit perception appear to be quite different. This dissociation provides evidence for unconscious processing of the unexpected critical objects, and it also suggests that unexpected objects that appear in a contextually novel colour are in some way treated differently from unexpected objects that appear in a contextually familiar colour.

It was also hoped that the time taken to make length judgments of the cross arm would provide a useful index of implicit perception. Unfortunately, response time did not demonstrate significant implicit perception; while participants did show a significant increase in response time with presentation of the critical object, this increase was confined to participants who reported seeing the unexpected object. Given that the word stem task demonstrated implicit perception, the present research implies implicit perception has occurred, but that response time is not sensitive to this implicit perception. Task factors may contribute to the failure to detect implicit processing of the critical words. For example, the displays already contained numerous distracters, which would cause small variations in performance that mask any effects deriving from implicitly perceived objects. In future experimentation, displays containing fewer distracters might allow unexpected objects to produce changes in response time.

A potential flaw in the present research is that Experiment 2 used multiple unexpected objects, which will have led to less precise control over expectations. For example, a participant might have had some awareness of the first critical object, which resulted in a change in expectations; but by the time the experiment ended, the participant could have forgotten about the initial awareness, and not reported it. However, it is unlikely that any change in expectations would go unaccompanied with conscious awareness, so by excluding any participants reporting explicit perception the effects of multiple unexpected objects on expectations should be eliminated. This is supported by the results of Experiments 1 and 2, which produced the same the same pattern of results for the word stem task, which implies the presentation of multiple unexpected objects had no effect on expectations.

Another possible criticism of the present research is that there was some indication that the word stem results in Experiment 2 were dependent on the word used. The words ‘Tree’ and ‘Help’ showed less difference in word stem target completion rates between attended and novel conditions than the words ‘crap’ and ‘idiot’. However, even if the comparison between implicit measures were restricted to words such as idiot and crap, interpretations regarding implicit perception or attention mechanisms would be unaffected, as a difference in explicit and implicit processing between conditions for one word is still a difference in explicit and implicit processing.

The Mechanisms of Attention

The results of the present research have implications for the mechanisms of attention. Firstly, the difference in explicit attention capture between the attended and ignored conditions indicates that the attention set can be an important determinant in the capture of attention: when participants are attending to certain features, these features will be more likely to capture attention. This result is in accordance with other research demonstrating that individual and task features can be important in determining attention capture (Braithwaite & Humphreys, 2003; Horstmann, 2005; Kyllingsbaek, Schneider, & Bundesen, 2001; Olivers & Humphreys, 2003; Patel & Sathian, 2000). The high rate of explicit attention in the novel condition indicates that features which are outside of the current attention set, novel features, are also likely to capture attention. This result is in accordance with other research demonstrating that the features of objects can determine attention capture, even in the absence of a relevant attention set (Horstmann, 2002; Theeuwes, 1994; Turatto & Galfano, 2001).

Richard, Wright and Ward (2003) suggested that there may be two separate processes of attention capture: a process driven by the goals of the observer, and a parallel process that is mostly unaffected by the attention set. The present research provides some evidence for this idea. While unexpected objects in the attended condition capture attention, novel objects were also capable of attracting attention. However, the rate of word stem target completions differed between critical objects that were of the same colour as the primary focus of attention (attended condition) and those of a contextually novel colour. This dissociation calls for some explanation. The different rates of implicit perception may be because of inhibition of information gleaned from an unfamiliarly coloured object, or the amount of preconscious processing each class of object receives before reaching a level allowing conscious report.

Firstly, some form of inhibition could produce a difference in implicit processing between attended and novel stimuli. If the novel object captures attention, some form of inhibitory control may be directed towards it because it is irrelevant to the primary task; this may in turn lead to reduced accessibility to the word during stem completion. However, this explanation is questionable, especially since there are suggestions that executive control does not operate on implicit processes (Tsushima, Sasaki, & Watanabe, 2006).

Secondly, the difference in implicit processing could be the result of a difference in the amount of conscious processing each object receives. Horstmann (2005) found that unexpected objects attract more attention than comparable expected objects. A similar effect may have produced a difference in implicit processing in our experiment, where novel stimuli, once detected by implicit processes, produce more explicit attention capture than attended stimuli. This produces the illusion of less implicit processing; the reason we observe fewer stem completions in the novel condition is that implicit processing is more likely to be accompanied by conscious awareness, and so is reported as explicit attention capture. Therefore, once implicit perception has occurred, the chances of the perceiver becoming aware of the object are greater for completely unexpected objects.

The second explanation is consistent with the demands placed on an observer in a natural setting; when engaging in a task, unexpected and unexplained events require more attention, as they alert the individual to unforeseen possibilities and dangers. This would be consistent with other research, where dynamic stimuli are more likely to capture attention than static stimuli (Chastain, Cheal, & Kuskova, 2002), looming objects are more likely to capture attention than retreating objects (Franconeri & Simons, 2003), and sudden onsets are more likely to capture attention than gradual onsets (Irwin, Colcombe, Kramer, & Hahn, 2000). In these examples, sudden looming objects are potentially threatening to the individual, and so it is important that observers become aware of such threats, through explicit attention capture.

A replication of these experiments, in which an unexpected object produced significantly different word stem target completions than a control condition would enable differentiation between the two explanations. In the control condition, where no object is presented, no inhibition would be expected, so the rate of implicit perception provides a comparison for the other conditions: If implicit differences between novel and attended objects were the product of inhibition, novel objects are expected to produce significantly less implicit perception than a control condition. On the other hand, if the difference between novel and attended objects is the result of a difference in the amount of explicit processing unexpected objects receive, novel and attended objects would produce more implicit perception than the control condition.

To achieve a significant difference between the experimental and control conditions, a more sensitive measure of implicit perception may be needed. Experiment 2 produced a more sensitive measure by increasing the number of trials containing unexpected objects, which resulted in more data per participant. However, this approach has limits, because when the number of critical trials is increased, the number of participants aware of the critical object increases. Increasing trials have only increase sensitivity so far, so alternative measures may be required. A slightly altered form of the word stem task requires participants to produce multiple word stems for each word, increasing the likelihood of implicit processes producing the critical word. In such a case, words need to be selected carefully, as a common word would result in too many target completions even without the presentation of the word, decreasing the overall sensitivity of the measure.

The second explanation also suggests a method to further investigate processes by which unexpected objects capture attention. Richard et al. (2003) suggested this is a parallel process, that is largely unaffected by attention set. If novel objects processed implicitly are more likely to explicitly capture attention, this suggests that the main determinant in novel objects capturing attention are these implicit processes. Therefore, if these implicit processes are parallel and unaffected by attention set, it seems likely that the processes by which unexpected objects capture attention are also parallel and unaffected by attention set. Further experimentation could investigate the implicit measure used in the present research; if rates of word stem target completion remained constant with the presentation of multiple unexpected objects, this would imply the attention process for unexpected objects operates in parallel.

Further experimentation could further examine the effects of expectations on attention capture. The present research has mainly been concerned with the expectations of two colours, where one is attended, and the other is ignored. Different expectations could be created by switching the target and background colours from trial to trial. In this case, this would create the expectation that two colours would appear, but would not create the expectation of which colour the target would be. Alternatively, distracters could occur as two colours, with the frequency of each varying for trial to trial. In the critical trial, distracters could appear only as one colour, with the critical object appearing in the other colour. In this case, the display would be physically the same as the current novel condition, but the expectations would be different. The rate of attention capture of the novel, attended and ignored in these situations would provide information about the role of intentions and of object features in capturing attention.

Unconscious Perception

The aim of the present research was to demonstrate unconscious processing using two measures, the change in response time, and word stem task. Unfortunately, there was no significant change in response time when participants were unaware of the presentation of the unexpected object, which did not demonstrate implicit perception. Fortunately, the word stem task was able to demonstrate implicit perception.

Interestingly, if the word stem data were analyzed using the classic dissociation paradigm (Reingold & Merikle, 1988, 1990), there would be little evidence for unconscious processing. There was no significant increase in word stem target completions over control conditions when a critical word was presented, so under the logic of the classic dissociation paradigm unconscious perception has not occurred. However, implicit perception can be demonstrated by considering the data from a multidimensional qualitative differences approach. The novel and attended conditions had approximately equal rates of explicit perception, but significantly different rates of implicit perception. This pattern of results is not consistent with a single process conscious perception model, which predicts that when explicit perception is equal, implicit perception would also be equal. Instead, these results suggest unconscious processing has occurred.

The pattern of implicit perception revealed by stem completions in the current experiments makes the results highly resistant to alternate interpretations. Snodgrass, Bernat and Shevrin's (2004) non-monotonic approach to demonstrating implicit perception has difficulty in eliminating the possibility of nonlinear conscious processes producing non-monotonic implicit measures. It could be argued that an increase in performance in the word stem task is the product of a small amount of conscious perception, and that these conscious processes are nonlinear; the implicit measures may increase with decreasing conscious awareness below a certain level. However, if nonlinear conscious processes produce the same amount of explicit perception, the same amount of implicit perception is expected. The current results indicated that implicit processes were qualitatively different, even when explicit processes were equal. This result cannot easily be explained by conscious processes, even if they are non-linear, which provides strong evidence for unconscious processing, and demonstrates the usefulness of using multiple dimensions of object features in the study of unconscious perception.

The difference in implicit perception between the novel and attended conditions is an example of bidirectional phenomena suggested by Snodgrass (2004). The current implementation of a multidimensional approach offers potential for producing these bidirectional effects in other paradigms. For instance, the expected and unexpected dimensions of attention set could be integrated into a semantic priming experiment. The present research gives reason to expect that attended and unattended objects would produce different amounts of semantic priming.

Attention and Meaning

Unfortunately, while the word stem task was useful as a measure of implicit perception, the effects of meaning on attention capture could not be analyzed because of experimental limitations. The unexpected objects in Experiment 1 were either words or non-words. If a difference in implicit processing were demonstrated between words and non-words, this would indicate that meaning is extracted prior to the capture of attention. However, the response time did not produce significant implicit perception, and the word stem task is not of use when dealing with non-words, so the present research is unable to investigate this claim.

Future research could investigate the effects of meaning on attention capture by manipulating the types of words presented, rather than manipulating whether a word or non-word was presented. This would enable use of the word stem task to examine the effects of meaning on implicit processes. There is reason to expect different words to produce different rates of implicit perception. In Experiment 2, there is some indication that the words ‘idiot’ and ‘crap’ produced a larger difference in implicit perception than ‘help’, or ‘tree’. The effect of word was not significantly different, and the order of presentation was not counterbalanced, so this could be the result of practice effects. Other experimentation has produced similar results; for example, Mack, Pappas Silverman, and Gay (2002) demonstrated that a person’s own name is likely to capture attention. While it would be difficult to use a word stem task when participants names are being used, this result indicates that implicit capture of attention by words with different meanings may be a useful direction for future research.

The Perceptual Cycle

The results from Experiments 1 and 2 are consistent with the predictions from the perceptual cycle account proposed by Neisser (1976b). Most et al.'s (2005) prediction that awareness would be the product of sustained attention is consistent with the result that an increase in response time was observed when participants were aware of the unexpected object. However, we cannot be certain that the increase in response time was the result of increased time perceiving the object; instead, the increase in response time could be the result of the participants wondering why an unexpected word had appeared on the screen. In other words, the increase in response time is the result of processing, after the object has been consciously perceived, rather than the result of processing the object so that it can be consciously perceived. To differentiate between these two accounts, participants could be instructed to continue as quickly as possible despite any unexpected events. A side effect of this change in procedure is a change in expectations, as participants have been alerted to the possibility of unexpected objects, which would be a shift from the Inattentional Blindness paradigm. However, the modified procedure would help ensure that the change in response time accompanying an unexpected object is the product of a change in time examining the critical object.

Most et al.'s (2005) prediction that under conditions of selective attention, attention capture will depend on attention set, is consistent with present results. In a cluttered display, where attention is directed to one object and other objects are ignored, unattended objects sharing the same colour as the primary target are more likely to capture attention than those not sharing the same colour. In terms of the perceptual cycle, the intentions of the perceiver are what motivate explorations. So when an individual is expecting certain features, and intends to observe some features but ignore others, their explorations will be guided by these intentions. Consequently, features that the perceiver is intending to observe will be the subject of attention.

The large difference in implicit processing (target stem completions) between the novel and attended conditions is an interesting result, which can be accommodated within the perceptual cycle framework. Under the perceptual cycle, the difference in implicit perception between stimuli in the attended and novel colours can be seen as involving the intentions of the perceiver. When an unexpected object enters the perceptual cycle, the perceiver needs to modify their anticipatory schemata in order to explain the change to the perceptual array, and direct further observations. When an unexpected object contains familiar features, it requires few changes to the anticipatory schema, so the perceptual cycle does not require many iterations to produce these changes, resulting in a decrease in the chances of the unexpected object reaching consciousness. Thus, not all processing that an attended object receives is conscious, meaning there is likely to be evidence for implicit processes. On the other hand, if an unexpected object contains unexpected features, large-scale changes to the anticipatory schema are required, which would mean multiple iterations, resulting in an increase in the chances of awareness. Thus, any processing that an unexpected object receives is likely to be conscious, decreasing the chances of observing unconscious processing.

The current experiments were not able to test Most et al. (2005)'s other predictions, further experimentation is needed to investigate these predictions. To test the prediction that explicit measures of perception are always accompanied by implicit measure of perception, an exhaustive measure of implicit perception is needed. If an increase in response time had produced significant implicit perception, it could be used to test this prediction; the expectation is that all participants who were aware of the unexpected object would also show an increase in response time when the unexpected object was presented.

On the other hand, to test the prediction that sustained attention must be preceded by a transient shift in attention; a measure of transient shift of attention is needed. One possibility is to use eye tracking to determine transient shifts in attention. It is expected that measures of sustained attention could only be produced after the eye has made a movement to unexpected objects.

Nevertheless, the other results are consistent with Most et al.'s reformulation of Neisser's (1976b) perceptual cycle. The present research indicates that a perceiver's observations are directed by their intentions, which in the case of selective attention depends on the task requirement. There is also evidence that sustained attention produces awareness, through multiple iterations of the perceptual cycle.

Conclusions

Capturing attention is a complex process, where capture can occur because of an observer's expectations, but capture can also occur for objects that are outside the observer's expectations. If an observer is attending to some objects and ignoring others, objects resembling attended objects will be likely to capture attention, while objects resembling ignored objects will often go unnoticed. At the same time, unexpected objects will often capture attention.

Complicating this picture, not all processing is available to awareness or conscious report. A multidimensional approach to implicit and explicit measures has demonstrated that attended and novel objects are both subject to unconscious processing. A difference in this processing indicates that novel objects may capture attention through different mechanisms than attended objects.

Lastly, the present research has demonstrated that there is value in conceptualizing perception as occurring in a cyclical, iterative fashion. The perceptual cycle provides a novel conceptualization, which can alert researchers to perceptual effects that might otherwise go unnoticed.

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Appendix: Word stem data for individual words in Experiment 2

Figure 7 shows the word stem results from participants unable to see the critical object in Experiment 2. An ANOVA was performed on the data, and while there was a significant main effect of Word / Trial (F (3, 273) = 8.18, p<.001), there was no significant interaction effect (F (9, 273) = 1.02, *n.s.*).

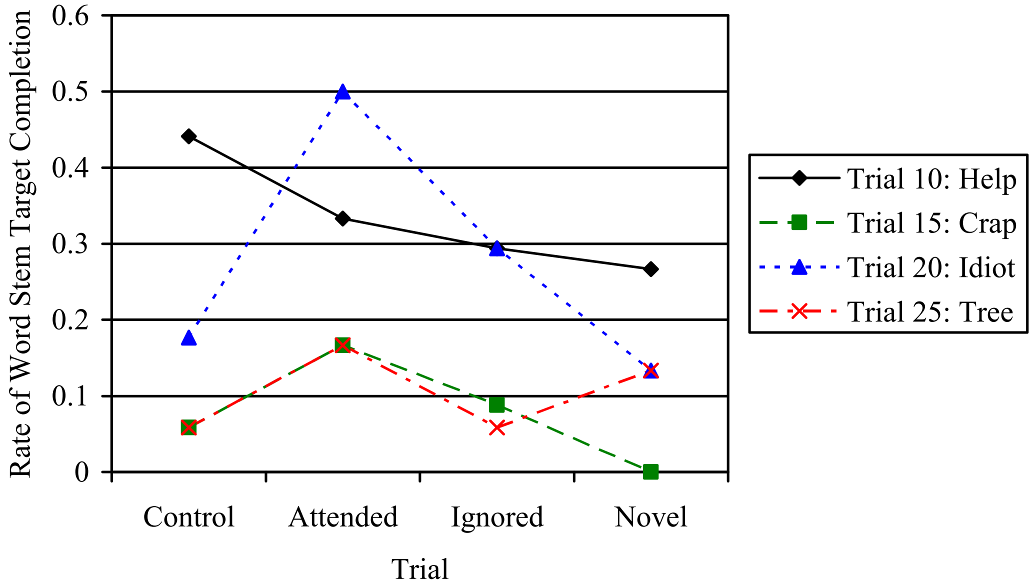

Figure 7: The rates of word stem target completion for the four critical words in Experiment 2.

Final instructions for Nathan:

Make sure Acknowledgements are there
Fix up table of contents, table of figures [Check that intro isn't written in white, change margins]
Fix up page numbers [TOC no numbering?], section breaks (continious, etc)
Do references
Fix up Summers, 2005 #108 [Abstract Only] … retrieved from Web of Science, 12 Dec 2005
Fix up any bad references – ", " -> ", " [need to redo this again and again!]
Then print it out [making sure you colour print the appropriate pages], then follow the instructions below.
Make two copies, ensuring that they are clean and complete.

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