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What You Do Is What You Set: Semantic Representations of Tasks and the Capture of Awareness

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Abstract

We designed two experiments in order to disambiguate the impact of meaning on the detection and awareness of an unexpected stimulus under conditions of inattentional blindness (IB). The key variable was the meaning of the unexpected stimulus. The meaning was either task-associated or task-unassociated. The unexpected stimulus was also always irrelevant to the performance of the task and shared no features with the expected stimuli. In both experiments, we found that an unexpected stimulus with task-associated meaning, independent of stimulus features and stimulus categories, enjoyed low levels of IB as well as high probability for entering conscious awareness. The results indicate that meaning is a prime determinant for the capture of conscious awareness. Our results also suggested that attentional sets encode a broad semantic instantiation of the current task, even if the task is entirely perceptual in nature.

Keywords: inattentional blindness; meaning; attentional set; awareness; detection; conscious perception.

Introduction

Numerous studies have confirmed that an individual focused on a task can often fail to consciously perceive the appearance of an unexpected stimulus – a phenomenon known as 'Inattentional Blindness' (IB) (Mack & Rock, 1998; Most et al., 2005). This failure to notice an unexpected stimulus has been attributed to the failure of that stimulus to capture attention. Some striking examples of IB have been demonstrated in recent studies. For example, a majority of movie watchers who were performing a task while watching the movie failed to notice a man in a gorilla suit walking across the screen (Simons & Chabris, 1999). A plethora of clinical and real-world evidence points to the robustness of the phenomenon and emphasizes its relevance to theories of attention, perception, and consciousness.

There is some debate as to which features of an unexpected stimulus can cause it to enter conscious awareness. Earlier research into IB has shown that the observer's name and a happy face icon are some of the few stimuli that consistently capture awareness under conditions known to cause IB (Mack & Rock, 1998; Mack et al., 2002). Mack et al. (2002) attribute the capacity of these stimuli to capture awareness to the stimuli's meaningfulness. Other results, however, support the need for additional work to investigate the relationship between meaningfulness and the capture of awareness. For example,

Gronau, Cohen, & Ben-Shakhar (2003) demonstrated that personally-significant stimuli (such as the observer's name) and task-relevant stimuli capture attention differently, and Mack & Rock (1998) themselves found a significant difference in IB when the unexpected stimulus was a smiley-face icon compared to a sad-face icon.

Work along these lines has benefited from Most et al.'s (2005) research on attentional sets. Their work demonstrates that increased levels of capture occurred when the unexpected stimulus shared visual features with the expected stimulus. Koivisto, Hyona, & Revonsuo (2004) also demonstrated that unexpected stimuli that share a semantic category with the expected stimuli show high probabilities of entering awareness. This last finding is, however, complicated by the fact that their unexpected and expected stimuli also shared visual characteristics.

In this paper, we report two studies designed to disambiguate the relationship between stimulus meaning and the capture of awareness under conditions known to cause IB. In both studies, we replicated the conditions of Mack & Rock's (1998) "Seeing Your Name" experiment. Participants were asked to attend to a cross presented for 200ms and to judge which arm of the cross was longer. At the last trial, an unexpected word was presented. The task-association of this unexpected word was manipulated across different groups: the word was either task-associated ("horizontal" or "vertical"), related to a task-associated word ("diagonal"), or task-unassociated ("helicopter", "vitamin" or "dictate"). However, the unexpected word was always irrelevant to the performance of the task, was emotionally neutral, and shared neither a common semantic category nor common visual features with the expected stimuli. Since the primary task was perceptual in nature, the task should not require the inclusion of any semantic information in the attentional set of the participant.

These studies allowed a direct test of the hypothesis that the probability for detection and awareness is increased when a task-irrelevant stimulus is meaningful. The effect of task instructions on the capture of awareness was also measured. One group of participants was read instructions that contained repeated occurrences of the task-associated words, whereas another group was read instructions that strictly avoided any mention of the task-associated words. It was hypothesized that the use of task-associated words in the task instructions could result in the fine-tuning of

attentional sets to recognize the semantic relationship between the word and the task, and thereby increase the probability for detection and awareness for this category of unexpected words.

Experiment 1

Methods

Participants One hundred and thirty one participants (52 men, 79 women) were tested from a pool of undergraduate students at Vassar College. All participants ranged between the ages of 18 to 24, had normal or corrected to normal vision, and were screened for diagnosed attentional disorders. The participants were recruited either via an email informing them about an opportunity to participate or through an online posting available to the Introductory Psychology students, who participated for course credit.

Stimuli and Apparatus Participants were presented stimuli on a computer monitor 30 cm wide and 24 cm tall (Dell D1025TM), which was set to a resolution of 1024 x 768 and a refresh rate of 85 Hz. All stimuli were presented using SuperLab Pro v.1.75 on a Macintosh running OS 9.

All presented stimuli were black and white. The stimuli included: a) a small fixation-cross (0.4° x 0.4°) presented at the center of the screen, b) a larger task-cross centered 2° from the center of the fixation-cross at an oblique (45°) trajectory, c) a visual mask and d) a black screen. In all trials, the task-cross had one of the following four dimensions: 3.7° x 3.1°, 3.2° x 3.6°, 3.8° x 3.6°, 3.5° x 3.8° and was presented in one of the four quadrants of the fixation-cross. In order to maintain the same visual angle for all participants, a chin rest was positioned 65 cm from the computer screen, thereby replicating Mack & Rock's (1998) visual angles. The type and location of task-cross presented during any given trial were selected randomly by the stimulus presentation program.

In each trial the first event was the presentation of the fixation-cross at the centre of the screen for 1500 msecs. After the 1500 msecs fixation interval, the task-cross was presented in one of the four possible oblique locations for 200 msecs. The task-cross presentation was followed by the onset of a visual mask that covered the entire screen for 500 msecs. After the mask, a black screen remained for 2500 msecs before the next trial began. Thus, each trial took 2200 msecs and there was an inter-trial-interval of 2500 msecs. Trial time and inter-trial-interval were constant for all trials and participants.

The participants were given a 3200 msecs window to register a response before it was counted as a miss. The response window began immediately following the presentation of the task-cross and ended with the beginning of the next trial (i.e. onset of the fixation cross).

Each participant saw 8 non-critical trials, followed by a 9th critical trial. For a non-critical trial, the initial fixation-cross persisted on the screen during the presentation of the task-cross. For a critical trial, a word replaced the fixation-
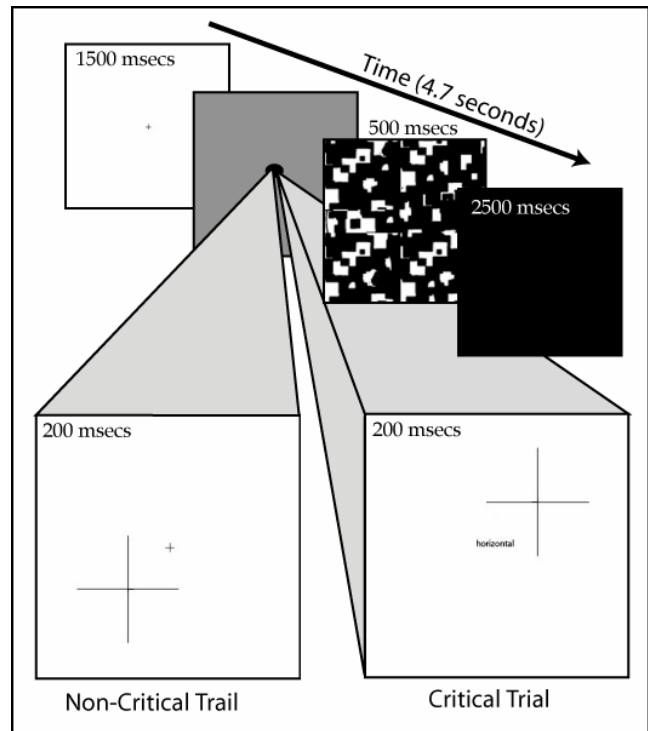

Figure 1: Sequence of Stimuli

cross exactly at the onset of the task-cross. The word was centered at the original location of the fixation cross. Thus, in the critical trial, both the task-cross and the unexpected word were presented for 200 msecs (see Figure 1).

The unexpected word was one of the following: a) "vertical", b) "horizontal", c) "diagonal", d) "vitamin", e) "helicopter" and f) "dictate". The words "vertical" and "horizontal" were the task-associated stimuli. They refer to the arms of the task-cross and are therefore meaningful in the context of the task. The word "diagonal" was selected because it is semantically related to the task-associated stimuli. The words "vitamin", "helicopter" and "dictate" served as task-unassociated counterparts of "vertical," "horizontal," and "diagonal," respectively. Each unassociated word begins with the same letter, is of equal length, and is used with equal frequency in the English language as its task-associated counterpart. All words were chosen to have low emotional loading. The words "helicopter" and "horizontal" were both 1.16° long, "diagonal" and "dictate" were both 1.07° long, and "vertical" and "vitamin" were also 1.07° long. All words were presented in lower case, 11 point font, and "Times New Roman" font type.

One difference between Mack & Rock's (1998) study and ours arose as a consequence of software randomization constraints in our study. Mack & Rock presented 3 non-critical trials prior to a 4th critical trial, while we presented 8 non-critical trials followed by a 9th critical trial. We know of no reason to expect that this difference in procedure should affect outcomes.

Procedure The study utilized a 2 (Task instructions: Primed / Unprimed) x 2 (Meaningfulness: Task-associated / Task-unassociated) x 3 (Word type: H-word / V-word / D-word) tier design, for a total of 12 groups. All participants were assigned randomly to one of two different groups: 'primed' and 'unprimed'. Participants within both of those groups were then randomly assigned to either a 'task-associated' or 'task-unassociated' condition. Participants in the 'task-associated' condition were then further randomly assigned to a 'word' condition where they would be either presented the word "horizontal", "diagonal", or "vertical" during the critical trial. Similarly, participants in the 'task-unassociated' condition were assigned to one of the following three 'word' conditions: "helicopter", "dictate", or "vitamin". Participants in the "horizontal" and "vertical" conditions were balanced across 'correct' and 'incorrect' conditions, where the number of unexpected word stimuli that provided the correct answer was balanced with the number that provided the incorrect answer within both the primed and unprimed condition.

Participants were tested individually in a small, well-lit, sound-attenuated room. For participants in the 'primed' group, the instructions repeatedly used the words "horizontal" and "vertical" to describe the task. This was done to prime the participants to the task-associations of those words. For the unprimed group, the words "horizontal" and "vertical" were never mentioned in connection with the task. Instead the experimenter pointed to the cross-arms while explaining the task.

In both instruction conditions, the participants were asked to complete nine length-discrimination trials. For each trial, the primary task required participants to determine which of the two arms of the task-cross was longer and to press the appropriate keyboard button to register an answer. The importance of both reaction time and accuracy were emphasized to the participants and they were asked not to sacrifice one for the other.

In accordance with the task-instructions used by Mack & Rock in their "Seeing Your Name" studies (1998), all participants were instructed to look directly at the fixation-cross at all times while performing the experiment.

Although there was no practice sequence prior to beginning the task, participants were shown pictures of all the stimuli that would be presented (excluding the unexpected word) and given substantial time to clarify any questions about the nature of the task. The experimenter left the testing room prior to the beginning of the task to eliminate possible experimenter effects during testing.

Immediately after the completion of the task, the investigator asked participants whether they had noticed anything unusual. If they answered 'no' or mentioned some other aspect of the task they considered unusual, then the investigator prompted them by asking whether they noticed any words appearing on the screen during the task. If the answer was still 'no' then the participants were thanked and debriefed. If participants answered 'yes' to the question about noticing anything unusual, they were asked to identify what they saw. After determining what the participants noticed during the task set, they were thanked and debriefed.

Results

Dependent Measures The attentional capture data for all participants fell into one of three categories: a) *Identification*, i.e. the participant noticed something unexpected, and correctly identified the unexpected stimulus; b) *Detection*, i.e. the participant noticed something unexpected, but could not correctly identify it; c) *Inattentional Blindness*, i.e. the participant did not notice the presentation of the unexpected stimulus.

In entertaining the possibility that consciousness may not be an all-or-nothing phenomenon (e.g. Most et al., 2005; Overgaard et al., 2006), we grouped the three categories described above to measure two aspects of capture of awareness: *detection rate* and *identification rate*.

Detection rate measures the frequency with which participants reported the presence of the unexpected stimulus. Hence, the detection rate is a comparison between the IB group (as defined above) and the Non-IB group (sum of *detection* and *identification* groups, as defined above).

Identification rate measures the frequency with which participants became conscious of the unexpected stimulus and could report its identity. The identification rate compares the *identification* group with the *non-identification* group (sum of *detection* and *IB* groups, as defined above).

The identification rate and detection rate measure "blindness" with two different thresholds. For *detection rate*, the participant must simply notice the presence of an unexpected stimulus (same as IB definition in Mack & Rock, 1998), whereas for *identification rate*, the participant must extract its identity and be able to explicitly report it (same as IB definition in Most et al., 2005).

Primary Task In order to establish that participants were engaged in and attentive to the task, we examined the performance data across all trials prior to the critical trial. Overall accuracy was 70.19%, and average reaction time was a very rapid 303 msecs, which indicates very effective task engagement.

Task-Association and Awareness Having ascertained that participants were actively engaged in the primary task, we analyzed the attentional capture results with a Chi-square test when possible; however, when any expected cell frequency was lower than five for a 2x2 test, or when more than one cell had a lower expected frequency than five for a 2x3 test, a Fisher's Exact Probability Test was used. All statistical tests were two-tailed.

For the task associated conditions (primed and unprimed) participants were randomly assigned to either *correct* or *incorrect* association of word to longer line. Because this is not a variable of interest, we performed a pretest to determine whether we could collapse the data across this

distinction. A Fisher's EPT revealed no significant effects of this manipulation (all p > .50), so data were collapsed.

We also found no difference between the attentional capture data for *primed task-associated* (N = 33) and *unprimed task-associated* (N = 32) conditions, and found that priming during task-instructions had absolutely no effect on the level of attentional capture: *p(two-tailed)* approached 1.0. The data from the *primed task-associated* and *unprimed task-associated* conditions were therefore collapsed into the *task-associated* condition. It should be noted that since "diagonal" was never used to describe the task in the primed-instructions (only "vertical" and "horizontal" were used), the above-mentioned data for *primed* and *unprimed* did not include any data from the "diagonal" condition. The collapsed *task-associated* data, however, do include data from the "diagonal" condition.

Finally, we compared the data from the *task-associated* condition with the data from the *task-unassociated* condition using 2 Chi-square tests, one each for *detection rate* and *identification rate*. There was no difference in the *detection rate* between the *task-associated* condition (N = 81, 14.8% IB) and the *task-unassociated* condition (N = 50, 18.0% IB), $\chi^2(1, N = 131) = 0.23$, p = 0.63. However, there was a significant difference in *identification rate* between the *task-associated* condition (N = 81, 76.5% ID) and the *task-unassociated* condition (N = 50, 54.0% ID), $\chi^2(1, N = 131) = 7.21$, p < 0.01. Thus, task-associated meaning increased the probability for conscious awareness and identification of the unexpected stimulus, but did not impact the probability of detection (see Table 1).

Table 1: Experiment 1 - Meaningfulness and Awareness (Chi-Square Percentage Deviations Noted Below Actual)

	Identification	Detection	Inattentional Blindness
Task-Associated	62 (76%) *(+12.7%)*	7 (9%) *(-46.1%)*	12 (15%) *(-7.6%)*
Task Un-Associated	27 (54%) *(-20.5%)*	14 (28%) *(+74.7%)*	9 (18%) *(+12.3%)*

Low Levels of Inattentional Blindness One surprising result to emerge from this study was the extremely low levels of IB. Since the task conditions in this study were meant to replicate those in the "Seeing Your Name" study by Mack & Rock (1998), it was expected that the levels of IB for the non-target words should match those for the control words in the Mack & Rock study. They reported an IB level of 55% (22 of 40 participants). In the present study the observed IB rate witnessed for the *task-unassociated* condition was only 18% (9 of 50), significantly lower than the rate observed in Mack & Rock (1998): $\chi^2(1, N = 90) = 13.47$, p < 0.001.

Discussion

The aim of this study was to examine whether the meaning of an unexpected stimulus was a key determinant in the capture of awareness. We found that meaning had an effect on identification rate but did not affect detection rate. Priming (via task-instructions) affected neither detection nor identification. The results thus support the view that meaning is a powerful factor in whether IB occurs. The unusually low rate of IB as compared with Mack & Rock's results (1998) presents something of a puzzle, however, which we set out to explore in a second study.

Experiment 2

One possible explanation for the low IB rate in the first experiment is that doubling the number of non-critical trials before the occurrence of the critical trial might have altered patterns of attention by making the critical event seem more anomalous when it did finally occur. In order to test this hypothesis we conducted another study using the same number of trials as Mack & Rock's (1998) original design. The major procedural difference between Experiment 1 and Experiment 2 was the number of non-critical trials (see Methods).

If Experiment 2 were to result in higher levels of IB, it would then be of interest to look for any difference in the effects of task-association under conditions of high-IB. Similarly, it was of interest whether priming would have an impact on capture levels under conditions of high-IB.

Methods

Participants One hundred and three participants (37 men, 66 women) were tested from a pool of undergraduate students at Vassar College. Recruitment conditions were the same as Experiment 1.

Procedure Besides the number of non-critical trials, all stimuli and other experimental procedures of this experiment were identical to those used in Experiment 1. However, unlike the first experiment, there were only two word conditions. For the *task-associated* conditions (*primed* and *unprimed*), participants were either presented the word "horizontal" or vertical" on the critical trial, and for the *task-unassociated* condition, participants were either presented the word "helicopter" or "vitamin". Each of the four different task-crosses was presented to all subjects, and each of the four task-crosses appeared on a critical trial for at least four participants in each condition. Thus, task-cross type was still balanced within participants, within conditions, and across conditions. The number of task-associated words that provided the correct answer was balanced with the number of task-associated words that provided incorrect answers within both the *primed* and *unprimed task-associated* conditions. The major change from Experiment 1 was the decrease in number of non-critical trials from eight to three.

Results and Discussion

Dependent Measures All dependent measures were the same as Experiment 1.

Primary Task For the all non-critical trials, the overall accuracy was 68.77% and the average reaction time was 331.91 msecs, which indicates very effective task engagement. The minor difference in averages between the two experiments was attributed to the increased weight of the first trial in the average for Experiment 2. Having determined that participants were actively engaged in the primary task, we analyzed the attentional capture data using the same statistical tools as Experiment 1.

IB Rates A 2x2 Chi-square test revealed no difference in the levels of IB between the *task-unassociated* condition in Experiment 2 and the *control* condition in the "Seeing Your Name" study by Mack & Rock (1998), $\chi^2(1, N = 78) = 0.07$, $p = 0.79$.

Task-Association and Attentional Capture A 2x3 Fisher's EPT revealed that there was no difference in attentional capture levels between the primed task-associated condition (N = 33) and the unprimed task-associated condition (N =32), p = 0.24. We collapsed the task-associated primed and unprimed conditions into the task-associated condition.

A significantly lower number of participants showed IB in the task-associated condition (N = 65, 24.6% IB) than in the task-unassociated condition (N = 38, 57.9% IB), $\chi^2(1, N = 103) = 11.41$, p < 0.001. Similarly, a significantly higher number of people experienced conscious capture in the task-associated condition (N = 65, 69.2% ID) than in the task-unassociated condition (N = 38, 34.2% ID), $\chi^2(1, N = 90) = 11.95$, p < 0.001 (see Table 2). Thus, under conditions of high-IB, meaning modulated both IB and conscious awareness.

Table 2: Experiment 2 - Meaningfulness and Awareness (No Percentage Deviations Noted Due to Exp. Freq. < 5)

	Identification	Detection	Inattentional Blindness
Task Associated	45 (69%)	4 (6%)	16 (25%)
Task Un-Associated	13 (34%)	3 (8%)	22 (58%)

Comparison between Experiment 1 and Experiment 2 Across Experiment 1 and Experiment 2, words with task-associated meaning were detected at the same rate, $\chi^2(1, N = 146) = 2.23$, p = 0.14, and identified at the same rate, $\chi^2(1, N = 146) = 0.98$, p = 0.3.

On the other hand, within the task-unassociated condition, there was a significantly lower level of IB in Experiment 1 (N = 50, 18.0% IB) than in Experiment 2 (N = 38, 57.9% IB), $\chi^2(1, N = 88) = 15.06$, p < 0.0001. However, identification rate approached but did not reach statistical significance, $\chi^2 = 3.41$, p < 0.06. Thus, the main difference between the two studies was a decreased level of IB for task-unassociated words in Experiment 1 compared to Experiment 2 (see Table 3).

Table 3: Difference between Capture of Awareness for Task-Unassociated - Experiment 1 and Experiment 2 (Chi-Square Percentage Deviations Noted Below Actual)

	Identification	Detection	Inattentional Blindness
Exp. 1 Task Un-Associated	27 (54%) *(+18.8%)*	14 (28%) *(+44.9%)*	9 (18%) *(-48.9%)*
Exp. 2 Task Un-Associated	13 (34%) *(-24.7%)*	3 (8%) *(-59.1%)*	22 (58%) *(+64.3%)*

General Discussion

Our experimental conditions provided a unique opportunity to examine the impact of meaning on the capture of awareness. Prior studies have shown that if unexpected stimuli shared visual features with the expected stimuli, the unexpected stimuli produced negligible levels of IB (Most et al., 2005). Work published after the completion of our studies showed that unexpected stimuli that share semantic categories with the expected stimuli show high levels of capture, even if they do not share visual features with the expected stimuli (Koivisto & Revonsuo, 2007). While this work demonstrated a possible role for semantic considerations in attentional allocation, their explicit task-instructions to attend to a particular semantic category could have primed the observer's attentional set to include semantic category information as task-relevant. Thus, the effect of semantic considerations on the capture of awareness remained unclear for broader contexts.

The studies reported here benefit from three experimental design components: a) the unexpected stimulus (a word) is categorically different from the expected stimulus (a Cartesian cross); b) the unexpected stimulus was task-associated yet task-irrelevant; and c) the primary task was perceptual in nature and thus should not have primed any semantic content as task-relevant. This allows the results reported here to extend the previous body of work by isolating the impact of meaning from feature-based, category-based, or expectation-based attentional biasing.

We found that the meaning of the unexpected stimulus, independent of stimulus features and stimulus category, determined the level of capture of conscious awareness. Unexpected words with task-associated meaning were far more likely to be detected and correctly recalled than unexpected words with task-unassociated meaning.

In Experiment 1 (low-IB condition), the task-associated meaning of the unexpected word affected the rate of conscious identification but did not affect the rate of detection. In Experiment 2 (high-IB condition), the task-associated meaning of the unexpected word affected both the rate of detection as well as the rate of conscious identification. Although it is beyond the scope the current report, we note here that this difference is most likely due to factors outside mechanisms for attentional allocation.

Our current results also reinforce the need for a broader understanding of the types of information that can be encoded in attentional sets. Our studies show that unexpected task-irrelevant stimuli that do not share visual features or semantic categories with expected stimuli can still capture attention due to their semantic relationship to the task. For this to be the case, task-comprehension must also result in a broader semantic instantiation of the task itself, rather than just encoding a collection of stimulus features that relate to the task.

While other researchers have considered the possibility of the attentional set as an explicit goal state of the observer (Atchley, Kramer, & Hillstrom, 2000; Most et al. 2005), to our knowledge, this is the first study to gather data to effectively demonstrate that attentional sets can include such a higher-level semantic instantiation of the current task.

We propose describing attentional sets as a collection of constraints deriving from a combination of multiple competing influences, including the semantic instantiation of the overall task (cf. Experiment 1, Experiment 2), task strategy (e.g. Smilek, Dixon, & Merikle, 2006), environmental context (e.g. Sawaki & Katayama, 2006), immediate task demands (e.g. Triesch et al., 2003), experience (e.g. Leber & Egeth, 2006), as well as potentially a "default" attentional set, which includes a disposition towards certain features such as sudden onset, unless overwritten by task-instruction (e.g. Prinzmetal & Taylor, 2006).

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