MEASURING UNCONSCIOUS PROCESSES IN VISUAL WORD RECOGNITION USING TWO-ALTERNATIVE FORCED CHOICE TASKS IN CONJUNCTION WITH CONFIDENCE RATINGS AND PSYCHOPHYSIOLOGICAL RECORDINGS

by

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DEDICATION

To my mother, Irina Gorbunova.

“The difficult I’ll do right now, the impossible will take a little while”

- *Crazy He Calls Me*
by Bob Russell

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ABSTRACT

The present dissertation aims to evaluate the phenomenon of visual masking as a tool for studying visual awareness focusing on two-alternative forced choice (2AFC) discrimination tasks. Two existing theories of masking – Bachmann's (1984) perceptual retouch theory and Marcel's (1983) recovery theory – are discussed along with the global neuronal workspace theory of awareness (Baars. 1989; Dehaene, Kerszberg, & Changeux, 1998). Performance accuracy on Semantic discrimination is compared to that on Orthographic discrimination as an indication of a potential difference between semantic and orthographic processing of masked word stimuli presented for 40 ms and 50 ms. This is further compared to an e-detection task previously used as an indicator of awareness in some masked priming experiments. Together, these tasks are further evaluated in terms of their relationship with participants' subjective reports collected in the form of confidence ratings. The implications and predictions drawn from the theories of masking and visual awareness as well as the notion of partial awareness (Kouider & Dupoux, 2001) are assessed taking into account the data obtained in the current experiments.

The relevance of these data for masked priming is determined by performing a comparison between 2AFC discrimination and detection tasks, and the lexical decision task. An ERP study is also presented, in which Semantic and Orthographic discrimination as well as e-detection are paired with confidence ratings and electrophysiological recordings in search of an ERP component that can be correlated with both subjective

(confidence) and objective (performance) measures of awareness. A binding account of visual awareness with special attention paid to visual masking is proposed and compared to the three existing theories.

CHAPTER 1. INTRODUCTION

> Consciousness is … a *feeling* of subjective and perceptual unity. It is as though a unique, but probably fictitious center, the *I*, were the recipient of all the sensory inputs, past and present, and as though all messages pertaining to an object of sensory reality were reunited somewhere in the mind to constitute a consciously perceived facsimile of the same reality.
>
> – Erich Harth (1995)

Questions concerning the nature and function of consciousness have perplexed scientists and philosophers for millennia. But until recently, it was not a viable topic of scientific study due to its highly subjective nature and lack of operational definitions. Today we are able to separate (at least on the basis of definitions) the various components of consciousness: from awareness of the self to altered states and disorders of consciousness to awareness of the external world. This dissertation will focus on the latter component of consciousness, since it is now possible to study it using behavioral and psychophysiological methods as well as taking individual's subjective experience into account. By potentially providing the link between subjective and objective measures of awareness, these methods could answer several of the very important questions for understanding awareness, such as: what does it mean to be unaware of a stimulus and can it influence us despite us being subjectively unaware of it? Are some measures of awareness more sensitive than others? How much information can be gathered from a stimulus we are unaware of having been exposed to? Are there limits to what kinds of information can be obtained? Can that information be used and are there constraints to how it can be used? Most of these questions have been at least partially answered by other researchers (e.g., Cheesman and Merikle, 1984, 1986), but the ability to tie all these answers into a coherent picture about awareness of the external world still eludes us.

Although attempting to answer many question in this dissertation, the author realizes the grandiose ambition of such an endeavor, and wishes to apologize for only touching on some of the very important topics due to lack of resources. Being a very broad topic that until recently was deemed unworthy of scientific discussion, the phenomenon of consciousness and its scientific investigation might still have to undergo several scientific revolutions and paradigm shifts before various philosophical theories are reconciled and our interpretations of growing experimental data concerning some components of this subject start to make sense.

Consciousness of the outside world requires one to have senses with which to gather information about it, and vision is arguably the most vivid, cherished, and therefore the most studied of them all. In the words of Matthew Luckiesh (one of the fathers of the science of seeing), "vision is the most important human sense and seeing is the most universally important controllable activity of human beings" (Luckiesh & Moss, 1938, pg. 1). The ability to read, a skill developed relatively recently that enables one to communicate across vast distances and long stretches of time, is undoubtedly a fascinating, uniquely human capability. It is therefore unsurprising that a general technique which constitutes presenting words very briefly and often also obscuring them with visual masks, has proved useful in studying not only lexical processes that underlie reading, but also the visual system (e.g., Herzog, 2007), memory (e.g., Di Lollo, 1980), emotion (e.g., Naccache et al., 2005), as well as cognition and consciousness in general. Moreover, masking is an invaluable tool for controlling the amount of visual awareness of a stimulus. This makes it an important method for investigating the nature of and difference between conscious and unconscious perception (Ansorge et al., 2007). In fact, the assertion that while preventing conscious awareness of a stimulus, masking allows most unconscious perception to remain intact has influenced some researchers to suggest that "masking may interfere with brain processes that are critically involved in the emergence of consciousness itself" (Price, 2001, p. 26; Bachmann, 1993; Marcel, 1983b).

Measuring consciousness

The debate about how to measure awareness has a long history and has yet to be resolved. As early as 1898, Boris Sidis (a student of William James) attempted to study unconscious perception by visually presenting letters at great distances from where his participants were seated. Despite claiming that they couldn't see what was being shown to them, they were able to identify letters correctly more often than what is expected by chance when encouraged to guess. However, in this study the assumption that participants were unconscious of the stimuli was based on introspective reports, and could have been due to individuals being too conservative about admitting awareness.

More recently, psychologists have been devising and using what can be referred to as objective measures of awareness. Forced-choice identification or discrimination tasks, in which one of the alternatives is identical or similar to the masked stimulus, seem to cope best with criterion bias that detection tasks, where alternatives are simply ‘yes’ and ‘no’, are prone to; but the latter are also used. In these tasks, chance performance is considered indicative of the absence of awareness, while better than chance performance on a discrimination task paired with chance performance on a detection task (inability to tell whether anything preceded the mask with a better than chance accuracy) has been taken as evidence of unconscious processing.

Today many theorists interested in measuring awareness specifically investigate to what extent our behavior and perception are guided by conscious and unconscious processes. Most psychologists hold that high-level representations such as semantic information are likely to require conscious access (Dulany, 1997; Perruchet & Vinter, 2002; Searle, 1992). According to this proposal, “any behavioral response or verbal report is primarily a reflection of consciously experienced mental activity” (Fisk and Haase, 2005). Conversely, many cognitive scientists maintain that consciousness is an epiphenomenon or the result of complex cognitive processes that are performed almost entirely on an unconscious level (e.g., Kihlstrom, 1987; Libet, 1985; Marcel, 1983; Velmans, 1991). This view’s necessary denial the relevance of consciousness to our mental life aside, it allows for the possibility of consciousness (whether or not an illusory construct) to be influenced by unconsciously perceived stimuli (Fisk and Haase, 2005). Because of these opposing viewpoints, it is important to find measures of unconscious processes in order to be able to resolve these issues as well as determine the relative contributions from conscious and unconscious processes to perception. A paradigm capable of separating conscious from unconscious mental activity is therefore of vital importance.

Mechanics of masking

Although the exact mechanisms of masking effects are not completely understood, it has been long noted that masking interferes with the normal course of visual perception. For example, in a typical masking experiment, a word is presented for 30-50 milliseconds. Despite the brevity of presentation, when the word is presented on its own, a normal observer has no trouble identifying it. However, when immediately followed by a mask that consists either of a random dot array (i.e., pattern mask), jumbled letters, pound signs or any other symbols, the word is usually perceived as a mere flash without the possibility of its conscious identification. This effect becomes even stronger when a mask that precedes the word is added. The latter is referred to as a forward mask, and the former as a backward mask according to the direction of perceptual interference they exhibit.

Not all types of masks have the same effect. For example, Jacobson (1974) found that words that are backward masked by letters that are oriented upright are more difficult to read than those followed by a pattern mask or letter pieces. Similarly, words masked by unrelated words or by pseudowords (i.e., non-words that satisfy phonological rules of a given language) are much more difficult to read than the same words followed by a pattern mask or an array of jumbled letters (Jacobson, 1974). Finally, he also found that compared to masks that are unrelated words, homophones produce a larger masking effect on the masked target words, while semantic associates on the contrary, facilitate their recognition (Jacobson, 1976). This means that apart from semantic association, the more similar in nature a mask is to the word being masked, the more robust the masking effect. This certainly does not apply to physical similarity, however. A mask that is identical to the target word and follows it immediately, produces a continuous stimulus that stays visible for the duration of the target and mask combined (i.e., the image of the target stays available for longer than if the target was presented alone). A word masked by its own anagram is read faster as a whole, but slower if participants are asked to spell it letter by letter compared to a word masked by an unrelated letter string (Jacobson & Rhinelander, 1978). The relevance of these findings to visual masking is that the relationship between the mask and the masked stimulus must be considered when designing a masking experiment as well as kept in mind when interpreting its results. Specifically, visual similarity of the mask to the masked stimulus, should be kept constant when manipulation of its visibility is not the goal of an experiment.

There are other ways to manipulate the degree of visibility, or level of energy, of a masked word. The most important of these are exposure duration (i.e., how long it is displayed), stimulus onset asynchrony (SOA), which is the delay between target stimulus and the mask stimulus, and the luminance, or total energy produced by the stimulus. Some evidence supporting the importance of these variables comes from the masked priming literature.

The masked priming paradigm originally proposed by Forster and Davis (1984) is a common technique for studying automatic lexical processes. In a general masked priming paradigm, a forward mask consisting of non-linguistic symbols such as pound signs is followed by a briefly presented masked word called a prime, which is in turn replaced by a target word. The participant must make a task-specified decision on that target word. The prime, depending on its relation to the target, can facilitate or inhibit the speed and accuracy of that decision. Because the prime is masked forwards and backwards (here, the latter type of masking is achieved by the target), most participants report not having seen it. Thus, the general consensus in the masked priming community is that participants are unaware of the prime and the influence it exerts on the target is due to automatic processes that do not require conscious control or use of strategies.

Using this paradigm, Ram Frost and his colleagues (2003) investigated the role of exposure duration and luminance on priming by manipulating these variables in a phonological priming experiment. In this experiment, the participant is asked to pronounce the target as quickly and as accurately as possible. Frost et al. (2003) found that the two factors are interchangeable, as they obtained very similar levels of priming effects with either of the manipulations.

The most drastic example of a luminance effect on the amount of information extracted from a masked stimulus is described by Lukatela and colleagues (1998), who obtained a phonological priming effect for visual stimuli with 29 ms exposure duration, but only when the room illumination was reduced "to that provided by a single desk lamp at floor level" (p. 671). This effect proved non-replicable under normal laboratory conditions (Frost et al., 2003). This shows that masking is highly sensitive to manipulations of the aforementioned variables, which should be taken into consideration when devising experiments, preferably with an inter-laboratory agreement on a standard setting which could be adopted by all laboratories that utilize masking in their research. Most psycholinguistic laboratories that employ masked priming indeed run experiments under normal lighting conditions, using cathode ray tube (CRT) screens with stimuli presented in black letters on white background.

Perceptual retouch theory

Although masking has become an increasingly popular technique, there are only a few theories of masking. One has been proposed by Bachmann (e.g., Bachmann, 1984 &1993) and is referred to as the perceptual retouch theory. It states that perceptual information obtained from a stimulus is not sufficient on its own for a conscious experience of that stimulus to arise. Bachmann argues that this depends on two independently activated neurophysiological systems: the specific system characterized by the passage of information from the retina to the primary visual cortex via the lateral geniculate nucleus (LGN), while the non-specific system is characterized by the subcortical midbrain structures, thalamic activating system and brainstem reticular formation, all associated with arousal. The phasic (orienting, stimulus-driven, as opposed to tonic, maintaining wakefulness) arousal provided by the thalamic activating system is of central importance to the perceptual retouch theory, in which re-convergence of these specific and non-specific systems at a later stage produces conscious experience of the visual stimulus. In other words, this interaction between the two systems adds "the quality of introspective awareness to the formerly preconscious stimulus representation built up by specific neuronal activities" (Bachmann, 1984, p. 70).

The relevance of this theory to masking concerns the difference in timing between the specific system and the slightly (40-90 ms) slower non-specific system (Bachmann, 1984). Although the evidence for this timing difference is unclear from the work of Bachmann, he speculates that in masking, by the time the "conscious quality" triggered by a stimulus is resolved by the non-specific system's afferent projections, the specific system has already resolved the visual properties of the mask (Bachmann, 1984). The result is that although the information about the prime has been accessed, conscious experience of it has been retouched to now be that of the mask. This could be a much more compelling explanation if the neurophysiological data used to support the claim about the difference in speed of the two systems were more clear and up-to-date. More research is needed to test this theory.

Recovery theory

Another theory of masking is provided by Marcel (1983b), who proposed that "without segmentable evidence of particular form or of particular location, the separate existence of an environmental event or aspect cannot be acknowledged or experienced" (p. 263). This idea is known as the recovery theory of masking, because its followers argue that masking prevents the recovery of unconsciously processed information.

Recovery refers to linking of perceptually acquired information to its spatio-temporal sensory source. In this theory, Marcel postulates that it is possible to access all kinds of information about a masked stimulus, including the high-level semantic information. However, without being linked to the physical location of the stimulus in space and time, one cannot become conscious of that information, no matter to what extent it has been processed. This could also be described from the point of view of memory. If a memory trace about having seen a stimulus is unavailable to the individual (due to having been replaced by the mask before such trace had time to form), all the other information is insufficient for creating a conscious experience of the stimulus, because it cannot be recovered.

This theory could also benefit from more psychophysiological research. For example, determining how fast the relevant memory trace can be formed could either support or refute this theory. Additionally, behavioral studies aimed at understanding whether high-level information is indeed available unconsciously despite subjective unawareness of the stimulus, could provide empirical evidence relevant to both theories.

The contrast between perceptual retouch and recovery theory of masking instantiates Dennett's (1991) famous distinction between Stalinesque and Orwellian explanations of certain perceptual illusions. The first theory, involving the delay between two processes, is Stalinesque, for just as Stalin in the 1930s staged illusory "show-trials" which were then more or less accurately reported by the media, the delayed experience of the prime is illusory, since it is now ascribed to the mask. The second explanation is

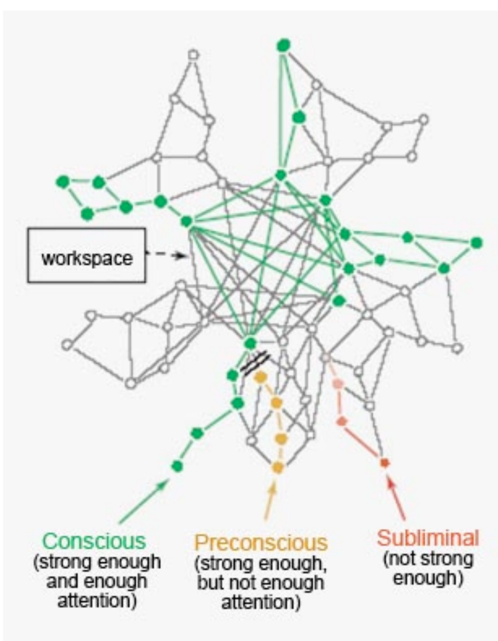
Orwellian. Just as the Ministry of Truth in George Orwell's *1984* regularly rewrites history to cover up disturbing information, the brain, in the recovery theory, replaces an initial experience of a particular temporal interval with another, conflicting experience of that same temporal interval. Since only the later experience is available to the participant when attempting to report the stimulus, the two accounts are subjectively indistinguishable.

Global (neuronal) workspace theory

This is a more general theory of awareness rather than a theory aimed to explain masking *per se*, but it is important in the discussion of why some cognitive processes are executed unconsciously, and how they become available to consciousness. The global workspace theory was originally proposed by cognitive psychologist Bernard Baars (1989) with the theory's central idea stemming from the modularity of mind hypothesis (e.g., Fodor, 1983), which postulates that the mind is divided into discrete cognitive modules capable of unconscious, domain-specific, automatic processing of relevant information, which is confined to those modules. The global workspace theory of consciousness states that in order for that information to reach consciousness, it must escape its specific module and become globally available to the others (Baars, 1983).

Taking this more philosophical theory of Baars (1989) and applying it to the current data suggesting brain region functional specificity, Dehaene, Kerszberg, and Changeux (1998) have modified the theory to suggest the existence of modular cerebral networks that are capable of processing information unconsciously and in parallel. These networks are connected via long-distance neurons whose location is distributed across brain regions. This distributed system of neurons (i.e., the global neuronal workspace) with long-distance connections that “potentially interconnect multiple specialized brain areas in a coordinated, though variable manner” (Dehaene’s et al., 1998, p. 14529), is thought to become active with “top-down attentional amplification” resulting in a coherent activity of these neurons (Dehaene & Naccache, 2001, p. 1; see Figure 1 for an illustration). Such activity has been indeed reported by some researchers as temporally coherent, phase-locked oscillations of around 40 Hz (e.g., Eckhorn, Bauer, Jordan, Brosch, Kruse, Munk & Reitboeck, 1988).

Figure 1. An illustration of the global neuronal workspace theory with distinction drawn between unconscious (subliminal), partially conscious (preconscious) and conscious processes as a function of activation strength and attention (taken from Dehaene et al., 2006).



Dehaene and Naccache (2001) propose that this coherent neuronal activity characterizes the global availability of modular information and therefore underlies the subjective experience of a conscious state. Moreover, this long-distance connectivity between the modules makes this information available for manipulation with many cognitive functions such as working memory, long-term memory, as well as intentional actions (Dehaene & Naccache, 2001).

Global neuronal workspace theory shares many similarities with perceptual retouch theory. Both incorporate neurophysiological data and assume functional specialization of brain regions, with Bachmann (1984) referring to those specialized regions as specific systems, and Dehaene et al. (1998) as modular cerebral networks.

Furthermore, both theories require some kind of merging of different systems in order for information being processed in the specialized regions to become consciously available. In the perceptual retouch theory it is the re-convergence of specific and non-specific subcortical systems that leads to a conscious experience, although the exact neuronal mechanisms of this re-convergence are unclear. In the global workspace theory, it is the attention-mediated coherence of distributed neuronal units that is thought to link modular networks, allowing unconsciously processed information to escape those modules and become globally available. This availability is interpreted as a conscious experience. Taking this similarity into account, it is possible to suggest that masking prevents this spillage of modular information into the workspace either by preventing attentional mediation, or by interfering with the phase-locked coherence of distributed neuronal network directly. Which of these is in fact being prevented by masking as well as the mechanisms of this prevention are begging to be discovered.

Determining the Absence of Awareness

Fisk and Haase (2005) reported two studies in which participants were asked to perform presence-absence detection, identification, and discrimination tasks on masked targets. In order to find support for unconscious perceptual processing, ideally participants would perform at chance levels on the detection task ("I didn't see anything!"), which Fisk and Haase (2005) refer to as awareness variable, yet perform above chance on stimulus identification (Haase & Fisk, 2001; Merikle & Reingold, 1990). This could then be interpreted as unconscious perception because perceptual processing seems to occur despite the lack of awareness (Fisk & Haase, 2005).

In a study reported by Merikle and Reingold (1990), participants performed detection and a two-alternative, forced-choice (2AFC) identification task on masked words and nonwords. In a 2AFC identification task, participants are presented with a brief masked stimulus and then with two alternatives. Participants have to identify which of the alternatives was the word that preceded the mask. They found that performance was significantly above chance on identification even after misses on detection, but only for word trials. Merikle and Reingold's (1990) interpretation of this finding was as evidence for semantic processing at an unconscious level. However, Forster, Davis, Schoknecht, and Carter (1987) used 2AFC recognition test of the prime administered immediately after the target presentation in a masked priming paradigm to find slightly better than chance performance, although under the same conditions, participants were unable to decide whether the prime was a word or a nonword.

It is important to consider that chance performance on detection (or even consistent failure to detect the stimulus) is not any better than self-report (subjective) measures of awareness in the amount of information it provides for researchers. A detection task is susceptible to criterion effects, where participants might choose a very conservative criterion for a 'yes' response and respond 'no' in all the cases when they are aware of a change in luminance but are unsure of its causes. If this is the case, a 2AFC technique might just prove more sensitive, since even the slightest amount of information gathered from a masked word could be sufficient for making the correct choice. If some information is indeed gathered from such a stimulus and one is able to use it in order to arrive to a correct response, despite not leading to a conscious experience of the stimulus, it is difficult to assert completely unconscious perception (Fisk and Haase, 2005).

Another way to approach this issue is from a memory perspective. If masking is assumed to prevent the formation of a memory trace that supports recall memory, but not recognition, then a 2AFC task is simply a task of recognition and it is not surprising that participants can perform better than chance on this task while being unable to identify the stimulus. However, this still does not explain how participants can perform better than chance on presence-absence detection while being below chance on discrimination. There is a difference between denying having studied a list of words and being unable to recall any of them.

Reingold and Merikle (1988) have devised two criteria for an ideal awareness indicator. These are exhaustiveness, or sensitivity to *all* conscious processes, and exclusiveness, or sensitivity to *only* conscious processes and not the unconscious ones. This means that a perfect indicator of awareness would measure everything conscious but nothing unconscious, thereby providing a clear dissociation between the two. Although presence-absence detection along with other forms of subjective report appear to best fit the requirements of an awareness variable as introduced by Fisk and Haase (2005), strictly speaking, they fall short of perfectly satisfying either the exhaustiveness or the exclusiveness criteria of Reingold and Merikle (1988).

On the other hand, common sense tells us that detection should be more sensitive to the presence of a masked stimulus than discrimination tasks (Fisk & Haase, 2005; Snodgrass et al., 2004). This is because detection sensitivity can be attributed to simple luminance changes. Because of their simplicity, such changes might have a lower threshold for conscious experience than semantic meaning or "wordness," which might require higher stimulus energy to reach consciousness (Fisk & Haase, 2005). However, not everyone agrees with this point of view. For instance, Doyle & Leach (1988) found an effect of the masked target's lexical status (i.e., whether it was a word or not), on their detectability, suggesting that this higher-level information was available simultaneously with or even before the lower level information about luminosity. Similarly, some participants in the experiments reported by Marcel (1983a) performed better than chance on 2AFC semantic discrimination tasks, in which one of the alternatives is a semantic associate of the masked stimulus, while being at chance on detection. This led Marcel

(1983a) to argue that the mask in fact erases the visual information about a stimulus, while leaving semantic information intact (this subsequently formed the basis of his recovery theory). However, other researchers were unable to replicate the results from either of the studies. This is partially due to Doyle and Leach (1988) having employed a backward binocular masking technique while most of the present experiments use simultaneous dichoptic masking (Greenwald and Klinger, 1990). Likewise, Marcel (1983a) calibrated stimulus exposure duration in the beginning (but not in the end) of his experiments for each participant until they were at chance on detection, which is a procedure rarely used today[1].

Indeed, Price (1991) used confidence ratings after each 2AFC "living – non-living" categorization trial in conjunction with presence-absence detection performance and spontaneity ratings after each block of trials. The latter involved participants rating how spontaneous their responses were. He found that categorization performance was above chance at interstimulus intervals (ISIs) when detection performance was at chance and almost all trials were rated as "complete guesses". However, this was only true when participants felt their responses to be more spontaneous rather than when they thought they were influenced by visual cues. This suggests that on their own, confidence ratings are highly unreliable and their use as a single variable for subjective awareness is questionable at most. Even the lowest ratings have more than one possible cause, such as a participant really being unaware of the stimulus and unsure of their response, or having

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[1] Most laboratories today expose all their participants to one or several pre-selected stimulus durations.

caught a glimpse of the stimulus, but still being unsure of their response, or finally, having suddenly realized that the response they made was incorrect, and trying to compensate for the error by selecting a low rating when in fact they are now aware of at least some information about the stimulus.

However, Cheesman and Merikle (1984) showed that collecting participants' confidence ratings at the end of each block of trials and comparing them to performance on a forced-choice task while varying the ISI between the target and the mask, allows for a dissociation between conscious and unconscious processes responsible for forced-choice performance. Specifically, they found that at certain ISIs participants' confidence about their response was zero (i.e., subjective threshold), but performance on a discrimination task between four color words was still above chance. Cheesman and Merikle (1985) also reported a priming effect for color patch naming using the same words presented below the subjective threshold, but no such effects when the words were presented below the objective threshold (i.e., ISIs when performance on the forced-choice task was at chance). While providing some validation for subjective measures of awareness, these authors caution against ascribing too much value to individual ratings, since these suffer from the possibility that some momentary awareness of a stimulus could have been forgotten or disregarded in addition to the problems mentioned above. Price (2001) agrees, suggesting that introspective ratings should not be taken at face value, but rather as a correlation between ratings and performance. In fact, he interprets the findings from Price (1991) as evidence for unconscious processing, noting that if participants were aware of masked stimuli in the categorization task, their ratings would be most likely driven by visual cues rather than being spontaneous.

Most interestingly, Cheesman and Merikle (1985) showed that the subjective threshold they obtained using end of block confidence ratings provided a boundary separating qualitatively different results. Above that boundary, increase in the proportion of congruent word-color patch trials led to a larger priming effect, but below it such manipulation did not affect priming. These findings provide an important dissociation between priming effects that are mediated by conscious strategies and expectations, and those that aren't. Moreover, this suggests that in order to dissociate between conscious and unconscious influences on stimulus perception in processing, both subjective and objective measures must be employed.

Although awareness is generally far from being a central research question in experiments that employ the masked priming paradigm introduced earlier, prime awareness plays a very important role. It is assumed that the information gathered from a masked prime must be contained exclusively in the lexical processing system (a cognitive modality where information about words is stored and accessed), because most participants say they are unaware of being exposed to the prime. Under this assumption, to become aware of the stimulus means to have that information escape the lexical system and be broadcast to other cognitive systems. This is similar to Bachmann's (1984) perceptual retouch theory, where the lexical processor constitutes the specific system, and the act of broadcasting corresponds to the non-specific system. However, the presence of behavioral changes observed in such experiments could also be interpreted as an implicit memory effect, where being exposed to a stimulus leads to the feeling of familiarity when the related target stimulus is presented. Under this interpretation, to be aware is to have an explicit memory trace of the prime, which should then be the same as asking subjects whether they saw the prime and getting a positive response. This description can be likened to Marcel's (1983a) recovery theory, where the explicit memory trace of the prime constitutes the spatio-temporal information necessary for recovery of all the other unconsciously perceived information about the stimulus in order for conscious experience to arise. This debate about which of the interpretations is more viable is not an easy one to resolve, but more empirical data can bring us closer to addressing it.

Partial Awareness

To speak of awareness as having a consciously available experience of a stimulus is, in the words of Price (2001), "too simplistic" (p. 35). Indeed, there might be a continuum of different degrees of awareness between the inability to make a presence-absence judgment and a confident report of the stimulus's identity. Similarly to the effects of masking not being "all or nothing", we might become aware of various kinds of information about the stimulus that would lead us to making the correct decision on a task but not necessarily to a full conscious experience of seeing and identifying it. Alternatively, we might not be subjectively aware of that limited information about a stimulus such as its meaning or the slight change in luminance, but these types of information might nevertheless be used in making the correct response in a semantic discrimination or presence-absence detection tasks, respectively.

Several researchers have become proponents of the notion of partial awareness. For example, Kouider and Dupoux (2004), who coined the phrase, argue that being sensitive to visual properties of the prime is necessary and sufficient for showing certain priming effects without being able to fully identify the prime, this is why they describe this type of awareness as “partial”, whereas full awareness would require full identification. These researchers found cross-modal priming with visually presented masked primes and auditory targets, but only for those subjects who were able to discriminate low-level visual properties of the prime, suggesting that partial awareness was a key factor for this type of priming. Although participants in such experiments report not having seen the prime, Kouider and Dupoux (2001) argue that some information about it must have been available to them and this is why they cannot be considered completely unaware of the stimulus. Similar trends are observed in phonological and semantic priming experiments, where priming effects are only observed for prime durations of at least 50 ms, while form and repetition priming have been observed even at shorter exposure durations (e.g., Perea & Gotor, 1997; Rastle, Davis, Marslen-Wilson, & Tyler, 2000; *cf*. Forster, Mohan, & Hector, 2003, for review). This suggests that in order to extract phonological, semantic, or the kind of information available to more than one modality (necessary for cross-modal priming) requires higher levels of awareness than those needed to extract lower-level information about the form of a masked stimulus. This conclusion is certainly at odds with interpretations of the results provided by forced-choice semantic discrimination and presence-absence detection tasks, which show that it is possible to perform at chance on the latter but above chance on the former (e.g., Cheesman & Merikle, 1984; Marcel, 1983a). These findings must be reconciled before a viable theory of visual awareness can be proposed.

In a slightly different view of awareness from that of Kouider and Dupoux's (2001), Bachmann (1984) provides an example of cortically damaged patients, who despite their inability to see due to being deficient of "any coherent spatiotopic (iconoclastic) knowledge of the sensory input" are reported to nevertheless possess "vague awareness", the result of intact functioning of subcortical structures (p. 70). This is similar to the phenomenon of blindsight, where objects can be located in space despite the absence of any conscious perception of the object (Weiskrantz, 1986). Bachmann (1984) interprets this "vague awareness" as evidence that some information about the input is available to the patient, so that their awareness of the outside world contains some content, which is not as detailed as a normal person's, and is therefore described as "vague".

This is a controversial topic with many researchers being uncomfortable about the idea of partial awareness. Deserving of much attention, this subject will be discussed in more detail in the final chapter.

CHAPTER 2. PROPERTIES OF DETECTION AND DISCRIMINATION TASKS

This chapter aims to provide basic explorations of detection and discrimination tasks. To determine what kind of information can be extracted from a masked prime, we use two-alternative forced-choice discrimination tasks (2AFC). In a typical masked priming paradigm (e.g., Forster & Davis, 1984) widely used in psycholinguistic research, with a forward as well as a backward mask and a prime duration of 50 ms, participants normally would deny that they had seen anything, but as was shown in the previous chapter, discrimination performance is often above chance under the same circumstances when participants are forced to guess.

The virtue of adopting this approach, is that we can get a clearer picture of how the prime is processed, whereas using the conventional masked priming paradigm we can only infer how the prime is processed based on the way it influences the response to the target. For example, it is often argued that semantic/associative priming is unobtainable at prime durations of 50 ms or less (e.g., Kouider & Dupoux, 2001; Rastle, Davis, & Marslen-Wilson, 2000). This could mean that the semantic properties of the prime were never activated, or that they were, but this had no impact on the recognition of the target word. To examine this issue, one of the 2AFC tasks used in the following experiments is a semantic discrimination task, in which two words are presented after the masked prime. The participant is asked to guess which word is more similar in meaning to the masked prime. If chance performance levels are obtained on this task, then the interpretation is equivocal. It could be that semantic activation has occurred, but that participants are unable to use this information, or that no activation has occurred at all. However, if performance levels are above chance, then it is clear that some semantic activation must have occurred, although it is not clear how this activation influences performance in this task.

Alternatively, the use of a task such as this could be taken as a measure of awareness of the prime. Since the main advantage of the masked priming paradigm was that subjects were assumed to be unaware of the prime, and therefore that any obtained priming effect could be treated as being completely automatic and non-strategic, it became necessary to develop some index of awareness that would enable comparisons to be made across conditions and across laboratories. In addition to Kouider and Dupoux's (2001) cross-modal priming effects which require participants to be able to discriminate low-level visual properties of the masked prime, Holcomb, Reder, Misra, and Grainger (2005) found evidence in an ERP study that masked semantic/associative priming effects on the magnitude of the ERP N400 were obtained only for participants who demonstrated awareness of the prime. Awareness in this case was indexed by the number of incorrect "Yes" responses in a go-nogo semantic categorization task when the masked prime was an exemplar but the visible target was not.

Other researchers have also included tests of awareness. Forster, Davis, Schoknecht and Carter (1987) used various tasks, such as whether the prime was the same as the target, or whether it was a word or a nonword. Finkbeiner, Forster, Nicol, and Nakamura (2004) included an awareness test in which participants were asked whether the masked prime contained the letter “e” or not. Due to the purely visual nature of this task, it is assumed that a better than chance performance on e-detection signifies partial awareness. Performance on this task should also correlate with performance on discrimination tasks that require other kinds of lexical information such as orthographic, phonological, and semantic. This e-detection task is therefore used in the following experiments as an index of awareness of lower-level visual properties of the prime.

Clearly, it would be helpful if we knew more about the relationships between different types of discrimination tasks. Moreover, the relationship between discrimination tasks and e-detection, although the two are very different in nature, could potentially provide converging evidence about awareness. Both kinds of tasks have been used as measures of awareness, but they could be tackling different sides of the issue. For example, if there is a high correlation between the e-detection task and a semantic discrimination task, then we might be more confident that semantic activation only occurs for items that on some trials are more visible, or for participants who demonstrate greater sensitivity to the prime. Another question of interest is whether it is possible to perform at above-chance levels in a semantic task but to be at chance in a purely visual task, such as e-detection. According to one view, this is entirely possible (Marcel, 1983a). Marcel reported that semantic information about a masked word persisted beyond the mask, despite the inability of participants to report any visual properties of the masked word. Marcel's interpretation was that the visual pattern mask following the prime erased any visually based code, but left both phonological and semantic codes intact. One might therefore expect that participants who are at chance when asked to say whether the masked word contained the letter 'e', might nevertheless perform better than chance when asked to choose which alternative was closer in meaning. Further, if Marcel's (1983a) view is correct, one might expect better performance on e-detection at 50 ms exposure duration compared to 40 ms, but for semantic discrimination to remain relatively constant at both exposure durations.

Finally, including a subjective measure of awareness will provide another reference point for the objective measures which are comprised of e-detection and 2AFC discrimination tasks. How does the phenomenology of awareness correlate with performance on these tasks? Are detection tasks in fact equivalent to subjective measures of awareness, as it has been suggested in the previous chapter?

The following experiments were designed to investigate these issues. In the first two experiments, three tasks were used. One task was a semantic discrimination task, where participants are asked to choose which of two alternatives is the closest in meaning to the prime. The second task was e-detection, where information obtained at the level of letters or even features could be sufficient for better than chance performance. The third task involved identity discrimination, where the participant's task is to select the alternative that is the same as the prime, and the two alternatives only differ by one letter. This task can be performed visually, but only if the person identifies all the letters. This task serves as a potential bridge between semantic discrimination and e-detection, since it could help determine whether participants choose to do the identity discrimination task by visual properties, or by using meaning. In the third experiment, only semantic discrimination and e-detection tasks were used in order to determine whether subjective ratings correlate more with visual or semantic information extraction.

Exposure durations of 40 ms (Experiment 1b) and 50 ms (Experiment 1a, 2, 3 and 4) were used, either of which would usually be accepted as minimizing any possibility of awareness, while still providing enough energy for the stimulus to be processed. Experiments 3 and 4 are aimed at investigating the nature of discrimination and detection tasks further by manipulating the difficulty of the identity discrimination task using a neighbor as the correct alternative and an all-letter-different word as the incorrect one, as well as determining the role that memory plays in these tasks by changing which letter participants have to report on each trial, while the letters are either presented before the masked prime or after.

As a matter of convenience, these masked words will be referred to as primes, even though there is no target that follows these words, and these tasks are not measuring priming. That is, the experimental objective is to estimate how much information could be extracted from these words if they were being used as primes in a masked priming experiment.

General Method

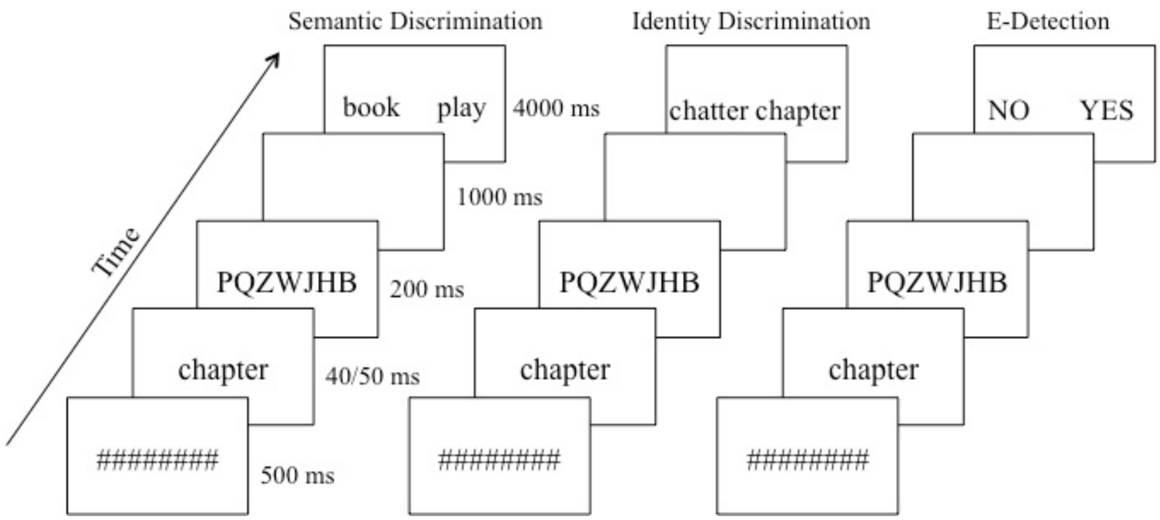
All of the experiments reported in this dissertation were conducted using the same general method unless stated otherwise. This general method is described in detail here.

Materials

Seventy-eight words were initially selected as primes (e.g., *market*) for the Semantic discrimination 2-AFC task (mean CELEX frequency =133.23 occurrences per million, mean length= 4.87 letters, mean number of neighbors = 5.59, and mean MRC imageability = 527.14). In this task, the correct alternative was an associate of the prime (e.g., *store*), and the incorrect alternative was a completely unrelated word (e.g., *desire*). The incorrect alternatives were matched to the correct alternatives for frequency (mean CELEX frequency =123.88), length (4.87 letters), number of neighbors (mean N=5.65) and imageability (mean MRC=455.42). Half of the primes contained an *e* (e.g., *chapter*) and half did not. In the e-detection and Identity discrimination tasks, half of the time the same primes that were used in the Semantic discrimination task were presented and the other half of the time its orthographic neighbor (e.g., *marker)* was presented (mean CELEX frequency =84.66, mean N=5.61, mean MRC=307.57). In the Identity discrimination task, one of the alternatives was the same word as the prime, while the other alternative was one-letter-different from it (e.g., market / market – marker). The third condition was an e-detection task, in which the alternatives were simply "yes" or "no". Twenty more items were used for practice and as fillers.

In all three tasks, the prime was presented under the same conditions as a masked prime in a typical lexical decision experiment except that the prime was followed by a backward mask instead of a target (see Figure 2). In each experiment, counterbalancing was performed to ensure that the results of the tasks generalize to visually similar words, and the following constraints were observed: (a) each pair of response alternatives was used twice (but not for the same subject), the correct alternative being different on each occasion, (b) no participant was presented with both the prime and its neighbor as targets, and (c) no participant was presented with the same pair of response alternatives more than once.

Figure 2. Examples of items.



Procedure

Participants were tested individually in sound-attenuated booths. The critical trials for both conditions consisted of the following sequence: a warning sign ######### was displayed for 500 ms in the middle of the screen, which was replaced by the prime in lower case letters. After 50 ms, the prime was replaced by a random consonant string in upper case of the same length. The letters were different in each trial. This mask was presented for 200 ms, and then after a blank interval of 1000 ms, the two response alternatives were presented side by side, and remained on the screen for 4000 ms or until the participant responded by pressing a button on a button box that corresponded to one of the alternatives. In each task 26 items were displayed in this way (i.e., the exposure duration of the target word was 50 ms). In addition, in each condition there were 4 items in which the prime was displayed for 100 ms. These trials were intended to motivate the participants to keep trying and also to ensure that they had normal vision.

Each participant was exposed to all the tasks in a particular experiment, with the order of the tasks randomized. The participants were told that some words would be visible and some would be very difficult to see, but that if they were uncertain, they should nevertheless guess which of the alternatives was more likely. It was stressed that they had to respond even if they had no information about the word. No feedback was provided. The items within each task were displayed in random order using a Pentium PC with a CRT monitor at 100-Hz refresh rate, using the DMDX program developed at the University of Arizona (Forster & Forster, 2003). In addition to presenting the items, this software records the participants' reaction times as well as whether each response is correct or incorrect. The items were displayed in black Courier New 12 pt font on a white background.

Experiment 1a

This experiment was aimed at replicating the findings obtained by Marcel (1983a) and establishing the relationship between e-detection, Semantic discrimination, and Identity discrimination tasks.

Method

Participants

Sixty University of Arizona undergraduate students participated in this experiment in exchange for partial course credit.

Materials and design

In addition to materials and design described in the General Method, for experiments 1a and 1b, six sets of materials were constructed so that each prime was observed in all three tasks and each neighbor of the prime was also tested in both Identity discrimination and e-detection tasks (for examples, see Table 1).

Table 1. Examples of items and counterbalancing in Experiments 1a and 1b.

Task	List A	List B	List C	List D	List E	List F
Semantic	*death* store funeral	*market* book store	*chapter* funeral book	*death* book funeral	*market* funeral store	*chapter* store book
Identity	*chapter* chatter chapter	*death* death depth	*market* marker market	*chatter* chapter chatter	*depth* death depth	*marker* market marker
E-detection	*market* NO YES	*chapter* NO YES	*death* NO YES	*marker* NO YES	*chatter* NO YES	*depth* NO YES

Procedure

Three tasks were employed in this experiment: e-detection, Semantic discrimination, and Identity discrimination. The procedure was as described in the General Method.

Results and Discussion

In all experiments discussed in this dissertation, the data from filler items were excluded from the final analysis. The mean percent correct choices for the two 2-AFC tasks and the e-detection task are shown in Table 2. Analysis of the participant means revealed significantly better than chance performance on all three tasks: Semantic discrimination (62.1% correct, $t(59) = 6.96$, $p < 0.001$), Identity discrimination (62.5 % correct, $t(59) = 8.19$, $p < 0.001$), and e-detection (65.5% correct, $t(59) = 8.17$, $p < 0.001$). In addition to the group analysis, individual performance was assessed to determine how many participants were performing above chance (for 26 items, the appropriate .05 cutoff was 69% correct, as determined by a sign test). This criterion indicated that 22 participants out of 60 performed significantly better than chance on Semantic discrimination, 19 out of 60 better than chance on Identity discrimination, and 26 out of 60 on e-detection.

In order to determine to what extent the three tasks involved a common set of abilities, the performance of participants on the three tasks was correlated. These correlations are reported in Table 3, along with the correlations computed across the items. As can be seen, the task correlations computed across participant means are all reasonably strong and significant, but the correlations computed across item means are not.

Table 2. Mean percent correct choices for semantic discrimination, identity discrimination, and e-detection tasks in Experiment 1a.

Semantic	Identity	E-detection
62.1*	62.4*	65.4*

* $p < .001$

Table 3. Cross-task correlations for semantic discrimination, identity discrimination, and e-detection obtained in Experiment 1a and computed separately for subject means (above the leading diagonal) and item means (in italics, below the diagonal).

Task	Semantic	Identity	e-detection
Semantic	-	0.332*	0.479**
Identity	*0.167**	-	0.486**
e-detection	*0.061*	*0.020*	-

* p < .05; ** p < .01

These data indicate that as a group, participants were able to perform all three tasks better than chance when the prime duration was 50 ms. Moreover, individuals who were good at one task tended to perform well in the other tasks. At the same time, the absence of any appreciable correlations between tasks when item means were used rather than participant means indicates that items that are easy or difficult in one task are not necessarily easy or difficult in others. This makes sense because we would expect participants to vary in terms of a general ability to recover information from a masked prime, and that this ability would be involved in all three tasks. Hence there are positive correlations between the three tasks using participant means. However, the factors controlling the difficulty of a particular item might vary across tasks. For example, an item in the semantic discrimination task might be easy because the correct alternative was very strongly associated with the target word, but the same item in the e-detection task would not necessarily be any easier than other items. Hence the correlations between tasks using item means are non-existent, or very weak. That is to say that there is no general property of *visibility* that determines the difficulty of an item. If some words were more visible than others for some reason (e.g., because they were high frequency words), then they would be more visible in all three tasks, and hence there would be strong correlations between the item means for the three tasks.

Two post hoc analyses were performed on the data. The first analysis was aimed at uncovering any relationship between position of the letter ‘e’ in primes (beginning, middle, or end of the word) and performance on the e-detection task. No significant differences were found (the means being 60.0% correct, 58.2%, and 59.2% respectively). The second analysis was performed on a subset of the data to determine how many participants performed better than chance on the three tasks when their performance on e-detection was at chance. Using the 69% correct cutoff obtained with the sign test for 26 items per task, 34 participants were at chance on e-detection, and 10 of those performed significantly better than chance on Semantic discrimination. No other significant effects were found using this method.

These data offer support for the claim of Marcel (1983a) that masking eliminates any visual record of the masked word, but has no effect on a semantic trace. However, this would also predict that performance on a purely visual task such as e-detection would be markedly inferior to a task such as semantic discrimination, and this clearly is not the case.

One problem in interpreting these results is that we have not established conclusively whether or not the variable that controls performance is prime visibility. The reason for this is that there is no direct evidence that e-detection is an index of prime visibility. It may be that the orthographic properties of the prime are processed (as they must be), but somehow this information is capable of influencing performance in the e-detection task without reaching consciousness. In an attempt to determine whether this is the case, the exposure duration was reduced to 40 ms in the next experiment. Our informal observation is that there are some rare individuals who are capable of identifying all masked primes at 60 ms, many masked primes at 50 ms, but none at all at 40 ms. Under these conditions, we might reasonably assume that prime visibility has been reduced to zero. We might then expect to find that performance on e-detection is reduced to chance levels. If semantic discrimination is still above chance, then this result would provide strong support for Marcel's proposal that visual awareness is not required for semantic activation to occur.

Experiment 1b

Method

Participants

Forty-two University of Arizona students participated in this experiment in exchange for partial course credit. None of the participants had taken part in Experiment 1a.

Materials and design

Materials and design for Experiment 1b were exactly the same as those for Experiment 1a, and have been described in detail in the General Method.

Procedure

This was described in the General Method, except all exposure durations in Experiment 1b were 40 ms instead of 50 ms.

Results and Discussion

Surprisingly, discrimination performance for the group as a whole on e-detection was not reduced to chance levels when prime duration was reduced to 40 ms (see Table 4). The mean accuracy across subjects for e-detection was 55.1%, $t(41) = 3.37$, $p < 0.01$. Mean accuracy in the Semantic Discrimination task was 53.7%, $t(41) = 2.19$, $p < 0.05$, but performance on Identity discrimination (52.0%) did not differ significantly from chance ($p > 0.05$).

Table 4. Mean percent correct choices for semantic discrimination, identity discrimination, and e-detection tasks in Experiment 1b (exposure duration = 40 ms).

Semantic	Identity	E-detection
53.7*	52.9	55.1**

* $p < .05$; ** $p < .01$

There were 4 participants who were above the 69% cut-off on e-detection, and one of those was also the only participant who was above chance on Semantic discrimination. There were 8 who were above chance on Identity discrimination (but the variance across participants in this task was much higher than in the other tasks and is the reason why mean performance did not differ significantly from chance), and 4 on e-detection. Finally, there were no participants who performed above chance on Semantic discrimination while being below 69% on e-detection. From the point of view of Marcel's hypothesis, this last result indicates that at 40 ms exposure duration, the semantic activation is not strong enough to survive masking without strong orthographic activation.

Cross-task correlations were also carried out using both subject and item means, as in Experiment 1a. No correlation was significant in either type of analysis. Correlations ranged from -0.11 to 0.04.

If we accept the assumption that prime visibility is at zero with a 40 ms prime, then the conclusion is that performance on e-detection and Semantic discrimination is influenced by factors of which the participant is unaware.

One puzzling aspect of the results of Experiments 1a and 1b is that the post-experiment debriefing sessions did not suggest that the participants were generally aware of the primes, yet as a group, they performed better than chance on tests that would normally be taken as evidence for partial awareness of the prime. One problem with the post-experiment reports was that it was difficult to determine whether participants were referring to the filler trials on which the prime was clearly visible, or to the experimental items. One way to eliminate this possibility is to obtain trial-by-trial confidence ratings, where the participant rates the degree of confidence in their choice on each trial. This was the procedure used in the next experiment.

Experiment 2

Method

Participants

Sixteen University of Arizona students participated in this experiment in exchange for partial course credit. None of the participants had taken part in the previous experiments.

Materials and design

Materials and design for Experiment 2 were the same as those described in the General Method, except that seventy-six items were used, and only the Semantic discrimination and e-detection tasks were employed. The rationale for dropping the Identity discrimination task is that it is very similar to the semantic task already employed (using visual cues would be prohibitively difficult due to the orthographic similarity of the incorrect alternative; similarity of group means supports this), while e-detection needs to be evaluated in the context of the subjective awareness measure and compared to the sensitivity of the Semantic discrimination task. We will return to the Identity discrimination task in Experiment 3. Additionally, a five-point self-rating scale was created to assess participants' decision confidence and subjective awareness, where a rating of 1 corresponded to a complete guess, and 5 indicated that the participant was absolutely certain of the decision or was able to identify the prime.

Procedure

In addition to the procedure described in the General Method, after each trial, participants were asked to rate their confidence by selecting a number from 1 to 5. Participants were encouraged to use the entire range. After having made their selection, participants pressed the foot pedal, which initiated the next trial.

Results and Discussion

The mean percent correct choices for the Semantic discrimination task and the e-detection task are shown in Table 5. A paired two-sample *t*-test was performed for subject means revealing a significantly better than chance performance on Semantic discrimination (mean = 61.9% correct, $t(15) = 3.97$, $p < 0.005$), and e-detection (mean = 67.2% correct, $t(15) = 4.65$, $p < 0.001$). Individual performance in this experiment was assessed according to a 63% significance cutoff (obtained using a sign test based on 38 items). According to this criterion, 11 out of 16 participants were better than chance on e-detection, and 7 were better than chance on Semantic discrimination. Only one participant performed significantly better than chance on Semantic discrimination while being at chance on e-detection.

As in Experiment 1a, the cross-task correlation based on participant means was significant ($r = 0.597$, $p < 0.05$), but no correlation was found for item means ($r = 0.027$, $p = 0.814$).

Table 5. Mean percent correct choices for semantic discrimination and e-detection in Experiment 2.

Semantic	E-detection
61.9*	67.2**

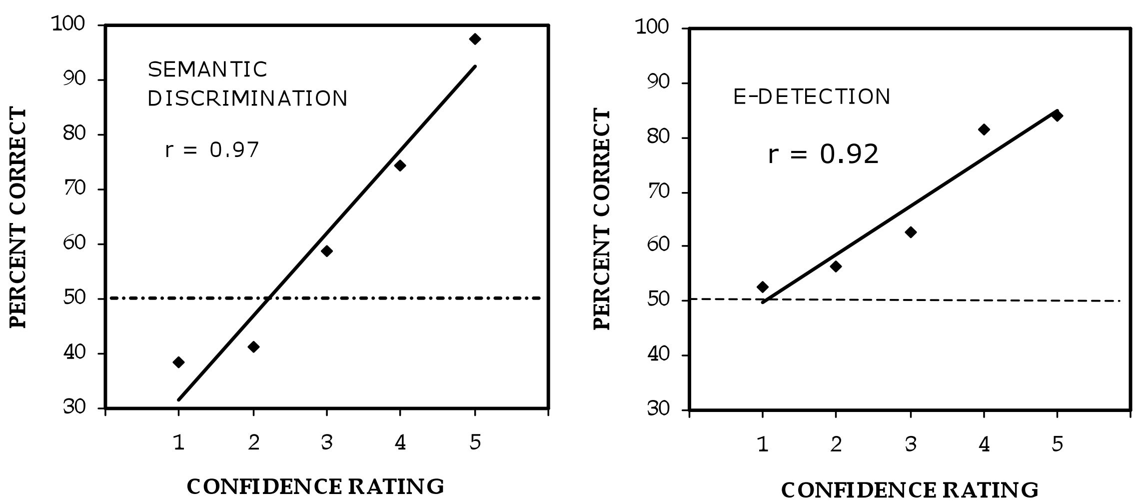
* $p < .005$; ** $p < .001$

On average, participants rated their confidence as 3 or lower 60% of the time on Semantic discrimination, and 64% of the time on e-detection, indicating that more than half the time, participants were not confident about their responses. However, accuracy in both tasks was strongly related to confidence across the entire range. This can be seen in Figure 3, which shows mean accuracy as a function of confidence rating. Item correlations between accuracy and confidence ratings were found to be significant in the Semantic discrimination task ($r = 0.974$, $p < 0.001$) as well as in the e-detection task ($r = 0.921$, $p < 0.001$). In the Semantic discrimination task, performance was significantly better than chance only on trials given a confidence rating of 3 or higher, while in the e-detection task, performance was slightly above chance even for the lowest confidence rating of 1, but not significantly so. For ratings of 2 and above, performance on e-detection was significantly better than chance.

It is of interest to note that ratings of 5 (highest confidence) were not all that uncommon. These high-confidence ratings occurred on 28% of the trials in the Semantic discrimination task, and 21% of the e-detection trials. One might ask how could this be, given that most researchers would feel comfortable with the assumption that a 50 ms masked prime would very seldom, if ever be visible. Part of the answer has to be that participants in these experiments were attending closely to the prime, whereas in a normal priming experiment, they would be attending more closely to the target.

Additionally, words and pseudowords are better masks than strings of consonants (Jacobson, 1974), so participants in 2AFC tasks can be considered more aware of the masked stimuli than those in lexical decision experiments with the same prime durations. Finally, it could be that when the alternatives in the Semantic discrimination task are presented, participants may suddenly have realized what they must have seen, and therefore felt very confident of their choice. This implies that information about the prime is sometimes on the verge of consciousness, a state that Dehaene, Changeux, Naccache, Sackur, and Sergent (2006) describe as "pre-conscious". This also suggests that the feeling of awareness of the prime might be ascribed retrospectively, after the selection of one of the alternatives has been made, and therefore contribute to a higher confidence rating.

Figure 3. Correlation between items as a function of self-rating and performance on the Semantic discrimination task obtained in Experiment 2.



Experiment 3

Continuing the investigation of the properties of discrimination tasks, Experiment 3 aims at manipulating the difficulty of the Identity discrimination task by comparing it with Orthographic discrimination, in which one of the alternatives is a one-letter different neighbor of the masked prime, while the other is an all-letter different word, with both alternatives being semantically unrelated to the prime. Thus, changing this task to Orthographic rather than Identity discrimination would eliminate semantic properties since the correct response is the neighbor of the prime. The Orthographic discrimination task can be performed on the basis of a few letters or even a single letter, i.e., the whole word does not have to be resolved in order to do this task.

Method

Participants

Sixteen University of Arizona students participated in this experiment in exchange for partial course credit. None of the participants had taken part in any of the previous experiments.

Materials and design

Seventy-six words were used in this experiment. In addition to an Identity discrimination task described in the General Method, an Orthographic discrimination task was included. In this task, the correct alternative is a semantically unrelated one-letter different neighbor of the masked prime, while the incorrect alternative is the semantically and orthographically unrelated word (e.g., market / marker – desire). The incorrect alternatives in the Orthographic discrimination task were identical in length and matched on frequency of occurrence (mean CELEX frequency = 82.9), the number of neighbors (mean N = 5.66), and imageability (MRC=345.83) to the correct alternatives. The materials were counterbalanced so that half of the time the items were presented as part of the Identity discrimination task, and the other half as part of the Orthographic discrimination task. Also, both neighbors were used as primes, but never for the same participant.

Procedure

The procedure was the same as that described in the General Method, except two tasks were used: Orthographic discrimination and Identity discrimination. In the Orthographic discrimination task, participants had to select the alternative that was most visually similar to the masked stimulus, that is, the correct response was a one-letter different word from the prime, rather than the same word as in the Identity discrimination task.

Results and Discussion

Mean percent correct choices obtained in Experiment 3 are presented in Table 6.

Table 6. Mean percent correct choices for Identity discrimination and Orthographic discrimination obtained in Experiment 3.

Identity discrimination	Orthographic discrimination
69.6*	61.5*

*p < .01

A paired two-sample *t*-test was performed for participant means revealing a significantly better than chance group performance on Identity discrimination (mean = 69.6% correct, $t(15) = 5.72$, $p < 0.001$), and Orthographic discrimination (mean = 61.5% correct, $t(15) = 5.44$, $p < 0.001$). A two-way analysis of variance (ANOVA) revealed a significant difference between the tasks in percent correct choices ($F_1(1,14) = 5.97, p < 0.05; F_2(1,74) = 6.82, p < 0.01$). The difference in reaction times was only significant in the by items analysis ($F_2(1,74) = 6.40, p < 0.05$), but not in the by subjects analysis ($p > 0.05$). Performance on these tasks was also found to correlate significantly in the by items analysis ($r = 0.254$; $p < 0.05$), but not in the by subjects analysis ($r = 0.315$; $p = 0.23$).

Individual performance in this experiment was assessed according to a 63% significance cutoff (obtained using a sign test based on 38 items). According to this criterion, 11 out of 16 participants were better than chance on Identity discrimination, and 8 were better than chance on Orthographic discrimination. Two participants performed significantly better than chance on Orthographic discrimination while being at chance on Identity discrimination, and five individuals were better than chance on Identity discrimination while being at chance on Orthographic discrimination.

It is unclear why performance on Identity discrimination is better than on Orthographic discrimination. The results of this experiment show that the tasks are in fact different and might employ relatively independent processes, since performance means differ significantly, and some participants are performing at chance on one task while being significantly better than chance on the other. The Orthographic discrimination task, having removed the possibility of using meaning, was meant to become closer in nature to e-detection. Similarly, because it might be easier to use meaning on Identity discrimination, this task is thought to be more similar to Semantic discrimination rather than e-detection. If this were true, we would expect to obtain group performance means on Identity discrimination to be similar to that obtained on Semantic discrimination, while Orthographic discrimination means to be close to e-detection means. However, Experiments 1a and 2 show that performance on Semantic discrimination (62.1% correct in Experiment 1a, and 61.9% correct in Experiment 2) is generally worse than performance on e-detection (65.5% correct in Experiment 1a, and 67.2% correct in Experiment 2). The data obtained in Experiment 3 have a completely inverted pattern.

Before we attempt to find a plausible explanation to these data, it is important to consider the suspicious difference between group performance mean (62.4% correct) obtained in Experiment 1a and that obtained in the current experiment (69.6%). This difference might be due to the different conditions surrounding performance on Identity discrimination task in Experiments 1a and 3. In Experiment 1a, participants also performed e-detection and Semantic discrimination, which in those instances (when one or both of these tasks were performed first) could have influenced the strategy used on the Identity discrimination task. On the other hand, in Experiment 3, the only other task participants were asked to perform was Orthographic discrimination. Whichever task came first could have potentially influenced the way the second task was performed. For instance, if participants were first exposed to Identity discrimination, in which the one-letter different alternative was incorrect, it might hinder their performance on

Orthographic discrimination where the one-letter different alternative is in fact the correct one.

To test this hypothesis, a post hoc analysis aimed to investigate the effect of task order was performed, with its results summarized in Table 7.

Table 7. Mean percent correct responses on Identity discrimination and Orthographic discrimination obtained in Experiment 3, taking task order into account.

Task\Order	Identity discrimination first	Orthographic discrimination first
Identity discrimination	64.8** % correct	74.3** % correct
Orthographic discrimination	64.8** % correct	58.2* % correct
Total	69.6** % correct	61.5* % correct

* $p < .05$; ** $p < .01$

When performance on the two discrimination tasks was broken down by task order, the difference between percent correct means was only evident when Orthographic discrimination task was presented first, with participants performing much better on the subsequent Identity discrimination task ($t(7) = 4.48$; $p < 0.01$). Although no other comparisons were significant (possibly due to lack of power), the difference between Identity and Orthographic discrimination performance obtained without taking task order into account is clearly being driven by those instances when Orthographic discrimination was performed first. This suggests that the strategies utilized by participants in order to maximize extraction of the relevant information on these tasks might indeed be influenced by the memory of preceding tasks. For example, having performed the orthographic task where participants must choose the alternative that is one-letter different from the prime, might help subsequently perform the identity discrimination task in which the correct alternative is now identical to the prime and therefore shares semantic features with it in addition to orthography. Moreover, since better performance was observed for the task that came second regardless of whether Orthographic of Identity discrimination was involved, there seems to be a practice effect taking place. A replication of this study using more participants would be necessary in order to determine whether these interpretations are correct.

It is also of interest to determine what role memory plays on a shorter time scale in these tasks. After the presentation of the masked stimulus, 200 ms must pass before the alternatives are presented. While it is assumed that participants remember the task's specific demands when attempting to extract relevant information from the prime, it is unclear whether the fact that this information has to be remembered until the alternatives are identified puts a higher cognitive load on the participant, potentially hindering their response. Experiment 4 investigates this issue by using a letter detection task in which the letter to be detected is either known before the presentation of the prime (as in the e-detection task), or after (as in the discrimination tasks). In both instances, the letter to be detected changes on every trial. It is hypothesized that if having to remember the prime before the alternatives are presented is an additional challenge in the discrimination tasks, performance should be better when the letter to be detected is known ahead of time rather than after the presentation of the masked stimulus.

Experiment 4

The purpose of Experiment 4a is to answer the question of whether e-detection is really a purely visual task and participants are able to perform it during the short time in which the prime is present on the screen. This is only possible if the letter to be detected is known beforehand. If, on the other hand, that letter were revealed after the presentation of the prime, this strategy would not work. In the latter case, participants might use residual visual and orthographic activation that was left by the prime in their memory. Either way, this might explain why performance on e-detection is generally better than on discrimination tasks.

If it is indeed the case that having to hold the prime in memory until the presentation of the alternatives (or the letter to be detected) hinders performance, then it would be reasonable to suggest that participants should be more accurate in this condition if the prime is a word rather than a non-word. This suggestion is based on the finding described by Reicher (1969) that it is easier to identify letters when they make up words rather than nonwords. This phenomenon is referred to as the word superiority effect. For example, Reicher showed that participants are at chance in identifying whether the letter *k* or *d* was presented as part of the stimulus *wosk*, but are much better than chance in discriminating between the same pair of letters in the word *work*. In Reicher's experiments, the letter pair was always presented after the stimulus. But what would happen if the alternatives were known ahead of time, as in the e-detection task?

O'Brien and Forster (unpublished, 2004) investigated that very question, using an e-detection task with 96 six-letter words and 96 nonwords. The stimuli were backward masked by unrelated words, and three exposure durations were used: 50 ms, 60 ms, and 150 ms. If one expects a difference in performance between word and nonwords stimuli, there should also be a difference between high and low frequency words, since high frequency words are responded to faster than low frequency words in a lexical decision task (e.g., Balota & Chumbley, 1984). For that reason, the conditions in O'Brien and Forster's experiment included high and low frequency words, as well as nonwords that were either one or two letters different (1LD and 2LD respectively) from words. The 1LD nonwords were further divided into two categories: those that came from a word not containing an *e*, and those that originated from words with an *e* (in this case, the *e* was replaced by another vowel). Apart from the latter condition, in which none of the items contained the letter *e*, all other conditions had half the items on which the correct response in the e-detection task was 'yes' and the other half of the items on which the correct response was 'no'. The reasoning behind including the condition where the 1LD nonword originated from a word that contained an *e* was to see whether participants are extracting meaning from these stimuli, and inferring whether they contained the letter *e* based on that information. If this were the case, we would expect more false positives in this condition. Examples of items used in O'Brien and Forster's (2004) study are presented in Table 8.

Table 8. Examples of items used in experiments reported by O'Brien and Forster (2004).

Condition		Words		1LD nonwords		2LD nonwords
		high freq.	low freq.	no e-base	e-base	
Examples	+	moment	legion	attace	-	ripuel
	_	almost	bazaar	astraf	itsalf	aulamn

O'Brien and Forster found that there were no more false positives with letter *e* substitutions and, critically, no difference in percent correct choices between words and nonwords (i.e., no word superiority effect). Similarly, the authors found no difference in e-detection performance on high and low frequency words. Moreover, none of the group performance means were significantly different from chance when stimulus presentation was 50 ms. This differs from what was obtained in Experiments 1a and 2. Even at 40 ms (Experiment 1b), performance on e-detection was found to be better than chance. The difference in results might stem from the difference in the way items were presented. In the experiments described in this chapter, the backward mask was a string of consonant letters, whereas in O'Brien and Forster's experiment, it was an unrelated word, since these authors were interested in making their item presentation as similar to the way they are presented in a lexical decision task as possible. This effort was made because the goal of these authors' experiment was to examine e-detection as a potential candidate for a test of awareness that could be run alongside normal tasks employed by researchers in the field of masked priming in order to devise a standard that could be applied across laboratories.

The issue of how e-detection along with discrimination tasks relates to experiments using masked priming will be discussed in detail in the next chapter. The importance of O'Brien and Forster's (2004) findings for the current experiment is that the word superiority effect was not observed in their experiment because in the e-detection task, participants know what to look for beforehand, while in Reicher's (1969) experiment, they had to wait for the two alternative letters to appear. While nonwords are not tested in the current experiment, we would expect better performance when the letters are presented after the masked stimulus (Experiment 4b) compared to when the alternatives are known beforehand (Experiment 4a) because the word superiority effect (an indication that memory is involved) should only occur in the latter condition.

Method

Participants

Seventeen University of Arizona students participated in Experiment 4a, and 19 participated in Experiment 4b. Data from one participant were excluded from analysis in Experiment 4a due to a response bias of more than 45%. For the same reason, data from three participants in Experiment 4b were excluded from analysis. None of the participants took part in any of the previous experiments.

Materials and design

One hundred words were selected for Experiments 4a and 4b. The words were divided into 25 groups according to the detection letter. All letters of the English alphabet were used except the letter z. Each detection letter group contained two words with that letter (i.e., calling for a 'yes' response), and two words without that letter (i.e., calling for a 'no' response). For instance, the letter detection group for the letter *b* included *blood*, *lamb*, *plane*, and *leak*. The 'yes' response items were matched to the 'no' response items on frequency of occurrence (mean CELEX frequency = 134.7 per million for 'yes' items, and 108.5 for 'no' items), length (mean length = 5.1 for 'yes' items, and 5.0 for 'no' items), and number of orthographic neighbors (mean N = 4.2 for "yes" items, and 5.4 for 'no' items). All responses that exceeded 4 seconds were discarded. There were 11 such responses in each experiment.

Procedure

The procedure followed in Experiments 4a and 4b was similar to that described in the General Method for the e-detection task, except that in the present experiments, the letter to be detected differed on every trial. In Experiment 4a, before the presentation of each item, a question appeared: Does the briefly presented word contain the letter *v*? The actual letter changed on every trial. As the participant became more familiar with the task, the question was shortened to just the letter participants are to look for in the next trial.

In Experiment 4b, a question was presented along with the 'yes' and 'no' response alternatives (i.e., after the presentation of the prime): Did the briefly presented word contain the letter *p*? The actual letter changed on every trial, and the question was shortened to just the letter to be detected as the experiment progressed.

The two experiments were run simultaneously, with a random assignment of participants to either of the experiments.

Results and Discussion

The results obtained in Experiments 4a and 4b are summarized in Table 9.

Table 9. Mean percent correct obtained in Experiment 4a and Experiment 4b.

Before (4a)	After (4b)
57.4*	61.2*

* p < .01

Group percent correct means for participants in both Experiment 4a and Experiment 4b were significantly above chance (4a mean = 57.4% correct, $t(15) = 2.13$; $p < 0.001$; and 4b mean = 61.2% correct, $t(15) = 2.14$, $p < 0.001$). However, the difference between the tasks was not significant.

The results obtained in Experiments 4a and 4b do not suggest that participants must place the prime into memory until the alternatives are presented. In fact, these results suggest that participants are not better at e-detection because they know what to look for ahead of time. On the other hand, performance on both letter detection tasks was lower than that observed in experiments 1a and 2. Perhaps there is something about keeping the letter to be detected constant as in e-detection that leads to a slightly better performance. However, a direct comparison of e-detection and letter detection tasks is necessary in order to resolve this issue. Unfortunately, it is beyond the scope of this dissertation.

General Discussion

Table 10 summarized mean percent correct choices observed in experiments 1a through 4b. The results obtained in these experiments show that participants are able to extract both orthographic and semantic information from masked stimuli presented for 50 and even 40 ms (Experiments 1a, 1b). Correlations obtained in Experiment 2 show that accuracy rates on Semantic discrimination as well as e-detection can in fact be predicted from confidence reports. Experiment 3 suggests that although Identity discrimination might be done using meaning rather than visually, it is not significantly different in performance accuracy from the Orthographic discrimination task, which can only be performed visually. Moreover, the order in which the tasks are presented to a participant might influence their performance and possibly the strategies they use in these tasks. Finally, as shown in Experiments 4a and 4b, superior performance on e-detection does not seem to be due to knowing ahead of time what to look for in this task. After all, in the Semantic discrimination task, participants also know that they are supposed to be looking for the meaning of the word.

Table 10. Mean accuracy rates obtained in Experiments 1a through 4b.

Task	Experiment	50 ms exposure	40 ms exposure
Identity discrimination	1a, 1b, 3	62.4***, 69.6***	52.9
Orthographic discrimination	3	61.5***	
Semantic discrimination	1a, 1b, 2	62.1***, 61.9**	53.7*

E-detection	1a, 1b, 2	65.4***, 67.2***	55.1**
Letter detection	4a (before)	57.4***	
	4b (after)	61.2***	

* p < .05; ** p < .01; *** p < .001

Experiments 1a and 1b show that at both 50 and 40 ms exposure durations, participants as a group performed at above-chance levels on e-detection as well as Semantic discrimination. Identity discrimination, however, was above chance at 50 ms, but was at chance at 40 ms. Moreover, e-detection, the most visual of the three tasks, produced the best performance in all experiments. Once again, we have little evidence in support of the proposal that masking eliminates the visual record without affecting the semantic record, at least as a general rule. On the contrary, the results support the argument that all properties of the prime, including the formation of a visual record, are activated, and survive the backward mask, but not necessarily in a form that produces explicit conscious awareness.

One possible view of how these tasks could be carried out is to suggest that participants use semantic information on all three tasks, including e-detection and Orthographic discrimination. This could be done in theory by inferring the form of the word from its semantic properties, and then deciding whether that form contains an ‘e’ or not, or whether it looks like one of the alternatives more than another. Correlations across participant means support this view. That is, individuals who perform well on the Semantic discrimination task also tend to be good at e-detection. However, this should also be true for items. Items that produce high accuracy in Semantic discrimination should produce high accuracy in e-detection. Thus we would expect to see significant correlations between item means on these tasks. This was not the case in either Experiments 1a and 1b, or Experiment 2. As pointed out earlier, this absence of correlations between item means also makes it very difficult to argue that some of the primes were more visible than others. For example, if this was the case (perhaps because of factors such as orthographic distinctiveness, or word frequency), then this could explain the above-chance discrimination performance. However, this would also predict significant correlations between the item means.

The cross-task correlations across participant means found in Experiments 1a, 1b, and 2 imply that participants possess different degrees of sensitivity to the properties of the prime that affect their performance on all three tasks. It is especially interesting that these correlations were absent with a 40 ms prime duration in Experiment 1b. This suggests that at 50 ms, the same ability is being tapped by the three tasks, but at 40 ms, quite different abilities seem to be involved. Alternatively, the lack of intersubject correlation at 40 ms exposure durations might stem from only a few participants performing better than chance, which is nevertheless driving the group result, while a lot more participants are above chance at 50 ms.

An important issue is whether above-chance performance on these discrimination tasks necessarily implies anything about conscious awareness. The reason this is important is that in masked priming experiments, we want the priming effect to function as an index of processes taking place in the lexical processing module, not in the frontal lobes. So if "cat" primes "dog", we want this to be because the lexical processor takes advantage of the relationship between these words, not because the participant is using some conscious strategy. As argued by Kouider and Dupoux (2004), some priming effects are observed only in participants who are sensitive to visual properties of the prime and are therefore described as being "partially aware" of the prime.

Similar to the Bachmann's (1984) notion of vague awareness and the global workspace theory (see Chapter 1), one way to think about partial awareness is that it indicates a stage of processing just prior to complete awareness. Once the lexical processor has identified the input, it transmits that information to other processing systems, which might be done via different channels (e.g., modules). One of those channels would eventually reach consciousness, but the others would not. For example, in order for the syntactic processor to use the information extracted from the lexicon, it may not be necessary for the individual to be consciously aware of the input. However, once information about the input is broadcast to other centers, it is possible that the decision system can pick up enough information to perform at above-chance levels in a discrimination task. This would then be similar to the way a blindsight patient is able to locate an object in space despite the absence of any conscious perception of the object (Weiskrantz, 1986).

With this analogy in mind, we could infer that an exposure duration of 50 ms is enough to trigger this broadcast of information about the prime for most individuals, but this is less likely at 40 ms. Of course, it is only occasionally that this fragmentary information is sufficient to enable the decision-making system to arrive at the correct decision, and for some individuals it may never be sufficient. It must be kept in mind that we are considering group performance, and that all we can conclude is that enough participants did well enough to rule out chance as an explanation.

Alternatively, it has been pointed out that these measures might instead be seen as measures of priming. In a normal priming experiment, if the prime is *stair*, then it would be expected that the word unit for *hair* would be activated because of orthographic similarity, and this activation may persist long enough to somehow alter the way in which this word is perceived when it is subsequently presented as a target word, e.g., it might seem more "familiar", and this might lead to a faster response, hence priming. Similarly, if *hair* was presented as an alternative in a 2AFC task, the same increase in familiarity might increase the probability of choosing this alternative as a guess, which might then be mistaken as an indicator of partial awareness. Deciding which interpretation is correct is no easy matter. Indeed, it could be that they are simply different sides of the same coin. The next chapter attempts to resolve this issue.

CHAPTER 3. THE RELATIONSHIP BETWEEN DETECTION AND DISCRIMINATION TASKS AND MASKED PRIMING

The masked priming paradigm has been applied widely in the study of visual word recognition. There are several reasons for choosing this paradigm. Firstly, because participants are unaware of the prime, it is believed that the influence of strategic processes is minimized, and that the observed priming effects tell us something about the operation of the lexical processor itself, rather than about more general problem solving routines that might be involved in decision-making. Secondly, if priming is obtained even though the prime is not consciously perceived, then priming is far more likely to be the product of purely automatic processes. Thirdly, some effects are readily obtained when the prime is masked, but not when it is visible (e.g., Badecker & Allen, 2002; Forster, Davis, Schoknecht & Carter, 1987; Kiang, 1999) so masking can serve as indirect evidence of a dissociation between conscious and unconscious processes. For instance, Forster et al. (1997) showed that a 1LD word prime facilitates the reaction times to the target if the prime is masked, but actually makes them slower when they are visible compared to when the prime is an unrelated word.

On the other hand, there are also cases where priming is much weaker when the prime is masked. Kouider and Dupoux (2004) argue that this is the case with visual-auditory priming mentioned earlier. Their proposal is that activation from the prime can only affect the processing of the target if both prime and target are represented in an amodal system such as the central cognitive system proposed by Fodor (1983), which can only happen if information about the prime reaches consciousness. Similar claims have been made about semantic or associative priming, and also phonological priming. In the case of semantic or associative priming, the claim would be that this type of priming is a product of strategic processes such as anticipation, or retrospective matching (Neely, Keefe & Ross, 1989), which are inoperative when the prime is masked. In the case of phonological priming, the claim would be that phonological recoding of the prime is not an automatic process.

Apart from evaluating detection and discrimination tasks as measures of awareness, this chapter focuses on establishing the relationship between these tasks and masked priming as well as the relevance of the findings obtained using the former to priming. Using Reingold and Merikle's (1988) terminology, this chapter aims to provide a stronger link between direct and indirect measures of awareness.

The goal of the first two experiments described in this chapter is a replication of the intervenor effect found by Forster (2009) but using discrimination and detection rather than priming. The intervenor effect is the influence of an unrelated word inserted between a prime and a target on the amount of priming exerted by that prime. Before considering the methodology and findings of Forster's (2009) experiments, the issue these experiments aimed to resolve requires introduction.

Evett and Humphreys (1981) found that a masked 1LD prime facilitates the recognition of the target (referred to as the form priming effect) but not as much as an identical prime (referred to as the repetition priming effect). It was proposed that this difference in priming effects was due to semantic properties of the target activated by the identity prime being added to orthographic activation produced by form prime (Evett &

Humphreys, 1981).

In order to investigate this claim, three types of primes were included in Forster's (2009) experiments that used a lexical decision task: an identity prime, a form prime, and an unrelated control prime. When a visible intervening word (exposure duration of 500 ms) was inserted between the prime and the target, repetition and form priming were equivalent (see Table 11). Compared to standard priming when the prime and target are presented adjacent to each other (i.e., no intervenor) the visible intervenor had the effect of reducing repetition priming to the level of form priming, which in turn was unaffected by this manipulation. This was taken as evidence that a visible intervening word disrupts semantic processing of the prime, while leaving orthographic processing intact, which supports Evett and Humphrey's (1981) proposal that there are two components to identity priming: orthographic activation and semantic activation.

When exposure duration of the intervening word was reduced to 50 ms, where it was now not readily visible, identity priming was still reduced, but form priming was eliminated completely. This suggests that a masked intervenor, in contrast to the visible one, disrupts orthographic processing while having no effect on semantic activation produced by the prime. Apart from providing a double dissociation between semantic and orthographic components of identity priming, these results also tell us something about the difference between semantic and orthographic activation in terms of awareness. Although in both conditions participants are supposed to be unaware of the prime, the intervening word disrupts semantic processing only when the participant is aware of that word, while the opposite is true for orthographic processing.

One plausible explanation of this pattern of results is that semantic activation from a visible stimulus overrides the weak (but nevertheless sufficient for priming) semantic activation produced by the prime, thus eliminating it. On the other hand, orthographic activation produced by the same prime proceeds to facilitate orthographic processing of the target, undisturbed by the intervening visible word, whose orthographic processing must surely take place as well. However, when both the prime and the intervenor are masked, semantic processing of the latter does not inhibit that of the former, while orthographic processing is inhibited. Could there be an unexpected similarity (or a common mechanism) between these results and the findings obtained by Marcel (1983) whose participants could perform semantic discrimination while being at chance on detection?

Table 11. Mean lexical decision times (ms) and percent error rates (in parentheses) for word targets as a function of prime-target adjacency and type of prime taken from Forster (2009).

	Prime type			Priming	
	Identity	1LD	Control	Identity	1LD
Target: *BATHROOM* Intervenor: *enthrall*	*bathroom*	*bothroom*	*visceral*		
Non-adjacent priming Visible intervenor <prime> intervenor TARGET	545 (6.9)	550 (10.4)	574 (7.2)	29	24
Adjacent priming precursor <prime> TARGET	525 (8.8)	543 (10.4)	-	49	31
Non-adjacent priming Masked intervenor <prime><intervenor>TARGET	558 (6.7)	582 (8.5)	580 (10.7)	22	-2
Adjacent priming <intervenor> <precursor><prime> TARGET	527 (5.6)	553 (8.5)	-	53	27

When the intervenor is masked, it is as if semantic activation from both the intervenor and the prime can coexist in the unconscious space, while orthographic activation cannot. This makes sense if the two types of activation are viewed as qualitatively different systems, with the semantic system as a large network of interconnected concept nodes similar to that proposed by Collins & Quillian (1972), and orthographic activation as a limited capacity visual sketchpad (Baddeley & Hitch, 1974) and similar to iconic memory (Di Lollo, 1980).

Taking this view into account, it can be proposed that there is no reason why two different patterns of concept activations cannot exist simultaneously in the semantic network. When one of these concepts becomes consciously available though, others are automatically inhibited (we would be utterly confused otherwise!). On the other hand, visually described orthographic information of the masked intervenor replaces that from the prime due to capacity limits. Only if one of these escapes the iconic memory and reaches consciousness can orthographic information from two different stimuli coexist. The pitfall of this explanation is that there is surely no way for the cognitive system to discern in the first 50 ms of the intervenor exposure whether its presentation will stop there and be replaced by the target, or continue for another 450 ms as in the visible case.

Two experiments were conducted in order to provide more evidence for the proposal that semantic and orthographic information occupy different cognitive systems that are dissimilarly affected by consciousness, as well as to determine whether information gathered from masked words in discrimination and detection tasks is comparable to the information obtained from a masked prime in a lexical decision task. Experiment 5a investigates the role a word mask plays in Semantic and Identity discrimination tasks, while Experiment 5b aims to answer the same question using e-detection. If these tasks measure the same processing mechanisms involved in masked priming, and assuming that the effect of a word mask in discrimination and detection tasks is comparable to a visible intervenor in lexical decision we expect performance on Semantic discrimination to suffer, but performance on e-detection to be unaffected compared to cases when the mask is a string of consonants. By including Identity discrimination, Experiment 5a also aims to make another attempt to determine whether participants are using meaning or orthographic information in this task. If performance on both Semantic and Identity discrimination is lowered by word masks, but performance on e-detection is unaffected, we can conclude that semantic properties of the prime are indeed extracted in Identity discrimination task and that it is therefore more similar in nature to the Semantic discrimination task than to e-detection despite the inconclusive results of Experiment 3 discussed in Chapter 2.

Experiments 6a and 6b continue to investigate the relationship between performance on discrimination, awareness and priming effects, focusing on the issue of whether Semantic activation requires awareness as suggested by many researchers who only obtain semantic priming at longer prime durations (e.g., Kouider & Dupoux, 2001; Rastle et al., 2000). Taking into account the findings provided by Forster (2009) as well as evidence obtained in Experiments 1-2, it seems that at 50 ms prime duration, semantic properties of the masked prime do get activated. However, it is unclear whether discrimination and lexical decision tasks use that activation in the same way when the prime is not identical to one of the alternatives or the target, respectively, but merely related to it. In other words, in order to establish a relationship between the mechanisms behind discrimination tasks and lexical decision, it is necessary to determine whether semantic activation that participants are able to utilize in the Semantic discrimination task is the same as or necessarily leads to priming in a lexical decision task. This is why Experiment 6 tests both of these tasks using the same items on the same group of participants. If semantic priming is absent, it is often interpreted as the failure of the prime to activate the appropriate representation. The purpose of Experiment 6 is to question this interpretation, and to draw a distinction between priming and activation. For example, it is entirely possible that a masked prime could generate semantic activation without priming semantically related target words. That is, the failure to obtain semantic priming does not necessarily imply that the prime failed to activate any type of representation above the level of form.

Similarly, a failure to obtain masked phonological priming does not necessarily imply that the phonological representation of the prime was not activated. Whether priming occurs or not may depend on other task variables, as appears to be the case in masked cross-language translation priming, where a masked prime in the non-dominant language is capable of priming its translation equivalent word in the dominant language in a semantic categorization task, but not in a lexical decision task (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Grainger & Frenck-Mestre, 1998).

There is a debate about whether masked semantic priming actually exists. It is unclear whether this debate is about priming, or about whether semantic activation occurs. For present purposes, let us assume that the 2AFC task provides a measure of activation, and concede that variations in discrimination performance might also result from changes in awareness of the prime. Experiments described in the previous chapter show that at 50 ms and even 40 ms exposure duration, semantic activation does occur enough to influence the participant into choosing the correct alternative more often than expected by chance. In the following experiments, prime durations of 40 ms (Experiment 6a) and 50 ms (Experiment 6b) are used, either of these would usually be accepted as minimizing the possibility of awareness, while still providing enough stimulus energy for the prime to be processed.

Experiment 5a

Method

Participants

Twenty-eight University of Arizona students took part in this experiment in exchange for partial fulfillment of course requirements. None of the participants took part in any of the earlier experiments.

Materials and design

Seventy-six items were used for this experiment. In half of the items the backward mask was an unrelated word (e.g., PEROXIDE), in the other half it was a string of consonant letters (e.g., (PQRSTWX). Both word masks and consonant masks differed on every item. The masks were always in upper-case letters. Four sets of materials were designed so that (a) each item appeared in both tasks, but not for the same participant, and (b) each item was presented with both types of masks, but not for the same participant. Otherwise materials and design were the same as described in the General Method.

Procedure

Semantic discrimination and Identity discrimination tasks were used in this experiment. The procedure was the same as described in the General Method, except half the time the primes were backward masked by an unrelated word, and the other half of the time the backward mask was a string of consonant letters.

Results and Discussion

A three-way ANOVA was performed on the data to establish significance of the differences between tasks and mask types.

Percent correct choices

When masks were words, participants' group performance was 57.0% correct in the Identity discrimination task (significantly better than chance $t(27) = 2.70$, $p < 0.05$), and 55.6% correct on the Semantic discrimination task ($t(27) = 2.68$, $p < 0.05$). When the backward mask consisted of consonant letters, performance on Identity discrimination was 66.0% ($t(27) = 6.34$, $p < 0.01$), which is significantly better than with word masks ($F1(1,24) = 11.97$, $p < 0.01$; $F2(1,72) = 8.33$, $p < 0.01$). Mean percent correct choices on Semantic discrimination were 66.5% ($t(27) = 7.25$, $p < 0.01$) when the mask was a string of consonants, which is significantly different from performance on items masked by words ($F1(1,24) = 21.59$, $p < 0.01$; $F2(1,72) = 14.96$, $p < 0.01$).

Accuracy rates did not show either a main effect of task, or an interaction, suggesting that participants are not more accurate on the Identity discrimination task than on the semantic task. There was, however, a main effect of mask type, whereby accuracy dropped significantly (in both tasks equally) when the mask was a word ($F1(1,24) = 28.73$, $p < 0.001$; $F2(1,72) = 19.06$, $p < 0.001$). The predicted result of word masks having an effect on the Semantic discrimination but not on Identity discrimination is not supported by these data.

Reaction times

Reaction times (RTs) data showed a different pattern of results. Shorter RTs were found in both tasks when the mask was a consonant string compared to a word mask (i.e., main effect of mask type; $F1(1,24) = 5.20$, $p < 0.05$; $F2(1,72) = 6.20$, $p < 0.05$). Mean reaction time in the Semantic discrimination task when the mask was a word was 1133 ms, and when the mask was a string of consonant letters, 1316 ms. This 183 ms difference was found to be significant ($F1(1,24) = 10.42$, $p < 0.01$; $F2(1,72) = 11.42$, $p < 0.01$). Mean reaction time for the Identity discrimination task was 1017 ms when mask was a word and 1014 when it was a string of consonants. In this task, the difference between mask types was not significant.

There was also a main effect of task, whereby participants were much faster in the Identity discrimination task, compared to the Semantic task regardless of mask type

(*F1*(1,24) = 13.59, $p < 0.01$; *F2*(1,72) = 33.46, $p < 0.001$). Finally, a significant interaction between task and mask type was observed (*F1*(1,24) = 8.79, $p < 0.01$; *F2*(1,72) = 8.86, $p < 0.01$).

Overall, the predicted interaction between the task and mask type is present in reaction times but not in accuracy rates. This lack of difference between tasks in accuracy rates is astounding because the difficulty in tasks is not comparable. As stated in discussions of the previous experiments, the fact that a word might be an easy item on Semantic discrimination (e.g., it can be very high on concreteness and high frequency) does not mean it will be easy on Identity discrimination task (e.g., has lots of neighbors). Hence, we would expect one task to be sometimes easier and sometimes harder than the other (randomly), but not equally difficult. It is important to note that faster reaction times in Identity discrimination suggest that in general, participants found it easier in this experiment, which is rather puzzling given the similarity of alternatives in this task. Future experiments could investigate whether a pseudoword intervenor is more similar to a word mask or a consonant string mask in the way it affects the processing of the prime, as well as whether words that are more concrete and high on imageability produce a larger intervenor effect than more abstract words.

As it was established in Experiment 3, the task that comes before Identity discrimination could have an effect on the way this task is performed. Semantic discrimination specifically draws participants' attention to meaning, therefore more individuals might be electing to use meaning in the Identity discrimination task when it was preceded by Semantic discrimination (which in this experiment occurred half of the time). If this is the case, the following explanation of the lack of difference between the tasks in accuracy is likely. If participants use meaning to perform both tasks and a word mask knocks out the semantic component as proposed by Forster (2009), it would affect both the Semantic and Identity discrimination, if participants use meaning to perform both tasks. E-detection, on the other hand, is a much more visual task, so if Forster's (2009) proposal that visible word masks should affect semantic but not visual information is true, we should not expect any difference in performance accuracy when masks are words or consonant strings in this task. Experiment 5b tests this hypothesis.

Experiment 5b

Method

Participants

Twelve University of Arizona students participated in this experiment in exchange for partial fulfillment of course requirements. None of the participants took part in any of the earlier experiments.

Materials and design

Materials and design were the same as in Experiment 5a, except the task was e-detection.

Procedure

The procedure followed in this experiment was the same as in Experiment 5a, except that the task was e-detection.

Results and Discussion

The results obtained in Experiment 5a and 5b are summarized in Table 12. A two-way ANOVA was performed on the raw data to establish significance of the differences between mask types. A paired sample means t-test was performed in order to establish whether participants' accuracy means were significantly above chance.

Table 12. Mean reaction times (RTs; ms) and accuracy rates (%) in Experiment 5a and 5b.

Task	Identity discrimination		Semantic discrimination		E-detection	
Mask type	Word	Consonants	Word	Consonants	Word	Consonants
RTs	1014	1017	1304	1128	567	546
mean	1015		1224		538	
Accuracy	57.0*	66.0**	55.6*	66.5**	52.2	62.7*

* $p < .05$; ** $p < .01$

Reaction times

Mean reaction times for the e-detection task were 546 ms when the mask was a consonant string and 567 ms when the mask was a word. The 21ms difference between two types of mask was not significant.

Percent correct choices

On average, participants were correct 52.2% of the time when the mask was a word, and 62.7% of the time when the mask was a string of consonant letters. Only the latter finding was significantly better than chance ($t(11) = 2.20$, $p < 0.01$). The difference between the accuracy rates for the two mask types was found to be significant ($F1(1,10) = 7.67$, $p < 0.05$; $F2(1,74) = 8.49$, $p < 0.01$).

The pattern of results observed in Experiments 5a and 5b fails to conform to expectations based on an interpretation of the intervenor results (Forster, 2009). In Semantic and Identity discrimination as well as in e-detection, a word mask significantly lowers performance compared to when the mask is a string of consonant letters. However, this happens in all three tasks, including e-detection, which is considered to be the most visual of the three tasks. Unless participants are using semantic information in e-detection as well, the word mask in these tasks can be thought to disrupt the visual component of the prime in all three tasks equally (i.e., is a better mask than a string of consonants in line with Jacobson’s (1974) findings). This suggests that the visible intervenor effect in a masked priming experiment might involve different mechanisms than the effect of a word mask in discrimination and detection tasks.

It would be interesting to test whether an intervenor that is not a completely unrelated word, but rather a word that shares some features with the target, while not being a close associate (e.g., *<bird> <bat> SPARROW*) would exhibit similar effects on semantic priming as a completely unrelated intervenor, or whether it would result in more competition between the overlapping semantic nodes of the prime and the intervenor. This may result in an elimination of semantic priming even when the intervenor is masked. Similarly, one could investigate the effects of task difficulty in the Semantic discrimination task using the less related word as the incorrect alternative.

Experiment 6

The results obtained in Experiments 5a and 5b suggest that the masked word in the 2AFC tasks is capable of producing activation, which is diminished equally in all 3 tasks due to a visible intervenor (i.e., a backward mask that is an unrelated word), but not priming.

Researchers specifically interested in measuring awareness distinguish between direct and indirect measures of stimulus processing (Price, 2001). Discrimination, detection, and identification tasks are all examples of direct measures, since participants are responding to the masked stimuli directly. On the other hand, indirect measures focus on the effect the masked words have on the processing of a subsequent stimulus, and therefore use priming paradigms. While most priming researchers do not look at priming as a measure of awareness, comparing the performance of the same participants on these tasks could shed light on the processes involved in them and the availability of information that can be extracted from the masked words in those tasks.

Some authors claim that indirect measures of awareness can be more sensitive than direct ones (e.g., Ansorge et al., 1998; Greenwald et al., 1988, 1995; Kemp-Wheeler & Hill, 1988). For example, Greenwald et al. (1995) showed that even when his participants were at chance in deciding whether a stimulus was presented on the right or left of a masked display, the meaning of “RIGHT” or “LEFT” nevertheless was perceived and was used to bias the outcome of these position judgments.

It is possible that semantic activation might be a necessary condition for semantic priming, but not a sufficient condition. For example, if one assumes that participants’ performance on a discrimination task was indicative of their awareness of the stimuli, then this discriminative ability can be explained as being due to activation produced by the stimulus. This activation can be either visual, and would take form of an imprint of the visual energy on the viewer’s retina, or, if Marcel’s (1983a) belief that masking erases only the visual record is correct, some left-over activation from stimulus processing that is not yet priming. It could also be argued that this leftover activation is identical to priming, and a discrimination task is therefore not a test of awareness, but an example of priming. Indeed, it could be the case that any task that claims to measure awareness is in fact a measure of priming in that the masked stimulus somehow manages to influence the way alternatives are perceived, making one simply more attractive than the other. The following experiment is designed to test just that by presenting individual subjects with a discrimination task as well as a lexical decision task of comparable parameters. If items that produce better than chance performance on Semantic discrimination do not produce a semantic priming effect in a lexical decision task under the same exposure durations, then the hypothesis that masked words in a discrimination task are able to produce semantic activation which is different from priming would be supported.

Method

Participants

Forty-four University of Arizona undergraduate students took part in this experiment in exchange for partial Introductory Psychology course credit. Eight were excluded from data analysis for high (more than 20%) error rates on the lexical decision task. None of the participants took part in any of the previous experiments.

Materials and design

The materials and design for this experiment are similar to those described in the General Method, except that here a total of 80 items were used. Each item consisted of three words: a base word such as market, a semantic associate such as store (these were mostly synonyms), which was matched to the base word (CELEX = 130.4; length = 4.91, range = 3-8; N = 5.46, range = 0-20) and an unrelated word such as *person* (CELEX=149; N = 5.21; range = 1-18). There were two tasks in this experiment: Semantic discrimination and lexical decision. The base word was presented as a masked prime in both tasks, with the unrelated word and the semantic associate of the base word as two alternatives in the Semantic discrimination task (e.g., <*market*> / *store – person*). The semantic associate of the base word was always the target in the lexical decision task, and the masked prime was either the base word (e.g., <*market*> *STORE*) or the unrelated word (e.g., <*person*> *STORE*). That way, the semantic associate was visible in both tasks, and the base word was always masked. Because the target acts as a backward mask on the prime in the lexical decision task, any difference in length between the two stimuli would make the prime more visible. It was impossible to select items that were the same in length due to the prime and target being semantic associates. In order to overcome this problem, a set of equal signs was added to both the prime and the target in order to equate them in length (e.g., <=*hound*=> ==*DOG*==). These equal signs made the two stimuli identical in length yet did not add any processing difficulty. This is because equal signs are non-linguistic in nature. In addition to word items, 40 nonwords were selected as targets for the lexical decision task. These were 1LD from words and were presented with unrelated nonword primes.

Procedure

The procedure for the Semantic discrimination task was followed exactly as described in the General Method with exposure durations in Experiment 6a being 40 ms and in Experiment 6b, 50 ms. Primes in the lexical decision task were presented for the same duration as the primes in the Semantic discrimination task in each experiment, but instead of being replaced by a backward mask, they were replaced by the target in capital letters, which acted as a backward mask. In the lexical decision task, participants were asked to respond ‘yes’ if the target was a word (e.g., *doctor*), and ‘no’ if it wasn’t (e.g., *dontor*). The target was presented for 500 ms, and participants were instructed to respond as fast as they could but not so fast that they make errors. After participant responded, the next item was displayed automatically.

Results and Discussion

Semantic discrimination

A two-tailed t-test for paired sample means was performed to determine significance of above-chance performance on Semantic discrimination. As a group, participants performed better than chance on Semantic discrimination when exposure duration was 40 ms in Experiment 6a (mean % correct = 54.7, $t(35) = 2.03$, $p < 0.05$) as well as when exposure duration was 50 ms in Experiment 6b (mean % correct = 64.7, $t(19) = 2.09$, $p < 0.01$). These findings replicate the results obtained in Experiments 1a and 1b, as well as provide additional evidence that semantic activation indeed occurs for masked stimuli presented for 50 ms and even 40 ms.

Lexical decision

Nonword items were not included in the subsequent analyses. Reaction times and error rates obtained in the lexical decision task in Experiments 6a and 6b are shown in Table 13.

Table 13. Reaction times (ms) and error rates (%) obtained in the lexical decision task of Experiments 6a and 6b.

Exposure duration	40 ms		50 ms	
Prime relatedness	Related	Unrelated	Related	Unrelated
Reaction times (ms)	594	590	548	550
% Error	8.02	6.62	9.65	4.55

Although discrimination performance was significantly above chance, no priming effect was obtained at 40 ms (-4 ms) or 50 ms (2 ms), (all F's < 1). However, there was a significant difference between the errors obtained when exposure duration was 50 ms revealed by a two-way ANOVA (*F1*(1,16) = 6.01, $p < 0.05$; *F2*(1,76) = 12.09, $p < 0.01$). It is not quite clear why participants were making significantly more errors when the prime was semantically related to the target compared to when the prime was unrelated and at 50 ms prime duration (there is also a similar trend at 40 ms). However, this result does not pose a problem for the proposal that although while semantic activation occurs as shown by better than chance performance on Semantic discrimination, it is not sufficient to produce priming in a lexical decision task. A priming effect or accuracy benefit in the related condition would have been interpreted as evidence against this hypothesis. However, in Experiment 6b, accuracy was found to suffer when the prime was semantically related to the target.

General Discussion

The results provided by the experiments discussed in this chapter show that a backward mask that is a word lowers performance on Semantic discrimination, Identity discrimination, and e-detection. While as a group participants continue to perform better than chance on Semantic discrimination and Identity discrimination even when the mask is a word, participants' performance on e-detection is only above chance when the mask is a string of consonant letters. This supports the finding described by Jacobson (1974) that the more similar a mask is to a word, the better masking effect it provides. However, this result does not support the intervenor effect obtained by Forster (2009) in masked priming experiments where a visible intervenor seems to disrupt semantic but not orthographic processing.

Paired with the inability to obtain semantic priming at 40 or 50 ms prime durations in a lexical decision task despite both of those durations being sufficient to produce better than chance performance on the Semantic discrimination task, these results suggest that masked priming experiments may indeed measure very different processes than those measured by discrimination and detection tasks. This certainly does not mean that discrimination and detection tasks must necessarily measure awareness, although these tests do seem more sensitive than masked priming, and are therefore better candidates for tests of awareness than priming experiments. One thing is for certain: Semantic discrimination is sensitive to semantic activation that is different from priming. Although far from claiming that discrimination tasks should be used as perfect tests of awareness, experiments discussed in this chapter reject the idea that they are just more sensitive examples of priming experiments. Finally, the fact that no semantic priming is observed for semantic associates raises doubts about whether the priming component from an identity prime that is eliminated by a visible intervenor word is in fact semantic in nature. That is, unless semantic activation from an associate is qualitatively different than that from a repetition prime.

Fisk and Haase (2005) caution against comparing priming which is thought to measure perceptual processing with tasks such as discrimination and detection that presumably reflect awareness. These authors argue that priming and 2AFC tasks represent overlapping processes, and it is impossible to dissociate which variable represents consciousness and which represents processing. So “any differences in sensitivity between these variables could simply be the result of experimental manipulations that might favor one variable over the other" (Fisk & Haase, 2005, p. 208).

The experiment presented in the next chapter adds a psychophysiological measure to subjective (self-report) and objective (performance on Semantic discrimination, Orthographic discrimination, and e-detection) measures of awareness. By using event-related potentials, it provides another dimension to evaluating these tests, making it to not only provide a better dissociation between the processes involved in the three tasks, but also to investigate whether participants are aware of some of their responses by combining confidence ratings on trials when participants responded incorrectly and a physiological marker of error awareness, termed error-related negativity.

CHAPTER 4. USING EEG AS ANOTHER MEASUREMENT OF UNCONSCIOUS PROCESSING AND AWARENESS

…we are still in the grip of a residual dualism…
- Searle (1998)

As demonstrated in previous chapters, masked stimuli can be processed and can influence one's subsequent decisions despite participants' inability to overtly report them. Even when participants are very confident about the responses they make, it does not necessarily mean that they are able to report the masked stimulus. However, it remains unclear whether research participants performing a task that involves priming exhibit general or task-relevant information extraction and processing of the prime and whether this processing differs qualitatively depending on the prime's perceptibility.

Furthermore, electrophysiological studies focusing on different aspects of awareness in visual word recognition have been limited to classical tasks such as lexical decision, stem completion (in which participants tend to complete a word stem with a specific word more often when that word has been presented previously) and semantic categorization (in which a decision is made whether a stimulus is an exemplar of a category such as animals). More generally, most of the previously published experiments in the area explore the differences in prime-target relationships and awareness of the prime. No published psychophysiological research has been dedicated to the differences in processing of the prime when the task is performed on the masked prime itself and not a subsequent visible target.

It is important to understand what role awareness plays in cognitive tasks that require extraction of meaning, orthography, phonology, or lower level visual information from masked words. Do people process words automatically by simply extracting all information that is available from a stimulus, or can task demands dictate what types of information will be selectively accessed? Experiment 3 discussed in Chapter 2 showed that the tasks participants perform first in a given experiment can influence the way subsequent tasks are performed. So it seems that at least some selective processing of the masked stimuli can be achieved. Another question that electrophysiological measurements could help answer is whether some types of processing require longer prime durations and more awareness of the stimulus than others. Semantic, phonological and cross-modal priming literature discussed in previous chapters suggests that these types of priming effects indeed require longer prime durations than orthographic priming, but results obtained in Experiment 6 suggest that this might not be due to semantic or phonological activation failing to be extracted at short exposure durations, rather such activation might need more time to lead to priming.

Finding underlying differences in neural activation involved in unconscious and conscious processing might shed light on the nature and function of conscious experience, which is becoming a focus of research interest in several fields of study. For instance, event-related potentials (ERPs) that are averaged from continuous EEG recordings, reflect cortical activity with an extremely high temporal resolution. It is therefore not surprising that searching for physiological correlates of subjective awareness has always been a major goal of ERP research (Verleger, 2009). As with behavioral methods, the study of awareness using ERPs has focused on measuring responses to stimuli that are difficult to perceive (e.g., masked stimuli). Relevant ERP components proposed in this context as perceptual correlates of awareness have included early components related to perception (e.g., visual P1), middle-latency negative peaks (posterior N2, N2pc), and the P3 complex. ERP signs of motor activation (Lateralized Readiness Potential) and semantic processing (N400) have also been studied in the context of awareness (Verleger, 2009). Therefore, ERPs provide a modality to test differences in timing required to process various kinds of information, while the spatial information of electroencephalogram (EEG) also enables extraction of some brain localization of these unconscious processes.

Existing evidence

Behavioral data from masked priming studies show that unconscious processing of visually presented word stimuli is generally not as flexible as conscious processing of the same stimuli (*cf*. Forster et al., 2009). This suggests that unconscious processing should elicit less brain activity, the temporal course of extracting semantic information should be longer than that of purely visual information, and that integration between modalities observed when stimuli are presented consciously should be strongly reduced under masked stimulus presentations.

Psychophysiological studies in the field have mainly explored differences between unconscious (masked) and conscious (unmasked) processing. For instance, Koivisto, et al. (2005) found enhanced ERP negativity to consciously perceived stimuli as compared to masked ones, at occipitotemporal sites around 200 ms after the onset of stimulus presentation. This ERP component referred to as the N200, has been studied as a marker of spatial attention for target location (Luck & Hillyard, 1994), and as a correlate of pre-lexical processing (Kast, Meyer & Jaencke, 2009). In general, some researchers found lower activation produced by masked stimuli as compared to visible ones. Dehaene et al. (2001) used fMRI and ERPs to show that, in comparison to the unmasked condition, the activation evoked by masked words was drastically reduced and was undetectable in prefrontal and parietal areas, correlating with participants' inability to report the masked words. Dehaene et al (2001) go as far as to claim that activation in these anterior brain regions is required for conscious perception.

However, other experimenters find more specific differences in psychophysiological patterns of activation between conscious and unconscious stimulus presentation. For example, Kiefer and Brendel (2006) found that masked priming in a lexical decision task affected the amplitude of the N400 ERP component, which is a negative deflection over the central and parietal electrode sites of the ERP that occurs at around 400 ms after the occurrence of a semantically unexpected stimulus and is thought to be associated with semantic integration. For example, the sentence "the pizza is ready to drink" should produce an N400 as compared to a sentence "the pizza is ready to eat", while "the pizza is ready to cry" will produce the largest N400, since it is the most implausible sentence of the three. In general, failures of expected input produce the N400 response. Kiefer and Brendel (2006) found that unrelated prime-target pairs elicit a larger

N400 than related pairs (N400 priming effect) even when primes are not consciously perceived.

Contrary to this finding, Ruz et al. (2003) described an experiment in which the N400 effect (a marker of semantic integration) was observed only when semantically related primes in a lexical decision task were consciously perceived, and disappeared completely when primes were masked. Similarly, Brown & Hagoort (1993) also found that N400 priming effects were only obtained for visible primes although behavioral priming was obtained in both, conscious and unconscious conditions.

These authors also described other differences in the ERP effects characteristic of unconscious semantic priming. Ruz et al. (2003) argue that conscious and unconscious processes might in fact be separable in the brain. They found an N200 effect together with later modulations in the left frontal and right fronto-central potentials instead of an N400 effect. On the other hand, Schnyer, Allen, and Forster (1997) have shown that a repetition priming effect even under conditions when primes are masked appears in the amplitude of N400. Deacon, Hewitt, Yang, and Nagata (2000), and Kiefer and Spitzer (2000) also showed the N400 component to be sensitive to unconscious semantic activation. Specifically, Kiefer and Spitzer (2000) found that conscious and unconscious semantic priming seem to involve similar brain areas, however the former shows increasing brain activation with time, while the latter decays within 200 ms.

Similarly, Matsumoto et al. (2005) also looked at different ERP patterns in an attempt to dissociate between conscious and unconscious repetition priming effects. They used a stem completion task in which the subjects were instructed to either complete the stem using the preceding prime (inclusion condition), or using a word other than the prime (exclusion condition). As the researchers observed stem completions with the prime word in both conditions, they were able to conclude that primes were processed unconsciously in the exclusion condition. They also found that the N400 priming effect (smaller N400 amplitude in repetition trials as compared to control trials) did not appear in the unconscious priming condition (exclusion condition). Matsumoto et al. (2005) also found an ERP pattern characteristic of unconscious word processing: a negative component at the left front lateral (LFLN) site. This negativity was enhanced by word repetition and lasted longer than N400. LFLN was also found by Nobre and McCarthy (1994) specifically in response to unconscious semantic priming. Various event-related fMRI studies have established that LFLN originates in the left inferior prefrontal cortex (LIPC) which is thought to be involved in semantic processing (e.g., Buckner et al., 2000; Fiez, 1997; Martin et al., 1995; Petersen et al., 1998; Wagner et al., 1997).

Misra and Holcomb (2003) described an experiment in which repeated targets of masked primes produced attenuation of N400 but no change in the late positive component (LPC), while unmasked primes also produced differences in the LPC.

Error awareness

Certainly, when dealing with tasks where participants feel like they are guessing due to being unaware of some component of the task, they tend to make a large number of errors. In decision making literature, there is a general consensus that erroneous responses in tasks that require speeded decisions, produce an ERP pattern referred to as the error-related negativity (ERN) (Yeung et al., 2004). Although not much attention has been paid to the possibility of using physiological measures to detect errors when participants are subjectively unaware of making those errors, Endrass et al. (2007) found ERP correlates of error awareness in masked priming. Specifically, they found that aware and unaware errors did not differ in ERN amplitude. Endrass et al. (2007) also described two components of error positivity (Pe): the late Pe (occurring around 400–600 ms after response onset) showed an increased parietal positivity for aware compared with unaware errors, while the early Pe (200–300 ms) showed no dissociation between aware and unaware errors. Similarly, Nieuwenhuis et al. (2001) also found an error-related negativity as well as an error-related positivity when participants were unaware of making errors on an antisaccade task. However, the authors of this study consider the errors to be unperceived when participants immediately corrected themselves and hence did not report them in a subsequent self-report. Nevertheless, these two findings are very important as they allow one to differentiate ERP patterns when errors were produced from accurate responses using more than a behavioral measure.

The ERN component is observed as a sharp negative deflection of up to 10 μV in amplitude from baseline at around 70-100 ms after a speeded erroneous response (usually motor) over the front and middle of the scalp. This negativity is thought to be generated in the anterior cingulate cortex (as supportive evidence from some studies using fMRI suggests). The ERN is considered to be a manifestation of the activity of a system associated with monitoring the accuracy of the response system and with compensating for errors (Gehring et al. 1993). According to Trujillo and Allen (2007), the ERN emerges from a phase-locking of ongoing theta-band activity, in the context of a general increase in theta power following errors.

Selection of information based on task demands

Several authors have explored the mechanisms involved in performing lexical decision and semantic categorization tasks. Whether the reader automatically attempts to access all the information available from a stimulus and then uses only the kind that is relevant to a particular task, or modulates this process only attempting to access task-relevant information, remains a topic of debate. Eckstein and Perrig (2007) suggest that processing of unconscious masked primes, previously considered to be automatic, can in fact be controlled intentionally, as they find different aspects of information being extracted from that prime depending on the task participants are undergoing. Forster et al. (2003) also describe that the kind of processing participants perform on targets in a certain task will be automatically performed on masked primes as well. However, the latter researchers do not claim that this difference in prime processing, which depends on task demands, is indicative of exertion of intention on unconscious processing in standard lexical decision or semantic categorization tasks. It is possible, though, that when the participant’s task is to extract certain kinds of information from the prime rather than a primed target, the processing of the prime could differ when task demands differ.

Eckstein and Perrig (2007) as well as Snodgrass et al. (2004) also claim that lexical decision is commonly considered to measure stages of word processing preceding semantic classification, and should be a more conservative test of conscious perception since it must involve more basic visual information processing than accessing meaning. It is important to test whether access of semantic information can happen independently of analysis of visual features of a stimulus or whether the former can only happen after the latter has been completed.

Similar to Marcel's (1983a) findings discussed in detail in Chapter 1, Eckstein and Perrig (2007) found that unconsciously presented masked primes could be classified semantically better than chance, but could not be discriminated lexically under the same prime durations. Experiments reported in previous chapters revealed that some individuals can indeed perform above chance on Semantic discrimination while being at chance on e-detection. All these findings suggest that semantic information persists despite unawareness of any visual features of the masked word.

Wheatley et al. (2005) conducted an event-related fMRI study which demonstrated that activity in the left posterior region of the fusiform gyrus and left inferior frontal cortex produced by reading brief but visible semantic word pairs was greater than that produced by identical word pairs, but smaller than unrelated pairs. The authors suggest that more meaning processing is involved in unrelated and semantically related words than in identical words, and that fusiform gyrus is responsible for automatic processing of object and word meaning.

Global awareness component

Verleger (2009) suggests that the P300 component, due to being closely related to decision making, classification, as well as attention, is a good candidate for an ERP correlate of awareness. Earlier components are either decoupled from variations in awareness or relate solely to attention (Verleger, 2009).

The P300 is a large positive-going potential that is of maximum amplitude over the parietal electrode sites with a peak latency of about 300-350 ms for auditory and 350-450 ms for visual stimuli and amplitude of 10-25 μV for visual stimuli in normal young adults. This component is directly proportional to the amount of information transmitted by a stimulus and how much meaning the stimulus carries. It is inversely related to the stimulus's probability of occurrence (Johnson, 1986). Since P300 is thought to indicate attentional resources, there is strong evidence that latency of P300 is proportional to the time required for stimulus categorization (Kutas et al. 1977). This means that a stimulus that is very rare, has a lot of meaning and carries a lot of information, but is easy to categorize, should elicit a large and relatively early P300. In a three stimulus "oddball" paradigm where targets and atypical non-targets are presented much more rarely that a standard non-target stimulus, the P300 can be broken down into two types: P3a and P3b. In this paradigm, the P3a is strongest over the frontal and central areas after the presentation of novel non-targets, while the P3b is most visible over parietal areas after being exposed to the targets. The P3a tends to be greater in amplitude and shorter in latency than the P3b, and is associated with interruption by the atypical non-target of attentional resources dedicated to target monitoring (e.g., Polich, 2007).

Experiment 7

This experiment is intended largely as an exploration into the possibilities of event-related potentials as a technique for studying visual awareness, and any results discussed below are preliminary serving as a basis for future research.

Although many different predictions can be made based on existing literature, the author will focus on just two conditional hypotheses. If extraction of semantic properties from a masked prime requires similar cognitive involvement to semantic processing of readily visible stimuli, and the Semantic discrimination task is the only of the three that requires such properties to become active, the N400 component should be attenuated in that task compared to Orthographic discrimination or e-detection. If error responses indicate that participants were able to extract less information from the masked words and were therefore less aware of them compared to correct responses, then we should expect a larger ERN to incorrect responses.

Materials

Participants

Twenty-eight University of Arizona students participated in this experiment in exchange for partial course credit. All participants were right-handed native speakers of English between 18 and 30 years old, had no history of traumatic brain injury associated with alterations of consciousness, and were not taking psychotropic medications such as psychostimulants, anti-psychotics, or anti-depressants. None of the participants took part in any of the previous experiments. The data from a total of seven participants were excluded from analysis due to high impedances (3), response bias of more than 40% on one or more of the tasks (3), and equipment failure (1).

Materials and design

Materials and design were as described in the General Method, except 102 items were used (34 per task). The tasks were: Semantic discrimination, Orthographic discrimination and e-detection. Exposure duration was 50 ms. Self-report after each trial provided a subjective measure of awareness of the masked stimuli.

Procedure

In addition to the procedure described in the General Method, participants were prepared for EEG recording before beginning the task while completing a health and handedness questionnaire and receiving instructions for the experiment. Participants were asked to sit in an upright reclining chair, located in a dimly lit room with constant temperature and sound attenuation. After participants gave their informed consent, the target electrode sites were prepared by cleansing with rubbing alcohol and lightly abrading with a skin preparation gel. Electrode impedances were reduced below 10 kOhms. Behavioral data and EEG were collected in a single experimental session.

Presentation of the experimental items and recording of each participant's reaction time and accuracy rate was accomplished on a Pentium PC computer using a

CRT monitor with a 60 Hz refresh rate. After each trial, participants were asked to rate their confidence on a scale from 1 (guessed) to 5 (seen).

EEG Recordings

Reaction times as well as item and response codes were recorded along with the electroencephalogram (EEG), while response accuracy was recorded on the stimulus presentation computer and later merged with the EEG traces offline. EEG activity was recorded from 62 Ag-AgCl electrodes embedded in an electrode cap placed according to the standard 10-20 system. Each electrode was referenced online to a site just posterior to Cz and re-referenced off-line to linked mastoids (A1 and A2 electrodes). Scalp recording locations included: AF3, AF4, FP1, FP2, FPz, Fz, F1, F2, F3, F4, F5, F6, F7, F8, FCz, FT7, FT8, FC1, FC2, FC3, FC4, FC5, FC6, Cz, T7, T8, C1, C3, C5, C2, C4, C6, CPz, TP7, TP8, CP1, CP2, CP3, CP4, CP5, CP6, Pz, P1, P2, P3, P4, P5, P6, P7, P8, POz, PO3, PO4, PO5, PO6, PO7, PO8, Oz, O1, O2, CB1, CB2 (cf. Pivik et al., 1993). Eye movements and blinks were monitored using four Ag-AgCl electrodes in two bipolar recording configurations: two on the outer canthi to record horizontal ocular movements; one above and one below the left eye to record vertical eye movements and blinks. A ground was located in the cap just anterior to Fz. All electrodes not part of the cap were affixed to the skin using adhesive collars. The data were sampled at 500 Hz, and the EEG signals were amplified with AC differential amplifiers (gain of 566016) and a bandpass filter of 0.05-100 Hz. Continuous EEG files were filtered digitally with a 15Hz, 96 dB low pass filter and a 1Hz, 48 dB high pass filter. Records were reviewed to exclude periods with artifacts and excessive activity, and eye-blink artifact reduction was performed using the Semlitsch et al. (1986) algorithm in Neuroscan 4.3.

EEG files were segmented into two sets of 1200 ms long epochs, beginning 200 ms before either the prime stimulus or the response respectively. Each epoch was baseline-corrected by subtracting the average value of the EEG 200 ms before the event from the entire epoch. EEG epochs were then sorted and averaged according to tasks and response types. Three different waveforms were created for primes in the Semantic discrimination (mean = 39.71 epochs, SD = 0.78), Orthographic discrimination (mean = 39.29 epochs, SD = 1.74), and e-detection (mean = 39.67 epochs, SD = 0.73) tasks. Responses that occurred faster than 100 ms after the onset of alternatives were discarded. A waveform representing correct trials was created by averaging correct responses (mean = 69.38 epochs, SD = 18.53). A waveform for incorrect trials was also created by averaging only those trials on which the participant selected an incorrect alternative (mean = 25.81 epochs, SD = 13.11). Waveforms were also created for correct and incorrect responses in each of the three tasks: in the Semantic discrimination task mean number of epochs for correct responses was 22.43 (SD = 6.72) and mean number of epochs for incorrect responses was 8.9 (SD = 4.58) ; 25.05 (SD = 5.82) and 7.81 (SD = 4.84) epochs respectively in the Orthographic discrimination task; and 21.9 (SD = 8.39) and 9.1 (SD = 5.94) in e-detection).

Peaks were identified by finding the minimum point (i.e., most negative peak) within a search window for each of the following components: a positive component occurring at around 400 ms post-prime (350-450 ms search window), an ERN component (30-120 ms post-response; Dikman & Allen, 2000), and an N200 component (160-230 ms post-response; Luck & Hillyard, 1994). Peak detection was performed automatically in Neuroscan 4.3. Each peak was verified by hand. Averaged waveforms were visually inspected for large differences in peak amplitude and only those were further statistically analyzed.

Results and Discussion

Behavioral data analysis

Pearson's correlations were obtained to compare participants' performance on the three tasks using the percentage of correct responses as the dependent variable. Two-tailed t-tests for paired means were also used to assess performance differences between the tasks, and to show whether they differed significantly from chance (50%) performance. Table 14 provides a summary of behavioral results obtained in this experiment.

As a group, participants performed better than chance on all three tasks: Semantic discrimination (69.0% correct, $t(20) = 7.29$, $p < 0.001$), Orthographic discrimination (74.6 % correct, $t(20) = 7.09$, $p < 0.001$), and e-detection (68.2% correct, $t(20) = 4.6$, $p < 0.01$). In addition to the group analysis, individual performance was assessed to determine how many participants were performing above chance (for 34 items, the appropriate .05 cutoff was 64% correct, as determined by a sign test). According to this criterion 15 participants out of 21 performed significantly better than chance on Semantic discrimination, 14 out of 21 better than chance on Orthographic discrimination, and 15 out of 21 on e-detection.

Table 14. Mean percent correct choices for semantic discrimination, orthographic discrimination, and e-detection tasks in Experiment 7.

Semantic	Orthographic	E-detection
69.0*	74.6*	68.2*

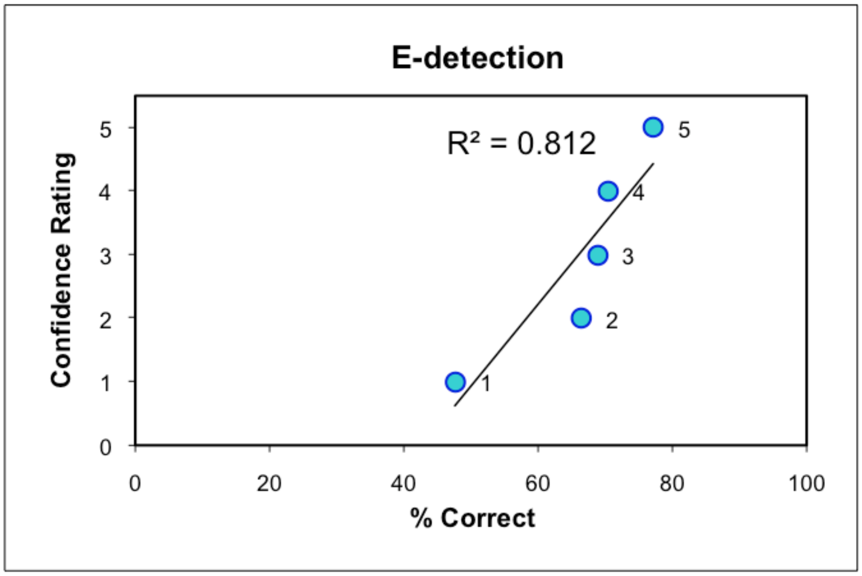
* p < 0.001

Significant correlations were observed for participants' performance on e-detection and Orthographic discrimination (r = .62, $p < 0.01$), Semantic discrimination and Orthographic discrimination (r = .71, $p < 0.01$), and e-detection and Semantic discrimination (r = .54, $p < 0.05$).

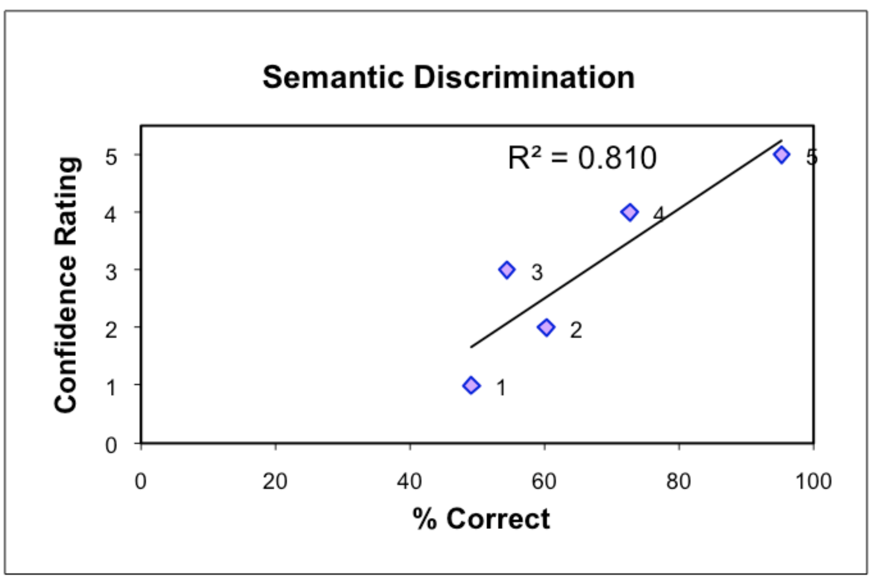
Correlations between participants' performance and confidence ratings were calculated for each task separately by plotting percent correct responses participants made as a function of confidence rating. All correlations were significant (r = .90, $p < 0.001$ for e-detection and Semantic discrimination, and r = .99, $p < 0.001$ for Orthographic discrimination). Figure 4 illustrates performance differences as a function of confidence ratings for each of the three tasks.

Figure 4. Correlation between performance (% correct choices) and confidence rating observed in Experiment 7 on (a) e-detection, (b) semantic discrimination, and (c) orthographic discrimination.

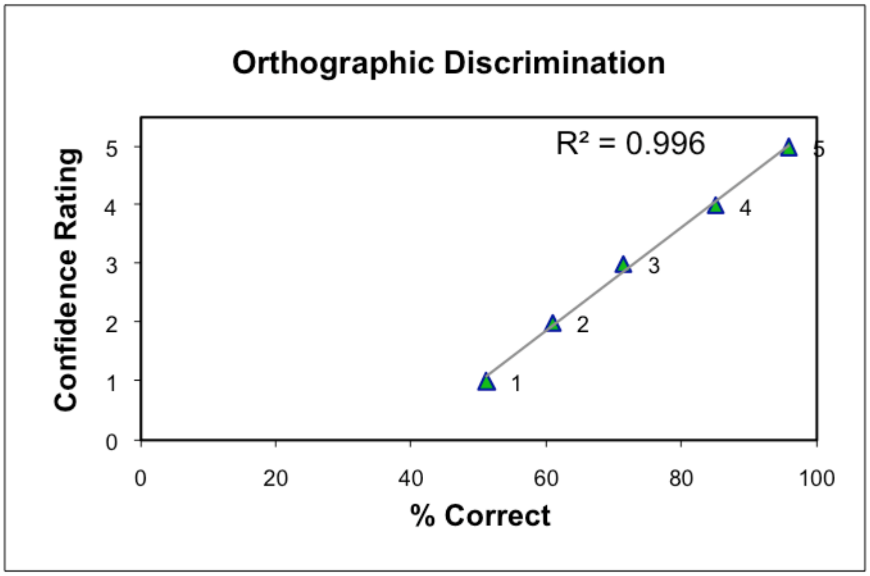
A.



B.



C.



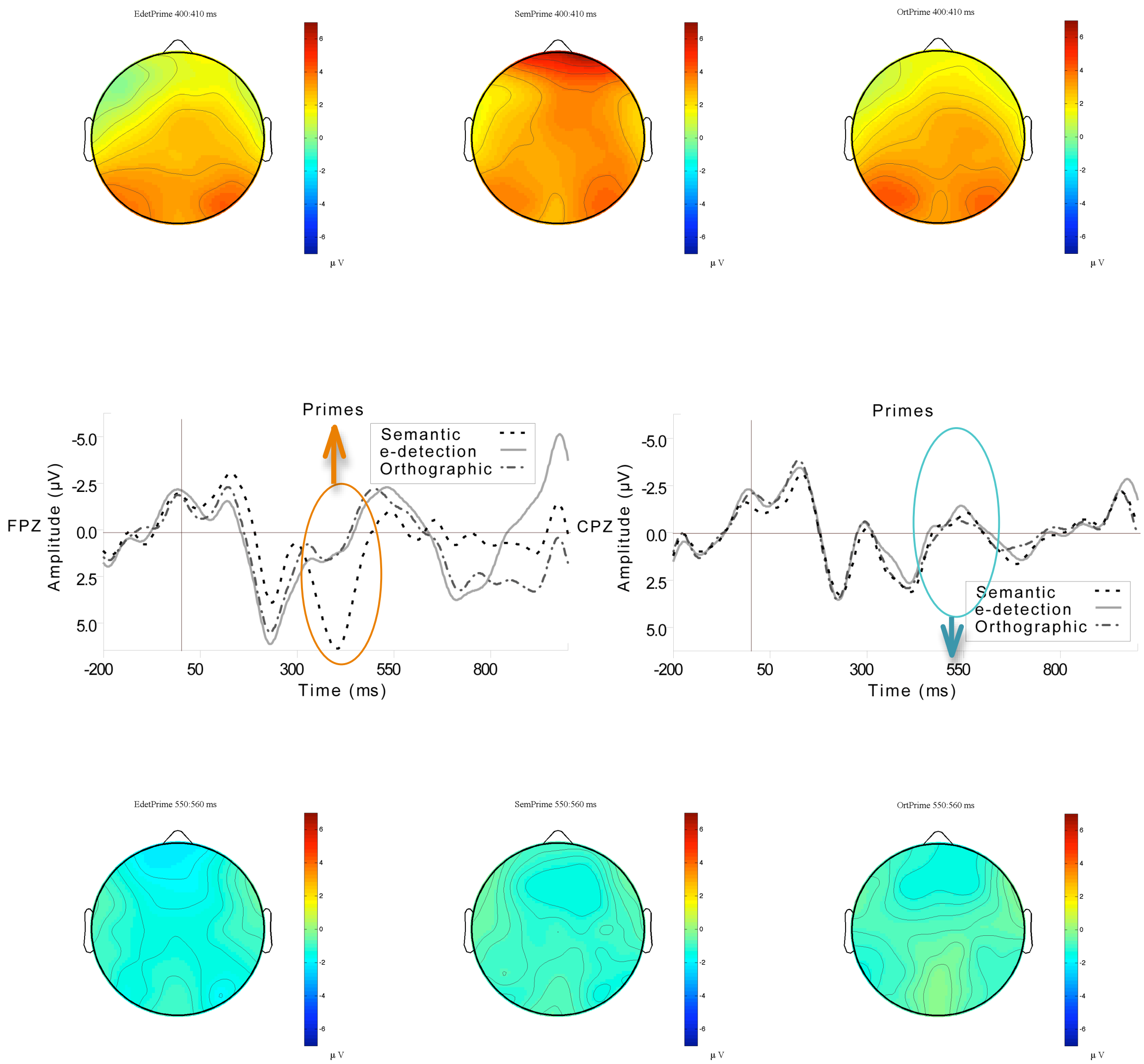
It is interesting that while in the Orthographic discrimination task the correlation between performance and confidence rating is almost perfect with performance rising steadily as confidence goes up, suggesting that awareness also rises incrementally, both e-detection and Semantic discrimination appear more clustered. Performance on these two tasks more readily supports a threshold hypothesis, where at some point there is enough awareness for participants to start performing better than chance on those tasks, until which performance hovers around 50%. On e-detection, performance is at chance only for items rated 1, while on Semantic discrimination, there is a noticeable increase in accuracy for ratings of 4 and 5 as compared to ratings 1, 2 and 3.

ERP data analysis

Repeated measures general linear models (GLMs) for five midline sites Fz, FCz, Cz, CPz, and Pz were used to find differences in the amplitudes of prime-locked ERP waves between the three tasks as well as response-locked ERP waves between tasks and correct and incorrect responses. Whenever the Mauchly's test of sphericity was significant (i.e., sphericity assumption violated) and the Epsilon (ε) was less than 0.75 for a particular contrast, the Greenhouse-Geisser correction was used as a test of significance of that contrast. Otherwise, the multivariate Wilks' Lambda (Λ) test was used.

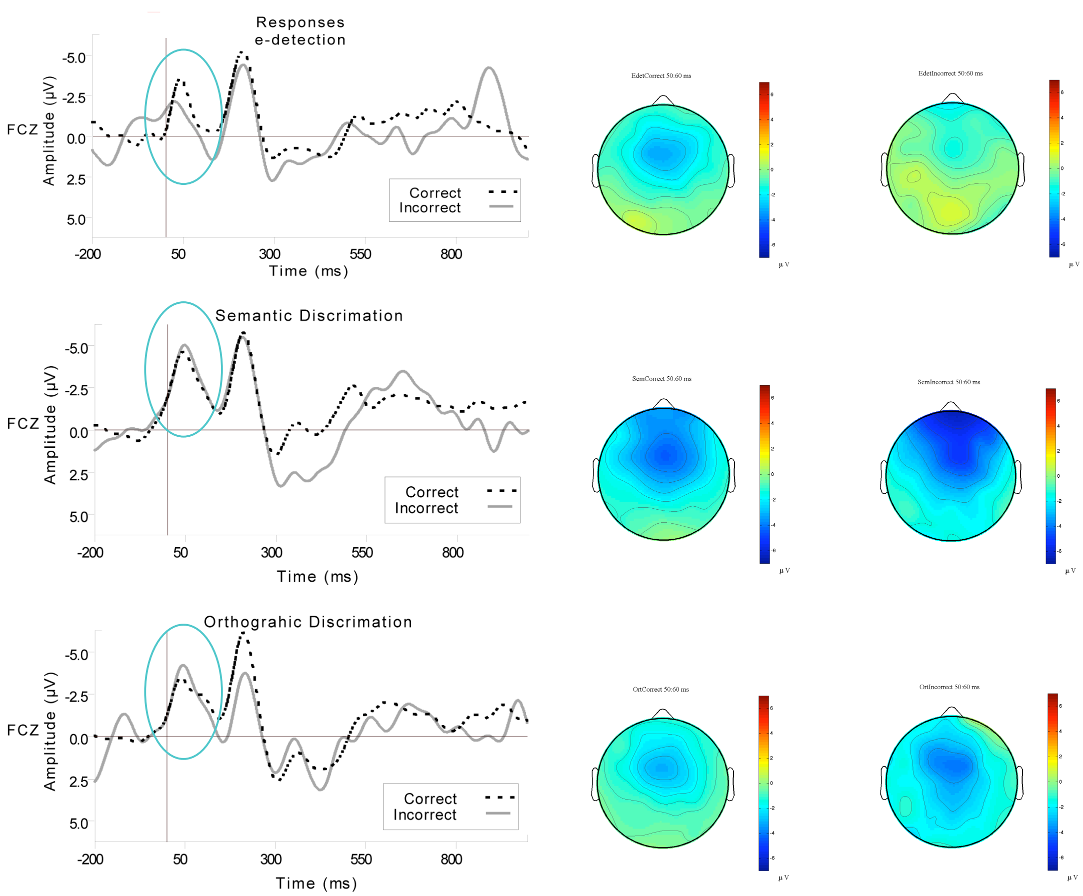
It is not easy to disentangle masked from masking stimuli (Verleger & Jaskowski, 2007) because they occur so closely in time. The working assumption adopted for the analysis here is that because the primes were presented in exactly the same way in all three tasks, any difference in prime-locked signals between the tasks would be due to the specific demands of the tasks. In order to find these differences, prime-locked waveforms were created. No visual difference in the N400 component (here observed as a negative peak around 550 ms post-prime) between the three tasks was found, so no statistical analysis was performed for this component. The FPz site was also included in the prime-locked ERP analysis, but not in the response-locked ERP analysis. This site was included due to a large positivity observed around 400 ms post-prime in the Semantic discrimination condition. This positivity was much larger than in the other two tasks and was only observed anteriorly. Despite the visual appearance of the waveform at FPz (in Figure 5), the Greenhouse-Geisser test did not reveal main effects of site or task, nor was there a significant site by task interaction for this component, all F's < 1, *n.s*. These waveforms at midline sites FPz and CPz along with topographic voltage maps for each condition at 400-410 ms (depicting the positivity) and 550-560 ms (depicting the N400 component) post-prime are presented in Figure 5.

Figure 5. Prime-locked event-related potentials and topographic head maps (grand averages for 21 participants). Top row: topography for e-detection, Semantic discrimination, and Orthographic discrimination, respectively, in the time range of 400-410 ms. Middle row: ERP time course e-detection (EdetPrime), Semantic discrimination (SemPrime), and Orthographic discrimination (OrtPrime), at electrode sites FPz and CPz. Bottom row: topography for the three tasks in the same order as above in the time range of 550-560 ms. The circled parts of the waveforms represent the peaks observed in the 400-410 ms and 550-560 time ranges. The direction of arrows indicates which topographies illustrate the peak.



Response-locked waveforms at FCz site for correct and incorrect responses in each of the three tasks as well as topographies in the time range of 50-60 ms are presented in Figure 6. The FCz site has been selected as a representative location for where the ERN component is typically reported.

Figure 6. Response-locked event-related potentials at electrode FCz and topographies in the time range of 50 – 60 ms (grand averages across 21 participants). Top row: ERP time course and topographies for correct (left topography) and error (right topography) trials in e-detection. Middle row: ERP time course and topographies for correct (left) and error (right) trials in Semantic discrimination. Bottom row: ERP time course and topographies for correct (left) and error (right) trials in Orthographic discrimination. Circled in the waveforms in the peak of interest (ERN) centered at approximately 50 ms.



For the ERN component, main effect of site was found significant, Greenhouse-Geisser correction $F(1.51, 20) = 43.0$, $p < 0.001$, but no main effect of task or response correctness, and no task by correctness by site interaction were observed (all *F*'s < 2.0, *n.s.*). Since a large negativity was observed at approximately 200 ms post-response with a visible difference between correct and incorrect responses, a post-hoc analysis of this N200 component was performed. The Greenhouse-Geisser correction test for main effect of site for the N200 component was found significant, $F(1.33, 20) = 41.25$, $p < 0.001$, as was the task by correctness by site interaction, $F(3.4, 20) = 4.48$, $p < 0.01$, but no main effect of task or response correctness, both *F*'s < 2.6, *n.s*. Further analysis for each individual site revealed no main effect of either task or correctness and no task by correctness interaction, all *F*'s < 3.6, *n.s.*

Another repeated measures general linear model was run in order to ensure that the number of epochs in each condition did not differ by task. Although main effect of task was not found to be significant ($F < 1.5$, *n.s.*), there was a significant task by correctness interaction, $\Lambda = 0.706$, approximate $F(4, 20) = 3.96$, $p < 0.05$ along with a significant main effect of correctness, $\Lambda = 0.281$, approximate $F(1, 20) = 51.1$, $p < 0.001$. While the latter effect is expected, since the majority of participants made correct responses much more often than incorrect ones, the presence of the interaction would throws doubt on the validity of the results were it not for the fact that none of the main effects of task were found significant in the previous tests. For the same reason, confidence ratings were not included as a factor in the present analyses, since the vast difference between the number of epochs included in the incorrect responses at high ratings and correct responses in low ratings would make any comparison between these contrasts invalid.

General Discussion

The results obtained in this experiment provide a replication of Experiments 1a and 2 described in Chapter 2. Once again it is suggested that participants are able to perform Semantic and Orthographic discrimination as well as e-detection at above chance levels on a 50 ms masked stimulus. Similar to the findings obtained in Experiment 2, correlations between confidence ratings and performance on the three tasks suggest that subjective report in the form of confidence ratings is a reliable measure of awareness that agrees with the results of objective measures tasks such as 2AFC discrimination tasks. Interestingly, the task with the closest to perfect correlation between percent correct choices obtained for each of the confidence ratings, was Orthographic discrimination. This task also yielded the best performance (74.6% correct). This is very similar to 74.3% correct obtained in Experiment 3 when the Orthographic task was performed first and was not preceded by the Identity task. This finding provides another piece of evidence that the similarity of Identity discrimination and Orthographic discrimination in conjunction with performing them one after the other, can influence the level of performance achieved on these tasks. It might be the case that the similarity between Semantic and Identity discrimination (both can be performed using meaning) influenced participants' performance in those experiments that employed both tasks.

Overall, it seems that the meaningful differences in the ERP data, if any, were too small to be detected. The only significant effect of potential importance was observed at the N200 component for the interaction between the three tasks, correct versus error trials, and the five midline electrode locations. However, this effect was not replicated for any of the sites when they were analyzed individually. Future experiments should focus on using more items at lower exposure durations, which is likely to provide a more even distribution of correct and error trials. More extensive statistical analyses aimed at inspecting the differences between correct and incorrect responses across confidence ratings for each task separately are necessary to fully understand the current data.

The lack of a significant difference in the ERN component between correct and incorrect responses might be due to insufficient trials on which subjects were incorrect (8-9 trials depending on task), or to other factors such as uncertainty or response conflict that can influence ERN amplitude and may have overshadowed any effect of correctness.. Although the ERP data are largely inconclusive, they do not go against these speculations and interpretations of behavioral results.

CHAPTER 5. GENERAL DISCUSSION

> Masking can be used to study consciousness by observing the breakdown of normal awareness when the temporal resolution of conscious perception is exceeded
> - Price, 2001, p. 57

Overall, the results of the research studies described herein show that one can extract various kinds of information from backward and forward masked words presented for 40 and 50 ms. These include: orthographic information that can be used in a letter-detection tasks as well as to successfully discriminate between two unrelated alternatives one of which is an orthographic neighbor of the masked word; conceptual information such as knowledge about semantic relationships (e.g., *river-ocean*) that can be used to make meaning-based discriminations but do not necessarily lead to semantic priming. Other researchers have shown that phonological information can also be obtained from masked words (Johnson & Forster, *in prep.*).

The results obtained in Experiments 1 through 7 of this dissertation are summarized in Table 15. These results suggest that following a 50 ms stimulus with a word mask has a similar effect as presenting that stimulus with a consonant mask for 40 ms. This supports the argument that primes are more difficult to see under the conditions of a masked priming paradigm where a prime stimulus is followed by a target that acts as a backward mask, as compared to stimulus visibility in 2AFC discrimination tasks. This means that the latter are more sensitive tests of both awareness and sensory activation produced by the masked stimulus.

Table 15. Mean accuracy rates (% correct) obtained in Experiments 1a through 7 (accuracy rates that do not differ significantly from chance are italicized).

Task	Experiment	Consonant mask		Word mask
		50 ms exposure	40 ms exposure	50 ms exposure
Identity discrimination	1a, 1b, 3, 5	62.4, 69.6, 66.0	*52.9*	57.0
Orthographic discrimination	3, 7	61.5, 74.1		
Semantic discrimination	1a, 1b, 2, 5, 6a, 6b, 7	62.1, 61.9, 66.5, 64.7, 67.3	53.7, 54.7	55.6
E-detection	1a, 1b, 2, 7	65.4, 67.2, 62.7, 65.8	55.1	*52.2*
Letter detection	4a (before)	57.4		
	4b (after)	61.2		

One of the most important questions raised in this dissertation, is whether the discrimination and detection tasks described in the previous chapters are measuring awareness, or else can tell us anything about the participants' levels of awareness at all. It seems that the answer to at least the second part of the question is yes. Particularly, the strong correlations between self-rating and performance observed in Experiments 2 and 7 suggest that subjective measures of awareness should not be discarded so readily, that there is useful information to be extracted from self-reports, and that perhaps researchers should devote more time into devising rating scales that could potentially separate different rating components such as item visibility and response confidence providing yet another clue about the nature of awareness.

The first part of the question, namely whether these tasks provide measures of awareness, is much more difficult to answer. First of all, Experiment 6, in which we failed to show semantic priming despite better than chance performance on the semantic discrimination task using the same items as primes in both tasks, could suggest that the level of awareness of the masked stimulus under the conditions in Experiment 6 (40 and 50 ms exposure durations) is enough to perform better than chance on the discrimination task but not to facilitate performance on the lexical decision task. Alternatively, this pattern of results might mean that both tasks are tests of priming, and the difference between the demands of the tasks is responsible for the failure to obtain the effect in lexical decision (i.e., participants might be more tuned to use semantic information in the discrimination task).

Furthermore, it might be the case that different strategies are being used in the two tasks. It is possible that in priming experiments where the task always involves some decision to be made about a visible target, and the existence of a prime is never emphasized, the prime's perception is indeed a product of automatic application of the task-related strategy to any visual stimulus. This is of course just what masked priming researchers are interested in. On the other hand, in discrimination and detection studies, when the participant's attention is directed to the masked word, the strategies for the identification or categorization of its various components (depending on the specific task) might be of a much more deliberate and therefore conscious nature. It is as if in 2AFC tasks participants are performing a task similar to those used in priming experiments on a target they can't readily see, rather than on a prime that is simply not followed by a specific target. Such a qualitative change in the way the prime is treated might be the reason why partial awareness of the components of the prime – where a participant is conscious of some of its aspects but not of others – becomes at all possible.

One explanation of the way priming works despite the identity of the prime not entering consciousness is that an episodic memory trace for the prime stimulus is never formed (Forster & Davis, 1984). Alternatively, it may be the case that a memory trace of the masked word is formed but its contents cannot not be brought into consciousness (Bodner & Masson, 2001). According to this account, a masked word creates a resource that can be recruited to aid word identification in a lexical decision task (Bodner & Masson, 2001). If behavior can be influenced without memory or consciousness, it shows in priming. For instance, Horner and Henson (2009) describe a repetition priming experiment where targets in a task are words that were previously presented in a different task. These authors argue that for a repetition priming effect to hold, it requires the primes to have been responded to in the same way (i.e., same valence and even same hand). However, if responses to prime and target are different, no repetition priming effect is observed (Horner & Henson, 2009).

This leads to the suggestion that priming might also be able to influence participants' behavior directly. Indeed, several authors have proposed a stimulus's direct influence on behavior in the form of a stimulus-response (S-R) binding as an alternative cause of priming. Specifically, in long-term rather than masked priming described by Horner and Henson (2009), the facilitation effect of seeing a stimulus again albeit in a different task can be attributed to the retrieval of direct links between the stimulus and the response associated with it that were formed during the first presentation of the stimulus.

This has been demonstrated by Dennis and Schmidt (2003) as well as by Schnyer et al. (2007) in classification tasks using long-term priming paradigms. In masked priming, some researchers such as Damian (2001) suggest that congruence effects are obtained only when there is a small response set, and the primes are included in that set having previously been presented multiple times as targets (Forster et al., 2003).

Similarly, Kiesel, Kunde and Hoffman (2006) argued that in "Is this number bigger than 5?" tasks unconscious number stimuli could lead to faster responses to target numbers by matching with predefined action trigger codes (i.e., when the prime stimulus has been previously associated with a specific response) rather than by semantic prime processing (i.e., when the prime is evaluated in terms of its meaning). Finally, using a negative-priming paradigm, Frings, Rothermund, and Wentura (2007) found shorter reaction times when distractors and responses repeated across trials. These findings all support the notion that priming might be in fact due to somewhat low-level S-R pairings rather than high-level perceptual processing.

However, in several experiments described by Neumann and Klotz (1994), where participants were presented with two kinds of squares and had to indicate by pressing a corresponding button on which side of the display the target square appeared, found that congruent prime stimuli consisting of smaller squares facilitated RT to target shapes (these also acted as masks) compared to neutral primes. These findings were interpreted as evidence for the formation of S-R mappings, which was also supported by the fact that in one of the experiments, the identity of the target square changed on every trial by a pre-trial cue. The priming effect described above only occurred when there was a lag of at least 250 ms between the pre-trial cue and the prime-target sequence. Taking this evidence into account, Neumann & Klotz (1994) suggested that this priming effect is not due to sensory processing of the prime facilitating the processing of the target, rather a direct effect on the motor system producing the participants' responses. This direct S-R mapping must however depend on the binding between the shape and location properties of the masked stimulus, which implies that some sensory information about the prime must be obtained and integrated for this effect on the motor processes to take place.

It is interesting to note that recent research in S-R learning failed to find evidence of such learning in amnesiac patients, despite their intact long-term priming (Schnyer, Dobbins, Nicholls, Schacter, & Verfaellie, 2006). Furthermore, findings that repetition decreases neuronal response in priming paradigms using fMRI (e.g., Dobbins, Schnyer, Verfaellie, & Schacter, 2004) has been attributed to S-R learning by some researchers (Horner & Henson, 2009). So the S-R and memory formation interpretations remain viable, although not unchallenged, and do not necessarily preclude the possibility that perceptual processing of a masked prime can occur leading to sensory activation. Given the results of Experiment 6 described in Chapter 3 of this dissertation, discrimination tasks can be considered more sensitive to such activation than priming experiments. Moreover, due to methodological differences, direct influences on behavior might be too crude to have considerable influence in these discrimination tasks.

Implications for Unconscious Processing

The most important evidence for the possibility of unconscious perception is the qualitative differences observed in priming effects when participants are aware of the prime versus when the primes are appropriately masked. Along with the Cheesman and Merikle's (1984) experiment described in Chapter 1 and experiments by Forster (2009) on the intervenor effect described in Chapter 3, a study reported by Marcel (1980) provides additional evidence for the possibility of dissociating between conscious and unconscious influences on visual perception. Marcel presented participants with three word stimuli, the first word either semantically related to one of the meanings of a polysemous middle word, or completely unrelated to it (e.g., *hand-palm-wrist*). The third word was always related to one of the meanings of the middle word. The participants' task was to perform lexical decision on the last word.

Marcel (1980) found that in the masked condition, semantic relatedness between the last and the middle word lead to reaction time facilitation compared to unrelated pairs, regardless of whether the context word was related to the third word or not (*hand-palm-wrist* and *tree-palm-wrist*). However, in the unmasked condition, facilitation only occurred when all three words were semantically related (*hand-palm-wrist*). This suggests that both meanings of the middle word are active in the masked condition, with the context word only able to inhibit one of the meanings if it reaches consciousness. This is in agreement with the proposal that different meanings can coexist in the unconscious semantic space, which was discussed in Chapter 3. To borrow terminology from quantum physics, the two meanings of an ambiguous word exist in superposition in the unconscious space, while in order to reach consciousness a collapse of a state vector has to occur, allowing only one meaning to be active at any given time.

Indeed, it might be that when one is aware of the stimulus, the information obtained from it is treated differently than information not yet available to consciousness. For example, once we become aware of certain information, it could be input into other cognitive systems to make non-automatic inferences, and might be automatically entered into working memory. This however is currently just a speculation, and future experiments are needed to help resolve this issue.

Interestingly, Price (2001) argues that in some instances, conscious awareness of the identity, or meaning, of a stimulus is in fact possible in the absence of awareness of its presence. He gives examples of some participants in his prime categorization studies in which they describe experiencing an after-image-like representation of the word, or even a mere concept of the stimulus, rather than a visual representation. That is, in such instances "the semantic content [is] divorced from its spatial and temporal location, and [is] instead attributed to an internally generated image" (Price, 2001, p. 36).

Such post-experimental accounts are not uncommon in most laboratories that use masking techniques, and although considered to be only good as anecdotal evidence, it is possible to draw some inferences about the validity of confidence reports in Experiments 2 and 7. Over the course of the experiment, participants might learn to trust these after-images or intuitions to their advantage (despite not being provided any feedback about their accuracy), which in turn might affect their confidence ratings. This adds another potential problem with interpreting confidence reports. Just as was speculated in Chapter 4 that at least some of the time, low ratings might result from participants realizing they have made an error, which would imply they had some awareness of the masked stimulus. This awareness, however, was for one reason or another not enough to lead to the correct response at the time it was made. As the experiment progresses and participants learn to trust and use the occasional after-image or spontaneous association that might have been effected by the primes, they may begin to select higher confidence ratings, despite the fact that the visibility of the primes hasn't changed.

Subjective measures of awareness are not the only ones prone to interpretation issues. The previous chapter mentioned an ERP experiment reported by Holcomb and colleagues (2005), in which participants sometimes responded to masked primes in a go-nogo semantic categorization task. The task was to respond only if an animal name was presented, and hence one would expect no response to a masked prime even though it was an animal name. However this was not the case. With a prime duration of 40 ms (but a long prime-target interval of 600 ms), on 18% of trials with a masked animal name as probe, subjects responded when they should not have. Holcomb et al. (2005) took this to mean that occasionally the prime was visible. However, when participants were classified according to how often they made such an error, there was no difference in the N400, whereas with a prime duration of 80 ms, there was a clear effect. If we assume that modulation of the N400 is a sign of conscious semantic processing of the prime, then the implication is that at 40 ms there was no conscious awareness of the prime, but at 80 ms there was.

Proponents of this argument would say that an overt response to a masked prime is possible without any conscious awareness. If we consider the literature on congruence effects in masked priming (Dehaene, Naccache, Le Clec'H, Koechlin, Mueller, Dehaene-Lambertz, van de Moortele, & Le Bihan, 1998; Forster, Mohan & Hector, 2003; Greenwald, Draine, & Abrams, 1996; among others), there is abundant evidence that an implicit response to a masked prime is generated, which can interfere with the response to the target. It is therefore possible that error responses in Holcomb's et al. experiment do not indicate awareness at all.

Turning to the memory literature, we find a similar phenomenon. Cleary and Greene (2000) report above chance performance in an "old/new" recognition memory task when the probe item is masked. Arndt, Lee, and Flora (2008) found similar results for stimuli that do not have pre-experimental representations (e.g., nonwords), providing evidence that representations underlying familiarity can mediate learning of novel stimuli, and therefore also strongly challenging episodic and existing representation theories of familiarity.

In order to establish the significance of this issue for priming, it would be necessary to determine whether participants who are better at e-detection also show more priming. Also, would the items used in the Semantic discrimination task produce semantic priming effects in a lexical decision task at the same exposure durations? Although better than chance individual performance in the semantic task shows that at 50 ms and even at 40 ms, semantic activation is occurring for some participants (but not for others), this activation might not be strong enough to produce priming in a lexical decision experiment. Such an experiment then would also address the question of whether 2AFC tests indeed measure activation (i.e., the amount of information gathered from the prime), or are in fact tests of priming. For example, in the current experiments, participants may be completely unable to decide which alternative matches the prime (hence, their subjective conviction that they are guessing), but because the correct alternative seems more familiar (as a result of priming), it is chosen, not because subjects believe that they saw this word, but because it seems a more attractive option. Thus, the effect produced by an unconscious perception of the prime would be taken as evidence for partial awareness.

An alternative explanation of why participants are unable to identify the prime in masked priming experiments with very short exposure durations is that despite activation of all the prime's properties taking place, there might be insufficient time for the activation generated in different information modalities (e.g., form, phonology, semantics) to bind together to produce a complete conscious experience of the masked word. Longer prime durations might not only allow for the integration of different kinds of information about the stimulus into a conscious experience of it, they might qualitatively change the variety and nature of that information. It might then be the case that at shorter prime durations, information available to the participant becomes more selective, even task-dependent. This is consistent with the results reported by Shen and Forster (1999), who argued that phonological information extracted from the prime was relevant for priming in a naming task, but not lexical decision. These tasks are commonly designed using 50 ms exposures, at which participants in Experiment 1 and 3 seem to be able to pick up some general information about the masked word (as suggested by the cross-task correlations). Taking this suggestion into account, it becomes possible to explain the lack of cross-task correlations at 40 ms in terms of the amount of information participants are able to obtain from masked words at that duration. This information seems to be enough for some individuals' better than chance performance on one or more of the three tasks, but it is so limited that it becomes task specific rather than general. Indeed, despite a certain amount of flexibility in the processing of masked stimuli, it seems that in general researchers tend to agree that ongoing unconscious processing is indeed confined to specialized modules and is not globally available (Baars, 1997; Merikle & Daneman, 1998) or "accessible to behavioral response systems in a truly flexible manner" (Price, 2001).

The findings obtained in the current experiments are consistent with the idea that binding of information is necessary for conscious experience. They also suggest that although some participants might be more sensitive to meaningful rather than orthographic information, which could lead to higher confidence ratings when only semantic information is available as opposed to cases where only visual information is available, as a group, participants are slightly better at gathering visual information (as suggested by higher % correct in e-detection in all 3 experiments). So perhaps, it is not being more aware of a prime that allows an individual to extract semantic information, rather it is having semantic information that leads to a stronger sense of conscious awareness, thus producing higher confidence ratings. This agrees with the binding argument, which is supported by the presence of subject correlations at 50 ms exposure durations, but not at 40 ms when participants are only able to extract task-relevant information. In the end, one still needs different information domains to come together for the individual to consciously experience and fully identify the prime, but even though visual information is more readily available (we are dealing with visual presentations after all), information about meaning plays a more important role in triggering awareness, maybe because we are used to interpreting the world and thinking about the meaning of objects in it, rather than in terms of their components. This might be the reason why semantic activation is thought to require conscious awareness, since the two are usually observed together, while it might be the case that the former actually brings about the latter.

This view is supported by several researchers, all of whom suggest that “the influence of nonconscious information is greater when subjects are not consciously thinking about which response to make” (Price, 2001, p. 43). For instance, Marcel (1983a,b) found that when participants were at chance on presence-absence detection, they were above chance on semantic discrimination only when they adopted a passive response strategy. This is similar to what was described by Price (1991), where his participants were above chance on semantic categorization of masked words only on trial blocks for which they rated their responses as more spontaneous. Similarly, Dixon (1981) and Snodgrass, Shevrin & Kopka (1993) also argued that passively letting answers pop spontaneously into one’s head is conductive to nonconscious processing rather than trying to scrutinize the display for any relevant (yet often irrelevant) cues. In fact, Snodgrass et al. (1993) specifically instructed some of their participants to just let the answers pop into their head in a four-alternative forced choice identification task. Those who followed the instructions performed significantly better than chance, while the performance of those who preferred the active strategy was below chance.

Armed with this evidence and the line of reasoning it supports, Price (2001) also speculates on a possible explanation of why performance on detection is often worse than that on forced-choice discrimination tasks at short exposure durations. He suggests that this might be because the former is generally considered to be easier with very little information needed in order to perceive the presence of a stimulus, so participants are less likely to give up an active strategy and use a passive one in this task (Price, 2001). This change in strategy indeed seems more likely in a seemingly more difficult task of discrimination, where participants are more likely to consciously thinking about the evidence for one of the alternatives.

By extension, one might find similarities with a study reported by Frank, O'Reilly, and Curran (2006), in which participants given a benzodiazepene drug midazolam performed better in a transitive inference paradigm when making implicit inferences was advantageous compared to participants who were given a placebo. Midazolam has been shown to disrupting hippocampal function and is therefore associated with producing explicit memory deficits (Frank et al. 2006). Could this be that participants who are able to adopt a passive mode of response in the discrimination tasks are “turning off” their explicit strategy system at will in favor of letting the implicit one rule? Although rather far from mainstream, this explanation seems quite likely.

Finally, one can look at these results in terms of the hypotheses for the sequencing of lexical access in word recognition. Kouider & Dehaene (2007) note that one hypothesis (Greenwald, 1992) is for a two-staged model, with a distinct limit between the first unconscious stage and the following conscious, strategizing stage. They compare this to a more dynamic model, in which “there is no fixed limit between conscious and non-conscious processing but, rather, subjects at any given moment can attend to one of the several (though not necessarily all) levels of representation and bring the corresponding information into consciousness” (Kouider & Dehaene, 2007). Given the results obtained in these experiments, the dynamic model seems more likely.

Relevance to Existing Theories of Masking

Both Marcel’s (1983b) and Bachmann’s (1984) theories of masking are similar to the binding argument in that they each employ some kind of interaction or coming together of different systems in order to achieve the conscious experience. In Marcel’s theory, it is the binding of perceptual information with spatio-temporal information that leads to a conscious experience of a stimulus. In Bachmann’s perceptual retouch theory it is the coming together of the modality specific perceptual information with the stimulus-driven phasic arousal that is of importance for phenomenology of awareness. Furthermore, the global neuronal workspace theory proposed by Dehaene, Kerszberg, and Changeux (1998) is very similar to the binding hypothesis offered here, except the latter does not depend on attention as heavily as does the former theory, while specifically addressing masking effects.

The binding account can be further compared with Marcel's theory if viewed from the point of view of memory. In Marcel's (1983b) recovery theory, if a memory trace about having seen a stimulus is unavailable to the individual, all the other information is insufficient to creating a conscious experience of the stimulus. In this theory, masking erases the memory trace. In the binding account, such a memory trace does not have time to occur, since masking prevents the immediate sensory memory from keeping the stimulus available longer than its exposure duration. This is not to be confused with claims that a mask disrupts the processing of the stimulus, with all the processing that does occur being equal to the exposure duration. In the binding account, processing continues after the stimulus has been replaced by the mask, with the latter only affecting the information about the former's spatio-temporal location.

It is of importance that a particular aspect of a stimulus should not be deemed important for consciousness simply because its perception is prevented by masking (Price, 2001). On the contrary, showing that a particular aspect of information about a stimulus is perceived despite masking, can help eliminate it as a sufficient condition for consciousness. According to this viewpoint, neither high resolution visual information such as letter detection, nor semantic information about a masked stimulus are sufficient for a full conscious experience of the stimuli, since better than chance performance on discrimination as well as letter detection tasks was obtained even when participants were not perfectly confident of their responses. This account is in agreement with the idea that binding of all the perceptual elements about a stimulus needs to occur in order it to be consciously perceived.

Furthermore, masking does not seem to prevent the process of informational binding simply due to a decreased activation strength produced by the stimulus. This notion is illustrated by Marcel (1983a), who showed that presenting the prime-mask sequence several times in a row before semantically related targets increased the priming effect without affecting the subjective level of awareness.

Concluding Remarks

The author realizes that just like the vast majority of consciousness researchers, the approach employed in this dissertation aims to understand what consciousness is by attempting to identify what it is not. Such an approach is obviously not a perfect one. As many philosophers have postulated, consciousness might be a much more global phenomenon than stimulus awareness or even phenomenological awareness, with these types of awareness simply being different sides of a very large iceberg. If philosophers are correct, even processes deemed unnecessary or insufficient for consciousness by masking studies could turn out to be a part of a complex dynamic network of cognitive and neural manifestations that might require non-linear integration in order to produce consciousness. Or perhaps, even in a less orthodox view, consciousness itself may be producing these only seemingly discrete and modular cognitive functions and cortical specializations.

Although this dissertation clearly raises more questions than it answers with its small contribution of empirical data to the field of visual awareness and masking, this is an inevitable price to pay for the joy and excitement of exploring a new and scarcely inhabited territory.

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