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Semantic guidance of attention within natural scenes

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When viewing real-world scenes composed of a myriad of objects, detecting changes can be quite difficult, especially when transients are masked. In general, changes are noticed more quickly and accurately if they occur at the currently (or a recently) attended location. Here, we examine the effects of explicit and implicit semantic cues on the guidance of attention in a change detection task. Participants first attempted to read aloud a briefly presented prime word, then looked for a difference between two alternating versions of a real-world scene. Helpful primes named the object that changed, while misdirecting primes named another (unchanging) object in the picture. Robust effects were found for both explicit and implicit priming conditions, with helpful primes yielding faster change detection times than misdirecting or neutral primes. This demonstrates that observers are able to use higher order semantic information as a cue to guide attention within a natural scene, even when the semantic information is presented outside of explicit awareness.

Our perceived visual world is a compromise between external input and internal expectations. It is constructed bottom-up by neuronal algorithms that capitalize on the many regularities in our visual environment in order to simplify the overwhelming amount of incoming perceptual information. In addition, top-down influences allow us to delineate objects and make sense of this incoming stream. Glance up for a moment and survey your surroundings. What do you see? Rather than noticing free-floating colours, or masses of lines, you probably noticed a chair or table, and maybe a tree or two outside the window. The sight of a particular arrangement of brown lines and green colour patches triggers not only the visual image of a weeping willow, but also the semantic content of

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''tree''. Consciously, we perceive the world at the level of objects, rather than in terms of edges, colour swatches, and motion transients. Our overall perception is of a stable, meaningful environment, and in general we are quite confident in our ability to correctly perceive the world as it ''truly'' is (Levin, Momen, Drivdahl, & Simons, 2000).

Visual illusions exploit our brains' automatic processes and reveal occasions in which our perceptions do not match reality. Change blindness is one such phenomenon that has been recently investigated. In a typical change blindness ''flicker paradigm'' (Rensink, O'Regan, & Clark, 1997), two pictures, identical except for a difference in a single object (e.g., a large shift in the horizon or disappearing and reappearing towers), are repeatedly alternated in an ABAB or AABB fashion with a blank mask transient inserted between each picture. In general, participants will examine these picture pairs for long periods without detecting any anomaly.

Normally when something changes in the world, there is an accompanying motion signal or other transient, which automatically attracts attention (Klein, Kingstone, and Pontefract, 1992). Change blindness results when some interfering transient (e.g., a saccade, eyeblink, flicker, or mudsplat) swamps or overloads the normal transient produced by the change (Rensink, 2000). Many researchers have argued that we overlook changes in this paradigm because the visual system does not maintain a detailed representation of the world (Chun & Nakayama, 2000; Rensink, 2002; Rensink et al., 1997). Therefore, unless one is attending to the location of change at the time of the switch (or just prior to the switch), it is very difficult to notice the difference. Although our general feeling is of residing in a stable, intricate visual environment, this theory argues that we do not internalize as much of our surroundings as we might think we do.

Our conscious, subjective experience is that of seeing an intact environment populated by meaningful objects. At some level, semantic labels and categories for these ''object files'' must be activated. But *at what level* does this label activation occur? At what processing stage does the semantic content of an object in a scene become available for higher order control of attention? *OLE_LINK5Some of the semantic meaning must be attached during the rapid ''gist'' labelling and overall spatial mapping of the scene during the first few hundred milliseconds of viewing (Potter, 1975, 1976). It seems then, that some semantic information is being linked to objects and organized extremely rapidly. Once the gist and layout of the scene has been ascertained, there are a number of objects that could potentially attract attention. How do we decide to which objects we should attend?

Previous studies of change blindness have shown that some types of changes tend to be noticed more quickly than others. Rensink and colleagues (O'Regan, Deubel, Clark, & Rensink, 2000) have proposed that changes to ''centres of interest'' in pictures tend to get noticed more quickly than changes of ''marginal interest.'' Werner and Thies (2000) found differences in detection ability based on the participant's level of expertise within a domain (in this case, American football). Hollingworth, Williams, and Henderson (2001) found that changes to semantically inconsistent objects tended to be detected more often than changes to objects that were semantically consistent with the rest of the scene. In an attempt to understand what aspects of our environment are most naturally encoded, Aginsky and Tarr (2000) cued participants as to what *type* of change would occur (though not what *object* would change). They showed participants colour photographs of natural scenes, and explicitly precued the participant as to whether the change would be a colour change, object position change, or object presence/absence change. Only the times to detect colour changes were facilitated with this cueing paradigm. The authors interpreted their results as an indication that colour is encoded as a ''surface'' property, which is not as central to the overall layout and gist of the scene as are the ''configural'' properties (presence/absence and position change). It is thought that the overall layout of the scene is ascertained very rapidly, with finer details filled during later allocation of attention (Biederman, 1981). In this two-stage model, alterations of the layout of the scene would be automatically detected, and thus not greatly facilitated by a cue. On the other hand, colour is often not as important to the overall structure of the scene, and would not be automatically encoded during the gist labelling. Because of this, cueing participants to pay more attention to colour *would* be useful in a change detection task, and thus would decrease detection time.

Studies have shown that semantically related word primes do facilitate picture categorization and naming (cf. Carr, McCauley, Sperber, & Parmelee, 1982; Smith, Meiran, & Besner, 2000). In addition, as a control condition to ensure that changes were detectable, the first studies of the flicker paradigm explicitly informed participants where to look for the change (Rensink et al., 1997) and found that this cueing reduced detection times. Given that explicit semantic information can obviously affect attention, it is of particular interest whether implicit primes would have the same effect. In other words, does linking semantic information to a pictorial scene require conscious/explicit processes? Or, are words actually processed enough at an unconscious level to be useful when linked to picture representations?

EXPERIMENT 1

None of the change blindness studies to date have attempted to implicitly modulate semantic attention within a natural scene. The existence of implicit semantic priming would imply that the processing of word primes could somehow tap into the attentional-guidance abilities at work during a person's everyday life. Natural scenes are interesting experimental stimuli precisely because the objects and the relationships between objects carry abstract semantic information as well as perceptual information. In any real-world scene there will be many possible objects to attend to, and these must be segmented from the relatively chaotic perceptual input. Explicitly priming the participant with the name of the object that changes is expected to decrease detection time, by quickly limiting the set of attended objects. In an attempt to establish whether a similar guidance of attention can be controlled implicitly, we determined the effects of a briefly presented, masked prime on detection times in a subsequent change blindness flicker paradigm.

Method

Participants. Participants were University of Oregon students who took part in exchange for credit in an undergraduate psychology course. All 32 participants were naïve to the hypothesis, and reported normal or corrected-to-normal vision, and fluency in English. Experiment duration was approximately 1 hour.

Apparatus. Stimuli were presented at eye level to the participant sitting at a desk in a darkened room. Stimuli were back-projected onto a translucent screen by a Barco Cine 7 projector at a screen refresh rate of 60 Hz. Participants sat at a comfortable viewing distance (approximately 100 cm) away from the screen. When projected, the pictures each measured 33.7 cm high $\times$ 44.5 cm wide and therefore subtended visual angles of approximately 19° and 25°, respectively. Words were presented in black, lowercase 12-point Charcoal font, were 2.5 cm high, and between 5 cm to 16.5 cm in length (corresponding to a visual angle of 1.4° $\times$ 2.3–9.4°). Response times were recorded with a custom-built button box, with participants using the index finger on the dominant hand for responses. Stimuli were presented using the PsyScript programming language (Bates & D'Oliveiro, 2003), running from a Macintosh G4.

Picture stimuli. The change-blindness stimuli used in this experiment were photographs of real-world scenes. One hundred stimuli came from a set used by Huettel, Güzeldere, and McCarthy (2001). Thirty-two pictures from this set were modified (to make the changes more salient) and twenty additional stimuli were created by the experimenter. Pictures included scenes of artificial objects, people, cityscapes, landscapes, and other ordinary scenes. Picture pairs were nearly identical, differing only in the presence/absence of an object or object part, the location for a particular object, or the colour of an object. Some changes were more difficult to detect than others, but all were noticeable once pointed out.

Once a change has been detected in a task like this, it becomes quite obvious upon subsequent viewing. Because of this, each stimulus pair was presented only once to each participant. To counterbalance the stimuli, the set was broken into four groups. Two pilot studies were run (6 participants and 12 participants, respectively) to assess overall detectability of changes, and to ascertain the general reaction times to stimuli. After the first pilot study, it was found that some changes were not detected by any (or very few) of the participants. These stimuli were subsequently altered to make the change more salient, and the second pilot study served to norm the new versions into picture groups of approximately equal average reaction times. Each picture was assigned two primes, one *helpful* prime (naming the changing object) and the other *misdirecting* (naming another, unchanging object in the picture). Half of the participants saw a particular picture stimulus paired with the helpful prime, and the other half with the misdirecting prime.

Procedure. On each trial, participants encountered one of two prime types. Prime words were either related to the object that changed (helpful), or related to another object in the picture (misdirecting). Primes were either 33 ms in duration, immediately followed by a 250 ms mask of uppercase Xs, or were 200 ms in duration with an immediate 83 ms mask of Xs. Most participants were only able to read approximately one third of the 33 ms primes, but the 200 ms prime length gave all participants enough time to reliably read the word aloud, while still maintaining task difficulty. These parameters yielded four equally probable priming conditions (33 ms/helpful, 200 ms/helpful, 33 ms/misdirecting, and 200 ms/misdirecting). Four base lists of stimuli pairings were then created by matching each of the four picture groups with a particular priming condition. Presentation order of pictures within each base list was then randomized for each participant. In this experiment each picture pair was thus viewed by each participant once, but was randomized across participants to occur equally often after each of the four priming conditions.

To determine precisely which primes were consciously perceived (*explicit*) versus those which were *not* consciously perceived (*implicit*), the participant was required to say the prime word out loud (or to say ''X'' out loud if the word was unreadable) immediately after prime presentation, but before the change-blindness stimulus appeared. In this way, we precisely determined on a trial-by-trial basis which primes were truly implicit or explicit.

During each trial (Figure 1), a black fixation cross was presented for 500 ms on a mid-level grey screen, followed by a prime and a subsequent mask for a total prime/mask duration of approximately 283 ms. Next, a blank delay period of 500 ms was introduced while participants attempted to read the prime word aloud. After this delay, pictures from a particular picture pair began alternating as follows: 300 ms for picture 1, 100 ms grey screen, 300 ms for picture 2, 100 ms grey screen, etc., in an ABAB fashion. Participants were requested to press a button as soon as they noticed a change. This button press halted further flickering, and blanked the screen. At this point, participants were required to verbally describe the object or location that changed. Both verbal responses (to prime and location of change) were manually recorded by the experimenter. In

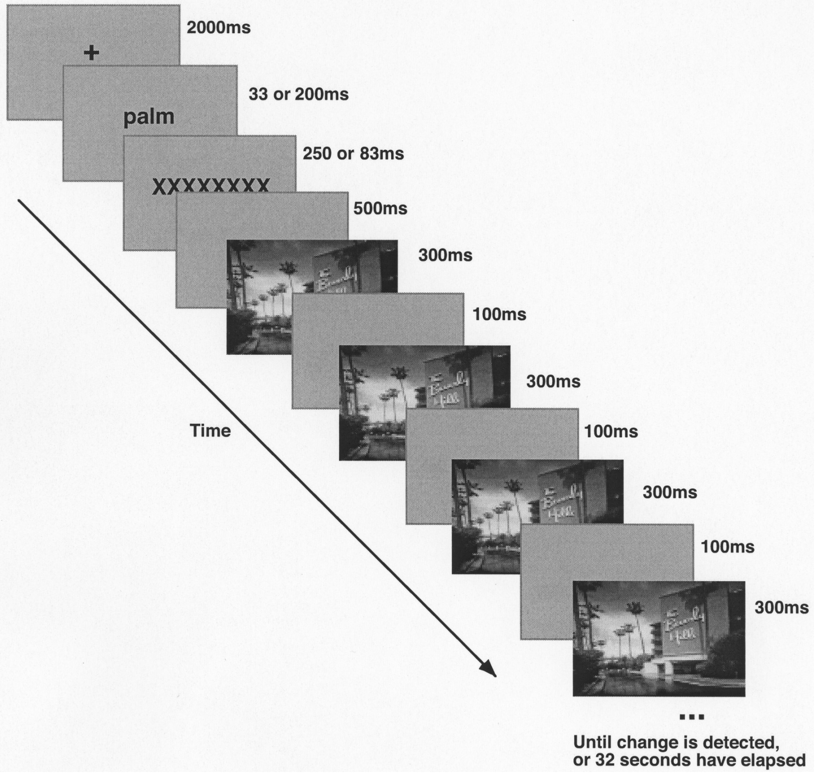


Figure 1. Experiment 1 trial layout. In this picture pair, the palm tree second from the left disappears and reappears in alternate pictures. In the pilot study with no priming, average reaction time for detecting this particular change was approximately 9 s.

four of the trials, the two pictures that flickered were identical. In these cases, as well as in cases in which the participant failed to notice the change, the flickering would halt after 32 s. At this point participants were requested to declare ''no change''. Each participant was given a demonstration consisting of 10 practice trials, followed by 124 experimental trials. At first, many participants found it difficult to report the prime, look for a change, press a button, and then describe the change. Those participants that needed extra practice in order to learn the proper response order were allowed two runs through demonstration pictures.

Results

The four trials in which no change occurred did not elicit any false alarms and were not used in any of the analyses. With one exception (which was excluded from subsequent data analyses), all long-duration (200 ms) primes were read by all participants, and were therefore coded as explicit during further analysis. Detection of the short-duration (33 ms) primes varied widely across participants (Figure 2). Most participants were able to read at least a few of the short-duration primes, and many reported that it became easier to read the briefly presented words as the experiment progressed. Some participants read as many as half of the short-duration primes, and a few participants read more than half. All short-duration primes that were read aloud were subsequently coded as explicit data points for further analysis. Incorrect reports of short-duration primes were also considered as explicit reports, as were occasions in which participants were capable of reading a fragment of the prime. Incorrectly read helpful primes were recoded as misdirecting, unless the response was a synonym for the helpful prime. Implicit data points refer only to those short-duration trials in which the participant said ''X'' instead of a correct or incorrect prime word.

In general, participants were able to detect the changes, seeing an average of 100 out of the 120 changes (83%) with detection accuracy ranging from 70% to 95% across participants. Across both explicit and implicit trials, participants detected significantly more changes that were preceded by a helpful prime (88%) versus those preceded by a misdirecting prime (77%), $t(31) = -5.633$, $p < .001$. Undetected changes were coded as having a reaction time of 32 s (cutoff of flicker). Because the reaction time distribution was quite skewed (Figure 3), the median reaction time for each condition for each participant was used as the dependent variable. Reaction times to short- and long-duration explicit primes were collapsed for each participant, since there were no significant differences in reaction time across these two prime durations.

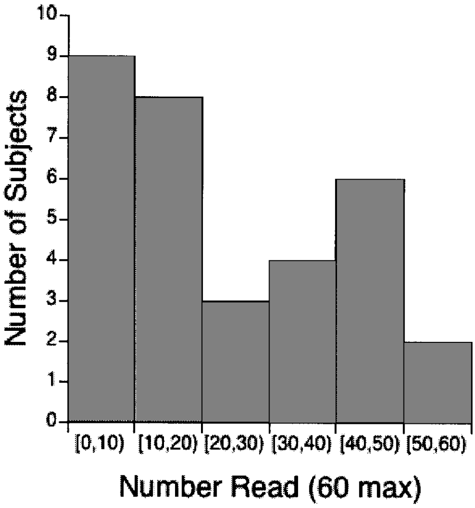


Figure 2. Number of 33 ms primes read across all participants in Experiment 1.

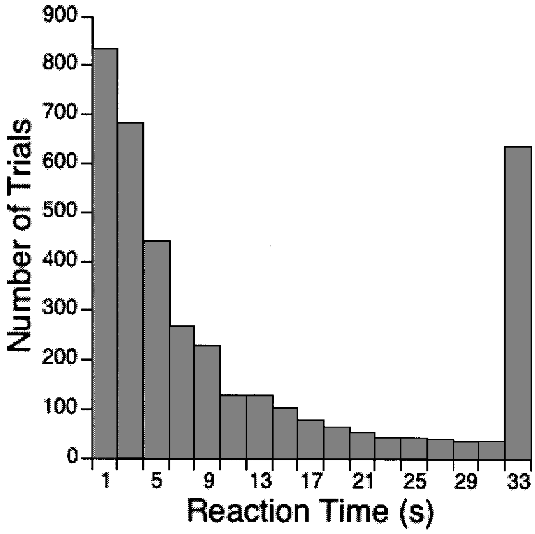


Figure 3. Distribution of reaction times across all participants and conditions in Experiment 1.

A two-factor repeated-measures ANOVA of detectability (explicit/implicit) by prime type (helpful/misdirecting) was performed on the data. Overall, there was a significant effect of detectability, $F(1, 31) = 9.425$, $p < .01$, with implicit trials lasting approximately 1.9 s longer than explicit trials (Figure 4A). There was also a significant effect of prime type, $F(1, 31) = 40.803$, $p < .001$, with helpful primes eliciting overall RTs approximately 4.8 s faster than the misdirecting primes. However, there was a significant interaction between detectability and prime type, $F(1, 31) = 4.966$, $p < .05$, indicating that the difference between helpful and misdirecting primes was not equal across both explicit and implicit trials. When tested separately, though, the effect of prime type was significant in both the explicit, $F(1, 31) = 111.225$, $p < .001$, as well as implicit, $F(1, 31) = 5.173$, $p < .05$, trials.

As noted above, the 32 participants differed with respect to prime-detection ability (Figure 2); some participants were able to read many of the short-duration primes, while others were only able to read a few. The nature of implicit processing is thought to depend heavily on precise stimulus parameters and the distance of these parameters from an individual's explicit detection threshold. As a result, implicit primes might have different effect sizes due to individual differences in prime detection abilities. To investigate this possibility, participants were divided according to the number of short-duration primes that each was able to read. Those participants who read more than the median number were grouped as *near-threshold* participants, while those who read fewer than the median were grouped as *far-from-threshold* participants. Each group was

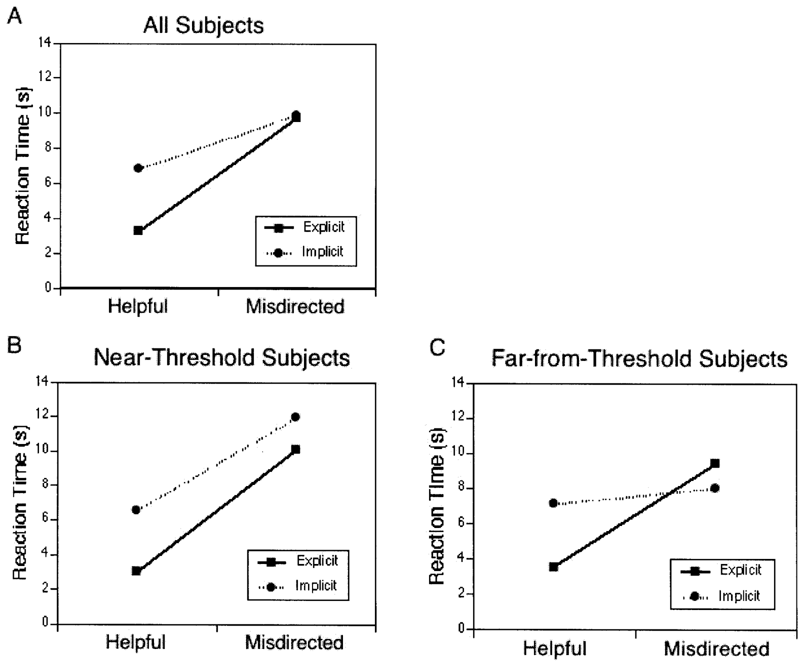


Figure 4. Experiment 1 results. (A) Across all participants, change detection times were shorter with helpful compared to misdirecting primes, in both the implicit and explicit conditions. (B) Those participants who could read more 33 ms primes (near-threshold) showed equal priming across both explicit and implicit trials. (C) Those participants who read fewer 33 ms primes (far-from-threshold) only had significant priming in the explicit trials.

then subjected to a separate two-factor, repeated-measures ANOVA of detectability (explicit/implicit) by prime type (helpful/misdirecting).

Near-threshold participants showed greater priming effects for implicit trials than did the far-from-threshold participants. Overall the near-threshold participants had a significant effect of prime type, $F(1, 15) = 20.732$, $p < .001$, with helpful primes eliciting faster reaction times than misdirecting (Figure 4B). In addition, there was a significant effect of detectability, $F(1, 15) = 6.221$, $p < .05$, with explicit trials eliciting faster reaction times than implicit trials. There was no interaction between detectability and prime type, suggesting that the explicit and implicit trials elicited semantic priming effects of the same magnitude for these near-threshold participants.

Far-from-threshold participants showed a very different pattern of results. Overall they did not have a significant effect of detectability, though they did have a significant effect of prime type, $F(1, 15) = 54.886$, $p < .001$, as well as a significant interaction, $F(1, 15) = 9.777$, $p < .01$. When the effect of prime type was tested separately, these participants showed a significant difference in the explicit trials, $F(1, 15) = 36.783$, $p < .001$, with helpful primes eliciting reaction times 5.9 s faster than misdirecting, but a nonsignificant 0.9 s difference in the implicit trials (Figure 4C).

Discussion

These findings replicate a previous study (Rensink et al., 1997) showing reduced change detection times after explicit cueing, and go further by demonstrating a similar reduction in detection times even in cases in which participants were not able to process a prime word enough to read it aloud (i.e., implicit trials). Importantly, this implicit priming effect seems to be driven by those participants who were able to read more of the short-duration (33 ms) primes. It is possible that for these participants, the short-duration primes were more fully processed by the visual system and thus were closer to their threshold for explicit detection. Even in those cases where these participants were not able to read the prime word aloud, they seem to have been able to process the prime to a greater degree than did those who needed more salient stimuli in order to be explicitly aware of them.

EXPERIMENT 2

When viewing the scenes in Experiment 1, participants reported that they tended to orient more quickly to an object related to the word they had previously read aloud, even though they had not been told that there would be any meaningful relationship between the prime and picture. Thus, when the immediately attended item was the object that changed, participants were naturally faster at detecting the difference. However, it is also possible that the difference in detection times between helpful and misdirecting primes could be at least partially explained by an additional effect: Namely that the misdirecting primes slowed the rate of detection by misguiding participants and causing them to waste time with attention focused on an unchanging portion of the scene.

An earlier study may shed some light on why changes in pictures preceded by misdirecting primes took longer to detect than those preceded by helpful primes. Bruner and Potter (1964) presented participants with unfocused pictures, and then incrementally brought the pictures into focus. At each step they asked the participant to guess what the picture might be. They found that participants who started with the fuzziest representations needed the picture to be in greatest focus before realizing exactly what the scene depicted. Those participants who started with a medium amount of focus were able to more quickly discern the gist of the scene. Bruner and Potter took this as evidence that a participant's original, erroneous top-down ideas about a scene (formed when there wasn't enough information to make an accurate assessment) can override what would otherwise be quite obvious. In other words, participants seemed to have a difficult time rejecting their first incorrect hypotheses, even though they were based on very degraded cues. Perhaps this failure to reject incorrect ideas is analogous to how the explicit semantic priming worked in the current experiment. Reading a prime word out loud seemed to allow participants to quickly orient attention within the scene. In the helpful prime cases, this was useful and allowed faster detection time. In the misdirected cases, however, it might have caused a perseveration on the incorrectly cued item, thereby preventing attentional resources from being allocated to any other item, including the item that was actually changing.

In Experiment 1, helpful primes elicited faster detection times than did misdirecting primes. However, it is impossible to determine whether helpful primes sped up change detection times, misdirecting primes slowed change detection times, or both. Experiment 2 served as a replication of Experiment 1, with the advantage of including *neutral* primes so that these possibilities can be distinguished. Furthermore, we used a staircase procedure to establish optimal priming parameters individually for each participant.

Method

Participants. Participants were members of the University of Oregon community who were paid for their participation in the study. All 21 participants were naïve to the hypothesis, and reported normal or corrected-to-normal vision, and fluency in English. Experiment duration was approximately 1.5 hours.

Apparatus. The equipment used was identical to that in Experiment 1.

Picture stimuli. The picture pairs for the change blindness portion of the task were identical to those used in Experiment 1.

Staircase procedure. In order to elicit approximately equal numbers of explicit and implicit responses from each participant, a thresholding task was performed in which the prime presentation time was held constant while the grey-value luminance was varied (background grey-value was 45%, where 0% = black and 100% = white). During the staircase, participants were presented with a mask of 10 random, black uppercase letters for 100 ms, then a prime word for 100 ms, and finally the same 10-letter mask for 200 ms. The initial colour of the prime words was black. In subsequent trials, if the participant could read the prime aloud, the prime was made lighter (i.e., closer to the grey level of the background), and if not, it was made darker. Using this procedure, the grey-value was varied with each reversal until it reached the threshold at which the participant could read the prime word aloud in approximately half of the trials, and responded ''X'' in the other half. After doing the staircase task twice, the grey-value threshold closest to the background colour was used as the prime colour for the change detection task. The entire staircasing procedure took approximately 10–15 min.

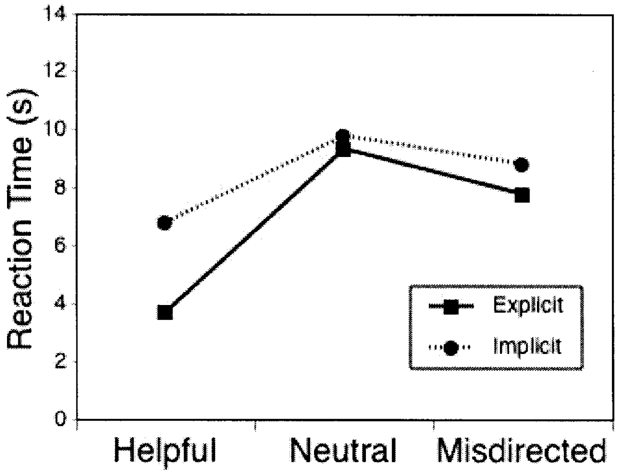
Procedure. Each pair of pictures was associated with the same helpful and misdirecting primes as in Experiment 1. In addition, each pair could also be associated with a neutral prime (a string of semirandom numerals). If participants detected a word as a prime, they were to read the word aloud. If a string of numerals was detected they were to respond ‘‘numbers’’; otherwise, they were to respond ‘‘X’’ to an unreportable prime.

The picture groups from Experiment 1 were rearranged to create three groups of pictures. Each participant was presented with 40 picture pairs preceded by helpful primes, 40 preceded by misdirecting primes, and 20 preceded by neutral primes. As with Experiment 1, the presentation order was randomized for each participant. Because of the individual staircasing of prime luminance, it was expected that for each participant approximately half of the primes would be read (explicit) and half would not be read aloud (implicit). Between subjects, each picture pair was randomized to occur equally often after helpful or misdirecting primes, and half as often after neutral primes.

The overall change blindness trial layout for Experiment 2 was nearly identical to Experiment 1, with a slight modification to the prime parameters. Participants were presented with a black fixation cross for 500 ms which was followed by a 100 ms black premask of random letters, then the prime word for 100 ms (with a luminance determined by the earlier staircase procedure) followed by a 200 ms black postmask of the same random letters. A 500 ms blank delay period followed as participants attempted to read the prime word aloud (or say ‘‘numbers’’ to a neutral prime or ‘‘X’’ if the prime could not be read). After this delay, pictures from a particular picture pair began alternating in an ABAB fashion as in Experiment 1. Participants were requested to press a button as soon as they noticed a change. Prime report and change detection responses were recorded manually by the experimenter.

Results

Again, the four trials that contained no change did not elicit any false alarms, and were eliminated from subsequent data analyses. The remainder of the trials were coded according to whether the participant could read the prime aloud (explicit) or not (implicit). If a helpful prime was misread, it was recoded as misdirecting, as were neutral primes that were reported as words. Some participants consistently read aloud words that were not at all related to the actual prime presented and as a result had very few trials coded as implicit, and few explicit trials coded as neutral or helpful. Because these participants (n = 6) seemed to be using a different response criterion in the change blindness task than in the thresholding task, their data was discarded.



Q1 **Figure 5.** Experiment 2 results. Across both explicit and implicit trials, change detection times were significantly shorter with helpful primes compared to neutral, while there were no differences with misdirecting and neutral primes.

A repeated measures ANOVA of detectability (explicit/implicit) by prime type (helpful/misdirecting/neutral) was performed on the median reaction time data for each condition. Overall there was a significant main effect of prime type, $F(2, 28) = 8.569$, $p < .01$. Planned contrasts indicated that helpful primes significantly differed from the neutral primes ($p < .005$), but that misdirecting primes did not differ significantly from neutral primes. Neither the main effect of detectability, nor the interaction of detectability and prime type reached significance, indicating that the effect of the primes was similar across both the explicit and the implicit trials.

Discussion

Experiment 2 replicated the helpful/misdirecting prime difference found in Experiment 1 in both the explicit and implicit trials. In addition, because of the addition of neutral primes, the results of Experiment 2 indicate that helpful primes do indeed facilitate reaction times relative to neutral primes, and show that misdirecting primes do not significantly hinder reaction times. It seems, then, that the perseveration hypothesis put forth in the Introduction of Experiment 2 does not explain the difference in reaction times between helpful and misdirecting primes. Instead, it appears that the helpful primes allowed participants to quickly orient to the changing object, which decreased reaction times. Misdirecting primes undoubtedly guided attention, but participants did not seem to spend any more time with attention on this inaccurate location than they would have during a search with a neutral prime (in which they would have looked at *some* location first).

EXPERIMENT 3

While the results of Experiments 1 and 2 demonstrate that Helpful primes facilitate change detection times relative to misdirecting and neutral primes even when subjects were unable to read the prime aloud, it is possible that these primes were not truly implicit. Although some studies have found evidence for implicit priming at the word level, other studies suggest that implicit priming may even occur at the level of word fragments. Abrams and Greenwald (2000) repeatedly presented participants with explicit targets (such as ‘‘smut’’ and ‘‘bile’’), and then found that subjects were slower at categorizing a target word as happy when preceded by an implicit prime (such as ‘‘smile’’) which shared some parts with the negatively valenced words already experienced. However, this effect was only seen when participants viewed targets many times. Our prime stimuli were not repeated in this manner, yet it does seem plausible that participants might have been capable of explicitly detecting fragments of the prime word, for example the ‘‘ch’’ out of ‘‘chair’’. While this information would not have allowed them to read the entire word aloud (and thus they might say ‘‘X’’ and the trial would be coded as Implicit), the explicit fragment ‘‘ch’’ might still have allowed enough information to later intuit that the prime must have been ‘‘chair’’ when later presented with a scene containing a chair, but no chimneys, chains, or chisels. In order to rule out the possibility of change detection mediated by explicit fragment recognition in this way, we replicated the previous experiments, with the addition of a forced-choice task at the end of each trial to verify that the primes were indeed implicitly processed, never reaching explicit awareness.

Method

Participants. Participants were University of Oregon students who took part in exchange for credit in an undergraduate psychology course. All 16 participants were naïve to the hypothesis, and reported normal or corrected-to-normal vision, and fluency in English. Experiment duration was approximately 1.5 hours.

Apparatus. The equipment used was identical to that in Experiment 1.

Picture stimuli. The picture pairs were identical to those used in the previous experiments.

Staircase procedure. The staircase procedure was identical to that in Experiment 2.

Procedure. The four groups of picture pairs were identical to those used in the previous experiments. As in Experiment 1, we used helpful and misdirecting, but not neutral, primes. Each picture pair thus had both a helpful and a misdirecting prime associated with it, though any individual subject was presented with only one of these at the onset of the trial. During each trial, the prime presentation (either helpful or misdirecting), picture presentation, and report of change object/location were identical to the procedure in Experiment 2. However, after the participant provided a verbal description of the observed change, a computer-generated voice read aloud the two prime words associated with that picture pair (one helpful and one misdirecting, with presentation order randomized). Participants then pressed the left of two buttons on the button-box if the first computer-generated word was the previously seen prime word, or the right button if the second word was the previously seen prime word.

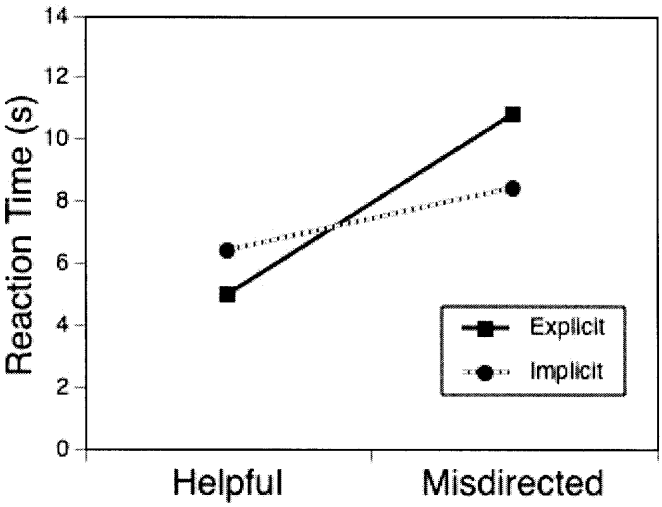
Results

Experiment 3 replicated the priming effect found in the previous experiments. Overall, helpful primes elicited faster change detection times than misdirecting primes. On average, changes preceded by helpful primes were detected 3.6 s faster than those preceded by misdirecting primes. A repeated-measures ANOVA of detectability (explicit/implicit) by prime type (helpful/misdirecting) found a significant main effect of prime type, $F(1, 15) = 8.741$, $p < .05$. Neither the detectability main effect nor the Detectability × Prime type interaction term reached significance, suggesting that priming effects were similar for both explicit and implicit conditions.

An analysis of the forced-choice responses following implicit primes found that participants' ability to correctly identify primes was not significantly different from chance, 52% correctly detected; average sensitivity $d' = 0.109$, $SE = 0.07$, $t(15) = 1.711$, n.s. In contrast, explicit primes elicited correct responses in the forced-choice paradigm 88% of the time, average $d' = 1.624$, $SE = 0.166$, $t(15) = 10.132$, $p < .001$. The relatively low forced-choice identification rate in the explicit condition was primarily due to those participants who occasionally incorrectly read aloud a word that had no semantic similarity to the presented prime. While these trials were treated as explicit in our analysis, neither option in the forced choice corresponded to the word that was read aloud. If these misread primes were omitted, the average correct forced-choice response for explicit primes was 95% (average $d' = 1.868$, $SE = 0.164$, $t(15) = 11.747$, $p < .001$.

Discussion

It seems reasonable to assume that if participants could extract some partial explicit information during the initial prime presentation, then that information should be available for both the change detection task as well as the subsequent



Q2 **Figure 6.** Experiment 3 results. Significant priming effects were found for both explicit and implicit priming conditions, in spite of the fact that participants were no better than chance at reporting the implicit primes in a two-alternative forced-choice task.

forced-choice response. For example, if a participant explicitly detected the ''ch'' from the prime ''chair'' then she should be able to use that partial information in the two-alternative forced-choice task to determine that ''chair'' was the correct choice rather than, for example, ''window''. In other words, if fragments of primes were being explicitly detected, then the participants should have responded above chance during the forced-choice response phase. The fact that their forced-choice response scores did *not* differ significantly from chance suggests that the primes were indeed processed implicitly.

If one considers visual processing as occurring along a continuum, it appears that primes could fall into three somewhat overlapping categories. At one extreme, stimuli that are effectively masked would yield no measurable priming effects. At the other extreme, an ineffective mask would yield an explicitly recognizable prime. Only between these extremes would one expect stimuli to be processed enough to yield implicit, but not explicit effects. This pattern of results is termed ''indirect-without-direct-effects'' (Merikle & Daneman, 1998) and has been used as the benchmark for true implicit processing. Previous studies of word–word priming (Draine & Greenwald, 1998) have found evidence for implicit priming in the absence of explicit awareness. In addition, studies investigating the semantic link between words and pictures have also found implicit priming effects. For example, Ferrand, Granger, and Segui (1994) found that implicitly presented primes facilitated picture-naming latencies.

In general, it seems that primes will have the greatest implicit effects when they approach (but do not surpass) the threshold required for explicit processing. For experiments that are designed to test implicit priming effects, this argues against relying on stimulus parameters that keep the explicit detection rate at zero, as parameters too far from threshold would not be expected to produce implicit processing. However, using prime parameters near this explicit detection threshold will necessarily allow a proportion of stimuli to be explicitly detected. This suggests that studies that attempt to demonstrate ''indirect-without-direct-effects'' should determine on a trial-by-trial basis whether a prime has been explicitly detected.

GENERAL DISCUSSION

Although the experimenter in the present study did not indicate that there was any relation between the prime and the picture pair, most participants reported that they naturally oriented more quickly toward an object related to the word that they had just read aloud. If the prime was helpful, they were able to detect the change more quickly. Most interesting are those trials in which participants were *not* able to read the primes aloud. In spite of the inability to consciously detect the prime, participants were still faster at detecting changes to helpfully primed objects. This finding, in conjunction with the finding that subsequent prime recognition was at chance, seems to be clear evidence that implicit semantic information can be used to increase the efficiency of visual processing when viewing a natural scene.

Natural scenes are interesting experimental stimuli because of their ecological validity, their overall complexity, and the fact that the items within the scene have related and overlapping semantic meanings associated with them. Unlike an array of unrelated objects, real-world scenes offer the chance to identify the semantic mechanisms at work in everyday scene perception. Our visual systems seem to be tuned for processing scenes, rather than unrelated arrays of objects. Just as acoustically presented words are processed more rapidly when presented as part of a structured sentence, our visual world seems to confer a processing advantage on coherently organized scenes (Biederman, 1981).

Some have argued that the visual world is segmented and comprehended though a two-stage process involving first the formation of a preattentive ''primal sketch'' assessing the overall layout and gist of the scene (Biederman, 1981; Schyns & Oliva, 1994), followed by a continued sweep of attention to detect specific features as needed during subsequent fixations. The primes in the present study theoretically could have affected reaction times by increasing the efficiency of either the primal sketch formation or the subsequent guidance of attention during the search, or both. However, the pattern of results demonstrated here suggests that most, if not all, of the effect occurred during the guidance of attention. First, the magnitude of the reaction time savings (a reduction of 2–4 s when a helpful prime was presented) is too great to have been derived from only a reduction in the primal sketch formation, which itself has been demonstrated to occur in a half-second or less (Potter, 1975, 1976). Second, there is no reason to expect that the helpful primes would lead to a faster determination of a scene's gist than would the misdirected primes, since both primes provided at least some semantic cues to the scene's general content. Thus, these findings indicate that implicit and explicit semantic information can be used by the brain to guide attention within a complex scene.

REFERENCES

Abrams, R., & Greenwald, A. (2000). Parts outweigh the whole (word) in unconscious analysis of meaning. *Psychological Science*, *11*(2), 118–124.

Aginsky, V., & Tarr, M. J. (2000). How are different properties of a scene encoded in visual memory? *Visual Cognition*, *7*(1/2/3), 147–162.

Q3 Bar, M., & Biederman, I. (1998). Subliminal visual priming. *American Psychological Society*, *9*(6), 464–469.

Bates, T. C., & D'Oliveiro, L. (2003). PsyScript: A Macintosh application for scripting experiments. *Behavior Research Methods, Instruments, and Computers*, *35*(4), 565–576. Computer software retrieved from http://www.maccs.mq.edu.au/~tim/psyscript/index.html

Biederman, I. (1981). On the semantics of a glance at a scene. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 213–253). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Bruner, J., & Potter, M. C. (1964). Interference in visual recognition. *Science*, *144*, 424–425.

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance*, *8*(6), 757–777.

Q4 Cheesman, J., & Merikle, P. (1984). Priming with and without awareness. *Perception and Psychophysics*, *36*, 387–395.

Chun, M. M., & Nakayama, K. (2000). On the functional role of implicit visual memory for the adaptive deployment of attention across scenes. *Visual Cognition*, *7*(1/2/3), 65–81.

Draine, S. C., & Greenwald, A. G. (1998). Replicable unconscious semantic priming. *Journal of Experimental Psychology: General*, *127*(3), 286–303.

Ferrand, L., Grainger, J., & Segui, J. (1994). A study of masked form priming in picture and word naming. *Memory and Cognition*, *22*(4), 431–441.

Hollingworth, A., Williams, C. C., & Henderson, J. M. (2001). To see and remember: Visually specific information is retained in memory from previously attended objects in natural scenes. *Psychonomic Bulletin and Review*, *8*(4), 761–768.

Huettel, S., Güzeldere, G., & McCarthy, G. (2001). Dissociating the neural mechanisms of visual attention in change detection using functional MRI. *Journal of Cognitive Neuroscience*, *13*(7), 1006–1018.

Q5 Klein, R. M., Kingstone, ?., & Pontefract, A. (1992) Orienting of visual attention. In K. Rayner (Ed.), *Eye movements and visual cognition: Scene perception and reading* (pp. 46–65). New York: Springer.

Levin, D. T., Momen, N., Drivdahl, S. B., & Simons. D. J. (2000). Change blindness blindness: The metacognitive error of overestimating change-detection ability. *Visual Cognition*, *7*(1), 397–341.

Merikle, P., & Daneman, M. (1998). Psychological investigations of unconscious perception. *Journal of Consciousness Studies*, *5*, 5–18.

O'Regan, J. K., Deubel, H., Clark, J. J., & Rensink, R. A. (2000). Picture changes during blinks: Looking without seeing and seeing without looking. *Visual Cognition*, *7*(1/2/3), 191–211.

Potter, M. (1975). Meaning in visual search. *Science*, *187*, 965–966.

Potter, M. (1976). Short term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory*, *2*, 509–522.

Rensink, R. A. (2000). The dynamic representation of scenes. *Visual Cognition*, *7*(1/2/3), 17–42.

Rensink, R. A. (2002). Change detection. *Annual Reviews of Psychology*, *53*, 245–277.

Rensink, R. A., O'Regan, J. K., & Clark, J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science*, *8*(5), 368–373.

Q6 Sanocki, T., & Epstein, W. (1997). Priming spatial layout of scenes. *Psychological Science*, *8*, 374–378.

Schyns, P. G., & Oliva, A. (1994). From blobs to boundary edges: Evidence for time- and special scale dependent recognition. *Psychological Science*, *5*, 195–200.

Smith, M. C., Meiran, N., & Besner, D. (2000). On the interaction between linguistic and pictorial systems in the absence of semantic mediation: Evidence from a priming paradigm. *Memory and Cognition*, *28*(2), 204–213.

Werner, S., & Thies, B. (2000). Is ''change blindness'' attenuated by domain-specific expertise? An expert–novices comparison of change detection in football images. *Visual Cognition*, *7*(1/2/3), 163–173.

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