Unconscious Processing at the Subjective Threshold - Semantic Comprehension?

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Statement

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Anna-Marie Armstrong
10th September 2013

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Summary

Our thoughts and behaviours can sometimes be influenced by stimuli that we are not consciously aware of having seen. For example, the presentation of a word that is blocked from entering conscious visual perception through masking can subsequently influence the cognitive processing of a further target word. However, the idea that unconscious cognition is sophisticated enough to process the semantic meaning of subliminal stimuli is controversial. This thesis attempts to explore the extent of subliminal priming. Empirical research centering on subjective methods of measuring conscious knowledge is presented in a series of three articles.

The first article investigates the subliminal priming of negation. A series of experiments demonstrates that unconscious processing can accurately discriminate between two nouns beyond chance performance when subliminally instructed to either pick or not pick a given noun. This article demonstrates not only semantic processing of the instructional word, but also unconscious cognitive control by following a two-word subliminal instruction to not choose the primed noun. The second article investigates subliminal priming of active versus passive verb voice by presenting a prime sentence denoting one of two characters as either active or passive and asking which of two pictorial representations best matches the prime. The series of experiments demonstrates that overall, participants were able to identify the correct image for both active and passive conditions beyond chance expectations. This article suggests that individuals are able to process the meaning of word combinations that they are not aware of seeing. The third article attempts to determine whether subliminal processing is sophisticated enough to allow for the activation of specific anxieties relating to relationships. Whilst the findings reveal a small subliminal priming effect on generalised anxiety, the evidence regarding the subliminal priming of very specific anxieties is insensitive. The unconscious is shown in these experiments to be more powerful than previously supposed in terms of the fine grained processing of the semantics of word combinations, though not yet in terms of the fine grained resolution of emotional priming.

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1. Introduction and Overview

1.1. A Brief History of Subliminal Priming

The idea that the thoughts and behaviours of an individual can be influenced by information presented outside of conscious awareness dates back centuries (Smith, 2011), with early Greek history demonstrating the use of subliminal messaging as a method of manipulation and persuasion. In the late nineteenth century, Peirce and Jastrow (1884) are believed to have provided the first empirical study relating to unconscious perception (Kihlstrom, Barnhardt, & Tataryn, 1992). In their experiment, in which they themselves were the participants, they attempted to distinguish the greater pressure of two barely discernible stimuli placed on the skin whilst reporting subjective confidence in their decisions. Their results indicated that they were able to successfully discriminate between the two pressures, at above chance performance, despite subjectively being unaware of any difference between the stimuli. Similarly, Sidis (1898) demonstrated the above chance ability of participants to reliably distinguish between letters and numbers at a distance at which the participants believed themselves to be guessing.

At the beginning of the twentieth century, Dunlap (1900) investigated subliminal perception using the Müller-Lyer illusion. The Müller-Lyer illusion is a well-known effect in which the judgments of line length are influenced depending on the direction of the arrow heads at the ends of the lines. That is, lines that end in ‘tails’ (i.e., > <) are judged to be longer than lines of equal length ending with ‘heads’ (i.e., < >). The participants in Dunlap’s study were required to judge the length of lines in which the arrow heads were formed from imperceptible shadows. Despite not being

consciously aware of the shadows, participants nevertheless reliably rated lines with ‘tails’ to be longer than those with ‘heads’. This subliminal Müller-Lyer illusion effect demonstrated by Dunlap later contributed to Hollingworth (1913) concluding that subliminal messaging would be a valuable tool to utilise within the field of advertising (Pratkanis, 1992).

Subliminal perception attracted considerable public attention and interest in 1957 when market researcher James Vicary claimed to have successfully used subliminal advertising in a Fort Lee, New Jersey, movie theatre (Weinberger & Westen, 2008). By using a tachistoscope, a device that allows for the very brief presentation of stimuli, Vicary proclaimed to have interspersed the messages ‘Drink Coca Cola’ and ‘Eat Popcorn’ into the showing of the film *Picnic* over a period of six weeks. Every five seconds, one of the two primes was presented onto the screen for approximately one third of a millisecond, thereby bypassing conscious perception of the message (Karremans, Stroebe, & Claus, 2006). Vicary claimed that these subliminal primes resulted in an approximate 57% increase in popcorn sales, and a Coke sales increase of approximately 18%.

Despite Vicary later admitting to having fabricated the results of his study (Pratkanis, 1992), public belief in the power of subliminal suggestion and subliminal advertising persisted. In the 1970’s, Key (1973) released a book entitled ‘Subliminal Seduction: Ad Media’s Manipulation of a not so Innocent America’ in which he presented a number of film and print advertisements that he believed contained subliminal messages in the form of sexual imagery and words. In 1978, following a national manhunt for the so called ‘blind, torture, kill’ killer in the United States, a Kansas television station inserted subliminal messages such as ‘Now call the chief’ into a news broadcast in the belief that it would persuade the relevant individual to contact

the police (Moore, 1982). In the same year, in an attempt to prevent shop lifting and theft, a number of Toronto department stores began to broadcast subliminal auditory messages into the shop itself. Similarly, a Seattle radio station attempted to increase its listening figures by broadcasting the subliminal auditory message 'TV's a bore' (Moore, 1982).

In 1985, the suicide of two teenagers in Nevada was blamed on the subliminally backmasked auditory message 'do it' in a song by the British heavy metal band Judas Priest (Loftus & Klinger, 1992). Backmasking of auditory words is achieved by reversing the sound, so that only when it is played backwards is it consciously perceived (Jones, 1991). Such was the fear surrounding the issue of subliminal priming, due to this and similar cases, that United States legislature lead to the necessity of placing warning labels on records and tapes sold in the state of Nevada (Thorne & Himelstein, 1984; Vokey & Read, 1985). Whilst in certain countries such as the United Kingdom and Australia the use of subliminal priming in an advertising context has been made illegal, the Federal Communications Commission in the United States has retained the right to revoke the broadcasting license of any company if they are found to be surreptitiously using subliminal messages (Bermeitinger et al., 2009).

In 1990, there were approximately 2,000 companies in the United States and Canada producing subliminal self-help audiotapes (Oldenburg, 1990). These tapes contained subliminal auditory messages that were designed to help with a variety of personal issues including weight loss, smoking cessation, self-confidence, memory, addiction, and mental health issues. Despite a definitive lack of empirical support for the effectiveness of these subliminal self-help aids (e.g., Greenwald, Spangenberg, Pratkanis, & Eskenazi, 1991; Merikle & Skanes, 1992), sales of subliminal message tapes in the United States reached an estimated fifty million dollars in 1987 alone

(Natale, 1988). However, despite public conceptions of subliminal priming and its effectiveness, just how much information and knowledge can be acquired through subliminal perception, or just how intelligent unconscious cognitive processing is, remains a controversial topic throughout psychological and empirical research (Greenwald, 1992).

1.2. Evidence Demonstrating the Comprehension of Subliminal Stimuli

Within the field of psychology, the intellectual capabilities of unconscious cognition and the extent of subliminal (i.e., below the limen of conscious perception, Kouider & Dehaene, 2007) processing is a familiar and often controversial theme (Greenwald, 1992; Van den Bussche, Van den Noortgate, & Reynvoet, 2009). Loftus and Klinger (1992) propose that the unconscious comprehension of subliminally presented letters would arguably demonstrate a more intelligent interpretation of unconscious processing than would the unconscious analysis of simple lines and angles. Similarly, the semantic comprehension of a single word would indicate a yet more sophisticated version of unconscious cognition, whilst the semantic and syntactic analysis of subliminally presented multiple word strings, or sentences, should certainly demonstrate an 'intelligent' unconscious.

In a typical subliminal priming experiment, a fixation point is followed by a prime stimulus that is presented for a brief duration of time and is prevented from entering conscious perception through the use of either a forward or backward mask (see Figure 1 for an example of the typical trial procedure used) (Carr & Dagenbach, 1990). This mask is typically in the form of either a pattern mask (i.e., a distribution of target fragments, random letters, or symbols), or noise mask (i.e., a mask composed of a set of random dots or squares) (Delord, 1998). The mask thus renders the prime

unconscious by interfering with conscious visual processing and analysis of the prime. However, other methods of masking such as contrast masking and continuous flash suppression involve the simultaneous presentation of prime and mask. Contrast masking interferes with conscious visual perception by presenting the stimulus at a subtly differing contrast level to the prime background (Lamy, Mudrik, & Deouell, 2008). Alternatively, continuous flash suppression involves the presentation of a rapidly changing stimulus to one eye in order to prevent the conscious perception of a further static stimulus presented to the other eye (Tsuchiya & Koch, 2005). However the prime is masked, when subsequently presented with a test stimulus or task, subliminal priming is assumed to have been successful if the prime effects either the processing of the test stimulus or task performance (Johnston & Dark, 1986).

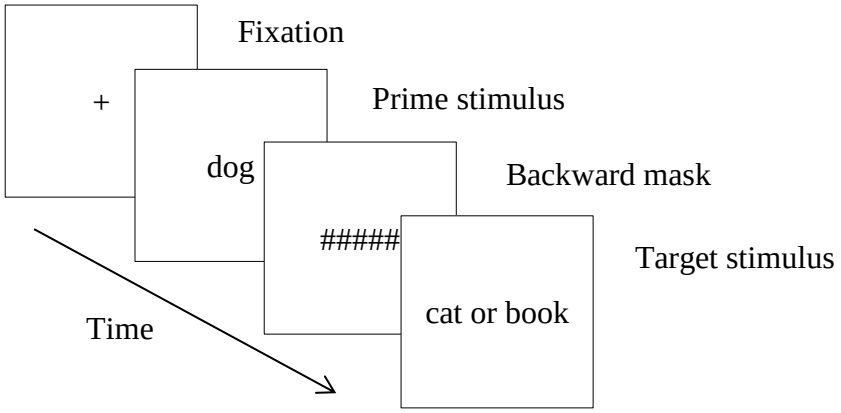

Figure 1: An example of the procedure used in a typical subliminal priming experiment.

An example of this priming effect can be seen when a subliminally presented word (e.g., dog) either accelerates the processing of a semantically related target item (e.g., cat), termed positive priming (e.g., Carr & Dagenbach, 1990; Dell'Acqua & Grainger, 1999; Draine & Greenwald, 1998; Greenwald, Klinger & Liu, 1989), or inhibits the processing of the test stimulus, termed negative priming (e.g., Abad, Noguera, & Ortells, 2003). One theory that attempts to explain the effect evidenced in

positive priming experiments is that of the spreading activation phenomenon (Collins & Loftus, 1975; Kiesel, Kunde, & Hoffmann, 2007; Klinger, Burton, & Pitts 2000). This theory suggests that conceptually and semantically related items within the mental lexicon, termed nodes, are stored together within an interconnected network (Marcel, 1983a; Neely, 1977, 1991). The presentation of a subliminal prime thus activates its representation within the network, with this activation subsequently spreading to its associated and interconnected nodes. This lexical activation consequently allows semantically related items to be processed more quickly, leading to an accelerated response.

1.2.1. Subliminal Priming of Single Words

Cognitive and neuropsychological research provides a wealth of evidence demonstrating the subliminal processing of single words. An example of the procedure adopted by a typical positive priming experiment demonstrating semantic processing of subliminal words is provided by Marcel (1983b). Marcel first briefly presented participants with either a word or a blank field followed immediately by a pattern mask. The participants were then required to judge whether or not a word had been presented. After each presence-absence judgment, the stimulus onset asynchrony (SOA – the time interval between the onset of one stimulus to the onset of the next) was reduced. Subliminality was measured by the point at which the participant reached an SOA at which they began to make judgment errors, at which point the threshold setting stage moved on to the experimental phase. This phase required the participant to make one of three separate judgments after each trial; 1) whether a word was presented or not, 2) which of two subsequent words shared a graphical similarity with the prime, or 3) which of two further words shared a semantic similarity with the prime. The results suggested that despite being unable to detect the presence of a word, participants were

nevertheless able to make correct judgments on graphic and semantic similarity. Correct responses as to whether or not a word was presented, or which of the two subsequent words were graphically similar to the one presented, need not necessarily have required a semantic interpretation of the subliminal prime. All that was necessary for these tasks to be successfully completed was for the participant to have been aware that 'something' was presented, and for simple recognition processes to map the overall shape of the prime to the overall shape of one of the two subsequently presented words. However, for a participant to have correctly inferred semantic similarity, a level of semantic activation of the subliminal prime to its associated nodes is presumed to have occurred.

Similarly, Ortells, Daza, and Fox (2003) demonstrated successful semantic activation by presenting participants with a set of subliminal primes that were either a body part (e.g., hand) or animal (e.g., cow). Participants were then required to categorise a set of target words that were also either body part or animal. On 20% of the trials, prime-target pairs were congruent (e.g., hand-finger; cow-bull), whilst on 80% of occasions, prime-target pairs were incongruent (e.g., hand-bull; cow-finger). The results indicated a congruency effect in that participants were significantly quicker to categorise targets when the prime-target relationship was congruent. Therefore, the presentation of a word outside of conscious awareness accelerated access to semantically and categorically related items within the mental lexicon, as explained by the spreading activation network.

Neuropsychological research provides further evidence demonstrating the successful analysis and semantic comprehension of single-word subliminal primes (Lau & Passingham, 2007). For example, Dehaene et al., (2001) used functional magnetic resonance imaging (fMRI) to demonstrate that masked words led to an activation of

brain areas that were not activated for masked blank intervals of the same duration. Similarly using fMRI, Diaz and McCarthy (2007) went further to demonstrate that unconscious backward masked words activated left hemisphere cerebral areas of the brain that are typically associated with language comprehension and conscious reading. In their experiment, participants were required to take part in a lexical decision task in which they had to decide whether a visible letter string was a word or non-word, having been subliminally primed with a semantically related word, unrelated word, or pronounceable non-word. As well as the expected results in terms of semantically related primes leading to an accelerated categorisation response, the results indicated that areas of the brain associated with conscious reading, including the inferior frontal gyrus, the angular gyrus, and posterior regions of the lateral temporal cortex, were activated during the presentation of a masked word in contrast to subliminal backward masked non-word letter strings which failed to produce any measurable activation. The authors conclude that the pattern of brain activation evidenced likely represents the neural correlates involved in the spreading semantic activation phenomenon.

1.2.2. Subliminal Priming of Pictures

A simple demonstration of subliminal priming using pictures is provided by Mandler, Nakamura, and Van Zandt (1987). Mandler and colleagues briefly presented participants with a series of irregular geometric octagons for a period of two milliseconds using a tachistoscope. When participants were subsequently presented with a series of novel and primed shapes and were asked to rate the shapes on the basis of preference, participants consistently rated the subliminally primed shapes as being both brighter and more likeable than the new, novel shapes. This effect relates to the mere exposure effect established by Zajonc (1968), which proposes that an individual's

attitude towards a stimulus object can be enhanced merely through its repeated exposure (Kunst-Wilson & Zajonc, 1980; Zajonc, 2001).

Cooper and Cooper (2002) placed twelve images of a Coca Cola can as well as twelve instances of the word 'thirsty' into an eighteen minute episode of '*The Simpsons*'. An experimental group viewed the altered version of the programme whilst a control group watched the original, unaltered, version of the same episode. Their results indicated that post-experimental thirst ratings differed significantly from pre-experimental ratings for the experimental group, but not for the control group, a result supported by Strahan, Spencer, and Zanna (2002). Whilst it is difficult to separate the individual contributions of the pictorial and textual stimuli in this experiment, Bar and Biederman (1998) subliminally presented participants with a series of line drawings of objects such as tools and means of transport and required the participant to name the object. Their results suggested that when subliminally presented again a short time later, naming accuracy increased by approximately 34%.

Whilst these studies demonstrate the ability to produce successful affective and behavioural priming from subliminally presented pictures and images, these studies fail to adequately demonstrate semantic activation from pictorial stimuli. However, Dell'Acqua and Grainger (1999) subliminally presented participants with a series of line drawings depicting concrete concepts from either artifactual (e.g., tools, vehicles) or natural (e.g., animals, vegetables) categories. When subsequently presented with a target word, participants were required to categorise the target as either artifactual or natural. The results indicated that participants were significantly faster to categorise the target when target and picture-prime were semantically congruent. Hermans, Spruyt, De Houwer, and Eelen (2003) similarly demonstrated this facilitation of semantic information through the use of prime-target congruency using subliminal real-life

pictures rather than drawings. Dell'Acqua and Grainger (1999) argue that due to the inability to derive phonological form from an image, successful subliminal priming from pictures indicates that sufficient semantic information must be unconsciously extracted from the image to activate associated semantic representations.

1.2.3. Subliminal Priming of Emotion

The subliminal priming of anxiety is one such area regarding emotion that has been heavily researched in psychological literature (Fox, 1996). Anxiety, an unpleasant psychological emotion, often leads to the development of cognitive biases that aid in the identification of potential threats (Mathews & MacLeod, 1985). These cognitive biases involve the rapid detection of, and diversion of attention to, threat related stimuli and often inhibit the processing of less vital information. This effect is often demonstrated by the use of the Emotional Stroop paradigm (Mathews, Mackintosh, & Fulcher, 1997). The Emotional Stroop paradigm uses emotive and neutral words and presents them in different ink colours. The participant is then required to ignore the word and respond with the ink colour. It is proposed that the anxiety experienced upon presentation of the emotive words prevents cognitive resources from quickly processing the ink colour, as research has consistently demonstrated that individuals high in anxiety are slower to respond to the ink colour of threatening and unpleasant words when compared to neutral words (Becker, Rinck, Margraf, & Roth, 2001; De Ruiter & Brosschot, 1994; Williams, Mathews, & MacLeod, 1996). Perhaps more interestingly, this cognitive bias effect towards anxiety inducing words is similarly evidenced in unconscious Emotional Stroop tasks in which the threatening stimuli is presented outside of conscious awareness (Fox, 1996; MacLeod & Hagan, 1992; Manguno-Mire, Constans, & Geer, 2005; Mogg, Bradley, Millar, & White, 1995; Mogg, Bradley, Wiiliams, & Matthews, 1993; Öhman, 1999; Li, Zinbarg & Paller, 2007; Van Honk, Peper, & Schutter, 2005).

Soares and Öhman (1993) and Öhman and Soares (1994) subliminally primed a group of fearful (i.e., spider or snake phobic) and non-fearful (i.e., control) participants with pictures of snakes, spiders, flowers and mushrooms. The skin conductance responses (SCRs) from fearful participants to spider and snake pictures demonstrated higher anxiety levels when compared to either neutral pictures or the SCRs from the control group. Tyrer, Lewis, and Lee (1978) subliminally or supraliminally presented groups of participants with a series of negatively valenced words such as 'cancer', 'death', and 'coffin' either whilst also presenting neutral words such as 'shelf' and 'brick' with a tachistoscope, or by embedding the words within a short film. Current ratings of anxiety taken both pre- and post-experimentally demonstrated an increase in anxiety levels for both subliminal and supraliminal priming conditions, a result supported by Kemp-Wheeler and Hill (1987). However, due to the lack of a control group in either of the two experiments conducted by Tyrer et al., it is unclear whether to attribute any increase in subjective anxiety to experimental manipulation or to experimental artefact.

Robles, Smith, Carver, and Wellens (1987) attempted to address this issue with the inclusion of a control group in an effort to determine whether subliminal stimuli could influence subjective mood ratings. Robles et al. embedded pictorial images into a two minute video of a woman walking through a forest. For the positive condition, these images were static pictures of smiling cartoon characters, and for the negative condition, the images consisted of violent stills from well-known horror films. For the control, or neutral, condition, the images inserted were of grey and featureless backgrounds. Immediately after the short film, the participants were required to complete a subjective anxiety measure. The results indicated that post-experimental anxiety ratings were

highest for those participants in the negative condition, and lowest for those in the positive condition.

In addition to the subliminal priming and activation of anxiety, research has demonstrated the successful subliminal activation of further emotional concepts such as fear (Lee, Kang, Lee, Namkoong, & An, 2011), sexual arousal (Gillath, Mikulincer, Birnbaum, & Shaver, 2007), disgust (Neumann & Lozo, 2012), and guilt (Zemack-Rugar, Bettman, & Fitzsimons, 2007). For example, Bargh and Pietromonaco (1982) subliminally exposed their participants to a series of words that related to the emotional concept of hostility, such as 'insult' and 'inconsiderate'. When compared to those exposed to fewer hostility related items, those participants in the high exposure conditions consequently reliably rated the ambiguous behaviours of a target individual as more hostile and aggressive.

The amygdala, an area of the brain located in the medial temporal lobes, has long been associated with the regulation of emotion (Sergerie, Chochol, & Armony, 2008). In addition to emotion regulation, the amygdala is increasingly believed to be vital in cognitively processing and evaluating the emotional content of incoming information (Gallagher & Chiba, 1996). In support of this, event-related potential (ERP) and fMRI studies have consistently demonstrated an increase in amygdala activation in response to the presentation of both supraliminal and subliminal emotive stimuli (Brooks et al., 2012; Morris, Öhman, & Dolan, 1998; Stenberg, Lindgren, Johansson, Olsson, & Rosén, 2000; Whalen et al., 1998). For example, Williams et al., (2006) subliminally and supraliminally primed participants with a series of faces depicting either fearful or neutral expressions. Functional neuroimaging results indicated an increase in activation of the amygdala in response to fearful stimuli in both subliminal and supraliminal conditions. More interestingly, Naccache et al. (2005) demonstrated a

similar result using emotive words as opposed to images. In their study, intracranial electrodes measured brain potentials from the amygdala whilst participants were subliminally primed with either negatively valenced (e.g., ‘danger’ and ‘kill’) or neutral (e.g., ‘cousin’ and ‘see’) words. The results demonstrated a pattern of amygdala activation in response to negatively valenced words that was similar to the activation evidenced in the conscious processing of emotive stimuli, providing further support for the semantic comprehension of subliminal stimuli.

1.2.4. Subliminal Priming of Arithmetic Computations

Naccache and Dehaene (2001) have argued that the majority of subliminal perception studies have tended to focus on the ability of unconscious cognition to derive semantic content from subliminal stimuli, whilst ignoring the possibility of conducting manipulations on subliminal stimuli outside of conscious awareness. However, in addition to words, pictures, and emotive stimuli, many subliminal priming studies have been used to demonstrate that numbers and arithmetic computations can also be processed and semantically categorised outside of conscious awareness. As a simple demonstration of the comprehension of numbers and number order, Dehaene et al. (1998) subliminally presented participants with a number between 1 and 9. When subsequently presented with a target number, participants were required to indicate with a left or right hand key press whether the target number was bigger or smaller than the figure 5. Reaction times indicated that participants were significantly quicker to classify the target number when the trials were congruent (i.e., subliminal prime and target both above or below 5) compared to incongruent (i.e., subliminal prime and target on opposite sides of 5). Furthermore, fMRI results indicated that the subliminal presentation of a number led to the left or right activation of the motor cortex corresponding to the hand that would indicate whether the subliminal prime number

was bigger or smaller than 5. For the incongruent trials, the authors argue that this initiation of a motor response corresponding to the primed number leads to a reaction time delay as the initial reaction needs to be inhibited. Whilst this study indicates the possibility that unconscious processing is able to comprehend the simple meaning of numbers and numerical order, further research suggests that unconscious processing is actually capable of completing some rather complex mathematical computations (Ric & Muller, 2012; Rusconi, Priftis, Rusconi, & Umiltà, 2006; Sklar & Hassin, 2011).

García-Orza, Damas-López, Matas, and Rodríguez (2009) investigated whether single digit multiplications could be computed unconsciously. In their study, participants were required to name aloud a visibly presented target numeral that appeared on a computer screen (e.g., '6'). Before the number appeared, participants were subliminally presented with a congruent or incongruent number prime (e.g., congruent with the target, '6', or incongruent with the target, '32'), or multiplication prime (congruent with the target, '2 × 3 = ', or incongruent with the target, '4 × 8 ='). When reaction times to number naming were compared for number and multiplication primes, the results suggested that participants were significantly faster to name the number when preceded by a number prime. This delay in response times suggests that multiplication primes are somehow analysed differently to number primes, but does not in itself demonstrate unconscious arithmetic. The time delay evidenced may instead be attributable to prime length differences or number versus symbol priming. However, support for unconscious single digit multiplications comes from the congruency results, which indicated that incongruent multiplication primes resulted in slower number naming latencies when compared to congruent trials.

Using continuous flash suppression that allows for the presentation of subliminal stimuli to reach presentation durations of up to 2 seconds, Sklar et al. (2012)

presented participants with a series or 3 digit arithmetic subtraction or addition equations (e.g., “9 - 3 - 4 =” or “3 + 2 + 4 =”). Participants were then required to read aloud a target number that either equalled the prime equation (i.e., congruent condition), or disagreed with the equation (i.e., incongruent condition). The results demonstrated a significant priming effect of congruency in the subtraction condition, indicating that participants were significantly quicker to name the number when it solved the primed equation. Interestingly, this priming effect was not evidenced in conditions whereby addition was the mathematical operation. The authors attributed this lack of a priming effect to a number of plausible explanations. Firstly, computing the solution to an addition equation is arguably easier, and thereby quicker, than for a subtraction equation. Therefore, the solution to an addition equation may have already decayed by the time the target appears, thereby eliminating any priming effects. The second explanation is based on research demonstrating that individuals often undertake numerous (and often unnecessary) parallel unconscious computations when presented with an easy, as opposed to difficult, mathematical task (e.g., Sackur & Dehaene, 2009). As a result, when primed with an addition equation, it is possible that participants conducted a number of unnecessary cognitive tasks which left fewer cognitive resources available to finding a solution to the equation. In support of this explanation, Sklar et al. conducted a further experiment which prevented participants from performing any unnecessary computations, which subsequently resulted in a positive priming effect for addition equations. Whilst not strictly addressing linguistic semantics, these studies do suggest an intelligent and sophisticated version of unconscious cognition capable of comprehending numerical order and mathematical operations.

1.2.5. Subliminal Priming of Multiple Words

In regards to semantic activation, Greenwald (1992) provided a comprehensive account on the abilities of unconscious cognition and issued a challenge relating to the subliminal processing of multiple word primes. This challenge asserted that in order to claim successful processing of multiple word stimuli, each word needs to be processed in unison, and that none of the individual words should independently impart sentence-level meaning. Greenwald and Liu (1985) attempted to meet this challenge by subliminally priming participants with two-word primes. In their first experiment, participants were required to evaluate a series of singular primes on the basis of their positive or negative valence. Their results indicated a positive priming effect, indicating semantic interpretation of the subliminal prime. In their follow up study, the same participants were then presented with a series of two-word primes (created from the earlier singular primes) that were designed to be of individually congruent valence with each other, but combine to create a prime of opposite valence. For example, the two words "enemy" and "fails" are of singularly negative valence. Yet when combined, "enemy-fails" becomes evaluatively positive. Whilst successful evaluation of "enemy-fails" as positive would provide evidence demonstrating the semantic analysis of sentence level meaning, the results indicated that subliminal priming was instead determined by individual word valence alone, leading the authors to conclude against the possible subliminal priming of multiple words.

However, further research investigating the subliminal priming of sentences has been more successful. The majority of studies successfully demonstrating the unconscious processing of multiple-word strings or sentences involve a method of priming termed subliminal psychodynamic activation (SPA). SPA involves the activation of psychopathological internal conflict relating to psychoanalytic theory

using subliminal stimuli (Silverman, 1983). For example, Silverman Ross, Adler, and Lustig (1978) subliminally primed a group of male participants with a set of primes relating to the Oedipus complex and subsequently rated dart throwing performance. The prime 'BEATING DAD IS WRONG' was intended to exacerbate the oedipal conflict, whilst the prime 'BEATING DAD IS OK' was designed to alleviate it. Their results indicated that the group of participants subliminally presented with the conflict-alleviating prime 'BEATING DAD IS OK' performed significantly better than either the group exposed to the conflict-exacerbating prime, or the neutral prime 'PEOPLE ARE WALKING'.

Superficially, the results of the Silverman et al. study appear to demonstrate the possible semantic activation of multiple-word subliminal primes. Although, a measurable difference in dart throwing performance need not necessarily require the unconscious semantic processing of each word of the prime, as any effect evidenced may instead be due to simple single-word priming of "OK" versus "WRONG". After all, the ultimate aim of SPA studies is to subliminally induce internal conflict, not to ensure that each word in the sentence prime is semantically attended to. However, Palumbo and Gillman (1984) replicated and extended the Silverman et al. (1978) study by additionally including the primes 'BEATING HIM IS WRONG' and 'BEATING HIM IS OK'. Their results replicated the Silverman et al. finding in that participants presented with the conflict-alleviating prime performed significantly better than those primed with the conflict-exacerbating prime. More interestingly, performance in the 'BEATING HIM IS WRONG' and 'BEATING HIM IS OK' conditions did not significantly differ from the control stimulus 'PEOPLE ARE WALKING'. That there was a measurable difference between the 'BEATING DAD IS WORNG' and 'BEATING HIM IS WRONG' conditions suggests that unconscious cognition was

capable of separating the semantic difference between DAD and HIM. However, again, this result may demonstrate single-word priming differences between “DAD” and “HIM” rather than sentence level meaning.

Despite some significant criticisms and contradictory evidence (e.g., Allen & Condon, 1982; Condon & Allen, 1980; Haspel & Harris, 1982; Heilbrun, 1980; Oliver & Burkham, 1982; Vitiello, Carlin, Becker, Barris, & Dutton, 1989), SPA studies employing multiple-word primes have received some positive support (Silverman & Weinberger, 1985). For example, Bronstein and Rodin (1983) primed a clinical sample of schizophrenic males with a series of subliminal primes that related to either SPA oneness conflicts such as ‘MOMMY AND I ARE ONE’, ‘MOMMY AND I ARE THE SAME’ and ‘MOMMY AND I ARE ALIKE’, or neutral primes such as ‘PEOPLE ARE WALKING’, ‘PEOPLE ARE LOOKING’ and ‘BOYS ARE STANDING’. Their results suggested that only the SPA prime ‘MOMMY AND I ARE ONE’ produced a reduction in subsequent pathological thoughts and behaviours within the sample. Silverman (1982) reported similar ameliorative effects using SPA oneness primes on a sample of patients with depression.

Other examples of studies demonstrating successful subliminal priming using sentences include a study conducted by Talbot, Duberstein, and Scott (1991). Talbot et al. subliminally primed a sample of male participants with SPA primes relating to oneness. Results demonstrated that participants primed with “Mommy is Leaving Me” made significantly lower subjective ratings of own attractiveness, and demonstrated a reduction in eating behaviour when compared to participants primed with “Mona is Loaning It”. Sohlberg and Birgegard (2003) similarly presented SPA oneness primes to a sample of female participants and measured subjective ratings on a number of psychological variables including depression and self-mother similarity. Their results

indicated that participants primed with ‘Mommy and I are one’ generated higher ratings on the self-mother similarity scale between seven and fourteen days after initial exposure. Ariam and Siller (1982) subliminally presented neutral and SPA oneness primes to a group of school students. Their results indicated that the students exposed to ‘Mommy and I are one’ primes demonstrated an increment in mathematical performance when compared to neutral conditions. Despite the criticisms aimed at SPA studies in general, these and other studies demonstrating similar effects (e.g., Hardaway, 1990; Silverman & Weinberger, 1985; Waller & Barter, 2005) nevertheless go some way towards demonstrating the possible semantic activation of multiple-word subliminal primes.

More recently, Sklar et al. (2012) investigated subliminal priming of sentences using continuous flash suppression that allowed for the presentation of subliminal stimuli to reach up to 2 seconds, increasing the chances of successful subliminal priming. Sklar and colleagues presented participants with a series of semantically coherent (e.g., “The lion ate a zebra”) and incoherent (e.g., “the bench ate a zebra”) sentences, and measured the time taken for the expressions to ‘pop’ into consciousness. The results indicated that semantically incoherent sentences popped into conscious perception significantly quicker than the semantically coherent sentences did. It is argued that the cognitive conflict which ensues as a result of analysing the semantically incoherent expression forces the sentence into consciousness in order to further analyse its content. The authors argue that as semantic coherence is determined by word combinations rather than the individual words themselves, then these findings demonstrate the successful subliminal priming of multiple-word sentences. However, there may have been a word-level effect influencing popping times as different words were used in different conditions (e.g., “bench” versus “lion”). Nevertheless, the results

of this experiment does raise the question of what sort of combinations of stimuli are possible to prime subliminally.

1.3. Evidence Against the Comprehension of Subliminal Stimuli

Despite a wealth of evidence demonstrating the successful semantic activation of subliminal words and even multiple-word sentences, controversy remains regarding the precise extent of subliminal priming (Draine, 1997; Kouider & Dupoux, 2004; Moore, 1982, 1988; Pratkanis & Greenwald, 1988). Pratkanis (1992) has argued that many studies that purport to have successfully demonstrated a subliminal priming effect are often either in some way flawed or are nonreplicable, whilst the majority of priming studies that have failed to demonstrate a subliminal effect go unreported due to non-significant results. Similarly, in his examination of unconscious cognition, Greenwald (1992) has argued that unconscious processing of subliminal stimuli is in fact far less sophisticated than is often reported, and often demonstrates nothing more elaborate than the processing of letters or word fragments. Therefore, rather than the semantic activation of subliminal primes, successful priming effects are often attributed instead to other processes such as the retrieval of pre-existing stimulus-response links, processing at the sublexical level, or partial conscious awareness.

1.3.1. Stimulus Response Links

A large body of research has been amassed which demonstrates the superior priming effect of subliminal primes that have first been practised as conscious targets (e.g., Abrams & Grinspan, 2007; Draine & Greenwald, 1998). That is, the priming effects of subliminal primes that have earlier been perceived as conscious targets prove more successful than non-practiced novel primes. More specifically, many researchers

argue that the effectiveness of subliminal primes are *dependent* upon whether or not they have been consciously presented beforehand (Abrams, Klinger, & Greenwald, 2002). This effect is demonstrated by Damian (2001), who presented participants with a series of real-world objects that could be classified as either small (e.g., 'apple') or large (e.g., 'house'). The participants were required to make size judgments on these target words having been subliminally primed with an object that was either congruent in size (e.g., spoon-apple) or incongruent (e.g., house-apple). Prime-target pairs were created by combining the same stimuli, meaning that whilst 'spoon' may occur as a size-congruent subliminal prime for 'apple' in one trial, 'spoon' could later appear as a target word in another trial. The results demonstrated a decrease in response time for size judgments when prime and target were congruent. However, a further experiment employing the same size judgement task using a set of novel prime-target pairs, that is, prime words that never appeared as targets, failed to demonstrate the same semantic congruity effect.

Therefore, significant criticisms have arisen regarding the use of practised primes as subliminal stimuli; with the superior priming effect evidenced being attributed to the creation of an episodic memory trace established during conscious rehearsal that is later automatically reactivated upon subsequent subliminal presentation (Damian, 2001; Elsner, Kunde, & Kiesel, 2008; Forster & Davis, 1984; Kiesel, Kunde, & Hoffmann, 2007; Kunde, Kiesel, & Hoffmann, 2003; Schlaghecken & Eimer, 2004). Abrams and Grinspan (2007) have proposed that all that is required to identify a stimulus that has been predicted by experience and expectation is simple cognitive processing at the level of individual features. When primes are consciously rehearsed, they acquire a memory trace between the stimulus and a given motor response. These automatised stimulus-response (S-R-) mappings subsequently remain in short term

memory and are later reactivated upon presentation of the same stimuli displayed subliminally. Therefore, whilst S-R links may lead to successful subliminal priming, these results indicate that the semantic analysis of subliminal primes need not necessarily occur as the semantic system is by-passed.

Functional neuroimaging studies have provided evidence to demonstrate that, when compared to novel stimuli, a previously exposed stimulus results in a decrease in neural activity (Schacter & Buckner, 1998). In an fMRI study investigating S-R mappings in conscious tasks, Dobbins, Schnyer, Verfaellie, and Schacter (2004) consciously presented participants with a series of pictures relating to everyday objects (e.g., acorn, push-chair). The participants' task was to determine whether the presented object was bigger or smaller in size than a shoe box. As well as a decrease in response time to previously exposed stimuli, the fMRI results indicated a decrease in activation within the left prefrontal and fusiform regions of the brain upon presentation of a previously presented item with its associated motor response. Therefore, the authors concluded that a previously attended to stimulus that has an associated response fails to elicit the same level of processing and analysis when compared to novel stimuli. Furthermore, similar results have been demonstrated when using subliminal stimuli (Dehaene et al., 1998; Eimer & Schlaghecken, 1998).

However, additional research has demonstrated effective subliminal priming that cannot be due to the retrieval of simple S-R mappings (e.g., Klauer, Eder, Greenwald, & Abrams, 2007; Kunde, Kiesel, & Hoffmann, 2003; Naccache & Dehaene, 2001; Van den Bussche et al., 2009). Rather than practiced stimuli leading to a learned association between a given stimulus and its motoric response, Abrams, Klinger, and Greenwald (2002) have argued that practice instead establishes mappings between a word and its semantic category. Abrams et al. (2002) required participants to categorise

a block of visible words as either pleasant (e.g., ‘happy’ and ‘warm’) or unpleasant (e.g., ‘scum’ and ‘kill’) in valence by using either the “a” or “5” key on a computer keyboard. The second phase of the experiment required the participant to categorise a series of subliminal primes based on their emotive valence, some of which were novel items, and some the previously practiced items. However, the key assignment for pleasant and unpleasant was reversed for practiced stimuli. Therefore, no motor response could have been learned between the stimulus and required key press. Nevertheless, the results demonstrated a significant priming effect of word valence despite key reversal, leading the authors to conclude that practiced subliminal primes actually activate mappings between words and their semantic categories as opposed to mappings between a stimulus and motor response.

1.3.2. Processing at the Sublexical Level

In addition to criticisms relating to the retrieval of pre-established S-R links, it has been argued that research demonstrating subliminal priming effects often demonstrate nothing more elaborate than the processing of individual letters or word fragments (Klinger, Burton, & Pitts, 2000). For example, Abrams and Greenwald (2000) have provided empirical evidence to suggest that far from analysing whole-word meaning, the unconscious analysis of words is actually only completed at the level of word-parts. In their first experiment, Abrams and Greenwald required participants to consciously evaluate the emotional valence of a set of parent primes that were unequivocally positive or negative in meaning. Having categorised the parent primes, participants were subliminally presented with a set of nonsensical ‘hulip-type hybrid primes’ that were created by combining two parent primes of congruent valence (e.g., humour-tulip-hulip; smut-bile-biut). The results indicated that when asked to rate emotional valence, participants were successfully able to categorise emotional valence

based on the valence of parent primes despite the nonsensical nature of the hybrid primes. In a follow up study (Experiment 2), participants were again required to evaluate the emotional valence of the same set of consciously perceived parent primes used in Experiment 1. However, a set of 'tumour-type hybrid' subliminal primes were generated by combining two congruent parent primes to create a semantically comprehensible prime of incongruent valence to parent primes (e.g., humour-tulip-tumour, smut-bile-smile). The results indicated that when asked to again rate valence, participants continued to categorise emotional valence according to the valence of the parent prime rather than the valence of tumour-type primes, even to the extent that 'smile' was categorised as negative. Greenwald and Abrams (2002) later went on to demonstrate that a single string of consonants (e.g., LLLLL) from a parent prime (e.g., 'tulip') was sufficient to generate a priming effect based on parental prime valence. These combined results led the authors to conclude that subliminal processing is limited to the unconscious appraisal of sub-word elements.

As a further example, Hutchison, Neely, Neill, and Walker (2004) investigated sublexical priming using a stem completion task, in which the participant is required to complete a word stem (e.g., dr_ _ _) with a primed word (e.g., dream) or a different word (e.g., drink). In their first experiment, Hutchison et al. (2004) compared the priming effects evidenced between a set of identity primes (e.g., 'candy', ca_ _ _) and a set of form primes sharing an orthographic overlap in which the last three letters overlapped with the missing letters in a given stem (e.g., 'windy', ca_ _ _), whereby the participant was required to complete the word stem with a non-primed word. If the unconscious analysis of subliminal primes occurs at the sublexical level, then the level of priming for identity primes should equal the level of priming for the orthographic form primes. Whilst the results indicated a significant priming effect for both identity

and form primes, this priming effect was significantly higher for identity primes, suggesting lexical as opposed to sublexical access. However, the authors argue that the additional priming effects evidenced with the use of identity primes may instead be due to greater phonological similarity between prime and target with identity primes when compared to form primes. Therefore, a further experiment aimed to compare the priming effects evidenced between a set of identity primes (e.g., 'write', wr_ _ _) and homophonic primes that shared the same phonology but differed in spelling (e.g., 'right', wr_ _ _). Therefore, if the unconscious analysis of subliminal primes occurs at the lexical level, any priming effects should be higher for the identity primes than for homophonic primes. Whilst the results indicated significantly higher identity priming effects when compared to homophonic priming, additional analyses reveal that these higher priming effects could be explained by combining the priming effects from sublexical, orthographic and phonological contributions; further supporting the contention that unconscious processing operates at the sublexical level rather than the semantic level.

However, Schütz, Schendzielarz, Zwitserlood, and Vorberg (2007) utilised a stem completion task to demonstrate that unconscious priming operates on the semantic level as opposed to the sublexical. Word stems were chosen on the basis that each stem (e.g., 'T_NT') had only two solutions; a dominant (e.g., 'tent') and a subordinate (e.g., 'tint') solution. Schütz et al. attempted to compare lexical and sublexical contributions to subliminal priming by using semantic and form related primes to prime the subordinate solution. Semantic primes (e.g., 'hue' to tint) were chosen based on their semantic similarity with the subordinate solution and dissimilarity with the dominant, and with the assurance that they differed orthographically and phonologically to the subordinate and dominant solutions. Similarly, form related primes (e.g., 'lint' to tint)

were chosen based on their semantic, orthographic, and phonological differences to the dominant solution, and orthographical and phonological similarity to the subordinate. Therefore, due to these prime differences, any positive priming effects evidenced in the semantic condition must be due to semantic and lexical activation. As predicted, the results revealed significant priming effects for form related primes, but also for semantic primes that shared no sublexical overlap with the solution. Similarly, Klauer, Eder, Greenwald, and Abrams (2007) demonstrated positive semantic priming in which a sublexical explanation would have predicted the opposite results.

1.3.3. Partial Awareness

In addition to S-R mappings and processing at the sublexical level, Kouider and Dupoux (2004) suggest that partial conscious awareness of a 'subliminal' prime often creates the illusion of positive semantic priming. The authors argue that awareness is often conceptualised as an all or nothing phenomenon. Whilst true in some cases, more complex stimuli such as words and sentences are mentally organised on several levels of detail including feature, letter and phoneme representations. Therefore, it may be possible that masking may obscure some of these levels of processing, but not all. This distinction between partial and global awareness then implies that partial awareness may allow for the reconstruction of a prime based on minimal letter and feature identification, with this reconstruction leading to semantic access and thus giving the appearance of semantic activation of subliminal stimuli. Kouider and Dupoux demonstrated this effect using the unconscious Stroop paradigm. Participants were presented with two types of prime; a set of four French colour words (e.g., 'rouge', 'jaune' etc.) and four pseudo colour words (based on a variation of the colour words, e.g., 'rugoe', 'janue' etc.) presented for either 29 or 43 milliseconds. When the participant was subsequently required to name the ink colour of a series of ampersands,

semantic activation of the prime was assumed to have occurred if colour naming was slower for incongruent conditions. The authors proposed that conditions leading to partial awareness (e.g., 29 ms) would make it difficult to distinguish between real and pseudo colours, yet the similarity between letter fragments (e.g., ja_ _e) would allow for the mental reconstruction of the prime and lead to a priming effect. However, longer prime durations (e.g., 43 ms) would lead to more of a global awareness of the prime, allowing for the distinction to be made between real and pseudo colours. Therefore, only if awareness of the prime is partial should there be a priming effect evidenced for both real and pseudo colours. As expected, the results revealed a positive priming effect for both real and pseudo colour words for shorter prime durations, but only for real colour words in longer prime durations, leading to the conclusion that the retrieval of semantic information of a prime is dependent upon (at least) partial conscious awareness.

In his extensive review of literature pertaining to subliminal perception, Holender (1986) has argued that evidence demonstrating positive subliminal priming effects are more often than not attributable to stimuli that are consciously identified due to, for example, dark adaptation. However, Klinger and Greenwald (1995) employed a method of dichoptic pattern masking to demonstrate how the influence of conscious perception can actually adversely affect unconscious cognitive processing. In their experiment, the participants' task was to determine whether two target words were associated (e.g., eagle-falcon) or unassociated (e.g., eagle-polka), having been primed with either a related (e.g., hawk) or unrelated (e.g., nurse) word. Before analysing the results, the participants were classified into one of two groups, either high or low detectors, based on their ability to detect masked prime words. The results indicated that participants classified as low detectors demonstrated a significant priming effect in

terms of response latencies to target associations. However, no semantic priming effect was evidenced for high detecting participants, supporting additional research suggesting that partial detection of the primed word actually interferes with semantic activation (e.g., Dagenbach, Carr, & Wilhelmsen, 1989). As an explanation, Klinger and Greenwald propose that there are two processes involved in the semantic activation of mental representations. The first of these processes is the aforementioned spreading activation phenomenon, which is in itself an unconscious process. The second process involves a limited capacity attentional mechanism that consciously attempts to activate semantically related mental representations which adversely interferes with unconscious processing. Therefore, high detectors were exposed to a briefly presented blurred or fragmented image of a word in which the conscious process attempted to activate mental representations, whilst the spreading activation phenomenon was simultaneously suppressed. This then led to the lack of semantic priming effects evidenced in high detecting participants. Therefore, partial conscious awareness of the prime may actually hinder unconscious processing rather than enhance it.

As demonstrated by the evidence both for and against unconscious cognition presented here, the degree of information complexity that can be retrieved from stimuli presented subliminally, or simply how intelligent unconscious processing is, remains a highly controversial theme within psychological literature (Van den Bussche et al., 2009). However, the point of this controversy often appears to revolve around the subject of what exactly constitutes subliminality, and individual researchers' interpretations of 'unconscious'. Put simply, how can researchers present stimuli subliminally whilst ensuring the exclusion of conscious awareness? In support of Holender (1986), Reder and Gordon (1997) propose that methodological issues make it extremely difficult to claim successful semantic activation of subliminal stimuli without

the possibility of success being attributed to an element of conscious identification of the prime (e.g., Jaśkowski, 2008). Therefore, this issue of what constitutes 'unconscious' needs further exploration.

1.4. What Constitutes 'Unconscious' and how can it be Measured?

It is widely accepted that subliminal perception can be defined as the presentation of a stimulus that subsequently affects the thoughts or actions of an individual despite the stimulus never entering the individual's conscious awareness (Velmans & Schneider, 2008). However, it is this term 'conscious' that remains somewhat contentious (cf. Kihlstrom, 1987) and needs further definition. Or, more precisely, a definition of consciousness is required in order to determine what renders a stimulus 'unconscious'. In its simplest form, Velmans and Schneider (2008) define consciousness as an awareness of our environment, our bodies, and of our thoughts. With this in mind, the term 'unconscious' can generally be conceptualised as 'unaware of'. Greenwald (1992) proposes that this definition of unconscious can be further subdivided into two quite different interpretations of unaware: outside of attention, and an inability or failure to introspect.

At any given time, an individual is exposed to a multitude of incoming information to which it is impossible to fully attend (Treisman, 1969). As such, an individual must selectively choose what to devote attention to. However, this does not mean that information falling outside of selective attention does not have an effect on consequent thoughts or behaviours (Greenwald, 1992). Consider, as an example, talking to another person at a crowded event. Although your attention may be selectively focused on the current conversation and the person you are talking with, you are nevertheless likely to be either consciously or unconsciously aware of other people in

the room, conversations going on around you, the background music that is playing, and so on. This is often aptly demonstrated by suddenly hearing one's name being spoken across a crowded room despite selective attention previously being focused elsewhere.

Empirically, the influence that stimuli presented outside of the foci of selective attention has on higher order cognitive functioning has been investigated by Rahnev, Huang, and Lau (2012). Participants were presented with four black circles against a dark background on a computer monitor, with each circle being located equally within one of the four quadrants of the screen. The participants were cued to focus on a particular circle, in which a series of white dots moved in random directions within each of the four circles. After 100 milliseconds, all of the white dots in the cued circle moved either upwards or downwards, whilst the dots in the circle at a diagonal moved in either a congruent or incongruent direction. After a further 400 milliseconds, a number appeared on the screen. The participant's task was to state whether the number was bigger or smaller than 5 if the dots were moving upwards. If the dots were moving downwards, the participant was required to state whether the number was odd or even. The results supported Rahnev and colleagues predictions in that shorter reaction times and higher accuracy levels were observed in trials in which movement in the cued and diagonal circles was congruent when compared to incongruent. Therefore, the authors conclude that higher cognitive functions such as task setting were nevertheless influenced by the direction of movement in the diagonal circle, despite that movement being outside of the focus of selective attention.

As well as outside of attention, the further interpretation of 'unaware of' refers to the inability or failure to subjectively report on experience (Greenwald, 1992). In other words, if an individual is known to have attended to a particular task or stimulus but is unable to report experience of having attended to it, then this provides evidence of

an unconscious experience. This type of metacognition, knowing about knowing, is believed to be a uniquely conscious process (Koriat, 2007). An example of this phenomenon is often experienced by proficient car drivers. Driving requires a combination of many physiological and psychological functions including hand and foot motor control, and visual regulation and vigilance. Nevertheless, an experienced driver can often complete a practiced journey with no conscious recollection of having completed said journey. However, this does not mean that the driving was in itself an unconscious process, it merely demonstrates the inability to subjectively *introspect* on an attended to process. Empirically, studies investigating unconscious cognition using subliminal stimuli often include a measure of introspection following the conclusion of experimental trials, to test for subjective experience (e.g., Diaz & McCarthy, 2007).

According to Jacoby, Lindsay, and Toth (1992) and Cleeremans and Jiménez (2002), the ability to control cognition and behaviour by excluding certain responses is an ability unique to consciousness. Therefore, in an attempt to isolate the separate contributions of conscious and unconscious perception to a given subliminal task, Jacoby (1991) developed the process-dissociation procedure (i.e., inclusion and exclusion tasks) for stem completion tasks. Inclusion tasks require the participant to complete a word stem (e.g., st_ _ _) with a previously presented subliminal prime (e.g., 'storm'). If, beyond a baseline performance, the participant is able to successfully complete the word stem, then it is assumed that there must have been conscious knowledge of the primed word (Debner & Jacoby, 1994). However, an exclusion task requires the participant to complete the word stem with a different word to the primed stimulus (e.g., 'steam'). If, as evidenced by a below baseline performance, the participant continues to complete the word stem with the primed word, then this can be used as evidence to demonstrate unconscious knowledge (e.g., Debner & Jacoby, 1994;

Jacoby, Toth, & Yonelinas, 1993). That is, if knowledge of the prime was conscious, the participant would fulfil task instructions by excluding the primed stimulus. Jacoby argues that it is precisely this inability to exercise cognitive control over excluding the primed word that provides evidence of unconscious knowledge.

However, further research investigating unconscious cognition has provided evidence to suggest that the unconscious is sufficiently capable of exerting cognitive control over responding (e.g., Capa, Bustin, Cleeremans, & Hansenne, 2011; Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Perner, 2007; Fu, Dienes, & Fu, 2010; Norman, Price, & Jones, 2011; van Gaal, Ridderinkhof, Scholte, & Lamme, 2010; Wan, Dienes, & Fu, 2008). Again, this empirical disagreement between what can and cannot be cognitively controlled through subliminal priming is in part due to the discrepancy between what constitutes conscious and unconscious perception. Therefore, we use higher order thought theory in an attempt to further explore the distinction between mental states and to define what makes a stimulus 'subliminal'.

1.4.1. Higher Order Thought Theory

Higher order theories of consciousness attempt to distinguish between the separate properties of consciousness by exploring the relationship between a particular conscious state and its associated higher order representation (Carruthers, 2011; Timmermans et al., 2012). In the 1980's, Rosenthal developed the higher order thought (HOT) theory of consciousness (Rosenthal, 1986, 2005), which supposes that a conscious mental state is a mental state of which we are conscious, and that the way in which we become conscious of a mental state is by thinking about it (Dienes, 2008).

1.4.1.1. A conscious mental state is a mental state of which we are conscious: Rosenthal proposes that there are two uses of the word consciousness; that of transitive consciousness and state consciousness (Dienes, 2008). According to Rosenthal (1993),

when an individual senses or thinks about an object, we can presume that the individual is transitively conscious of that object. Therefore, transitive consciousness refers to an individual being conscious of an object, of 'something'. For instance, one can look at an apple on the table and be (transitively) conscious of the apple. Alternatively, state consciousness refers to being conscious by virtue of having perceptions or thoughts which are themselves conscious. For instance, one can *consciously see* that the apple is on the table. Subliminally seeing an apple would mean one was transitively conscious of the apple, but the seeing was not state conscious. This distinction between transitive and state consciousness can be aptly demonstrated by patients with a neurological disorder known as blindsight. Blindsight is a condition whereby damage to the striate cortex and optical nerve fibres leads to information within the visual field not being transmitted to the brain, consequently resulting in blindness (Overgaard, Fehl, Mouridsen, Bergholt, & Cleeremans, 2008). However, despite a lack of conscious visual information, when asked to respond to an object in the affected visual field, blindsight patients are often able to correctly identify object position, motion, or even colour (e.g., Stoerig & Cowey, 1989; Weiskrantz, Warrington, Sanders, & Marshall, 1974). Therefore, a patient with blindsight that can correctly indicate that a balloon in the affected visual field is moving upwards is demonstrating transitive consciousness; the balloon *is* moving up. However, the patient is lacking state consciousness; they are not conscious of *seeing* that the balloon is moving upwards.

1.4.1.2. The way we become conscious of a mental state is by thinking about it:

According to HOT theory, a mental state becomes conscious when we either perceive it or think about it. That is, I can either see that the apple is on the table, or I can think of the apple being on the table; however, both perceiving and thinking result in awareness of the apple. Therefore, Rosenthal proposes that a HOT affirming that we are in that

mental state is necessary in allowing a mental state to become conscious. Continuing with the apple on the table as an example, a first order thought would have content that 'the apple is on the table'. However, it is the higher order thought 'I am aware that I see the apple is on the table' that makes us introspectively aware of having that perception.

When applied in a subliminal context, similar to a blindsight patient, an individual should be transitively conscious of the presented prime but should lack state consciousness as they would not be conscious of having perceived the prime. For instance, the subliminal presentation of the prime 'lion' should activate the first order thought 'the word lion'. Whilst perhaps sufficient to activate semantic associations, it is the absence of a higher order thought - with content 'I see the word lion', that renders the prime subliminal. Therefore, although perception of the prime involves being conscious of the prime, the lack of a higher order thought indicates that subjectively, we lack conscious *awareness* of the prime. Higher order thought theory, and higher order theories of consciousness in general, highlight the importance of utilising a subjective measurement of subliminality when assessing the extent of unconscious cognition.

Rosenthal's theory is given as a clear example of a higher order theory. But one may dispute for example whether the higher order representation has to be a thought rather than a perception (Carruthers, 2011), or something else (simply the right sort of representation; Cleeremans, 2011). Cleeremans proposes a higher order representation theory that requires a higher order network to represent the accuracy of a lower order network in order for the lower order content to be conscious. By not stipulating the higher order representation must specifically be a thought, the theory can assign conscious states to organisms more easily than Rosenthal's theory, and also allows a computational theory to be more easily built. In terms of linking theory to methodology, Cleeremans theory will serve just as well as Rosenthal's so long as it is assumed that the

higher order network would express its content in verbal report whenever the person is probed for the content; i.e., what appears as possibly sub-personal content in the theory is made personal when probed.

1.4.2. Subjective and Objective Thresholds

One explanation that attempts to account for the apparent failure of many studies to successfully demonstrate subliminal semantic priming focuses on the adherence to strict objective measures when measuring subliminality. Objective methods of assessing unconscious cognition presume that any trial accuracy beyond a baseline (i.e., chance) performance indicates conscious knowledge of the prime (Seth, Dienes, Cleeremans, Overgaard, & Pessoa, 2008). In other words, regardless of whether or not you are introspectively aware that you saw the prime, if you are correct then you must have conscious knowledge. As such, many subliminal studies use either an arbitrary presentation speed of sufficiently short duration to ensure chance level performance (e.g., Hutchison et al., 2004), or systematically reduce prime duration until the participant is performing at (or below) chance level (e.g., Greenwald & Liu, 1985).

Snodgrass, Bernat, and Shevrin (2004) propose a nonmonotonic relationship between priming and awareness as stimulus intensity increases. That is, rather than the traditional positive relationship in which performance steadily increases as stimulus intensity increases between the thresholds, performance actually decreases initially before then becoming positive. The authors suggest that unconscious processing is maximal at the objective detection threshold (ODT; presence/absence tasks, when the ability to determine whether a word was presented is at chance) and then decreases as stimulus intensity increases until it reaches the objective identification threshold (OIT; discrimination tasks, when the ability to identify which particular word had been presented was at chance). This initial decrease in performance is attributed to increasing

conscious processing which is not yet sufficient to perform high level tasks overriding unconscious processing. This nonmonotonic U shaped performance curve then continues to increase until it reaches the subjective threshold and beyond. Whilst performance at the subjective threshold is analogous to performance at the ODT threshold, Snodgrass (2002) and Snodgrass and Shevrin (2006) argue that conscious processing, albeit weak conscious processing, is responsible for the priming evidenced at the subjective threshold. Therefore, Snodgrass and colleagues argue that only stringent objective measures which preclude all conscious processing produce maximal priming effects.

However, Miller (1991) has argued that the distribution of thresholds for conscious awareness varies across sets of trials, and that it is this variability in thresholds that may have resulted in previous studies failing to demonstrate subliminal priming. More precisely, the use of static thresholds at minimum baseline accuracy will significantly reduce the likelihood of demonstrating subliminal perception due to this variation in prime detection. For example, if a participant's true objective threshold is at 40 milliseconds for half a set of trials and 20 milliseconds for the other half, the single lowest estimate of detection would be used for subsequent experimental trials, resulting in a biased estimation of subliminal perception. Consequently, the use of objective methods in measuring priming levels has been heavily criticised for testing not just unconscious cognition, but degraded unconscious cognition (Dienes, 2004, 2008; Lau & Passingham, 2006).

Therefore, what objective methods of assessing subliminal perception by definition fail to take into account is individual subjectivity; that is, an individual's conscious awareness of their own accuracy (cf. Merikle, 1992; Merikle, Smilek, & Eastwood, 2001). It was Cheesman and Merikle (1984, 1986) that first distinguished

between the two types of subliminal thresholds; objective and subjective. In a series of experiments, Cheesman and Merikle presented participants with a colour word (blue, green, red or yellow) in which the participants were required to state which of the four colour words had been presented. After each block of 40 trials, the SOA was reduced until the participant was performing at chance level. In addition to reducing SOA, after each block of trials, participants were required to rate how confident they were that they had chosen the correct word. Participants were encouraged to give a rating between 25-100%; with a confidence rating of 25% indicating that they were guessing, whilst a confidence rating of 100% indicated that they were certain they had responded correctly. The subjective threshold then referred to the point at which participants *believed* they were performing at chance (i.e., they were not consciously aware of having seen the prime), whilst the objective threshold referred to the point at which participants actually *were* performing at chance. The point being that the two thresholds differed in prime duration, with a later colour naming task resulting in unconscious processing occurring below the subjective threshold but limited unconscious processing below the objective. These results demonstrate the importance of using subjective thresholds when attempting to determine the full extent of unconscious processing.

The relative impact of feedback on performance and accuracy delivered at the objective and subjective thresholds was directly investigated by Masters, Maxwell, and Eves (2009). Once individual objective and subjective thresholds had been determined by a position detection phase, participants took part in a golf-putting task in which they were required to hit a golf ball at a target which was hidden from view. After each trial, the participant was presented with feedback which indicated the location of their ball relative to the target area. Participants were randomly allocated to one of three conditions; condition one received feedback at the objective threshold, condition two

received feedback at the subjective threshold, and condition three received feedback supraliminally (i.e., at an SOA that guaranteed conscious awareness). The results indicated that across trials, participants that received their feedback supraliminally and at the subjective threshold improved in their performance and accuracy, whilst those receiving feedback at the objective threshold did not. Although, in a meta-analysis investigating subliminal priming moderators, Van den Bussche, Van den Noortgate, and Reynvoet (2009) demonstrated that whilst priming effect sizes increased as prime visibility increased (i.e., between the objective and subjective thresholds), there was not a significant effect of using objective versus subjective thresholds. However, as demonstrated by the theories of consciousness discussed previously, any measure of subliminal perception should search for the presence of higher order thoughts (i.e., being consciously aware of the prime) as opposed to merely focusing on performance accuracy.

1.4.3. Subjective Methods of Measuring Subliminality

Perhaps the most widely used methods of measuring individual subjective thresholds for subliminal stimuli are the guessing criterion used by Cheesman and Merikle (1984), and the zero-correlation criterion (ZCC). Using the guessing criterion, subjective thresholds of awareness are assessed by asking the participant to rate confidence in their accuracy after every trial or block of trials (Dienes, 2008). Subjective thresholds are thus reached as soon as the participant believes they are performing at chance. If performance accuracy is then beyond chance expectations and yet the participant believes themselves to be guessing, then this should be considered as evidence of unconscious knowledge (Ziori & Dienes, 2006). On the other hand, the zero-correlation criterion assumes that if knowledge of the prime is conscious, then there will be a relation between confidence and accuracy (Dienes, 2008). If however

there is zero relation, then this too should be considered as evidence of unconscious knowledge.

As mentioned above, if a participant believes themselves to be guessing whilst at the same time performing at above chance expectations, it can generally be assumed that they possess unconscious knowledge. However, Sandberg, Timmermans, Overgaard, and Cleeremans (2010) argue that this above chance performance may instead be a consequence of participants failing to be complete in their subjective estimates of conscious awareness. That is, some tests of subjective awareness may fail to fully account for conscious contributions to task performance. Currently, the three primary methods of actualising the guessing criterion in measuring whether or not one is aware of knowing (i.e., subliminal perception) are confidence ratings (CR), post decision wagering (PDW), and the perceptual awareness scale (PAS). The simplest and most straightforward method of measuring confidence in accuracy requires the participant to rate on a scale of 'guess' to 'know'. Therefore, CRs can either be indicated on a graded Likert scale from complete guessing to complete certainty (e.g., Dienes et al., 1995) or on a percentage scale from 50% (i.e., depending on item numbers) indicating guessing, to 100% indicating absolute certainty (e.g., Cheesman & Merikle, 1986).

Verbal confidence ratings may be prone to bias as a result of participants perhaps believing that they know something (i.e., a degree of conscious knowledge), but not reporting it. Therefore, the PDW method developed by Persaud, McLeod, and Cowey (2007) involves the participant placing a wager on the likelihood of their response being correct. If they are accurate, they win and if they are not, they lose. Persaud et al. applied the PDW in combination with an artificial grammar task, in which participants were required to place either a high (£2) or low (£1) wager based on their

decisions being correct. The PDW method operates under the assumption that a higher wager indicates a higher certainty in accuracy, which in turn indicates a higher likelihood of possessing conscious knowledge. However, Dienes and Seth (2010a) directly compared CR and PDW in an artificial grammar task and found that CR was a more sensitive method of assessing subjective awareness. The authors argued that a level of risk or loss aversion can consequently result in a suboptimal wagering performance. That is, the prospect of losing money may be more of an incentive to be conservative in wagering and thus not represent the conscious status of knowledge. Therefore, the authors developed a "no loss gambling" method of PDW; wherein the participant could choose to either gamble on their accuracy, or on a secondary measure in which the odds were 50/50 (e.g., a coin toss). Whether the participant chose to gamble on accuracy or the 50/50 odds, the participant either won or did not win; but they did not lose. In this way, gambling on the 50/50 odds corresponded with 'guessing'. When CR was again directly compared to the no-loss gambling paradigm, both methods were equally sensitive in measuring conscious awareness.

Ramsøy and Overgaard (2004) constructed the PAS measurement of subjective awareness as a purely introspective measure of visual experience as opposed to asking a participant to report on their own accuracy. The PAS requires the participant to rate the clarity of visual experience on a four point scale; (1) no experience (i.e., answers are a guess, no visual experience), (2) brief glimpse (i.e., a feeling that something has been shown but no idea of what), (3) almost clear experience (i.e., a feeling of almost being certain, properties of the stimulus known), (4) clear experience (i.e., no ambiguity whatsoever). Therefore, PAS can often be used as a measure of subjective awareness when there is no correct answer to the task (Overgaard, Timmermans, Sandberg, & Cleeremans, 2010). Sandberg et al. (2010) investigated the predictive ability of PAS,

CR and PDW to measure the separate contributions of conscious and unconscious processing in an identification task. Participants viewed one of four shapes (circle, square, diamond, or triangle) for varying durations (ranging from 16 to 192 milliseconds) and were required to indicate which shape they had seen with a key press. After making their choice, the participants were required to indicate awareness using one of the three scales. The results demonstrated that CR was a better measure of unconscious processing than PDW. However, of the three scales, PAS was the most sensitive since the ZCC results indicated the occurrence of more conscious processing, as people can be aware of seeing something before knowing that they have seen something relevant.

As a rebuttal to the Sandberg et al. conclusion that PAS provides the most exhaustive measure of conscious awareness, Dienes and Seth (2010b, 2010c) argue over the distinction between any content versus relevant content. Whilst the participant may be consciously aware of having seen ‘something’, that does not imply that the consciously perceived content is in any way relevant to the task at hand. Therefore, Dienes and Seth argue that CR is a far more reliable indicator of the conscious status of content and knowledge. Similarly, in an investigation into the unconscious processing of visual emotion in faces, Szczepanowski, Traczyk, Wierzchoń, and Cleeremans, (2013) found CR to be a more sensitive measure of conscious awareness than either PAS or PDW (though see Sandberg, Bibby, & Overgaard, 2013). However, what is clear from the literature is that what constitutes the best subjective measure of the conscious status of knowledge and perceptual awareness remains a matter of further debate.

1.5. Summary and Outline of Articles

As reviewed here, the literature regarding subliminal perception remains controversial. What can and cannot be primed, what constitutes consciousness, and the most appropriate measurement of unconscious perception is varied and debateable. Whilst a number of studies have demonstrated successful priming of single words, pictures, emotion, arithmetic, and multiple word strings, other studies have attributed subliminal priming effects to the retrieval of stimulus response links, priming at the sublexical level, or partial conscious awareness. However, the controversy regarding subliminal perception appears to concentrate around the diverse interpretations and measurements of 'unconscious'. Each of the following three articles employs the definition of conscious, and therefore unconscious, as defined by higher order thought theory of consciousness. That is, if an individual is not aware of having seen the prime, then the content is perceived unconsciously. Therefore, we utilise subjective thresholds of conscious awareness and subliminality as measured by confidence ratings and the zero correlation criterion (ZCC). Each of the three articles attempts to address a number of the issues raised throughout this literature review.

1.5.1. Article I - Subliminal Understanding of Negation: Unconscious Control by Subliminal Processing of Word Pairs

The first article utilised subjective measures of conscious awareness and knowledge in an attempt to demonstrate successful semantic priming of two word primes. This was achieved by presenting participants with a subliminal instruction to either pick or not pick an accompanying noun when subsequently presented with the accompanied noun, and a further noun. In doing so, this article attempted to address Greenwald's (1992) two-word challenge by necessitating comprehension of both words

in the prime in order to fulfil task instructions. Furthermore, by subliminally instructing the participant to exclude, we attempted to challenge Jacoby, Lindsay, and Toth's (1992) assertion that the ability to control cognition by excluding certain responses is an ability unique to consciousness. In addition to endeavouring to demonstrate subliminal semantic priming of two word primes, we attempted to ensure that any priming effects evidenced could not be attributable to S-R mappings or partial conscious awareness. This article has been accepted for publication:

Armstrong, A.M., & Dienes, Z. (2013). Subliminal Understanding of Negation: Unconscious Control by Subliminal Processing of Word Pairs. *Consciousness and Cognition*, *22*(3), 1022-1040.

1.5.2. Article II - Subliminal Understanding of Active vs. Passive Sentences

The second article attempted to investigate whether or not unconscious cognition was sophisticated enough to distinguish between active and passive verb voice. This was achieved by presenting participants with a short subliminal sentence in which one of two characters (i.e., characters A or B) were active or passive within the sentence. When subsequently presented with two pictorial representations (i.e., one depicting character A as active and B passive; the other depicting character B as active and A passive), participants were required to choose the picture that best represented the prime sentence. Naccache and Dehaene (2001) have argued that the literature pertaining to unconscious processing has largely ignored the possibility of conducting semantic manipulations on stimuli perceived subliminally. Therefore, Article II attempted to successfully demonstrate that participants would be able to draw sufficient semantic information from the prime to construct a visual representation of the prime sentence, allowing the participant to correctly infer who was active and who was passive to identify the correct pictorial representation. As in Article I, we attempted to achieve

semantic priming whilst ensuring any priming effects could not be attributable to partial conscious awareness, as measured by the guessing criterion and ZCC, or S-R mappings. This article has been accepted for publication:

Armstrong, A.M., & Dienes, Z. (in press). Subliminal Understanding of Active vs. Passive Sentences. *Psychology of Consciousness: Theory, Research, and Practice,*

1.5.3. Article III – Supraliminal and Subliminal Priming of Specific Relationship Anxieties

The third article attempted to contribute to the literature demonstrating the activation of anxiety through supraliminal and subliminal priming. Whilst the majority of research investigating the activation of anxiety through priming has tended to focus on inducing a global level of anxiety, Article III attempted to investigate whether it was possible to prime very specific anxieties relating to relationships. Therefore, the focus of Article III was centred around the possibility of supraliminally and subliminally eliciting four separate relationship anxieties; the fear of being close to a partner, the fear of being far from a partner, the fear of being controlled by a partner, or the fear of being controlling with a partner. Once the participant had been primed, they were required to categorise a series of emotional adjectives as congruent or incongruent with the anxiety induced, and a series of self-related items as something to be fearful of or not. The response times and congruency results were then compared to a control group that had received no priming. Therefore, we attempted to demonstrate that not only is it possible to activate a generalised level of anxiety through supraliminal and subliminal presentation of stimuli, but that unconscious cognition is sophisticated enough to semantically differentiate between relationship anxieties, allowing for the activation of more specific anxieties. This article has been submitted for publication:

Armstrong, A.M., & Dienes, Z. (submitted). Supraliminal and Subliminal Priming of Specific Relationship Anxieties. *Journal of Experimental Psychopathology*,

In summary, this thesis aims to investigate just how powerful processing of subliminal stimuli can be when subliminality is established using a method that attempts to maximise the power of unconscious processing (i.e., subjective vs. objective thresholds): Can people exclude responses when instructed to do so subliminally, can people process syntax of subliminal word combinations, and can the unconscious resolve very specific anxieties through subliminal priming?

2. Article I - Subliminal Understanding of Negation: Unconscious Control by Subliminal Processing of Word-Pairs

2.1. Abstract

A series of five experiments investigated the extent of subliminal processing of negation. Participants were presented with a subliminal instruction to either *pick* or *not* pick an accompanying noun, followed by a choice of two nouns. By employing subjective measures to determine individual thresholds of subliminal priming, the results of these studies indicated that participants were able to identify the correct noun of the pair – even when the correct noun was specified by negation. Furthermore, using a grey-scale contrast method of masking, Experiment 5 confirmed that these priming effects were evidenced in the absence of partial awareness, and without the effect being attributed to the retrieval of stimulus-response links established during conscious rehearsal.

2.2. Introduction

Just how much information and knowledge can be acquired through subliminal perception, or just how intelligent unconscious cognitive processing is, remains a familiar and controversial theme (Greenwald, 1992; Norman, 2010). In a classic priming experiment, subjects are briefly presented with a word, or prime, that is prevented from entering conscious perception through the use of a forward or backward mask. When subsequently presented with a further target word, participants are quicker to categorise the target if both the prime and target are semantically related. Whilst the

unconscious analysis of letters is more sophisticated than the analysis of individual lines or angles, the semantic analysis of subliminal words or even multiple word-strings would indicate a far more intelligent and sophisticated interpretation of 'unconscious cognition' (Loftus & Klinger, 1992). Evidence suggests that the subliminal presentation of a word facilitates lexical and semantic access (e.g., Abad, Noguera, & Ortells, 2003; Carr & Dagenbach, 1990; Dell'Acqua & Grainger, 1999; Forster & Davis, 1984; Fowler, Wolford, Slade, & Tassinary, 1981; Gaillard et al., 2006; Marcel, 1983a; Ortells, Daza, & Fox, 2003), although the precise interpretation of these results will be addressed below.

Subliminal psychodynamic activation (SPA) studies offer evidence of some of the most sophisticated subliminal priming effects, apparently demonstrating the semantic analysis of multiple word primes (Bronstein & Rodin, 1983; Nissenfeld, 1979; Silverman, Ross, Adler, & Lustig, 1978; Silverman & Weinberger, 1985; Waller & Barter, 2005). However, SPA studies have been heavily criticised by others that have tried and failed to replicate results (Allen & Condon, 1982; Condon & Allen, 1980; Heilbrun, 1980). Furthermore, whatever the replicability of the results, given that the sentences used differ in the specific words used, any effect evidenced may instead be attributable to simple single-word priming. In fact, there still exists controversy regarding whether or not the semantic analysis of subliminal primes even occurs (Abrams & Greenwald, 2000; Damian, 2001; Hutchison, Neely, Neill, & Walker, 2004; Kouider & Dupoux, 2004). In an article investigating the extent of unconscious cognition, Greenwald (1992) has argued that unconscious cognitive processing is far less sophisticated in its analytical capabilities than is often reported. Greenwald's (1992) argument rests on the premise that additional research has demonstrated unconscious analysis and processing of nothing more elaborate than word fragments.

As an example, Abrams and Greenwald (2000) required participants to categorise a set of consciously perceived ‘parent’ primes as either positive or negative in valence. Participants were subsequently required to categorise a set of subliminally perceived ‘hulip-type hybrid primes’, a non-word hybrid of two positive or two negative parent primes (e.g., humour-tulip-hulip, smut-bile-biut). Results indicated that participants were successfully able to categorise emotional valence despite the nonsensical nature of the hybrid primes. In a follow up study, having consciously categorised parent primes, participants were required to positively or negatively categorise a set of so called ‘tumour-type hybrid primes’. These primes were similarly created by combining two congruent parent primes to create a semantically comprehensible prime of different valence to parent primes (e.g. humour-tulip-tumour, smut-bile-smile). Results indicated that participants continued to classify emotional valence according to the valence of the parent prime rather than tumour-type prime, even to the extent that ‘smile’ was categorised as negative. The results of this study compellingly suggest that words are analysed at the level of (consciously primed) word-parts as opposed to whole-word meaning.

However, Sklar et al. (2012) have suggested that subliminal processing may have appeared limited in past research because of the small time windows that processing is given for backward masked stimuli (typically in the order of 30 ms). Their solution was to use continuous flash suppression, maintaining stimuli as subliminal for as long as two seconds. Impressively, they found that semantically incoherent sentences (e.g., “The bench ate a zebra”) broke through suppression faster than coherent sentences (e.g. “The lion ate a zebra”). However, as with SPA studies, there may have been a word-level effect influencing breakthrough as literally different words were used in the different conditions (in this example, “bench” versus “lion”). In a second series of

experiments, they found that three-term subtractions (e.g. 9 - 3 - 4) (though not additions) primed the speed of pronunciation of the subsequent correct answer. In neither the sentence coherence nor three-term subtraction experiments did the stimuli constitute obvious "set phrases" that may have been previously well learnt as a unit.

These results raise the question of what sort of combinations of stimuli are possible to process subliminally. For example, Van Opstal, Gevers, Osman, and Verguts (2010) demonstrated that a same/different judgement task on consciously perceived number targets (e.g., 1-1 or 1-3) extended to subliminal letter stimuli (e.g., a-A or a-D) even when participants were unaware of the presence of the letters. Van Opstal, Calderon, Gevers, and Verguts (2011) extended this finding by demonstrating that responding to the subliminal same/different judgements (e.g., a-A) could be modulated by unconscious context (e.g., either a-a or a-D). Therefore, priming effects were dependent upon the processing of both elements. We similarly wished to demonstrate semantic priming of two-element (word) primes and unconscious cognitive control by investigating whether it is possible to process instructions to exclude (i.e., negation) subliminally. As we will discuss, negation has a special place in consciousness research.

The use of negation allows easy control of stimuli, because stimuli can consist of the same words, just with or without "not". The use of negation also addresses one of the theoretical limits assigned to unconscious processes. According to Jacoby, Lindsay, and Toth (1992), what the conscious is uniquely equipped to do is control behaviour by excluding certain responses. Unconscious control exerted by subliminal stimuli was investigated by, for example, Lau and Passingham, (2007), in which a subliminal shape indicated which of two tasks to perform; and by van Gaal, Ridderinkhof, Scholte, and Lamme (2010), in which a subliminal no-go cue slowed down responses and activated a frontal-parietal inhibition network (see van Gaal, de Lange, & Cohen, 2012, for a

review of related work). Van den Bussche, Segers, and Reynvoet (2008) indicated limits to unconscious control in that the proportion of conscious stimuli could be used to modulate responding but not the proportion of subliminal stimuli. In contrast to previous studies that have looked at subliminal control, we will be exploring it in the specific case of linguistic negation processing. Although not dealing with linguistic negation, the previous work is encouraging in showing that there exists a mechanism by which unconscious control could operate. In this respect, the current work is consistent with Dienes and Perner's (2007) cold control theory of hypnosis, which postulates that hypnosis consists of unconscious executive control. It is also consistent with the findings of, for example, Norman, Price, and Jones (2011) and Wan, Dienes, and Fu (2008), who showed people could exert control over the use of structural knowledge, even when it was unconscious. That is, while the processing of subliminal linguistic negation has not been shown, it is plausible that the unconscious can deal with control and exclusion. Thus, the subliminal processing of negation in two-word phrases presents itself as possible on those theories that allow unconscious control (contrast Jacoby et al.), but beyond what has so far been shown to occur subliminally.

The present set of studies attempted to assess whether, contrary to Abrams and Greenwald (2000), subliminal perception is sensitive to the semantic comprehension of word combinations and sentence structure. In summing up his argument against complex unconscious cognition, Greenwald (1992) issued an empirical two-word challenge. This two-word challenge asserts that to demonstrate successful subliminal priming of two-word primes, neither word should individually impart the final meaning. Therefore, to claim successful unconscious processing of multiple words, each word would need to be individually processed. The present experiments aimed to meet this challenge by presenting participants with a two word instruction, instructing them

which of two subsequent words to choose. Therefore, performance would depend on the successful semantic processing of both words.

One explanation to account for the failure of many studies to demonstrate successful subliminal semantic activation of single or multiple word primes may be due to the adherence to strict objective thresholds using backward masking when measuring subliminality. Objective methods of assessing unconscious cognition presume that trial accuracy, beyond what would be expected by chance, indicates conscious knowledge (Seth et al., 2008). However, objective methods of assessing subliminal perception fail to take into account subjectivity; that is, an individual's conscious awareness of accuracy. The two thresholds differ, with unconscious processing occurring below the subjective threshold but limited unconscious processing below the objective. Therefore, the use of objective methods in measuring subliminal perception and unconscious processing have been heavily criticised for testing not just unconscious cognition, but degraded unconscious cognition (Dienes, 2004, 2008; Lau & Passingham, 2006). This indicates that to determine the full extent of unconscious processing, it is necessary to use the subjective threshold (compare Masters, Maxwell, & Eves, 2009; contrast Van den Bussche, Van den Noortgate, & Reynvoet, 2009, who found no significant effect of using objective versus subjective thresholds in a meta-analysis of subliminal priming effects [1]).

Therefore, using subjective methods of measuring subliminality, the following series of experiments required the participants to choose between two common nouns

[1] The mean effect for subjective thresholds was 0.85 (SE ≈ 0.5) and for objective, 0.68 (SE ≈ 0.24). While the difference is non-significant, a rough Bayes Factor calculated on the difference (0.17, SE ≈ 0.55), using a uniform from 0 to 0.85, is 0.87, indicating the non-significant result is insensitive (as the Bayes factor is between 1/3 and 3), and no conclusions follow from this contrast (see Dienes, 2011, for more on Bayes Factors, which are also explained in more detail below). Note also that these studies were not designed to test the difference between subjective and objective thresholds under otherwise equivalent conditions, unlike, for example, Cheesman and Merikle (1984).

(e.g. ‘kite-moon’), having been subliminally instructed with which noun to choose (e.g. ‘pick kite’, or ‘not kite’). Correct identification of the instructed noun would then indicate that unconscious cognition is capable of both processing and comprehending more complex demands, such as the pick and not instructions in this study. Furthermore, successful subliminal priming of negation would be in contrast to a similar experiment carried out by Draine and Greenwald (1996), who failed to demonstrate the priming of negation (at the objective threshold) and concluded that the process of negation exceeded the processing powers of unconscious cognition. Whilst it could be argued that success in the ‘pick’ conditions may not necessarily demonstrate the semantic comprehension of pick but rather simple recognition processes or partial word analysis (e.g., Abrams & Greenwald, 2000), success in the ‘not’ conditions would require the participant to inhibit initial recognition processes. In turn, this inhibition of recognition processes would imply lexical and semantic comprehension of negation. Therefore, if correct identification is above chance expectations, then this would indicate that cognition is capable of processing word combinations outside of conscious perception, as measured by the guessing criterion (Cheesman & Merikle, 1984, 1986) and/or the zero-correlation criterion (ZCC). Like Sklar et al. (2012), we will attempt to determine the limits of subliminal perception when it is given more time to operate than allowed by objective thresholds found with backward masking.

2.3. Experiment 1

Current investigations into subliminal perception and unconscious cognition have shown the superior priming effects of practiced versus novel primes (Abrams & Grinspan, 2007; Abrams, Klinger, & Greenwald, 2002; Draine & Greenwald, 1998). That is, the priming effects of subliminal primes that have earlier been perceived as

conscious targets prove more successful than non-practiced novel primes. This effect has been attributed to consciously perceived primes creating an episodic memory trace which is later re-activated upon subsequent subliminal presentation (Forster & Davis, 1984).

Therefore, to achieve maximum likelihood of successful subliminal priming effects, all subliminal primes in Experiment 1 were first practiced as a series of conscious trials. It was expected that for the conscious trials, participants would identify the correct noun in both 'pick' and 'not' conditions on close to 100% of the trials. For the subliminal trials, it was hypothesised that, using a subjective threshold, participants would identify the correct noun for 'pick' and 'not' conditions beyond chance expectations (that is, beyond 50% correct). In addition, the inhibition of recognition processes necessary in 'not' conditions makes it likely that noun identification in 'pick' conditions would be faster than noun identification in 'not' conditions. Therefore, it was hypothesised that response times to noun identification in 'pick' conditions would be faster than in 'not' conditions for both conscious and subliminal trials. In this first experiment we attempted to make the effect likely to occur, so that its absence would be informative. To anticipate, in subsequent experiments we tighten up alternative explanations to determine if the effect goes away.

2.3.1. Method

2.3.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependent variable, 25 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. Fifteen of the participants were female and ten male, with ages ranging from 18 to 40 years (M = 22.63, SD = 8.52).

2.3.1.2. Apparatus and Materials

The experiment was presented on a Dell laptop with a 60Hz screen refresh rate, limiting minimum stimulus presentation to 16 ms, with 16 ms increments. The study was created using E-Prime version 2.0. Trials were created from 20 common nouns, making up a total of 10 noun-pairs (e.g. '*baby-yard*' and '*ant-sky*'). All nouns were between 3-5 letters in length, and noun-pairs were phonemically and semantically distinctive and matched in length (see Appendix A for the noun pairs used in practice, conscious, SOA, and subliminal trials in Experiment 1). Each screen display was centrally presented in lower-case, black, bold Courier New font, and point size 18 on a white background. From a viewing distance of 60 cm, the dimensions of the conscious and subliminal primes subtended 1.43° of visual angle (height), and a range of 4.76-6.65° of visual angle (width). The arrangement of each of the 10 noun-pairs and instructions were counterbalanced so that participants viewed each of the eight permutations for each noun-pair (e.g. '*pick yard...1. baby, 2. yard*', '*pick yard...1. yard, 2. baby*', '*not yard...1. baby, 2. yard*' and '*not yard...1. yard, 2. baby*' etc.), creating a total of 80 distinct conscious and subliminal trials.

2.3.1.3. Procedure

Participants were tested individually in a small quiet space. All participants had normal or corrected to normal vision, and English was the first language for all participants. All trials consisted of four separate components: a fixation cross presented for 350 ms, the stimulus instruction (e.g. '*pick baby*' or '*not baby*'), a backward mask, longer in length than the stimulus and in the form of a series of ampersands (i.e., &&&&&&&) presented for 150 ms, and the final component consisting of the noun-pair choice (e.g. '*1. baby, 2. yard*') in which the participant was required to indicate the number corresponding to the noun in which they had been instructed to choose. The

experiment was separated into four continuous phases; conscious trials, SOA setting, subliminal trials, and re-testing the SOA threshold to check for drift.

2.3.1.3.1. Conscious Trials. Having read the instructions, the procedure began with a set of six practice conscious trials to accustom the participant to the task required. The common noun-pairs used in all practice trials were different from those used in experimental conscious and SOA setting phases. Following the fixation cross, the stimulus instruction was presented for 350 ms to ensure conscious perception. Programming in E-Prime ensured that the offset of the stimulus instruction was immediately followed by the onset of the backward mask in all experimental trials. This was especially important for subliminal trials in order to eliminate conscious visual perception. After the backward mask, participants were presented with the noun-pair choice in which they were required to press '1' if they had been instructed to choose the first word, and '2' if they had been instructed to choose the second. The noun-pair choice remained on the screen until the participant had made their choice. Having made their choice, a 250 ms pause preceded the onset of the next trial. Having completed the set of six practice trials, participants were instructed to continue to the experimental conscious trials. The procedure for the conscious trials followed the exact procedure used in the practice trials. Participants completed two blocks of 40 randomly presented conscious trials, with an emphasis placed on accuracy as opposed to speed. Participants were not informed whether their choice was correct or incorrect.

2.3.1.3.2. SOA Setting. The SOA of each participant was assessed separately to ascertain individual subjective thresholds. Following the two blocks of conscious trials, participants moved on to the SOA setting phase. Participants were required to complete the same task format used in the conscious phase. Participants were presented with the fixation cross and the instruction prime, followed immediately by a backward mask and

then the noun-pair choice. Following each trial, participants were required to rate, on a scale of 50-100%, how confident they were that they had chosen the correct noun; 100% would indicate that the participant absolutely knew which noun to choose, whilst 50% would indicate that they were purely guessing. During this part of the experiment, if a participant rated confidence to be anything above 50%, stimulus duration was reduced by 16 ms after each trial, from a starting point of 140 ms. Once a participant had rated confidence to be at 50% (guessing), the SOA remained at that same presentation duration for the following trials. Once confidence had been rated at 50% (chance performance) for five successive trials, the experiment proceeded to the subliminal phase. If during any of these five successive trials participants rated confidence to be anything above 50%, SOA was again reduced until five successive trials at 50% confidence had been completed. Before the SOA setting phase began, participants completed a set of six practice trials to accustom themselves to the confidence procedure. For the practice trials, prime presentation was held at 140 ms. The common noun-pairs used in both practice and SOA setting phases were different from those used in conscious and subliminal phases.

2.3.1.3.3. Subliminal Trials. Once the SOA setting phase had been completed, the subliminal phase of the experiment consisted of the same 80 trials used in the conscious phase, divided into the same two blocks of 40 randomly placed trials. There were no practice trials for the subliminal phase. Stimulus duration for the subliminal trials was determined by the point at which participants had rated confidence to be at 50% for five successive trials during the SOA setting phase. To prevent rhythmic pressing of the "1" and "2" keys, and to remind participants of the task required, each block of 40 subliminal trials additionally contained 10 randomly placed conscious trials (at 350 ms exposure) (cf. Pratte & Rouder, 2009), creating two blocks of 50 trials.

2.3.1.3.4. Threshold Drift. The final phase of the experiment aimed to assess whether individual subjective thresholds of awareness had drifted through the course of the experiment. If the SOA at the finish of the experiment was lower than at the beginning of the subliminal trials, this could indicate that participants may have been consciously aware of the subliminal primes (Kouider & Dupoux, 2004). The SOA threshold drift phase followed the exact format used in the SOA setting phase, using the same materials, with 16 ms decrements in presentation duration from a starting point of 140 ms. Once the participant again rated confidence to be at 50% for five successive trials, the participants were thanked and the experiment ended. After completion of the experiment, participants were fully debriefed and received an information sheet giving some background to the study as well as experimenter details.

2.3.2. Results

2.3.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 16 ms to 64 ms, with an average experimental subliminal presentation duration of 48 ms (*SD* = 15).

2.3.2.2. Trial Accuracy.

It was expected that for the conscious phase of the experiment, participants would get approximately 100% of the trials correct. In fact, the mean number of correct identifications for conscious trials was slightly off 100% (*M* = 97%, *SE* = .5). For the 'pick' trials, mean correct identification averaged at 95% (*SE* = .9), whilst for 'not' trials, mean correct identification averaged at 98% (*SE* = .4).

Mean correct noun identification for subliminal trials was 62% (*SE* = 2), with accuracy for ‘pick’ (*M* = 66%, *SE* = 2) and ‘not’ (*M* = 59%, *SE* = 2) conditions being presented in figure 2, with a 50% reference line indicating chance performance. For all statistical tests, we used an alpha level of .05 to determine significance. Accuracy in both ‘pick’ (*t*(24) = 7.46, *p* < .001, *d* = 3.05) and ‘not’ (*t*(24) = 3.9, *p* = .001, *d* = 1.59) conditions significantly differed from what would be expected by chance. In addition, a paired-sample t-test looking at the percentage of occasions participants simply chose the subliminally presented noun (i.e. ignoring the preceding instruction) significantly differed between ‘pick’ (*M* = 66%, *SE* = 2) and ‘not’ (*M* = 41%, *SE* = 2, *t*(24) = 5.97, *p* < .001, *d* = 2.44) conditions. Such discrimination was also assessed in terms of (logistic) d’, which differed significantly from zero, *M* = .60, *SE* = .11, *t*(24) = 5.62, *p* < .001, *d* = 2.29.

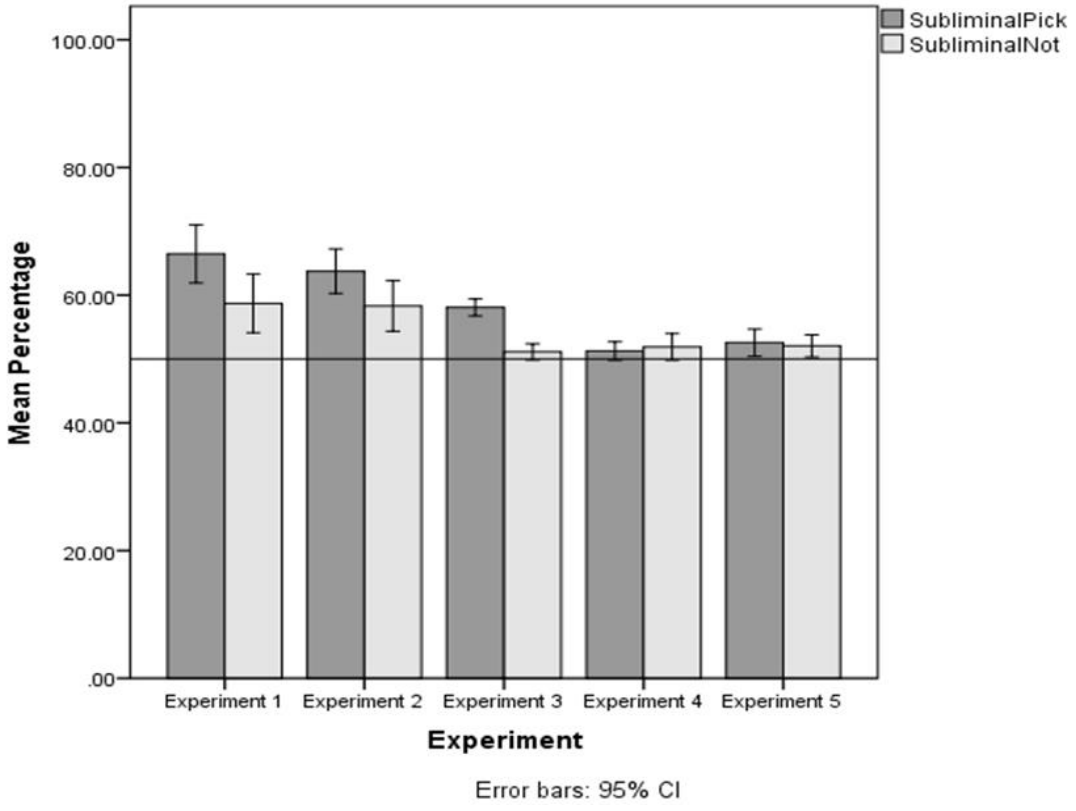

Figure 2: Mean percentage values for correct identification of the noun in subliminal *pick* and *not* conditions for Experiments 1, 2, 3, 4 and 5, with a 50% reference line indicating chance performance.

There was a significant relationship between initial SOA and performance accuracy for both subliminal ‘pick’, $r = .5$, $p = .009$ and ‘not’, $r = .4$, $p = .04$ conditions, indicating possible conscious processing, or else better unconscious processing for longer SOAs.

2.3.2.3. Response Time.

The time taken to identify the instructed noun was recorded for both conscious and subliminal ‘pick’ and ‘not’ conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in ‘pick’ conditions ($M = 712$ ms, $SE = 20$) when compared with ‘not’ conditions ($M = 844$ ms, $SE = 32$, $t(24) = -5.92$, $p < .001$, $d = 2.42$). Similarly, for the subliminal trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in ‘pick’ conditions ($M = 864$ ms, $SE = 50$) when compared to ‘not’ conditions ($M = 894$ ms, $SE = 50$, $t(24) = -2.27$, $p = .03$, $d = 0.93$).

2.3.2.4. Threshold Drift.

Data from the threshold drift phase revealed that subjective threshold durations ranged from an SOA of 32 ms to 80 ms, with a mean experimental subliminal presentation duration of 48 ms ($SD = 16.24$), matching the sample mean value found in the SOA setting phase, $t(24) = .04$, $p = .97$, $d = 0.02$. For 15 of the 25 participants, SOA’s at the finish of the subliminal trials differed from the SOA at the start of the subliminal phase. Subjective thresholds reduced by 16 ms for seven of the participants, and by 32 ms for one participant. For six of the participants, SOA increased by 16 ms, and for one participant the SOA increased by 48 ms. There was a significant relationship between the SOA setting stage and the SOA threshold drift phase, $r = .4$, $p = .04$, indicating there was some consistency in measuring the threshold.

2.3.2.5. Trial Accuracy and Response Time.

When the data from the eight participants whose SOA had reduced by ≥16 ms was removed, d' significantly differed from zero (M = .56, SE = .15, $t(16) = 3.60$, p = .002, d = 1.8), and accuracy in both subliminal 'pick' (M = 64%, SE = 3, $t(16) = 4.81$, p < .001, d = 2.41) and 'not' (M = 58%, SE = 3, $t(16) = 2.63$, p = .02, d = 1.32) conditions significantly differed from what would be expected by chance alone. Similarly, when the instruction is ignored, the percentage of occasions participants simply chose the subliminally presented noun significantly differed between 'pick' (M = 64%, SE = 3) and 'not' (M = 42%, SE = 3, $t(16) = 3.8$, p = .002, d = 1.90) conditions. In addition, on removal of the eight participants, participants remained significantly quicker to identify the noun in subliminal 'pick' conditions (M = 845 ms, SE = 64) when compared to 'not' conditions (M = 1139 ms, SE = 86, $t(16) = -2.66$, p = .02, d = 1.33).

2.3.3. Discussion

Noun identification in the subliminal 'pick' trials indicated that participants correctly identified the noun on an average 66% of the trials, whilst accuracy in subliminal 'not' trials averaged 58%. Therefore, as hypothesised, participants successfully identified the correct noun at above chance expectations for both subliminally presented 'pick' and 'not' trials. Whilst it could be argued that correct identification in the subliminal 'pick' trials may have demonstrated the ability of unconscious processing to merely recognise letter patterns, correct identification in the subliminal 'not' trials would require the inhibition of these recognition processes. Furthermore, the occasions in which the participant simply chose the subliminally presented noun significantly differed between 'pick' and 'not' conditions, further demonstrating the appropriate use of the subliminal instruction. Consequently, the

success of Experiment 1 in demonstrating successful subliminal priming in the ‘not’ condition may demonstrate the semantic comprehension of ‘not’.

The use of the guessing criterion for establishing subliminal perception could be criticized on the grounds that participants come with different interpretations as to what “guess” means. However, in the instructions, and on each screen shot when participants were required to rate confidence, they were given a definition of what ‘guessing’ (and ‘know’) means. The participants were told to give a value of 50% if they believed that they were purely guessing; that they had no idea which word to choose and that they may as well have tossed a coin. They were also told that if they had any confidence at all, if they believed they saw anything of potential relevance at all, they were to give a value above 50. Poorly defined end points on a confidence scale can render the guessing criterion meaningless; thus, the instructions precisely defined the required concept of “guess”.

Further support for the unconscious processing of negation in subliminal conditions was provided by response time data, which demonstrated the difference in cognitive difficulty between ‘pick’ and ‘not’ instructions. Once the word *pick* has been read and cognitively processed, the word indicates that the accompanying noun is the correct noun to choose. Therefore, upon presentation of the noun-pair choice, the letter mapping and recognition processes required to identify the just-presented noun respond quickly. However, the word *not* indicates that the accompanying noun is not the correct noun to choose. Consequently, upon presentation of the noun-pair choice, it is first necessary to identify the just-presented noun using the same letter mapping and recognition processes used in ‘pick’ trials, before then indicating the other noun. Therefore, the additional time required to indicate the correct noun in ‘not’ conditions should be evident in both conscious and subliminal response times. Response times for

the conscious trials suggested that, as predicted, it took significantly longer to identify the noun in ‘not’ conditions when compared to ‘pick’ conditions, an average 131 milliseconds longer. Although it only took an average 30 milliseconds longer to identify the noun in subliminal ‘not’ conditions when compared to ‘pick’ conditions, this difference in response times was also significant, thereby demonstrating the difference in task difficulty, even though participants were not consciously aware of which noun to choose.

Past research investigating the extent of subliminal priming paints a controversial and confusing picture. Whilst some studies clearly demonstrate successful (e.g., Diaz & McCarthy, 2007; Ortells, Daza, & Fox, 2003), and even sophisticated (e.g., Silverman, Ross, Adler, & Lustig, 1978; Silverman & Weinberger, 1985) semantic subliminal priming, other studies suggest that the unconscious analysis of words is actually only completed at the sublexical level (e.g. Abrams & Greenwald, 2000; Hutchison, Neely, Neill, & Walker, 2004). Experiment 1 aimed to successfully demonstrate the cognitive processing of subliminally presented two-word instructions using individual subjective thresholds. That is, if the individual believed they did not know the correct noun to choose, it can be assumed that they did not possess conscious knowledge (Dienes, 2008).

However, whilst the results of Experiment 1 appear to have demonstrated successful unconscious semantic processing, threshold drift data suggests that for eight of the participants, subliminal subjective thresholds may have reduced between SOA settings phases and completion of the subliminal trials. This in turn may indicate conscious, as opposed to unconscious, knowledge of which noun to choose for some of the participants. In addition to potential conscious awareness, significant criticisms arise due to the use of practiced versus novel primes (Damian, 2001; Kunde, Kiesel, &

Hoffmann, 2003; Schlaghecken & Eimer, 2004). Abrams and Grinspan (2007) argue that simple processing at the feature level is all that is needed to identify a stimulus that is predicted by experience and expectation. As mentioned previously, when primes are practiced consciously they acquire memory traces between a given stimulus and motoric response. These stimulus-response (S-R) mappings remain in short-term memory and are later re-activated upon presentation of the same trials presented subliminally. Whilst these S-R mappings may result in successful subliminal priming, it indicates that the semantic analysis of subliminal primes need not necessarily occur as the semantic system is by-passed. That is, participants may simply have formed an S-R link between, for example, "not baby" and "yard" (although "yard" was associated with each button press equally in this situation). A subsequent correct response merely relies on the successful retrieval of the established S-R link and not the semantic processing of "not". Experiment 1 used conditions that were most likely to find a priming effect if there were one, and so the results motivate further and more rigorous testing of subliminal priming. Therefore, the issue of practiced versus novel primes and S-R mappings are explored further in Experiment 2.

2.4. Experiment 2

In Experiment 2, participants performed the same task performed in Experiment 1; a set of conscious trials were followed by an SOA setting phase, a set of subliminal trials and finally a threshold drift phase. However, separate sets of common nouns were used in conscious and subliminal trials to avoid potential successful subliminal priming being attributed to the retrieval of S-R links. To achieve maximum likelihood of successful priming without the establishment of S-R links, participants first practiced 'pick' and 'not' trials consciously with one set of nouns. Participants then

consciously viewed the list of nouns that would be used in subliminal trials, in an attempt to activate word representations, before continuing with the experiment. In this way, any positive results could not be credited to the retrieval of S-R links as at no point had the subliminal nouns been paired with any particular response.

2.4.1. Method

2.4.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependent variable, 25 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the participants took part in Experiment 1. Eighteen of the participants were female and seven male, with ages ranging from 18 to 44 years (M = 20.96, SD = 6.2).

2.4.1.2. Apparatus and Materials

Apparatus for Experiment 2 replicated that used in Experiment 1. The 10 noun-pairs used in Experiment 1 were used as conscious trials in Experiment 2, with an additional 20 common nouns between 3-5 letters in length creating a further 10 phonemically and semantically distinctive noun-pairs for subliminal trials (see Appendix B for noun pairs used in practice, conscious, SOA, and subliminal trials in Experiments 2, 3, 4, and 5).

2.4.1.3. Procedure

Procedure replicated that of Experiment 1, however following the conscious trials and before the SOA setting, participants were presented with a list of the 20 nouns that would be used in the subliminal trials. Each noun in the list appeared at the centre of the screen for 2000 ms, with a 150 ms pause between each noun. This list of 20 nouns was presented twice.

2.4.2. Results

2.4.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 16 ms to 64 ms, with an average experimental subliminal presentation duration of 48 ms (*SD* = 15).

2.4.2.2. Trial Accuracy.

The mean rate of correct identifications made on conscious trials was 95% (*SE* = .01). Mean correct identifications was 94% (*SE* = .8) for 'pick' trials, and 97% (*SE* = .6) for 'not' trials. The mean number of correct noun identifications for the subliminal 'pick' (*M* = 64%, *SE* = 2) and 'not' (*M* = 58%, *SE* = 2) conditions are presented in figure 2 with a reference line indicating 50% chance performance. On subliminal trials, accuracy on both 'pick' ($t(24) = 8.17$, $p < .001$, $d = 3.34$) and 'not' ($t(24) = 4.31$, $p < .001$, $d = 1.76$) conditions significantly differed from what would be expected by chance. A paired-sample t-test looking at the percentage of occasions participants simply chose the subliminally presented noun (i.e. ignoring the preceding instruction) significantly differed between 'pick' (*M* = 64%, *SE* = 2) and 'not' (*M* = 42%, *SE* = 2, $t(24) = 6.67$, $p < .001$, $d = 2.72$) conditions. Overall subliminal d' values also differed significantly from zero (*M* = .51, *SE* = .08, $t(24) = 6.63$, $p < .001$, $d = 2.71$). There was a significant relationship between initial SOA and performance accuracy for both subliminal 'pick', $r = .7$, $p < .001$ and 'not', $r = .6$, $p = .001$ conditions, indicating possible conscious processing, or else better unconscious processing for longer SOAs.

2.4.2.3. Response Time.

The time taken to identify the noun they had been instructed to choose was again recorded for both conscious and subliminal 'pick' and 'not' conditions. A paired-sample t-test revealed that on average, for the conscious trials, participants were significantly quicker to identify the noun in 'pick' conditions (*M* = 685 ms, *SE* = 11)

than in ‘not’ conditions (M = 875 ms, SE = 28, $t(24) = -6.53$, $p < .001$, $d = 2.67$). Whilst the results suggested that participants were similarly quicker in subliminal trials to identify the noun in ‘pick’ (M = 885 ms, SE = 49) conditions when compared to ‘not’ conditions (M = 952 ms, SE = 33), a paired-sample t-test revealed that this difference in response times was not significant ($t(24) = -1.76$, $p = .09$, $d = 0.72$).

However, from the non-significant result we were unable to determine whether this implied that there was evidence for the null hypothesis, that there would be no difference in response times between subliminal ‘pick’ and ‘not’ conditions, or that there was no evidence for any conclusion (Dienes, 2011). To do this, we can use a Bayes Factor. Whilst values under 1/3 are substantial evidence in support of the null hypothesis, values over 3 are seen as substantial evidence in support of the experimental hypothesis (Jeffreys, 1963); a Bayes Factor of 1 indicates the evidence is exactly neutral between the two theories. Values between 1/3 and 3 indicate data insensitivity and no conclusions should be drawn. To calculate the Bayes Factor, it is first necessary to specify the likely mean response time difference. The difference in subliminal response times for ‘pick’ and ‘not’ conditions in Experiment 1 was 30 ms. Thus, a half normal was used with a standard deviation equal to 30 (as per the guidelines in Dienes, 2011, Appendix). The sample mean difference between subliminal ‘pick’ and ‘not’ conditions was 67 ms (SE of the difference = 38), leading to a Bayes Factor of B = 2.46, indicating more support for the experimental hypothesis than the null hypothesis (Bayes Factor greater than 1), but also indicating that the data were not sensitive.

2.4.2.4. Threshold Drift.

Data from the threshold drift phase revealed that subjective SOA durations ranged from an SOA of 16 ms to 80 ms, with an average experimental subliminal presentation duration of 48 ms (SD = 17), matching the mean value found in the SOA

setting phase, $t(24) = .65$, $p = .52$, $d = 0.27$. However, for 17 of the participants, SOA's at the end of the experiment differed from the SOA at the start of the experiment. Subjective thresholds reduced by an average of 16 ms for ten of the participants, and for seven of the participants, SOA increased by 16 ms. There was a significant relationship between the SOA setting stage and the SOA threshold drift phase, $r = .67$, $p < .001$, indicating there was some consistency in measuring thresholds.

2.4.2.5. Trial Accuracy and Response Time.

When the data from the 10 participants whose SOA had reduced by 16 ms was removed, overall d' values remained significantly above zero ($M = .47$, $SE = .1$, $t(14) = 4.64$, $p < .001$, $d = 2.48$). Accuracy in both subliminal 'pick' ($M = 63\%$, $SE = 2$, $t(14) = 6.03$, $p < .001$, $d = 3.22$) and 'not' ($M = 57\%$, $SE = 3$, $t(14) = 2.72$, $p = .02$, $d = 1.45$) conditions significantly differed from what would be expected by chance. Similarly, when the instruction is ignored, the percentage of occasions participants simply chose the subliminally presented noun significantly differed between 'pick' ($M = 63\%$, $SE = 2$) and 'not' ($M = 43\%$, $SE = 3$, $t(14) = 4.64$, $p < .001$, $d = 2.48$) conditions. On removal of the 10 data sets, the difference in response times between subliminal 'pick' ($M = 975$ ms, $SE = 39$) and 'not' conditions ($M = 1019$ ms, $SE = 76$), remained non-significant ($t(14) = -.55$, $p = .59$, $d = 0.29$).

2.4.3. Discussion

The accuracy data from the conscious trials in Experiment 2 replicated that found in Experiment 1. For the subliminal trials, participants correctly identified the noun in 'pick' trials at an average rate of 63%, whilst correct identification in subliminal 'not' trials averaged at 57-58%. The results of Experiment 2 replicate those found in Experiment 1 in that the data appears to support the hypothesis that participants would successfully identify the correct noun, above chance performance, for subliminally

presented ‘pick’ and ‘not’ instructions. Similarly, when the instruction was ignored, the occasions in which the participant simply chose the subliminally presented noun significantly differed between ‘pick’ and ‘not’ conditions, providing further evidence to support the appropriate processing of the subliminal instruction. As in Experiment 1, response time data suggested that for conscious trials, participants were significantly quicker to identify the noun in ‘pick’ conditions when compared to ‘not’ conditions, by an average 189 ms. Although participants were on average 67 ms quicker to identify the noun in subliminal ‘pick’ conditions when compared to ‘not’, this difference in reaction time was not statistically significant. However, a Bayes Factor indicated insensitive data not strong enough to yet draw conclusions, albeit with more support for the hypothesis of a difference in response times than for the null hypothesis.

Experiment 2 aimed to replicate the findings from Experiment 1, whilst avoiding the assumption that successful subliminal priming was a result of the retrieval of S-R links established during conscious rehearsal of stimuli. By consciously viewing the nouns to be used in subliminal trials, presented individually, participants gained the advantage of practiced rather than novel primes (Kunde, Kiesel & Hoffmann, 2003), but were prevented from establishing S-R links by viewing the nouns in the absence of either ‘pick’ or ‘not’ instructions or an associated motor response, supporting research demonstrating that semantic priming can extend to novel and unpractised stimuli (e.g., Naccache & Dehaene, 2001). The results of Experiment 2 appear to support the contention that participants would successfully discriminate between the two nouns at above chance performance in subliminal trials.

However, whilst the results of both Experiments 1 and 2 provide support demonstrating successful unconscious processing of logical negation, threshold drift data from both experiments could suggest that conscious processing may be responsible

for success in subliminal ‘pick’ and ‘not’ conditions. It has been found, for example, that practice with an initially subliminal task can result in participants learning to be conscious, admittedly over considerably more trials than we used (Schwiedrzik, Singer , & Melloni, 2009, 2011). In both Experiments 1 and 2, the threshold drift phase aimed to determine whether individual subjective thresholds of subliminality remained the same at the start and at the end of the subliminal phases of the experiment. If subjective thresholds at the end of the experimental subliminal condition were lower than at the start, it could be argued that participants may have consciously been aware of the stimulus instruction, and thus possessed conscious knowledge as to which noun to choose. While there was not an overall drift down in subjective thresholds, some participants drifted down whilst some drifted up. When the data from those participants whose SOA had drifted down were excluded, the effect remained intact. However, the presence of changes in the assessed thresholds mean that it is possible there existed trials where perception was conscious. The issues regarding conscious awareness and threshold drift were explored further in Experiment 3.

2.5. Experiment 3

Experiments 1 and 2 provide evidence that the cognitive unconscious is capable of analysing the syntactic function of subliminally presented ‘pick’ and ‘not’ instructions without attributing the priming effect to the retrieval of established S-R links. However, individual visual thresholds may vary from trial to trial as a result of, for example, dark adaption (Holender, 1986). This variation in visual threshold may in turn allow conscious perception of stimuli that is intended to be subliminal. The threshold drift data from both Experiments 1 and 2 demonstrate this possible variance in subjective thresholds as for a number of participants; the measured SOA differed

between the start and finish of the subliminal phase. For those participants whose SOA reduced between SOA setting and threshold drift, conscious perception of subliminal primes may be responsible for any successful priming effects. For those participants whose SOA increased between SOA setting and threshold drift, we cannot be sure there was a simple linear increase. Therefore, Experiment 3 aimed to replicate Experiments 1 and 2 by investigating subliminal processing whilst continually assessing subjective thresholds (cf. Marcel, 1983b, who also assessed stability of thresholds throughout the priming phase). This was achieved by requiring participants to rate their confidence in selecting the right noun after each trial in the subliminal phase.

As in Experiments 1 and 2, it was hypothesised that for the subliminal trials, participants would correctly identify the noun for both 'pick' and 'not' conditions beyond 50% chance expectation. As evidenced in Experiment 1, it was predicted that response times to noun identification in 'pick' conditions would be faster than in 'not' conditions for both conscious and subliminal trials.

2.5.1. Method

2.5.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependent variable, 24 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the participants took part in Experiments 1 or 2. Nineteen of the participants were female and five male, with ages ranging from 18 to 32 years (M = 20.21, SD = 3.27).

2.5.1.2. Apparatus and Materials

Replicated Experiment 2.

2.5.1.3. Procedure

Replicated Experiment 2. Participants were also asked to rate their confidence in choosing the correct noun on a scale of 50-100% after each subliminal trial. Participants were required to rate over 50% if they believed they had any awareness of which noun to choose, and to rate 50% if they believed they were guessing.

2.5.2. Results

2.5.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 16 ms to 64 ms, with an average experimental subliminal presentation duration of 48 ms (*SD* = 17).

2.5.2.2. Trial Accuracy.

The mean rate of correct identifications made on conscious trials was 98% (*SE* = .4). Mean correct identifications was 96% (*SE* = .8) for 'pick' trials, and 99% (*SE* = .3) for 'not' trials. For the subliminal trials, only those trials in which participants rated confidence to be at 50% (i.e. guessing) were included in the analysis. Of the 80 subliminal trials, the number of trials upon which each participant rated confidence to be above 50% ranged between 0 and 26 trials (*M* = 7, *SD* = 7). Mean percentage correct responses for subliminal 'pick' (*M* = 58%, *SE* = .6) and 'not' (*M* = 51%, *SE* = .6) conditions are presented in figure 2, with a 50% reference line indicating chance performance. On subliminal trials, overall d' values significantly differed from zero (*M* = .20, *SE* = .02, $t(23) = 10.57$, $p < .001$, $d = 4.40$). Accuracy on 'pick' ($t(23) = 12.58$, $p < .001$, $d = 5.25$) trials was significant, whilst 'not' ($t(23) = 1.84$, $p = .07$, $d = 0.77$) trials did not significantly differ from what would be expected by chance alone. In the previous two experiments, the subliminal 'not' trials produced an effect approximately 8% above baseline. A Bayes Factor, using a half-normal with *SD* equal to 8%, of B = 2.09, indicated that the data were insensitive, but if anything supported the hypothesis

of a subliminal effect. Furthermore, looking at the percentage of occasions participants simply chose the subliminally presented noun (i.e. ignoring the preceding instruction) significantly differed between 'pick' (M = 58%, SE = .6) and 'not' (M = 49%, SE = .6, $t(23) = 10.82$, $p < .001$, $d = 4.51$) conditions. Only if *pick* and *not* were differentially processed could there be a significant difference between 'pick' and 'not' trials in the proportion of times the presented word was selected. There was a not a significant relationship between SOA and performance accuracy for both subliminal 'pick', $r = .3$, $p = .09$ and 'not', $r = .1$, $p = .73$ conditions.

Conscious knowledge of the subliminal instruction was also assessed using the zero-correlation criterion (ZCC) to establish whether there was a relationship between confidence and accuracy on trials when the participant rated confidence to be above 50%. The difference in accuracy between 'guess' and 'any confidence' was -.54%, which was not significant ($t(23) = 1.69$, $p = .11$, $d = 0.70$). A Bayes Factor was conducted to assess whether the data supported the null hypothesis that there was no relation between confidence and accuracy. Firstly, the range of effect sizes expected if there were conscious knowledge needed to be specified. The maximum slope was determined by the overall accuracy in Experiment 3 (3%) divided by the proportion of confident responses (.08)[2]. Therefore, the maximum slope = 37.5%. Using a uniform distribution between 0 and 37.5 (sample M = -.54, SE = .31) produced a Bayes Factor of 0.00, providing strong evidence for the null hypothesis that there was no relation between confidence and accuracy[3]. The correlation between confidence and accuracy

[2] Let X be a weighted average of the performance above baseline when guessing (G) and when confident (C), with the weights being the proportions of each type of response. That is, X = (1 - pc) * G + pc * C. By definition, our measure of confidence accuracy relation, the slope, is C–G. This will be maximum when all guessing responses are at baseline, i.e. when G = 0. In this case, slope = C–G = C. Also in this case, X = pc * C, with the G term dropping out. Rearranging, C = X/pc. Thus, since maximum slope = C in this case, maximum slope = X/pc. QED. See, for example, Guo et al. (2013) and Li et al. (2013) for the previous use of this method for the zero correlation criterion.

[3] Kanai, Walsh and Tseng (2010) offer a subjective discriminability of invisibility (SDI) index to further discriminate between a lack of confidence as a result of either perceptual or attentional blindness.

was additionally measured using Type II d'. Type II d' did not significantly differ from zero (M = -.01, SE = .01, $t(23)$ = -1.69, p = .10, d = 0.70). A Bayes Factor was conducted to assess whether the Type II data supported the null hypothesis that there was no relation between confidence and accuracy. Given plausible assumptions, Type II d' does not exceed Type I (Barrett, Dienes & Seth, in press). Thus, the alternative hypothesis that there existed some relation between confidence and accuracy (i.e., some conscious perception) was modelled as a uniform distribution between 0 and the mean Type I d' of .2. The Bayes Factor of 0.03 provided strong support for the null hypothesis and hence the existence of subliminal perception.

2.5.2.3. Response Time.

The time taken to identify the noun they had been instructed to choose was recorded for both conscious and subliminal 'pick' and 'not' conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in 'pick' conditions (M = 728 ms, SE = 23) than in 'not' conditions (M = 851 ms, SE = 35, $t(23)$ = -4.7, p < .001, d = 1.96). Participants were similarly quicker in subliminal trials to identify the noun in 'pick' conditions (M = 834 ms, SE = 45) when compared to 'not' conditions (M = 854 ms, SE = 43), however, as evidenced in Experiment 2, a paired sample t-test revealed that this difference in reaction times was not significant ($t(23)$ = -1.63, p = .12, d = 0.68). The mean effect from Experiments 1 and 2 was 48 ms; this was as the standard deviation of a half-normal, as before. With a sample mean difference between subliminal 'pick' and 'not' conditions of 20 ms (SE of the difference = 13), the Bayes Factor was B = 1.47

However, due to the lack of trials in which a stimulus was 'absent', or an appropriate equivalent, we were unable to apply the SDI in this case. For Type II sensitivity, Maniscalco & Lau (2012) show their meta-d' measure is superior in principle to Type II d' (see also Barret et al, in press, for confirmation with detailed analyses); however, meta-d' is more unstable for small N than Type II d' in our experience, so we have used the latter.

indicating data insensitivity and no conclusions should be drawn, with the evidence slightly telling against the null hypothesis.

2.5.3. Discussion

Using individual subjective thresholds (Cheesman & Merikle, 1984), the results of Experiments 1 and 2 suggested that when presented with a subliminal prime instruction to choose a particular noun, unconscious cognition is able to successfully choose the correct noun above mere chance performance. Experiment 3 validated the threshold-setting procedure used in the previous experiments. The ZCC indicated a sensitive confirmation of the null hypothesis of no conscious awareness, ruling out partial awareness (Kouider & Dupoux, 2004). Note that partial awareness of the displayed noun in itself is not sufficient to know in any way which choice to make; a participant would need to consciously have partial information of both the noun and the instruction (‘not’ versus ‘pick’). Any such awareness should be reflected in confidence ratings; the ZCC, by contrast, supports the claim that perception was subliminal. It could be argued that maybe participants gave up on using the confidence scale (despite clearly using it appropriately on conscious trials). Even this objection cannot be plausibly sustained because the Bayes factor which indicated strong evidence for the ZCC assumed that the population effect could be indefinitely small. Thus, the alternative hypothesis that was rejected is consistent with participants trying to some degree but in a noisy way (i.e. “giving up” to some degree). The “giving up” hypothesis, to survive this test, would need to assert a priori that participants gave up completely. Without any prior basis for asserting complete failure to follow instructions, the “giving up” hypothesis can be rejected.

There were trials on which participants indicated some confidence. The results for the ZCC implied that participants used confident responses when they had no better

access to information than when they used guess responses. Thus, participants may have been driven by a need to vary the response used, and thus sometimes gave a confidence greater than 50%. Such a tendency will add noise to measuring the threshold, partly explaining the lack of 100% reliability in threshold measurement, and also indicating how the apparent threshold drift in some participants in previous experiments could have been spurious.

Because noun pairs were repeated, it might be argued that if a noun pair that had been confidently seen was repeated, the subliminal choice effect we observed may in fact depend on consciously primed specific stimulus-response links. However, trials were not repeated exactly, as noun pairs were only repeated for counter-balancing reasons. Thus having once associated a given noun with a left response, there is a higher probability that that same noun will be associated with right response on its next appearance. Thus, S-R links would induce subjects to make incorrect rather than correct responses. Further, the results of the ZCC indicate that "confident" responses may not have reflected conscious perception, but rather, for example, a desire to use all response options.

Whilst an effect of 'not' versus 'pick' remained in Experiment 3, the demonstration would be stronger if the accuracy of 'not' trials were individually significantly above baseline performance. However, research has demonstrated that the type of mask used, for example a string of letters or ampersands, can adversely influence the processing of stimuli by interfering with phoneme, grapheme and semantic interpretation (Di Lollo, Enns, & Rensink, 2000; McClelland, 1978; Perfetti & Bell, 1991; Walley & Weiden, 1973). Therefore, Experiment 4 aimed to develop a more sensitive method of delivering subliminal stimuli.

2.6. Experiment 4

To render a prime unconscious, it is necessary to mask the prime in order to avoid conscious perception. The most common method of masking is to use backward masks in the form of symbols (e.g. hatch marks or ampersands), or letter strings (Kiesel, Kunde, & Hoffmann, 2007). However, previous research has highlighted the detrimental effect that backward masking can have on the cognitive comprehension of subliminal primes (Di Lollo, Enns, & Rensink, 2000; McClelland, 1978; Perfetti & Bell, 1991; Walley & Weiden, 1973), due to interference during the pattern and letter recognition part of processing (Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003). Kouider and Dehaene (2007) state that for a prime to be subliminal, it needs to be presented for a sufficiently short duration, and the mask needs to either share stimulus features or fit the contours of the prime closely. Therefore, Experiment 4 attempted to successfully demonstrate subliminal semantic priming using a grey-scale contrast masking method established by Lamy, Mudrik, and Deouell (2008). The experiment followed the same format as Experiment 3 in that participants viewed the list of nouns to be used in subliminal trials to gain the advantage of practice without the establishment of S-R links, and continually assessed subliminal subjective thresholds.

As in Experiments 1, 2 and 3, it was hypothesised that for the subliminal trials, participants would correctly identify the noun for both ‘pick’ and ‘not’ conditions beyond 50% chance expectation. As evidenced in the previous 3 experiments, it was predicted that response times to noun identification in ‘pick’ conditions would be faster than in ‘not’ conditions for both conscious and subliminal trials.

2.6.1. Method

2.6.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependent variable, 22 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the participants took part in Experiments 1, 2, or 3. Sixteen of the participants were female and six male, with ages ranging from 18 to 31 years (M = 20.23, SD = 3.44).

2.6.1.2. Apparatus and Materials

Replicated that used in Experiments 2 and 3.

2.6.1.3. Procedure

2.6.1.3.1. Conscious Trials.

The stimulus instruction was presented within a rectangular box of the same size as used for the fixation. From a viewing distance of 60 cm, the dimensions of the rectangular box subtended 2.39° of visual angle (height), and 11.31° of visual angle (width). As evidenced in Experiments 1, 2, and 3, the conscious and subliminal primes subtended 1.43° of visual angle (height), and a range of 4.76-6.65° of visual angle (width). The contrast between prime and background was measured in terms of luminance using a Cambridge Research Systems ColorCal colorimeter defined in terms of CIE 1931 coordinates. The luminance of the grey text in conscious trials was Y = 14.35 cd/m^2 (x = 0.277, y = 0.216) against a grey background luminance of Y = 61.04 cd/m^2 (x = 0.293, y = 0.268) (see figure 3 for an example of the contrast between prime and background for conscious trials). The stimulus instruction was presented on the screen for 250 ms to ensure conscious perception. The stimulus instruction was immediately followed by the two-noun choice (e.g. '*1. baby*' and '*2. yard*') presented in the centre of the screen.

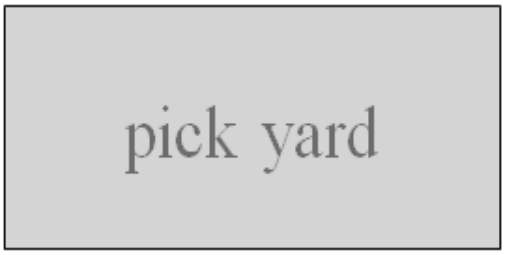

Figure 3: An example of a conscious contrast mask requiring the participant to 'pick' the noun yard.

2.6.1.3.2. SOA Setting.

Using the same background luminance values described for the conscious trials, the luminance for the grey text in SOA setting and subliminal trials was $Y = 57.89$ cd/m^2 ($x = 0.0.292$, $y = 0.265$) (see figure 4 for an example of a subliminal contrast mask).

Figure 4: An example of a subliminal contrast mask requiring the participant to 'pick' the noun *yard*.

2.6.1.3.3. Subliminal Trials.

The subliminal phase of the experiment contained three blocks of 40 subliminal trials (with the third block being a replication of the first block). The presentation duration of the stimulus instruction was determined by the point at which the participant rated confidence to be at 50% for five successive trials in the SOA setting phase. Confidence ratings were taken after each trial. Randomly placed within each block of 40 subliminal trials was an additional 10 conscious trials (using the same contrasted luminance values described in conscious trials, presented for 300 ms) to

prevent rhythmic pressing of the “1” and “2” keys, and to remind participants of the task required (cf. Pratte & Rouder, 2009).

2.6.2. Results

2.6.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 32 ms to 112 ms, with an average experimental subliminal presentation duration of 56 ms (*SD* = 21).

2.6.2.2. Trial Accuracy.

The mean number of correct identifications for conscious trials was slightly off 100% (*M* = 97%, *SE* = 1). For the ‘pick’ trials, mean correct identification averaged at 97% (*SE* = 1), whilst for ‘not’ trials, mean correct identification averaged at 96% (*SE* = 1). For the subliminal trials, only those trials in which participants rated confidence to be at 50% (i.e. guessing) were included in the analysis. Of the 120 subliminal trials, the number of trials upon which each participant rated confidence to be above 50% ranged between 0 and 89 trials (*M* = 20, *SD* = 22). Mean percentage correct responses for subliminal ‘pick’ (*M* = 51%, *SE* = 1) and ‘not’ (*M* = 52%, *SE* = 1) conditions are presented in figure 2, with a 50% reference line indicating chance performance. On subliminal trials, overall d’ values significantly differed from zero (*M* = .07, *SE* = .03, $t(21) = 2.60$, $p = .02$, $d = 1.13$). Taken individually, neither accuracy on ‘pick’ ($t(21) = 1.84$, $p = .08$, $d = 0.80$) or ‘not’ ($t(21) = 1.89$, $p = .07$, $d = 0.82$) conditions significantly differed from what would be expected by chance. However, when looking at the percentage of occasions participants simply chose the subliminally presented noun, noun identifications significantly differed between ‘pick’ (*M* = 51%, *SE* = 1) and ‘not’ (*M* = 48%, *SE* = 1, $t(21) = 2.6$, $p = .02$, $d = 1.13$) conditions, indicating the appropriate processing of ‘pick’ versus ‘not'. There was a not a significant relationship between

SOA and performance accuracy for both subliminal ‘pick’, $r = .2$, $p = .39$ and ‘not’, $r = .1$, $p = .67$ conditions.

As in Experiment 3, conscious knowledge was assessed by ZCC. The difference in accuracy between ‘guess’ and ‘any confidence’ was 1.11%, which was not significant ($t(21) = -1.88$, $p = .07$, $d = 0.82$). A Bayes Factor was conducted to assess whether the data supported the null hypothesis that there was no relation between confidence and accuracy. The maximum slope was determined by the overall accuracy in Experiment 4 when confidence was ignored (3%) divided by the proportion of confident responses (.17). Therefore, the maximum slope = 17.65%. Using a uniform distribution between 0 and 17.65 (sample $M = 1.11$, $SE = .59$) produced a Bayes Factor of 0.48, suggesting that the data were insensitive and we are thus unable to say whether or not the ZCC is satisfied. Type II d’, another way of measuring the ZCC, did not differ significantly from zero ($M = .01$, $SE = .01$, $t(21) = 1.88$, $p = .08$, $d = 0.82$). Using a uniform distribution between 0 and the mean Type I d’ of .07 (sample $M = .01$, $SE = .01$) produced a Bayes Factor of 0.50, providing only weak evidence for the null hypothesis. However, the guessing criterion indicates that there was some unconscious knowledge.

2.6.2.3. Response Time.

The time taken to identify the noun the participant had been instructed to choose was recorded for both conscious and subliminal ‘pick’ and ‘not’ conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in ‘pick’ conditions ($M = 746$ ms, $SE = 20$) than in ‘not’ conditions ($M = 920$ ms, $SE = 34$, $t(21) = -5.14$, $p < .001$, $d = 2.24$). Similarly, participants were slower in subliminal trials to identify the noun in ‘not’ conditions ($M = 942$ ms, $SE = 36$) when compared to ‘pick’ conditions ($M = 874$ ms, SE

= 52). However a paired sample t-test revealed that this difference in reaction times between subliminal ‘pick’ and ‘not’ conditions was not significant ($t(21) = 1.69$, $p = .11$, $d = 0.74$). Using the average effect for Experiments 1, 2 and 3, 39 ms, as the standard deviation of a half-normal, with a sample mean difference between subliminal ‘pick’ and ‘not’ conditions of 68 ms (*SE* of the difference = 40), a Bayes Factor of B = 2.55, indicated insensitive data, but with more support for the experimental hypothesis than the null hypothesis.

2.6.3. Discussion

For the subliminal trials, the accuracy data suggested that participants chose the correct noun beyond chance expectations at an average rate of 51-52%. When analysed individually, participants did not significantly choose the correct noun beyond what would be expected by chance for either ‘pick’ or ‘not’ conditions, because of data insensitivity. Nevertheless, participants did choose the presented noun significantly more often in the ‘pick’ rather than the ‘not’ condition, supporting the theory that people do process the instructions appropriately. However, the aim of Experiment 4 was to develop a more sensitive method of subliminal priming than that used in Experiment 3 by utilising a grey-scale contrast method of masking (Lamy et al., 2008). Despite using the grey-scale contrast method, Experiment 4 failed to demonstrate successful priming in subliminal ‘pick’ and ‘not’ conditions.

However, further research has demonstrated the superior priming effects achieved when primes are presented repeatedly (Atas, Vermeiren, & Cleeremans, 2012; Marcel, 1983b). This superior priming effect was demonstrated by Wentura and Frings (2005), who used objective thresholds to compare the effectiveness of a single standard masked prime with a masked prime that was presented ten times in quick succession. The results indicated that only the repeated masked prime condition produced a

significant priming effect. That is, repeatedly presenting a masked prime increased subliminal priming without increasing subjective awareness. The issue of repeated prime presentation was explored further in Experiment 5.

2.7. Experiment 5

Experiment 5 aimed to refine the grey-scale contrast method of masking utilised in Experiment 4 whilst taking advantage of the superior effects of repeated priming (Marcel, 1983b; Wentura & Frings, 2005). Experiment 5 replicated the procedure and format used in Experiment 4, but rather than one presentation of the prime, each prime was repeated three times. As in Experiments 1, 2, 3 and 4, it was expected that for the subliminal trials, participants would correctly identify the noun for both 'pick' and 'not' conditions beyond 50% chance expectation. As evidenced in Experiment 1, it was predicted that response times to noun identification in 'pick' conditions would be faster than in 'not' conditions for both conscious and subliminal trials.

2.7.1. Method

2.7.1.1. Design & Participants

One problem with the previous study was low power. The dz for the accuracy on not trials was 0.40. For a power of 80%, a sample size of 51 is needed. In a repeated measures design with the number of correct identifications being the dependent variable, 51 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the participants took part in Experiments 1, 2, 3, or 4. Forty four of the participants were female and seven male, with ages ranging from 18 to 32 years (M = 19.69, SD = 2.53).

2.7.1.2. Apparatus and Materials

Replicated Experiments 2, 3 and 4.

2.7.1.3. Procedure

Replicated Experiment 4. However, there were three equal duration presentations of the prime for conscious, SOA, and subliminal trials, with a 150 ms pause between each presentation.

2.7.2. Results

2.7.2.1. SOA Setting.

Subjective threshold durations of the single prime presentation ranged from an SOA of 16 ms to 192 ms (a cumulative range of 48 ms to 576 ms), with an average experimental presentation duration of 64 ms (*SD* = 35, with a cumulative mean presentation duration of 192 ms).

2.7.2.2. Trial Accuracy.

The mean number of correct noun identifications for conscious trials was 95% (*SE* = 1). For the 'pick' trials, mean correct identification averaged at 95% (*SE* = 1), whilst for 'not' trials, mean correct identification averaged at 95% (*SE* = 1). For the subliminal trials, only those trials in which participants rated confidence to be at 50% (i.e. guessing) were included in the analysis. Of the 120 subliminal trials, the number of trials upon which each participant rated confidence to be above 50% ranged between 0 and 86 trials (*M* = 23, *SD* = 26). Mean percentage correct responses for subliminal 'pick' (*M* = 53%, *SE* = 1) and 'not' (*M* = 52%, *SE* = 1) conditions are presented in figure 2, with a 50% reference line indicating chance performance. On subliminal trials, overall d' values significantly differed from zero (*M* = .11, *SE* = .03, $t(23) = 3.59$, $p = .001$, $d = 1.02$). Accuracy on 'pick' conditions significantly differed from chance expectations ($t(50) = 2.43$, $p = .02$, $d = 0.69$), as well as performance accuracy on 'not'

($t(50) = 2.37$, $p = .02$, $d = 0.67$) conditions. In addition, a paired-sample t-test looking at the percentage of occasions participants simply chose the subliminally presented noun significantly differed between 'pick' ($M = 53\%$, $SE = 1$) and 'not' ($M = 48\%$, $SE = 1$, $t(50) = 3.6$, $p = .001$, $d = 1.02$) conditions. There was a not a significant relationship between SOA and performance accuracy for both subliminal 'pick', $r = .2$, $p = .18$ and 'not', $r = -.1$, $p = .59$ conditions.

Conscious knowledge was again assessed in Experiment 5 using the ZCC. The difference in accuracy between 'guess' and 'any confidence' was 5.04%, which was not significant ($t(50) = -1.72$, $p = .09$, $d = 0.49$). A Bayes Factor was conducted to assess whether the data supported the null hypothesis that there was no relation between confidence and accuracy. The maximum slope was determined by the overall accuracy in Experiment 5 when confidence was ignored (2%) divided by the proportion of confident responses (.19). Therefore, the maximum slope = 10.53%. Using a uniform distribution between 0 and 10.53 (sample $M = 5.04$, $SE = 2.93$) produced a Bayes Factor of 2.84, suggesting that the data were insensitive (albeit providing more evidence for there being some rather than no conscious knowledge), and we are thus unable to say whether or not the ZCC is satisfied. Type II d', an alternative measure of the ZCC, also did not significantly differ from zero ($M = .10$, $SE = .16$, $t(50) = 1.15$, $p = .26$, $d = 0.33$). Using a uniform distribution between 0 and the mean Type I d' of .11 (and a sample Type II d' of $M = .04$, $SE = .04$) produced a Bayes Factor of 1.15, indicating that the data were insensitive and that we are unable to draw conclusions as to whether or not there was any conscious perception. However, the guessing criterion indicated that there was some unconscious knowledge. Figures 5 and 6 demonstrate the relationship between accuracy and all confidence values separately for 'pick' and 'not' trials for Experiments 3, 4, and 5 collectively.

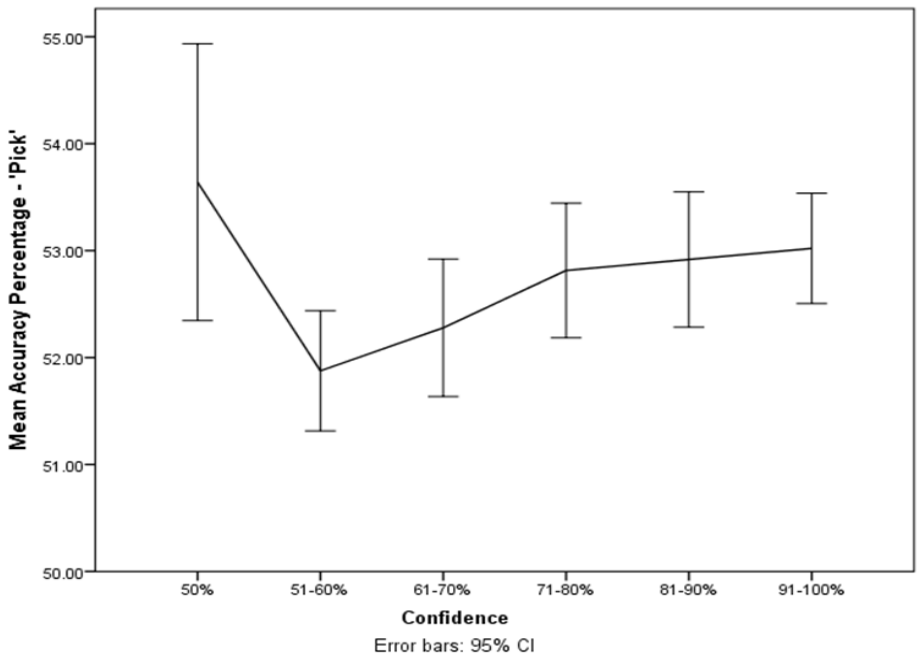

Figure 5: Mean accuracy percentage for 'Pick' trials across all confidence. Values demonstrate the relationship between accuracy and confidence across all 'pick' trials from Experiments 3, 4, and 5.

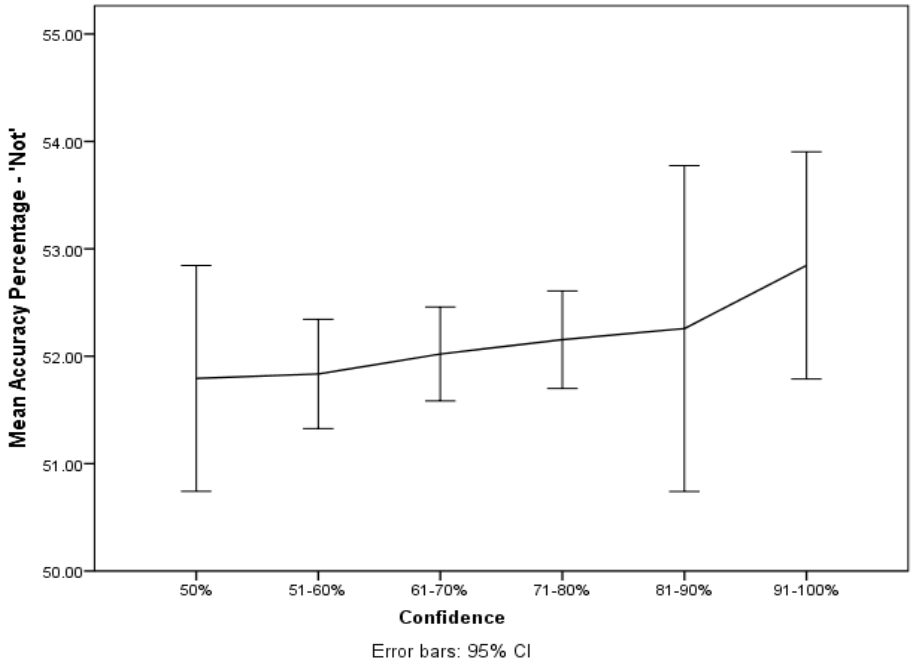

Figure 6: Mean accuracy percentage for 'Not' trials across all confidence. Values demonstrate the relationship between accuracy and confidence across all 'not' trials from Experiments 3, 4, and 5.

2.7.2.3. Response Time.

The time taken to identify the noun the participant had been instructed to choose was recorded for both conscious and subliminal 'pick' and 'not' conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in 'pick' conditions (M = 711 ms, SE = 15) than in 'not' conditions (M = 883 ms, SE = 24, $t(50) = -9.97$, $p < .001$, $d = 2.82$). Similarly, for the subliminal trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the noun in 'pick' conditions (M = 866 ms, SE = 29) when compared to 'not' conditions (M = 959 ms, SE = 25, $t(50) = -4.46$, $p < .001$, $d = 1.26$).

2.7.3. Discussion

Participants in the subliminal 'pick' condition correctly identified the noun at an average rate of 53%. Similarly, the results suggest that participants chose the correct noun on an average 52% of occasions for subliminal 'not' conditions. Experiment 5 showed that participants could successfully identify the correct noun at above chance expectations for both subliminally presented 'pick' and 'not' trials. However, the degree of priming in Experiment 5 was not significantly greater than in Experiment 4 (difference in tendency to pick the displayed noun in 'pick' versus 'not' in Exp 4, M = 3%, SE = 1; Exp 5, M = 5%, SE = 1, $t(71) = -.68$, $p = .49$, $d = 0.16$), indicating that even though repeated presentation boosted sample priming by more than 50%, the data were not sensitive enough to discern whether or not this was a real effect.

As evidenced in Experiments 1, 2, 3 and 4, the response time data for conscious trials shows the difference in task difficulty between 'pick' and 'not' conditions in that it took significantly longer to identify the instructed noun in 'pick' trials when compared to 'not', an average 171 milliseconds longer. Similarly, there was

a statistically significant response time difference between ‘pick’ and ‘not’ trials in subliminal conditions. Therefore, even though confidence ratings ensured that priming was below the subjective threshold, participants were still an average 93 milliseconds slower to identify the noun in ‘not’ conditions when compared to ‘pick’ conditions.

2.8. General Discussion

The present research investigated the ability of unconscious cognition to process the semantic meaning of subliminal stimuli. In a series of five experiments, participants were subliminally primed with a two word instruction, instructing the individual with which of two subsequent nouns to choose. This prime was in the form of an instruction to either *pick* the accompanying noun (the second word in the instruction, e.g., ‘*pick yard*’), or to *not* pick the accompanying noun (e.g., ‘*not yard*’), when presented with the accompanying noun and a paired noun (e.g., ‘*1. baby, 2. yard*’). If able to correctly identify the instructed noun, this should demonstrate the semantic comprehension of the subliminal instruction.

Experiments 1 and 2 demonstrated that participants were able to choose the correct noun beyond what would be expected by chance alone for both subliminal ‘pick’ and ‘not’ conditions, without this effect being attributed to the retrieval of S-R links (Exp 2). To minimise the likelihood of conscious awareness, Experiment 3 measured confidence after each trial and excluded trials in which the participant rated any degree of confidence in their decision from the analysis. However, the results indicated that participants failed to identify the correct noun, beyond chance performance, for ‘not’ conditions. The Bayesian analysis conducted on the trial accuracy data indicated support for the experimental hypothesis that participants would choose the correct noun depending on subliminal instruction. Experiments 4 and 5 aimed to develop a more

sensitive method of subliminal priming by adopting a grey-scale contrast method of masking employed by Lamy et al. (2008). The results of Experiment 5 additionally adopted a method of repeated priming and demonstrated that participants identified the correct noun beyond chance for both ‘pick’ and ‘not’ conditions.

In addition to looking at above chance accuracy, we also looked at the percentage of occasions that participants chose the noun based on the primed noun. That is, if the participant chose the primed noun, this would lead to a correct response for ‘pick’ trials, but an incorrect response for ‘not’ trials. Therefore, if the participant merely chose the primed noun, there would not be a significant difference in accuracy between ‘pick’ and ‘not’ trials. However, the results suggested that there was a significant difference in choosing the primed noun for ‘pick’ and ‘not’ in each of the five experiments (including Experiments 3 and 4 where accuracy for each instruction separately did not significantly exceed chance expectations), indicating appropriate processing of the presented instruction.

Response time data for the conscious trials in Experiments 1-5 demonstrated the difference in cognitive task difficulty between ‘pick’ and ‘not’ conditions. For the ‘pick’ instruction, the reader is informed that the accompanying noun is the correct noun to choose. So when subsequently presented with the noun-pair choice, the participant needed to first match the noun they had just been presented with, with the two nouns on the screen, and then indicate which noun they had been instructed to choose. For the ‘not’ trials, the reader is informed that the accompanying noun is the incorrect noun to choose. When presented with the noun-pair choice, the participant has two tasks. The first is to identify the noun they had just been presented with, and the second is to indicate the other noun in order to fulfil task instructions. This relative difficulty in task expectations was reflected in the response time difference between conscious ‘pick’ and

'not' trials, as participants were on average quicker to identify the noun in 'pick' trials in each of the five experiments. Perhaps more interestingly, this response time difference between 'pick' and 'not' trials was similarly evidenced in subliminal conditions. Although this response time difference was only statistically significant in Experiments 1 and 5, the Bayes Factor in Experiments 2 and 4 indicated that the non-significant results were not evidence for the null hypothesis. Furthermore, a meta-analysis indicated an overall significant result for the response time difference over all subliminal conditions ($p < .001$)[4]. These response time data lend further support to the argument that participants were able to comprehend the logical function of both subliminal *pick* and *not*, demonstrating unconscious cognitive control.

The series of experiments presented here demonstrate that unconscious processing of two-word primes is feasible, a controversial idea in current literature. Whilst there exists numerous studies demonstrating the ability of unconscious processing to semantically analyse single and even multiple word strings (e.g., Abad, Noguera, & Ortells, 2003; Bronstein & Rodin, 1983; Carr & Dagenbach, 1990; Dell'Acqua & Grainger, 1999; Marcel, 1983b; Silverman & Weinberger, 1985; Sklar et al., 2012; Waller & Barter, 2005), still other studies doubt the ability of subliminal perception and the cognitive unconscious to complete more complex analyses than pattern and feature recognition (e.g., Abrams & Greenwald, 2000; Condon & Allen, 1980; Greenwald, 1992). One argument attempting to explain the inability of many studies to find unconscious semantic activation involves the use of objective thresholds, which not only test unconscious cognition, but degraded unconscious cognition (Dienes, 2008), or the use of limited processing time resulting in degraded unconscious cognition (Sklar et al., 2012). Conversely, subjective methods of assessing subliminal perception

[4] A meta-analysis conducted on all response time differences between subliminal 'pick' and 'not' conditions ($M = 37$, $SE = 8$) revealed a significant relationship, $t(142) = 4.51$, $p < .001$, $d = 0.76$.

assume that if an individual possesses knowledge, yet is unaware that they possess this knowledge, then there is evidence of unconscious knowledge (Ziori & Dienes, 2006). Experiments 3-5 here only included trials in which confidence was rated to be at 50% (i.e., guessing), thereby indicating a lack of conscious knowledge according to subjective measures of subliminality. Whilst confident responses on a number of trials may indicate partial conscious awareness, participants may also sometimes give confidence ratings above 50% just because they think they should, or because they hallucinate (see figures 5 and 6). A meta-analysis of the overall ZCC indicated an overall non-significant relation between confidence and accuracy ($p > .05$)[5], whilst a Bayes Factor of $B = 0.36$[6] suggested that the data were not quite sensitive enough by conventional standards (i.e., less than 0.33) but more strongly supports the claim of no conscious knowledge rather than partial conscious knowledge.

Figure 2 indicates that when changing the paradigm from pure back masking to contrast masking, the proportion of times the displayed noun was chosen changed. The tendency to pick the displayed noun in experiments 1/2/3 combined was 53% overall (*SE* = .4), significantly different from the tendency in experiments 4/5 combined (50%, *SE* = .54=), $t(145) = 5.02$, $p < .001$, $d = 0.83$. If a subject had awareness of just the displayed noun, nothing follows about whether they should pick it. If a subject had awareness of just the instruction (pick or not) nothing follows about which noun to choose. But if the subject had awareness of the whole phrase, they should pick the displayed noun to an equal extent above 50% on PICK trials as they reject it below 50% on NOT trials. Thus awareness has the tendency to move displayed noun choice

[5] The meta-analysis conducted on all of the ZCC data revealed that the relationship between confidence and accuracy was non-significant, $t(94) = -0.52$, $p > .05$, $d = 0.11$.

[6] The maximum slope was determined by the mean overall accuracy in Experiments 3, 4 & 5 when confidence was ignored (3%) divided by the mean proportion of confident responses (.15). Therefore, the maximum slope = 20%. Using a uniform distribution between 0 and 20 (sample $M = 1.87$, $SE = 3.6$) produced a Bayes Factor of $B = 0.36$.

towards 50%. Therefore, although correlational results may indicate a possible systematic relationship between higher SOAs and performance accuracy in Experiments 1 and 2, the finding of a bias above 50% in the earlier rather than latter experiments thus argues against any claim that participants had more awareness in the first three experiments than in the last two. Given we tightened up the measurement of awareness in the last experiments, this is an important point.

Jacoby (1991) developed the process-dissociation procedure to demonstrate the separate contributions of both conscious and unconscious knowledge using stem completion tasks (cf. Marcel, 1983b, who showed a failure to exclude in subliminal conditions). Inclusion tasks require the participant to complete the stem with a word that has been presented outside of conscious awareness. Exclusion tasks require the participant to complete the stem with a different word to the unconsciously primed word. If knowledge of the primed word is conscious, this should lead to a below baseline performance, however evidence suggests that participants continue to complete the stem with the primed word above baseline performance (Debner & Jacoby, 1994; Jacoby, Toth, & Yonelinas, 1993). Jacoby argues that it is this inability to exclude primed words that is evidence of unconscious knowledge. Therefore, conscious equates to cognitive control, whilst unconscious equates to a lack of cognitive control. From a higher order perspective (e.g., Lau & Rosenthal, 2011), the ability to exclude an item indicates conscious perception only if the instruction is, or is taken to be, to exclude if you think you saw the stimulus, that is if there was an appropriate higher order thought of seeing. In these experiments, exclusion instructions were not conditional on higher order thoughts: participants were simply instructed to exclude a particular item. Thus, on a higher order perspective, there is no reason why exclusion could not occur unconsciously. We argue that the series of experiments presented here provides

evidence of unconscious knowledge precisely because participants were able to demonstrate unconscious cognitive control by following the subliminal instruction to *not* choose the presented word (in contrast to Draine and Greenwald, 1996, who failed to demonstrate subliminal priming of negation at an objective threshold). Additional research using subjective measures of unconscious have similarly demonstrated unconscious cognitive control in grammar studies (Dienes et al., 1995; Norman, Price, & Jones, 2011; Wan, Dienes, & Fu, 2008), the serial reaction time task (Fu, Dienes, & Fu, 2010), and in hypnosis (Dienes & Perner, 2007). In the current case, not only could participants exclude a specified item when the item was subliminal, they could exclude it when the instruction to exclude was itself subliminal, which is the novel feature of the experiments reported here.

We used subjective measures to establish the conscious status of perception. Some researchers believe objective measures most sensitively determine the conscious status of perceptual states (see e.g. Snodgrass, Bernat, & Shevrin, 2004; Snodgrass & Shevrin, 2006). To some extent, which measure one prefers depends on which theory of consciousness one subscribes to (Dienes & Seth, 2010a): On higher order and global workspace theories, conscious knowledge either entails or disposes awareness of the perception, which would be reflected in confidence ratings (consistent with the current methodology); on the other hand, according to Wordly Discrimination Theory (Dienes & Seth, 2010d), the very fact that participants chose the correct word at above chance levels entails that the perception of the word was conscious, whatever the confidence rating. Holders of the latter sort of theory may say that while participants may sincerely and earnestly believe they saw nothing of relevance, that just goes to show they lacked higher-order or reflective awareness, but the perception itself was still conscious. We do not wish to quibble over words. We have shown that the sort of awareness picked out by

higher order thoughts is not necessary for the processing of linguistic negation, whether one calls it “unconscious perception” (as seems natural to us) or “reflectively unconscious perception”, or some other name.

A second line of criticism over our methods may accept the logic of subjective methods in principle (e.g., Timmermans, Schilbach, Pasquali, & Cleeremans, 2012), but deny we used the best subjective method. Methods involving gambling may motivate careful and honest reports of awareness, and future research could use, for example, the “no loss gambling” of Dienes and Seth (2010b; see also Mealor & Dienes, 2012). Another approach is to ask subjects to report not on their accuracy, which is something ultimately unknowable to a subject (cf. Dienes & Perner, 2004), but on the quality of the visual experience itself, quite apart from its unknown mapping to the world (Ramsøy & Overgaard, 2004). The Perceptual Awareness Scale (PAS) of Ramsøy and Overgaard asks subjects to distinguish four degrees of visual clarity, from no visual experience (1), to a glimpse (but no idea of what) (2), to almost clear image (3) to clear image (4). Sandberg et al., (2010) compared confidence ratings and PAS for measuring conscious perception of shapes, and argued PAS was more exhaustive. People can be aware of seeing something before knowing that they have seen something relevant. Dienes and Seth (2010c) argued that as perception is defined in part by its contents, having some conscious experience is consistent with other perceptual contents remaining unconscious, which PAS would miss out on, but confidence ratings would be sensitive to. Further, Szczepanowski, Traczyk, Wierzchoń, and Cleeremans, (2013) argued that confidence ratings were more sensitive than PAS for emotional facial expression; maybe this is true in general for stimuli more complex than shapes. But what constitutes the best subjective measure of perceptual awareness is still a matter of debate. Future research should determine the replicability of the current results when

PAS and other scales are used. Additionally, whilst the current work was motivated on the grounds that subjective measures are more sensitive than objective measures, this still remains a conjecture in the current case. Future studies may benefit from a direct comparison of subjective and objective measures in the case of unconscious negation. Furthermore, due to the limitations in subliminal presentation using computers (i.e., presentation speeds using a 60Hz computer monitor being limited to 16 ms screen refresh rates), a tachistoscope allowing millisecond manipulation would be optimal so that there is an accurate estimate of both subjective and objective thresholds (cf. Masters et al., 2009).

In his study investigating the limitations of unconscious cognition, Greenwald (1992) concludes that unconscious processing is not able to complete more sophisticated analyses than letter recognition and partial word detection. In summing up, Greenwald issues a two-word challenge in which the investigations into multiple-word subliminal primes need to ensure that each word needs to be processed in unison, that no single word should be sufficient to impart sentence-meaning. The studies presented here attempted to meet this challenge by using two-word subliminal primes as instructions to choose a subsequent word. Whilst the 'not' conditions in this study appear compelling in their need to require semantic comprehension of not in order to inhibit recognition, the semantic analysis of the second word is not necessarily vital in choosing the correct word; recognition is all that is required to discriminate between the two words. Further research into this arena may benefit from adapting the study to make semantic interpretation of the second word vital.

Future research into the unconscious processing of subliminally presented multiple word-strings may also benefit from developing a more sensitive method of delivering subliminal stimuli. Experiments 4 and 5 presented here aimed to address this

issue by employing a grey-scale contrast method of masking established by Lamy et al., (2008). Although Experiment 5 produced some positive results, participants were indicating the correct noun at an average rate of 52%, only 2% above a baseline of 50% performance. Therefore, whilst it was expected that the longer presentation durations afforded by contrast masking would result in greater semantic processing, this was not necessarily the case. However, Lamy and colleagues (2008) successfully demonstrated unconscious processing by reducing the contrast between prime and background whilst keeping presentation speed constant until subjective thresholds were reached. In Experiments 4 and 5 presented here, prime and background contrasts were held constant whilst presentation durations were reduced. It is possible that reducing the contrast rather than reducing duration may have resulted in a greater depth of processing and thus higher accuracy. Furthermore, Wentura and Frings (2005) indicated that maximum priming effects were evidenced when subliminal primes were presented 10 times in quick succession, whilst Marcel (1983) found an increasing priming effect up to 20 prime repetitions. Therefore, further research may improve subliminal priming effects by investigating the benefits of contrast masking and repeated priming.

The current study makes a start towards showing processing of syntax under subliminal conditions in showing people can process a linguistic “not”, and extract meaning from the combination of words. Nonetheless, a stronger case for subliminal syntax would be made if the effect was stronger for “not baby” rather than “baby not”, which would indicate that syntactically correct word order is also important for processing word combinations. Armstrong and Dienes (in press) provide further support for the syntactic processing of subliminal phrases by showing that when active (e.g., the boy hits the girl) and passive (e.g. the boy is hit by the girl) sentences are presented

below the subjective threshold, participants can nonetheless pick an appropriate picture at above chance levels.

2.9. Conclusion

To conclude, we present a series of experiments that utilised subjective thresholds of subliminal priming to demonstrate a significant priming effect that cannot be attributed to partial conscious awareness or the retrieval of S-R links. Previous research into the effects of priming has often demonstrated at best the semantic comprehension of single-word primes, and at worst simple letter and pattern recognition processes. However, our results suggest that far from simple and unsophisticated analyses, unconscious cognition is capable of processing the logical function of negation when instructed to choose between two nouns.

3. Article II - Subliminal Understanding of Active vs. Passive Sentences

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3.1. Abstract

Three experiments attempted to demonstrate the unconscious processing of active versus passive sentences. Using subjective measures to assess individual thresholds of subliminal perception, participants were presented with a prime sentence that denoted whether one of two characters was either active or passive within the sentence (e.g., '*A is injecting B*', '*A is injected by B*'). When subsequently required to choose between two pictorial representations (i.e., character A as active, character B as active), participants were overall able to identify the correct image for both active and passive conditions beyond chance expectations (when averaged over all experiments). As expected, participants also took longer to respond to passive rather than active sentences. In sum, the present research demonstrates that people are able to process the meaning of word combinations that they are not consciously aware of seeing.

3.2. Introduction

In a typical subliminal priming experiment, a briefly presented prime is prevented from entering conscious perception through the use of either a forward (before the presentation of the prime) or backward (following the presentation of the prime) mask (Perfetti & Bell, 1991). This mask is typically in the form of either a pattern mask (i.e., a distribution of target fragments, random letters, or symbols), or noise mask (i.e., a mask composed of a set of random dots or squares) (Delord, 1998).

Short presentation durations in combination with the mask then render the prime unconscious by interfering with conscious visual processing and analysis of the prime. When subsequently presented with a test stimulus, successful subliminal priming is assumed to have occurred if the prime has in some way influenced the processing of the test stimulus (Johnston & Dark, 1986). Whilst studies demonstrating simple analyses of subliminal primes are commonly accepted within psychological research (Abrams & Greenwald, 2000), there nevertheless exists a considerable debate regarding whether or not the semantic processing of subliminal stimuli is possible (Naccache & Dehaene, 2001).

An enduring question within the literature is just how intelligent unconscious cognition can be (e.g., Greenwald, 1992; Loftus & Klinger, 1992; Marcel, 1980; Peirce & Jastrow, 1884; Sklar et al., 2012). Many studies indicate that the presentation of a subliminally presented word subsequently facilitates lexical and semantic access (e.g., Abad et al., 2003; Carr & Dagenbach, 1990; Dell'Acqua & Grainger, 1999; Draine & Greenwald, 1998; Forster & Davis, 1984; Fowler, Wolford, Slade, & Tassinary, 1981; Gaillard et al., 2006; Marcel, 1983a). However, controversy regarding the extent of unconscious priming remains (Abrams & Greenwald, 2000; Damian, 2001; Hutchison et al., 2004; Kouider & Dupoux, 2004); with Greenwald (1992) arguing that the effects of subliminal perception are far less sophisticated than is often reported. For example, rather than semantic access to subliminal primes, many researchers have instead attributed the effects of subliminal perception to the retrieval of stimulus-response (S-R) links (i.e., conscious rehearsal of prime-target combinations lead to the creation of an episodic memory trace between stimulus and response that is reactivated upon subliminal presentation, leading to the illusion of priming effects, e.g., Damian, 2001; Kunde etal., 2003; Schlaghecken & Eimer, 2004), sublexical priming (i.e., processing of

subliminal words or sentences being limited to the processing of subword elements, e.g., Abrams & Greenwald, 2000), or partial conscious awareness (Kouider & Dupoux, 2004).

An explanation that has been offered in an attempt to account for the failure of many studies to demonstrate successful subliminal semantic priming of single and even multiple words focuses on the use of objective thresholds when measuring subliminality. When assessing unconscious cognition, objective methods presume that any trial accuracy above chance level performance indicates conscious knowledge (Seth et al., 2010). For example, in the Greenwald and Liu (1985) study investigating multiple word priming, the stimulus onset asynchrony (SOA - the time interval between the onset of one stimulus to the onset of the next) for subliminal trials was determined by the point at which performance accuracy in determining whether the words LEFT or RIGHT appeared at the left or right hand side of the screen fell *below* chance level performance. As a consequence, it is not then surprising that participants were unable to unconsciously analyse the semantic function of a two word prime. The use of objective thresholds in assessing subliminal perception do not just test for unconscious cognition, but degraded unconscious cognition (Dienes, 2008; Lau & Passingham, 2006).

It was Cheesman and Merikle (1984, 1986) that first distinguished between objective and subjective thresholds, with the subjective threshold referring to the point at which participants *believed* they were performing at chance, and the objective threshold referring to the point at which they *were* performing at chance. Their results indicated that the unconscious analysis of subliminal primes occurs below the subjective threshold, but that unconscious cognition below the objective threshold is limited. (cf. e.g., Masters, Maxwell, and Eves, 2009) The subjective threshold, whose function is to measure the point at which participants are not aware of seeing, allows a fuller

investigation into the limits of the unconscious when compared to the objective threshold, which degrades not only conscious seeing, but also seeing itself (cf. Dienes & Seth, 2010).

Sklar et al. (2012) similarly argued that back masking with objective thresholds unnecessarily confounds processing time with whether processing is subliminal versus supra-liminal. That is, as the subliminal condition has typically involved very rapid presentation of the stimulus, it is not then surprising that the level of processing can be low compared to conscious processing over extended times. Thus, Sklar et al. used continuous flash suppression (CFS; the presentation of a rapidly changing stimulus to one eye to prevent the conscious perception of a further static stimulus presented to the other eye, Tsuchiya & Koch, 2005), which allowed presentation of stimuli over hundreds of milliseconds (rather than e.g., 16-32 ms for backward masking at objective thresholds). They argued that using CFS, participants could be shown to semantically process word and number combinations subliminally. Specifically, they found that coherent sentences (e.g., "I made coffee", "I ironed clothes") broke through suppression slower than incoherent sentences (e.g., "I ironed coffee"). These results are intriguing, though somewhat different individual words were presented in the congruent and incongruent conditions (e.g., "made" versus "ironed"). In another series of experiments, three-term subtractions (e.g., "9 - 4 - 5") primed processing of their solutions (e.g., time to pronounce "0"). These results raise the question of what sort of novel combinations can be processed subliminally, and also under which conditions subliminal processing can fully express itself. Thus, we will explore processing of word combinations using backward masking or contrast degraded stimuli, and to promote rich unconscious processing, we will use subjective rather than objective thresholds.

Whereas mental arithmetic (cf. Sklar et al, 2012) appears to involve executive resources even for single digit problems (DeStefano & LeFevre, 2004), the resources needed for processing syntax is less clear. The processing of the syntax of single simple clauses appears automatic and unconscious (see e.g., Li et al, 2013; Rebuschat & Williams, 2009; Williams, 2009, for the implicit learning of syntactic structures), and it has been argued that such syntactic processing does not take up executive resources (Caplan & Waters, 1999, though see accompanying commentary). If a three term subtraction can be performed subliminally, parsing simple syntax for a few words should be possible. Armstrong and Dienes (2013) used backward masking at subjective thresholds to investigate subliminal processing of word combinations involving negation. Participants were subliminally primed with either e.g., "pick dog" or "not dog" then asked to select from two words, e.g., "dog" or "cat". The pick instruction was associated with picking the noun at above baseline levels, and the "not" instruction with picking the noun at below baseline levels. Thus, participants must have subliminally processed word combinations.

We will use a similar methodology but explore the processing of active versus passive syntax. The present research consists of presenting participants with textual primes that depict one of two characters (either character A who was always female, or character B who was always male) as either active or passive within the sentence (e.g., 'A is attacking B', 'A is attacked by B', 'B is attacking A' or 'B is attacked by A'). When subsequently presented with two schematic images, one in which character A is active whilst character B is passive, and the other in which character A is passive whilst character B is active, the participant was required to choose the picture that best represented the prime.

Conscious comprehension during reading involves a set of processes that range from the recognition of certain patterns in the printed material, such as letters and words, to the construction of an abstract representation of the text (Cain, Carreiras, Garnham & Oakhill, 1996). This representation of the situation described in the text is known as a mental model. If it is possible to correctly identify the schematic image representing the sentence prime, beyond chance expectations, this may suggest that the participant was able to draw sufficient semantic information from the subliminal prime to allow for the creation of a mental model. This mental model would then enable the individual to map this model onto the most appropriate schematic representation available. To our knowledge, whether or not unconscious cognition is sophisticated enough to differentiate between activity and passivity remains an unexplored avenue of research. Therefore, using individual subjective thresholds for novel stimuli, if identification of the correct schematic image is above chance expectations, this would indicate that unconscious cognition is capable of carrying out more complex analyses than previously assumed (e.g., Abrams & Greenwald, 2000; Greenwald, 1992), and consistent with the arguments by Sklar et al (2012) and Armstrong and Dienes (2013) that word combinations can be subliminally processed.

3.3. Experiment 1

Although practiced stimuli have often been shown to produce superior priming effects when compared with unpractised novel stimuli (Draine & Greenwald, 1998), criticisms have arisen due to the likelihood that successful subliminal priming merely relies on the retrieval of S-R links established during conscious rehearsal (Forster & Davis, 1984). Therefore, in Experiment 1, participants first completed a set of conscious trials to accustom themselves to the task required, which differed from the content of

subliminal trials. However, to achieve maximum likelihood of successful subliminal priming whilst controlling for S-R links, participants consciously viewed the list of verbs (in their simple present form, e.g., injects, washes etc.) to be used in subliminal trials in an attempt to activate schematic representations but in isolation from a given motoric response, thereby preventing the formation of S-R links.

It was expected that for the conscious trials, participants would identify the correct schematic image on close to 100% of the trials for both active and passive conditions. For the subliminal trials, using subjective thresholds of conscious awareness, it was hypothesised that participants would identify the correct schematic image for both active and passive conditions beyond chance expectations (that is, beyond 50%). In addition to trial accuracy, response times would be measured with the expectation that identification of the image in the active condition would be faster than in the passive condition.

3.3.1. Method

3.3.1.1. Design & Participants

In a repeated measures design with the number of correct schematic image identifications being the dependent variable, 31 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. Twenty three of the participants were female and eight male, with ages ranging from 18 to 35 years (M = 22.93, SD = 5.6).

3.3.1.2. Apparatus and Materials

The experiment was created using E-Prime version 2.0 and presented on a Dell laptop with a 60Hz screen refresh rate, limiting minimum stimulus presentation to 16 ms, with 16 ms increments. Each textual screen display was centrally presented in lower-case, black, bold Courier New font, and point size 18 on a white background.

Conscious trials were created from a set of four verbs (e.g., *pokes, burns*), whilst subliminal trials were created from a set of twelve verbs (e.g., *injects, films*) (see Appendix C for a list of verbs used in practice, conscious, SOA, and subliminal trials). All verbs in conscious and subliminal trials were chosen on their ability to be suitably represented in a pictorial format. Examples of the type of schematic image used can be seen in figures 7 and 8 (see Appendix D for a list of images used in practice, conscious, SOA, and subliminal trials). From a viewing distance of 60 cm, the conscious and subliminal primes subtended 1.43° of visual angle (height), and a range of 6.18-8.06° of visual angle (width). The dimensions of the pictorial stimuli ranged from 11.4-12.59° of visual angle (height), and from 9.28-10.02° of visual angle (width).

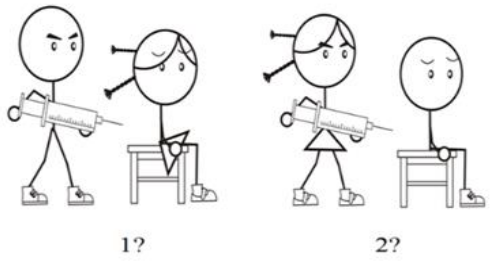

Figure 7: An image depicting the verb 'injects'. In the first image B is active, and in the second image A is active

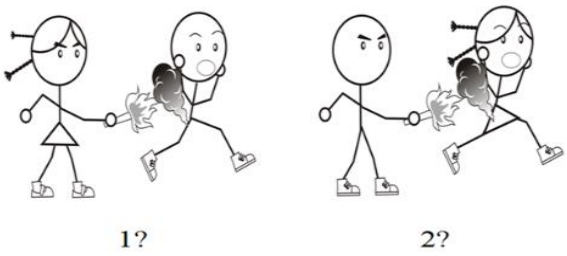

Figure 8: An image depicting the verb 'burns'. In the first image A is active, and in the second image B is active

The arrangement of sentence-image trials were counterbalanced to ensure participants viewed each of the eight prime-image permutations for each verb (e.g., 1. '*A is injecting B*', first image A injecting B, and second image B injecting A; 2. '*A is injecting B*' first B injecting A, second A injecting B; 3. '*A is injected by B*' first A injecting B, second B injecting A; 4. '*A is injected by B*' first B injecting A, second A injecting B; 5. '*B is injecting A*' first A injecting B, second B injecting A; 6. '*B is injecting A*' first B injecting A, second A injecting B; 7. '*B is injected by A*' first A injecting B, second B injecting A; 8. '*B is injected by A*' first B injecting A, second B injecting A), creating a total of 32 conscious trials and 96 subliminal trials. Therefore, each verb created four trials in which A was the active protagonist whilst B was passive, and an additional four trials in which B was the active protagonist and A passive.

3.3.1.3. Procedure

Participants were individually tested in a small quiet room. Once it had been explained to the participant that they would be taking part in an unconscious processing study, they were left alone to complete the experiment, thereby minimizing the potential role of experimenter demand characteristics. All participants had normal or corrected to normal vision, and English was the first language for all participants. Each of the conscious and subliminal trials consisted of four separate components: a fixation cross presented at the centre of the screen for 350 ms, the prime sentence (e.g., '*A is injecting B*' or '*A is injected by B*'), a backward mask in the form of a series of ampersands (i.e., &&&&&&&&) designed to exceed the length of the sentences (and were the same length for active and passive trials) presented for 150 ms, and the final component consisting of the two image choice depicting both A and B as active protagonists. Participants were required to indicate the number with a key press (either number 1 or 2) corresponding to the image that best represented the sentence prime. The experiment

was divided into three continuous phases; a set of conscious trials, an SOA setting stage to establish subjective thresholds, and a set of subliminal trials. Practice and SOA setting trials used three verbs and schematic images that were separate to those used in conscious and subliminal trials (see Appendix C and D for the verbs and schematic images used in practice and SOA trials).

3.3.1.3.1. Conscious Trials.

Once the participant had read the presented instructions, the procedure for the conscious trials began with a set of six practice trials. The verbs and schematic images used in all practice trials were different from those used in experimental conscious and subliminal phases. Following the presentation of the fixation cross, the active or passive sentences were presented on the screen for 350 ms to ensure conscious visual perception. Programming in E-Prime ensured that the offset of the stimulus sentence was immediately followed by the onset of the backward mask in all experimental trials, with this being especially important in preventing conscious perception in subliminal trials. With the offset of the mask, participants were presented with the two image choice, in which one image depicted A as active, and the other depicted B as active. The participant was expected to press either the '1' or '2' key on the keyboard, depending on whether the first or second image best represented the sentence prime. The two images remained on the screen until the image choice had been made, at which point the next trial proceeded after a 250 ms pause. Having completed the set of six practice trials, participants were instructed to continue on to the experimental conscious trials with the conscious trials replicating the exact procedure used in practice trials. Participants completed one block of 32 randomly presented trials, with an emphasis on accuracy as opposed to speed. Participants were not informed whether their image choice was correct or incorrect. Having completed the conscious trials, participants viewed the list

of 12 verbs to be used in subliminal trials. Each verb was presented on the centre of the screen for 1500 ms, with a 100 ms pause between each verb, with the list of verbs being presented twice.

3.3.1.3.2. SOA Setting.

The SOA of each participant was tested to ensure individual subjective thresholds for subliminal perception. Once the conscious trials were completed, the participants moved on to the SOA setting phase. The task format replicated that used in conscious trials; participants were presented with a fixation cross, prime sentence, a backward mask and then the two image choice. Once the participant had chosen the image they believed represented the prime sentence, they were required to rate, on a scale of 50-100%, how confident they were that they had chosen the correct image; 100% would suggest that the participant knew which image to choose, whilst 50% would suggest that they were purely guessing. If during the SOA setting phase a participant rated confidence to be anything above 50%, stimulus duration was reduced by 16 ms after each trial from a starting presentation duration of approximately 140 ms. Once a participant had rated confidence to be at 50% (just guessing), the SOA remained at that same presentation duration for the following trials. Once confidence had been rated at 50% (chance performance) for five successive trials, the SOA setting phase finished and the participant moved on to the subliminal phase of the experiment. If during any of those five trials participants rated anything above 50%, the SOA was again reduced until the participant rated confidence to be at 50% for five successive trials. If a participant reached minimum stimulus presentation duration (16 ms) whilst still rating confidence to be above 50%, they were excused from the experiment[7].

[7] One participant reached minimum stimulus presentation of 16 ms whilst still rating confidence to be above 50% during the SOA setting phase. The participant was excused from the experiment before reaching the subliminal phase and their data on the initial phases of the experiment were removed from further analysis.

Before the SOA setting phase began, participants completed a set of 6 practice trials to accustom themselves to the confidence procedure. For these practice trials, stimulus presentation was held at 140 ms. As with all phases, practice stimuli differed from experimental stimuli.

3.3.1.3.3. Subliminal Trials.

After participants completed the SOA setting phase, subliminal trials commenced with no further practice trials. The 96 subliminal trials were divided into two blocks of 48 trials, allowing the participant to pause between blocks. For the subliminal trials, prime sentence duration was determined by the point at which participants had rated confidence to be at 50% for five successive trials. As research has suggested that individual visual thresholds for subliminal stimuli may vary from initial threshold setting to experimental testing, or even on a trial by trial basis as a result of illumination levels and dark adaptation (Holender, 1986), confidence ratings for image choice were again required after each subliminal trial (an improvement on the block by block confidence ratings of e.g., Cheesman & Merikle, 1984, 1986). To prevent rhythmic pressing of the '1' and '2' keys, and to remind participants of the task required, each block of 48 subliminal trials additionally contained 10 randomly placed conscious trials (at a presentation duration of 350 ms) using different stimuli from the subliminal trials (cf. Pratte & Rouder, 2009), creating two blocks of 58 trials. After completion of the experiment, participants were thanked and fully debriefed. Each participant received an information sheet giving some background information on the study as well as providing experimenter details.

3.3.2. Results

3.3.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 16 ms to 80 ms, with an average experimental subliminal presentation duration of 48 ms (*SD* = 15.24).

3.3.2.2. Trial Accuracy.

It was expected that for the conscious phase of the experiment, participants would choose the correct schematic image on close to 100% of trials for both active and passive sentences. The mean number of correct identifications for conscious trials was slightly off 100% (*M* = 93%, *SE* = 1). For the sentence primes in which A or B was active, mean correct identification averaged at 94% (*SE* = 1), whilst correct identification in passive sentence primes averaged at 93% (*SE* = 1, see figure 9 for an illustration of subliminal active and passive accuracy across all experiments). For the subliminal trials, only those trials in which participants rated confidence to be at 50% (i.e. guessing) were included in the analysis. Of the 96 subliminal trials, the number upon which each participant rated confidence to be above 50% ranged between 0 and 20 trials (*M* = 10, *SD* = 6). For all statistical tests, we used an alpha level of .05 to determine significance. Accuracy on subliminal trials (*M* = 51%, *SE* = .8) did not significantly differ from what would be expected by chance alone ($t(29) = 1.49$, $p = .15$, $d = 0.55$). When the accuracy of active (*M* = 52%, *SE* = 1) and passive (*M* = 51%, *SE* = 1) subliminal sentences were analysed individually, neither active ($t(29) = 1.59$, $p = .12$, $d = 0.59$) nor passive ($t(29) = .49$, $p = .63$, $d = 0.18$) conditions significantly differed from chance performance. Discrimination was also assessed in terms of (logistic) d', which did not significantly differ from zero, *M* = .05, *SE* = .04, $t(29) = 1.49$, $p = .15$, $d = 0.55$.

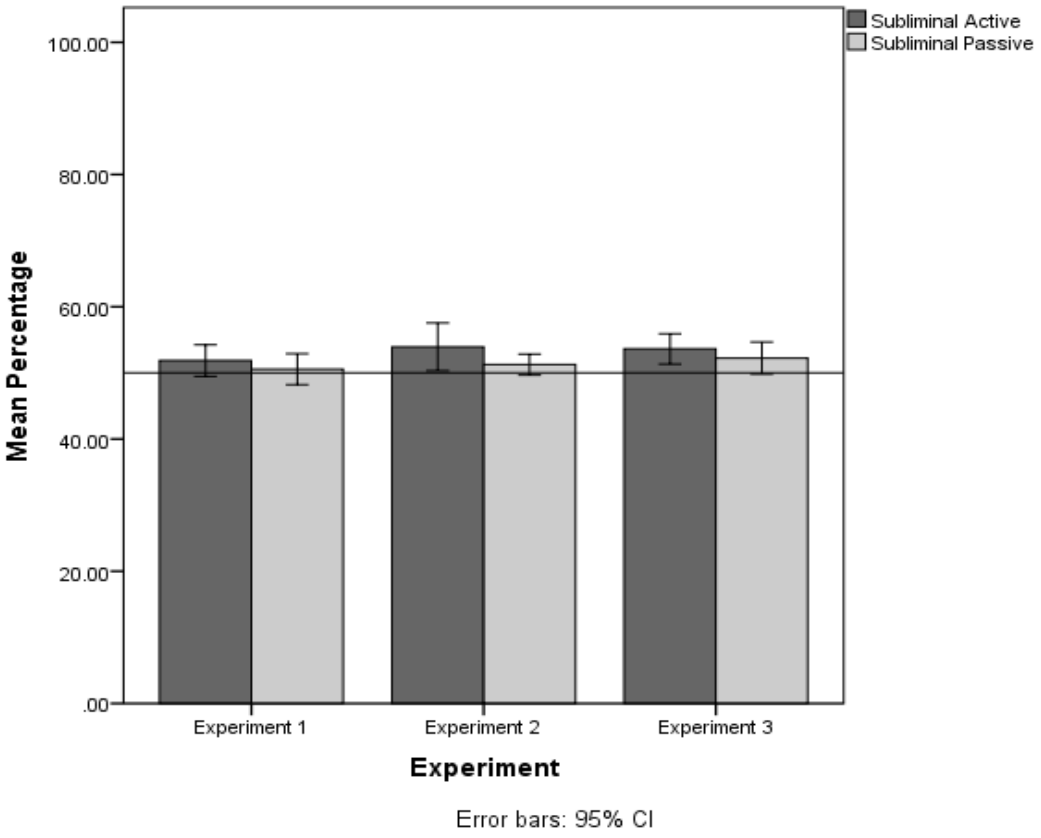

Figure 9: Mean percentage values for correct identification of the image in subliminal active and passive conditions for Experiments 1, 2 and 3 with a 50% reference line indicating chance performance.

However, we were unable to determine from this non-significant trial accuracy result whether this implied that there was evidence for the null hypothesis (i.e., that trial accuracy was at chance performance), or that there was no evidence of any conclusion (Dienes, 2011). To determine whether there was evidence for the experimental hypothesis (i.e., that trial accuracy would be above chance performance), we instead used a Bayes Factor. Whilst values under 1/3 are considered as evidence in support of the null hypothesis, values of 3 and over are considered as substantial evidence in support of the experimental hypothesis, and values in between 1/3 and 3 indicate that the data are insensitive (Dienes, 2011; Jeffreys, 1961). Armstrong and Dienes (2013; Experiment 3) used the same presentation conditions and showed a 5% effect of processing subliminal negation. That task should have roughly the same difficulty as the

current task. Thus, to represent the plausibility of different possible population effects, we used a half-normal with a standard deviation of 5% (following the recommendation of Dienes, 2011, Appendix). A sample mean of 1% above baseline (*SE* = .8), led to a Bayes Factor of B = 0.60, indicating the data were insensitive and did not discriminate between the hypothesis of a subliminal effect and the null hypothesis.

3.3.2.3. Response Time.

The time taken to identify the schematic image that best represents the sentence prime was recorded for both conscious and subliminal active and passive conditions. For the conscious trials, a paired sample t-test suggested that on average, participants were significantly quicker to identify the schematic image in active conditions (*M* = 2272 ms, *SE* = 281) when compared to passive conditions (*M* = 2764 ms, *SE* = 279, *t*(29) = -3.42, *p* = .002, *d* = 1.27). For the subliminal trials, participants were also significantly quicker to identify the schematic image for active conditions (*M* = 2118 ms, *SE* = 251) when compared to the passive condition (*M* = 2346 ms, *SE* = 277, *t*(29) = -2.68, *p* = .02, *d* = 0.99).

3.3.3. Discussion

For the conscious trials, correct identification of the image averaged at 93-94%. When required to choose the correct image in subliminal conditions, correct identification averaged at 52% for active sentence primes, and 51% for passive sentence primes, with this image identification not being significantly above chance expectations. A Bayes Factor indicated that the data were insensitive and cannot be taken as providing strong support for the null hypothesis.

However, support for the unconscious processing of subliminal verb voice was provided by the response time data. Although the participants were told that emphasis was placed on accuracy as opposed to speed, it was nevertheless interesting to analyse

reaction times. According to Miller (1962) and Chomsky (1965), passive sentences require more time consuming processing than do active sentences. In order to arrive at the semantic representation of the sentence, the passive form needs to be transformed into its basic structure, or 'kernel', to determine who or what is the agent. Here, the basic kernel sentences are the active forms (e.g., A is injecting B), with the passive forms (e.g., B is injected by A) being a derivative of these kernel sentences. Understanding of these passive sentences is then gained through the use of a passive transformation. The average 492 ms response time difference evidenced in conscious trials supports this and additional research demonstrating the difference in cognitive difficulty between understanding active versus passive sentences (e.g., Gough, 1965, 1966). More interestingly, this response time difference between active and passive primes was similarly evidenced in subliminal conditions, with participants being on average 228 ms faster to identify the image in active conditions when compared to passive conditions.

The use of the guessing criterion for establishing subliminal perception could be criticized on the grounds that participants came with different interpretations as to what "guess" means. However, in the instructions, and on each screen shot when participants were required to rate confidence, they were given a definition of what 'guessing' (and 'know') means. The participants were told to give a value of 50% if they believe that they were purely guessing; that they had no idea which word to choose and that they may as well have tossed a coin. They were also told that if they had any confidence at all, if they believed they saw anything of potential relevance at all, they were to give a value above 50. Poorly defined end points on a confidence scale can render the guessing criterion meaningless; thus, the instructions precisely defined the required concept of "guess".

Therefore, using individual subjective thresholds of measuring subliminal perception (Cheesman & Merikle, 1984), the results of Experiment 1 do not indicate one way or another whether people are able to correctly identify the image for active and passive primes beyond chance performance. However, the significant results evidenced in the response time data suggests that the subliminal priming of active versus passive sentences warrants further investigation. Since research has demonstrated that the type of mask used, more specifically the use of letter strings or symbols (e.g., ampersands and hatch marks), can negatively influence the cognitive processing of subliminal stimuli due to phoneme, grapheme and sematic interference (Di Lollo, Enns, & Rensink, 2000; McClelland, 1978; Perfetti & Bell, 1991; Walley & Weiden, 1973), Experiment 2 aimed to develop a more sensitive method of presenting subliminal stimuli.

3.4. Experiment 2

Experiment 2 adopted a grey-scale contrast method of masking established by Lamy, Mudrik, and Deouell (2008). This method uses a prime that is presented in grey, within a background of grey at a slightly different contrast level. This method allows a considerably longer exposure of the prime without the use of backward masking. As in Experiment 1, it was expected that for the conscious trials, participants would identify the correct schematic image on close to 100% of the trials for both active and passive conditions. In addition, it was hypothesised that participants would identify the correct schematic image for both active and passive conditions beyond chance expectations (that is, beyond 50%) for the subliminal trials. Furthermore, it was predicted that identification of the correct image in the active condition would be faster than in the passive condition for both conscious and subliminal trials.

3.4.1. Method

3.4.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependent variable, 28 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the participants took part in Experiment 1.Twenty one of the participants were female and seven male, with ages ranging from 18 to 24 years (M = 19.43, SD = 1.55).

3.4.1.2. Apparatus and Materials

The experiment was presented on a Dell laptop with a 60Hz screen refresh rate, and the study was created using E-Prime version 2.0. All materials, sentence primes and verb-lists used in Experiment 2 replicated those used in Experiment 1.

3.4.1.3. Procedure

All participants were tested individually in a private room. All participants had normal or corrected to normal vision, and English was the first language for all participants. The experiment followed the same format as used in Experiment 1 in that all participants completed a set of conscious trials, viewed a list of the verbs to be used in subliminal trials, an SOA setting phase, and a subliminal phase.

3.4.1.3.1. Conscious Trials.

The conscious phase contained the same six practice trials and 32 randomly placed experimental trials used in Experiment 1. The fixation was in the form of a cross presented within a rectangular box which was centrally presented on the screen for 350 ms. From a viewing distance of 60 cm, the dimensions of the rectangular box subtended 2.39° of visual angle (height), and 11.31° of visual angle (width). The conscious and subliminal primes subtended 1.43° of visual angle (height), and a range of 6.18-8.06° of visual angle (width). The fixation was immediately followed by either the active or

passive sentence. This sentence was presented within a rectangular box of the same size as used for the fixation. The contrast between prime and background was measured in terms of luminance using a Cambridge Research Systems ColorCal colorimeter defined in terms of CIE 1931 coordinates. The luminance of the grey text in conscious trials was Y = 14.35 cd/m^2 (x = 0.277, y = 0.216) against a grey background luminance of Y = 61.04 cd/m^2 (x = 0.293, y = 0.268) (see figure 10 for an example of the contrast mask used). The prime sentence was presented for 300 ms to ensure conscious perception, and the sentence was immediately followed by the two images centrally presented on the screen.

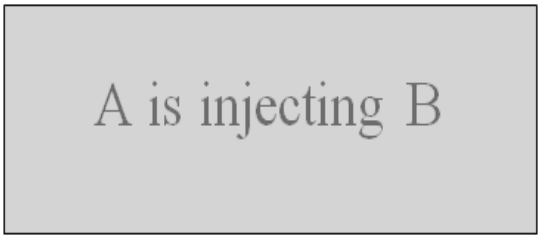

Figure 10: Example of an active conscious contrast prime using the verb 'injects'.

Figure 11: Example of an active subliminal contrast prime using the verb 'injects'.

3.4.1.3.2. SOA Setting.

For the SOA setting phase, the trials followed the same format used in Experiment 1. Using the same background luminance described for conscious trials, the luminance values for the prime sentences in SOA setting and subliminal trials was Y = 57.89 cd/m^2 (x = 0.292, y = 0.265) (see figure 11 for an example). Once the participant had chosen the image that best represented the prime sentence, they were again required

to rate how confident they were that they had chosen the correct image on a scale of 50-100%. From a starting presentation duration of 500 ms, stimulus duration was reduced by 16 ms each time a participant indicated any confidence in their image choice.

3.4.1.3.3. Subliminal Trials.

The subliminal phase of the experiment contained the same two blocks of 48 subliminal trials used in Experiment 1, with the presentation duration of the prime being determined by the point at which the participant rated confidence to be at 50% for five successive trials in the threshold setting phase. Confidence ratings were again taken after each trial. Randomly placed within each block of 48 subliminal trials was an additional 10 conscious trials (using the same luminance values described in conscious trials, presented for 300 ms). After completing the subliminal trials, participants were fully debriefed and received an information sheet giving some background to the study as well as experimenter details.

3.4.2. Results

3.4.2.1. SOA Setting.

Subjective threshold durations ranged from an SOA of 32 ms to 176 ms, with an average experimental subliminal presentation duration of 80 ms (*SD* = 37).

3.4.2.2. Trial Accuracy.

As in Experiment 1, it was expected that participants would choose the correct image on approximately 100% of the trials for both active and passive sentences for the conscious phase of the experiment. The mean number of correct identifications for conscious trials was slightly off 100% (*M* = 93%, *SE* = 2). For the sentence primes in which A or B was active, mean correct identification averaged at 93% (*SE* = 2), whilst correct identification in passive sentence primes averaged at 94% (*SE* = 2). For the subliminal trials, only those trials in which participants rated confidence to be at 50%

(i.e., guessing) were included in the analysis. Of the 96 subliminal trials, the number upon which each participant rated confidence to be above 50% ranged between 0 and 57 trials (M = 18, SD = 12). Accuracy on subliminal trials significantly differed from what would be expected by chance alone (M = 53%, SE = 1, $t(27) = 2.73$, p = .01, d = 1.05). Analysed individually, accuracy on active conditions (M = 54%, SE = 2) significantly differed from chance expectations ($t(27) = 2.24$, p = .03, d = 0.86), whilst accuracy on passive conditions (M = 51%, SE = 1) did not significantly differ from what would be expected by chance alone ($t(27) = 1.62$, p = .12, d = 0.62). A Bayes Factor was determined to assess whether there was evidence within the data to support the experimental hypothesis that accuracy on passive conditions would be above chance level. We used the same half normal with a standard deviation of 5% as in the last experiment. A sample mean of 1% above baseline (SE = 1), lead to a Bayes Factor of B = 0.53, indicating that the data were insensitive and did not in fact provide strong support for the null hypothesis (Dienes, 2011).

However, a paired sample t-test compared the percentage of occasions that participants simply chose the picture based on the assumption that the lead-in character was active for both active (M = 54%, SE = 2) and passive (M = 49%, SE = 1) conditions. This difference in accuracy was significant ($t(27) = 2.73$, p = .01, d = 1.05). This result indicates not only knowledge of the lead-in (or final) character, but also the unconscious processing of verb voice in active and passive conditions, as only if the verb within the sentences was appropriately processed should there be a difference in choice of the lead character. Furthermore, overall subliminal d' values differed significantly from zero (M = .12, SE = .04, $t(27) = 2.72$, p = .01, d = 1.05).

As well as utilising the guessing criterion to assess subliminal perception, evidence of conscious knowledge was also assessed using the zero correlation criterion

(ZCC) to determine whether there was a relation between confidence and accuracy on trials when the participant rated confidence to be at versus above 50% (the divide between complete guessing and some confidence being the theoretically relevant one for determining the conscious status of knowledge; Dienes, 2004). The difference in accuracy between trials in which the participants were guessing and trials in which confidence was ignored was 0.42%, which was not significant ($t(27) = -1.57$, $p = .13$, $d = 0.60$). In addition, a Bayes Factor was conducted to assess whether the data supported the null hypothesis of no relationship between confidence and accuracy or were just insensitive. Firstly, the range of effect sizes expected if there were conscious knowledge needs to be specified. The maximum slope was determined by a method used previously by Armstrong and Dienes (2013), Guo et al., (2013) and Li et al., (2013). The maximum slope was determined by the overall accuracy in Experiment 2 when confidence was ignored (3%) divided by the proportion of confident responses (.19). Therefore, the maximum slope = 16% (see Armstrong and Dienes, 2013, for this method applied in past subliminal perception research and its detailed justification). Using a uniform distribution between 0 and 16 (sample $M = 0.42$, $SE = .27$) produced a Bayes Factor of 0.13, providing substantial evidence for the null hypothesis that there was no relation between confidence and accuracy[8]. That is, there was substantial evidence against even partial awareness. The correlation between confidence and accuracy was additionally measured using Type II d'. Type II d' did not significantly differ from zero ($M = .01$, $SE = .01$, $t(27) = 1.55$, $p = .13$, $d = 0.60$. A Bayes Factor was conducted to assess whether the Type II data supported the null hypothesis that there was no relation between confidence and accuracy. Given plausible assumptions, Type II d' does not exceed Type I (Barrett, Dienes & Seth, in press). Thus, the alternative hypothesis that there existed

[8] The Kanai et al (2010) index of awareness (the zero correlation criterion applied just to stimulus absent trials), which discriminates between perceptual and attentional blindness is a useful addition to subjective measures but cannot be applied in this case because of the lack of trials in which a stimulus was absent.

some relation between confidence and accuracy (i.e., some conscious perception) was modelled as a uniform distribution between 0 and the mean Type I d' of .12. The Bayes Factor of 0.29 also provided substantial evidence for the null hypothesis.

3.4.2.3. Response Time.

The time taken to identify the schematic image that best represented the sentence prime was recorded for both conscious and subliminal active and passive conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the image in active conditions (M = 2244 ms, SE = 280) when compared to passive conditions (M = 3092 ms, SE = 247, $t(27) = -4.53$, $p < .001$, $d = 1.74$). Furthermore, for the subliminal trials, participants were similarly significantly quicker to identify the image for active conditions (M = 2023 ms, SE = 114) when compared to passive conditions (M = 2367 ms, SE = 140, $t(27) = -2.76$, $p = .01$, $d = 1.06$).

3.4.3. Discussion

For the subliminal primes, the average identification of the correct image averaged at 54% for the active condition, and 51% for passive conditions. Therefore, as hypothesised, participants successfully identified the correct image for active conditions beyond what would be expected by chance alone. For the passive conditions, the data were insensitive. However, when the accuracy was compared for the occasions which participants simply choose the image corresponding to the lead-in character (i.e., ignoring the active and passive verb form), correct identification was significantly different. That is, if the participant merely 'knew' which character was the protagonist based on which character came first without having processed the voice of the verb, there should not be a significant difference between active and passive conditions.

Therefore, only if the active versus passive voice of the verb was appropriately processed should there be a significant difference between conditions.

Furthermore, as found in Experiment 1, participants were significantly faster to identify the image in active conditions when compared to passive conditions. In the conscious phase of this experiment, participants were on average 848 ms quicker to identify the image for active trials when compared to passive trials, and an average 344 ms quicker for subliminal trials. These response time differences reflect the difference in cognitive difficulty in understanding active and passive sentences, with the understanding of passive sentences relying on a passive transformation to make sense.

The aim of Experiment 2 was to develop a more sensitive method of presenting subliminal stimuli than used in Experiment 1 by using a grey-scale contrast method of masking established by Lamy et al., (2008). Whilst we have demonstrated potential successful subliminal priming of active sentences, Experiment 2 has failed to demonstrate successful subliminal priming of passive sentences. However, superior priming effects can be produced through the use of multiple prime presentations (Atas, Vermeiren, & Cleeremans, submitted; Marcel, 1983b). For example, Wentura and Frings (2005) used objective thresholds of measuring awareness and compared the effectiveness of a single masked prime to a prime that was repeatedly presented ten times in quick succession. The results suggested that only the repeated presentation of the prime produced a significant priming effect. Therefore, this issue of repeated priming was explored further in Experiment 3.

3.5. Experiment 3

Experiment 3 aimed to expand on the results evidenced in Experiment 2 by attempting to develop a more sophisticated method of priming to increase the possibility

of successful priming of passive sentences. Wentura and Frings (2005) found a superior priming effect when a prime was presented 10 times in quick succession. Atas et al., (submitted) and Marcel (1983b) demonstrated an increasing priming effect when using up to 20 prime repetitions. It is believed that the multiple exposure of the prime has a cumulative effect of strengthening the prime by increasing the total prime duration yet still remaining out of conscious awareness (Wentura & Frings, 2005). Therefore, Experiment 3 continued to utilise the grey-scale contrast method of masking evidenced in Experiment 2 but increased prime exposure to 3 presentations. Armstrong and Dienes (2013) found that an increase from one to three repetitions with the same grey-scale masking as used here may increase subliminal priming by more than 50%.

As evidenced in Experiment 2, it was expected that participants would identify the correct image, beyond chance expectations, for active sentence primes. Furthermore, it was expected that participants would also choose the correct image for passive conditions beyond chance level performance. In addition, it was predicted that identification of the correct image in the active condition would be faster than in the passive condition for both conscious and subliminal trials.

3.5.1. Method

3.5.1.1. Design & Participants

One of the problems with the previous study was low power. The dz for the accuracy on passive trails was 0.3 in the previous experiment. Given that repeating the prime may increase the effect by 50% (Armstrong & Dienes, 2013), we would be attempting to pick up an effect size of dz = 0.45. For a power of 80%, a sample size of 40 is needed. In a repeated measures design with the number of correct identifications being the dependent variable, 40 undergraduate psychology students from the University of Sussex took part in this study in exchange for course credits. None of the

participants took part in Experiments 1 or 2. Twenty nine of the participants were female and eleven male, with ages ranging from 18 to 39 years (*M* = 20.75, *SD* = 4.95).

3.5.1.2. Apparatus and Materials

The experiment was presented on a Dell laptop with a 60Hz screen refresh rate, and the study was created using E-Prime version 2.0. All materials, sentence primes and verb-lists used in Experiment 3 replicated those used in Experiments 1 and 2.

3.5.1.3. Procedure

Experimental procedure replicated that of Experiments 1 and 2; with a conscious phase, an SOA setting phase, and the subliminal trials. For the conscious trials, the prime sentences were presented three times, with each presentation remaining on the screen for 250 ms with a 150 ms pause between each presentation. For the SOA setting phase, each of the three presentations of the prime started at a presentation duration of 500 ms, with a 150 ms pause between each presentation. When a participant rated confidence to be above 50%, each of the three prime presentations reduced by one screen refresh (16 ms). For the subliminal trials, prime duration was determined by the point at which participants rated confidence to be at 50% in the SOA setting phase and consisted of the same two blocks of 48 trials, with the additional 10 conscious trials in each block (with each of the three presentations at 300 ms).

3.5.2. Results

3.5.2.1. SOA Setting.

Subjective threshold durations of the single prime presentation ranged from an SOA of 32 ms to 176 ms (a cumulative range of 96 ms to 528 ms), with an average experimental presentation duration of 64 ms (*SD* = 37.05, with a cumulative mean presentation duration of 192 ms).

3.5.2.2. Trial Accuracy.

The mean number of correct image identifications for conscious trials was 94% (*SE* = 1). For the sentence primes in which either A or B was active, mean correct image identification averaged at 95% (*SE* = 2). Correct image identification for passive sentences averaged at 94% (*SE* = 2). For the subliminal trials, only those trials in which participants rated confidence to be at 50% (i.e. guessing) were included in the analysis. Of the 96 subliminal trials, the number upon which each participant rated confidence to be above 50% ranged between 0 and 50 trials (*M* = 13, *SD* = 14). Accuracy on the subliminal trials overall significantly differed from what would be expected by chance alone (*M* = 53%, *SE* = 1, *t*(39) = 3.47, *p* = .001, *d* = 1.11). Similarly, on subliminal trials, overall d' values significantly differed from zero (*M* = .13, *SE* = .04, *t*(39) = 3.47, *p* = .001, *d* = 1.11). When analysed individually, accuracy on active prime sentences (*M* = 54%, *SE* = 1) significantly differed from chance expectations (*t*(39) = 3.12, *p* = .003, *d* = 1.00), whilst accuracy on passive sentence primes (*M* = 52%, *SE* = 1) did not significantly differ from what would be expected by chance alone (*t*(39) = 1.86, *p* = .07, *d* = 0.60). However, a Bayes Factor was determined to assess whether there was evidence within the data to support the experimental hypothesis that accuracy on passive conditions would be above chance level. We used the same half normal with an SD of 5% as before. A sample mean of 2% above baseline (*SE* = 1), lead to a Bayes Factor of B = 2.61, providing weak evidence to support the experimental hypothesis that accuracy in passive conditions was above chance performance.

In addition, a paired sample t-test compared the percentage of occasions that participants simply chose the picture based on the assumption that the lead-in character was active for both active (*M* = 54%, *SE* = 1) and passive (*M* = 48%, *SE* = 1) conditions. This difference in accuracy was significant (*t*(39) = 3.47, *p* = .001, *d* = 1.11).

As evidenced in Experiment 2, this result indicates the unconscious processing of verb voice in active and passive conditions, as only if the sentence was appropriately processed should there be a difference in accuracy of image choice.

As in Experiments 1 and 2, conscious knowledge was again assessed by ZCC. The difference in accuracy between trials in which the participants were guessing and trials in which confidence was ignored was 0.27%, which was not significant ($t(39) = -1.14$, $p = .26$, $d = 0.37$). In addition, a Bayes Factor was conducted to assess whether the data supported the null hypothesis that there was no relation between confidence and accuracy in Experiment 3. The maximum slope was determined by the overall accuracy in Experiment 3 when confidence was ignored (3%) divided by the proportion of confident responses (.13). Therefore, the maximum slope = 23%. Using a uniform distribution between 0 and 23 (sample $M = 0.27$, $SE = .24$) produced a Bayes Factor of 0.04, providing substantial evidence for the null hypothesis that there was no relation between confidence and accuracy. That is, the knowledge was entirely unconscious by subjective measures. Type II d', another way of measuring the ZCC, did not differ significantly from zero ($M = .01$, $SE = .01$, $t(39) = 1.04$, $p = .31$, $d = 0.33$). Using a uniform distribution between 0 and the mean Type I d' of .13 (sample $M = .01$, $SE = .01$) produced a Bayes Factor of 0.27, also providing substantial evidence for the null hypothesis.

3.5.2.3. Response Time.

The time taken to identify the schematic image that best represented the sentence prime was recorded for both conscious and subliminal active and passive conditions. For the conscious trials, a paired-sample t-test suggested that on average, participants were significantly quicker to identify the image in active conditions ($M = 2307$ ms, $SE = 130$) when compared to passive conditions ($M = 2797$ ms, $SE = 116$,

t(39) = -3.42, *p* = .001, *d* = 1.10). Furthermore, for the subliminal trials, participants were similarly significantly quicker to identify the image for active conditions (*M* = 2075 ms, *SE* = 95) when compared to passive conditions (*M* = 2390 ms, *SE* = 142, *t*(39) = -2.14, *p* = .04, *d* = 0.69).

3.5.3. Discussion

The average accuracy rate for the correct image identification in subliminal trials was 54% for the active condition and 52% on passive conditions. As expected, participants identified the correct image beyond chance expectations for active conditions. Whilst the 2% above baseline performance for subliminal passive trials was an improvement on the performance rate evidenced in Experiments 1 and 2, this was not significant. However, as evidenced in Experiment 2, there was a significant difference between active and passive conditions when the verb form was ignored. Hence if the participant merely saw the lead-in character letter and choose the image accordingly, there should not be a difference in accuracy between active and passive conditions. Furthermore, participants were significantly faster to identify the image in active conditions when compared to passive conditions for both conscious and subliminal trials. During the conscious phase, participants were an average 490 ms faster to identify the image in active conditions. For the subliminal trials, participants were on average 315 ms faster. Therefore, despite awareness of the prime sentence being outside of subjective conscious perception, the response time difference nevertheless reflected the difference in cognitive difficulty in understanding active versus passive sentences.

3.6. General Discussion

The present research aimed to investigate the extent of subliminal perception by attempting to determine whether unconscious processing was able to distinguish between active and passive sentences. In a series of three experiments, participants were subliminally presented with a textual sentence in which the verb form denoted whether one of two characters (i.e., either character A or B) was active or passive. Participants were subsequently presented with two schematic images, one image of which depicted character A as active and the other depicting character B as active, and asked to judge which image best represented the sentence prime. If the correct image was chosen beyond chance expectations, this would provide evidence to demonstrate the cognitive processing of verb voice outside of subjective conscious awareness.

Experiment 1 attempted to demonstrate successful subliminal priming using the traditional method of backward masking to render the prime sentence subliminal. Using this method, the prime sentence was followed by a string of ampersands to block conscious perception of the prime. The results of Experiment 1 did not provide sensitive data to determine if people were able to identify the correct image beyond chance expectations for either active or passive subliminal conditions. As prior research has suggested that the use of letter strings or symbols such as the ampersands used in Experiment 1 can adversely affect the cognitive processing of textual primes due to interference during phoneme and grapheme interpretation (Di Lollo et al., 2000), Experiment 2 aimed to develop a more sensitive method of masking the subliminal primes. This was achieved by adapting the grey-scale contrast method of masking employed by Lamy et al. (2008). The results suggested that participants were able to correctly identify the image representing the prime sentence beyond chance

expectations for active conditions, and that participants could distinguish active from passive conditions. In addition, this knowledge was shown to be entirely unconscious by the zero correlation criterion (Dienes, 2004), so partial awareness was not responsible for the effect (Kouider & Dupoux, 2004).

Both Wentura and Frings (2005) and Marcel (1983b) have provided evidence to suggest that the multiple presentation of a subliminal prime is more effective than the standard single prime presentation due to cumulative exposure. Therefore, in Experiment 3, methodological procedure replicated that evidenced in Experiment 2 with the exception that the participant was presented with 3 repetitions of the prime sentence in quick succession. The results of Experiment 3 suggested that, as evidenced in Experiment 2, participants were able to correctly identify the image representing the prime sentence beyond chance expectations for active conditions; further, participants could once again distinguish active from passive conditions. Furthermore, a Bayes Factor using the ZCC provided strong evidence in support of the null hypothesis that there was no relation between confidence and accuracy: All knowledge appeared unconscious.

Whilst we argue that the accuracy results evidenced in Experiments 2 and 3 demonstrate the potential for unconscious cognition to comprehend verb voice, it could be argued that success was instead determined by simple processing of prime length or the presence or absence of ‘by’. That is, shorter primes (e.g., ‘A is injecting B’ vs. ‘A is injected by B’) indicated active conditions in the same way that the absence of ‘by’ indicated *active*. However, without at least an awareness of the lead-in character (or indeed the final character), knowledge of prime length or identification of ‘by’ would have been insufficient to correctly identify the schematic image when presented with a choice of images depicting characters A and B as both active and passive. It is possible

that participants learned to attend to the final letters of the prime (i.e., ‘by B’ vs. ‘¬B’) which would inform them of which image to choose. However, whilst not as sophisticated as the full unconscious analysis of verb voice, this would nevertheless demonstrate the processing of the syntactic functioning of two word primes (lead-in character/final character, and ‘by’).

Similarly, it could be argued that successful priming evidenced in active conditions could indicate simple priming of the lead-in character. That is, processing the first word (i.e., character) and indicating the corresponding picture in which the lead-in character was active would allow success on the active trials without actually necessitating the processing of verb voice. However, if this were the case, there would be no differences between active and passive conditions in the percentage of occasions that participants choose the image depending on simply which character came first. Yet, the results of both Experiments 2 and 3 found a significant difference in image choice between active and passive conditions, therefore indicating differential processing of verb voice.

Nonetheless, it could still be argued that the performance in the active condition was produced by word priming from the first position (which subjects had learned to attend to from conscious trials) and the greater complexity in the passive condition disrupted even word priming and participants performed at chance. Such a theory needs to explain why e.g., “is injecting” is less complicated than “is injected by” without postulating the semantic or syntactic processing of word combinations as such. The simplest answer could be the relevance of the number of words. That is, the first noun can be processed when there are 4 words displayed but not 5 (cf. the decrement in priming by additional words found by Kahneman & Henik, 1981). One way of testing this theory is to compare “is injecting” with “injected by” in the same paradigm that we

have otherwise used. If it is a matter of simple word priming then by making the display more simple, participants should classify below chance levels in the passive condition. If subjects process the voice of the verb, they should classify at above chance levels. However, we need not run this further experiment to settle the question; we can provide evidence with the existing data by a meta-analysis over the three experiments. The overall mean accuracy for the passive condition was 51% with a standard error of 0.4, which is significantly above baseline, $t(97) = 2.26$, $p = .03$, $d = 0.46$ (and a meta-analysis for the active condition revealed a mean performance level of 53.2% with a standard error of .77, $t(97) = 4.14$, $p < .001$, $d = 0.84$). Both of these tests remain significant after applying Hochberg's (1988) sequential Bonferroni correction. Thus, taken as a whole, the set of three experiments provides compelling evidence for the subliminal processing of active versus passive verb voice.

Further evidence to support the argument that participants were able to cognitively process verb voice outside of conscious awareness was provided by the response time data. Miller (1962) and Chomsky (1965) have argued that passive sentences are more difficult to comprehend when compared to active sentences as they require more extensive processing. This processing results from the need to participate in a passive transformation in order to return the sentence to its basic structure, of which the passive sentence is a derivative. The response time difference evidenced in conscious trials in all experiments supports this and other research (e.g., Gough, 1965, 1966) by demonstrating that participants were significantly quicker to choose the image when the sentence prime was active compared to passive for conscious trials. Over all three experiments, participants were on average 610 ms faster. More interestingly, this difference in response time was also evidenced in subliminal trials. Across all three experiments, participants were on average 274 ms faster to identify the image in active

conditions when compared to passive conditions. Similarly, a meta-analysis indicated an overall significant result for the response time difference in all subliminal conditions ($p < .001$)[9]. This significant result lends further support to the unconscious processing of verb voice in subliminal active and passive conditions.

We used subjective methods (the guessing criterion; and the zero correlation criterion supported by Bayes Factors to interpret non-significant results) to establish the subliminal nature of the stimuli. The use of the guessing criterion in measuring subliminal perception is often criticised on the grounds that participants may have differing interpretations as to what 'guess' means. Poorly defined end points on a scale of confidence can render the guessing criterion meaningless; thus, the instructions precisely defined the required concept of "guess". Therefore, when instructed to rate confidence, participants were told to give a value of 50% if they believed they were guessing, and they were told that if they had any confidence at all, if they believed that they saw anything of potential relevance, then they were to give a value of above 50%.

If we had used objective measures, i.e., the ability of the participant to discriminate the content of what was displayed, the perception would be declared conscious, because that is exactly what participants did: they could pick the right picture. On the one hand, these results illustrate the usefulness of subjective rather than objective measures in determining the full richness of unconscious processing. On the other hand, our argument could be turned on its head, and the sceptics declare that we had not established subliminality rigorously enough, because it is only objective measures that convince the sceptic. As objective rather than subjective measures pick out fewer cases as being genuinely subliminal, using objective measures is more convincing. In other words, we should aim to minimise the rate at which we make Type

[9] A meta-analysis conducted on all response time differences between subliminal active and passive conditions ($M = 274$, $SE = 63$) revealed a significant relationship, $t(95) = 4.33$, $p < .001$, $d = 0.89$.

I errors (false alarms concerning subliminal perception). The problem with the strategy of minimizing Type I errors is that it requires indefinitely strong evidence to make a case, combined with a 100% miss rate no matter what the evidence is. While sometimes it may be scientifically useful to seek to minimise one error type, a useful general strategy is to try to minimise total errors by balancing the two error types. That is, the goal may not be to convince the sceptic no matter what, but to get the most unbiased measure of a phenomenon (in order to determine its properties so as to develop and test models).

Objective measures, to be unbiased, presume the "Worldly Discrimination" theory of consciousness, namely that, the content directly expressed in any behaviour (e.g., pointing to where a dog is) is the content of a conscious mental state (e.g., consciously knowing ''There is the dog!'') (Dienes & Seth, 2010a). Thus, according to worldly discrimination theory a person shows that they are consciously aware of a feature in the world when they can discriminate it with choice behaviour. By contrast, the more common theories of consciousness that are variants of higher order theories or global workspace/integration theories would not endorse the claim that simple discrimination implies conscious awareness (e.g., Baars, 2002; Lau & Rosenthal, 2012; Seth et al, 2008; Timmermans et al, 2012). Rather, according to both these latter classes of theory, a person who consciously sees would be able to indicate they see specific content rather than guess it when probed about whether they are seeing it; i.e., the conscious status of the seeing would be revealed by appropriate subjective measures. According to these theories, the measures we used were at least the right sort of measure to use.

According to yet another class of theory, brain activity in specific local areas (perhaps with local recurrence) generates phenomenal consciousness. Thus, conscious

perception can co-occur with the sincere and earnest denial of perceiving - and even perhaps when a person cannot discriminate what was there (e.g., Block, 2009). According to such theories, in the current studies we have not measured whether perception was conscious or unconscious per se, but whether perception involved reflective or introspective consciousness. But on all accounts, we have measured the sort of consciousness that comes with the accurate expression of higher order thoughts when a person is probed. We have explored the limits of unconscious perception when unconscious seeing means not being aware that one saw anything relevant. Investigating the limits of processing with and without this metacognitive capacity is an interesting empirical question, no matter what labels are used.

Rather than asking participants if they saw anything relevant, one can ask if they had any visual experience of the stimulus whatsoever (Ramsøy & Overgaard, 2004; Sandberg et al., 2010). For example, what is the extent of subliminal processing when people do not believe they even saw a flash? Using our confidence ratings, people may have been aware of seeing a flash of the prime; they just had no conscious experience of content relevant to the judgment. If so, the relevant content used in the judgment was unconscious (Dienes & Seth, 2010b). Nonetheless, future studies could explore the relation between different conscious visual contents (e.g., "a flash") and the complexity of subliminal processing allowed.

We made use of both the guessing and zero correlation criteria of unconscious knowledge. The guessing criterion allows the conclusion that some knowledge was unconscious but leaves open whether in addition there was some conscious knowledge. The zero correlation criterion tests whether there was any conscious knowledge, with the absence of conscious knowledge resulting in a non-significant relation between confidence and accuracy (where that relation can be expressed as a correlation, slope,

difference or Type II or meta d', see e.g., Dienes, 2008; Maniscalco & Lau, 2012; Mealor & Dienes, 2010). However a non-significant result in itself does not distinguish between (a) insensitive data and (b) evidence in support of the null hypothesis. Obviously, the zero correlation criterion, in order to legitimate the conclusion of unconscious knowledge, requires evidence in favour of the null hypothesis – not insensitive data. A Bayes factor is required to make the distinction between insensitive data and evidence in favour of the null hypothesis. Thus, wherever we obtained non-significant zero correlation criteria, we analysed with a Bayes factor, using methods employed previously by Armstrong and Dienes (2013), Guo et al., (2013), and Li et al., (2013).

Naccache and Dehaene (2001) have argued that whilst the majority of priming studies have focused on the ability to derive semantic understanding from subliminal stimuli, the possibility of manipulating this semantic comprehension has largely been ignored. Therefore, the current research attempted to determine whether the information contained in a short subliminal sentence could be translated to a schematic representation. If successful, this would demonstrate not only the semantic understanding of active and passive verb form, but also the ability to manipulate this information and translate it into a pictorial image. The trial accuracy data suggested that participants were indeed able to translate the prime sentence into a schematic image for active conditions. Furthermore, both the difference evidenced between the percentage of occasions participants choose the image corresponding to the lead-in character and the response time data similarly suggests that participants were able to at least process the distinction in verb voice between active and passive sentences.

3.7. Conclusion

To conclude, we presented a series of three experiments that attempted to subliminally prime active versus passive sentences using individual subjective thresholds of conscious awareness. Past research investigating the extent of subliminal priming has tended to focus on the ability to derive semantic understanding from subliminal stimuli. We hoped to demonstrate that in addition to semantic comprehension of activity versus passivity, participants would be able to successfully manipulate that comprehension by translating into a visual schematic representation. Our results indicated that under subliminal conditions, participants were able to identify the correct image for both active and passive verb forms beyond mere chance expectations. In sum, despite the passivity some have claimed for the unconscious, it can be as active as it is passive.

4. Article III – Supraliminal and Subliminal Priming of Specific Relationship Anxiety

4.1. Abstract

This paper explored whether supraliminal and subliminal priming is sophisticated enough to activate anxieties with specific contents (namely, the fear of being close, far, controlled or controlling in a relationship). Participants were primed with emotive words during a neutral classification task and then required to classify words as either congruent with the primed anxiety, or incongruent. The results from supraliminal and subliminal conditions were then compared with a control group that received no priming. The results suggested that participants were faster to categorise anxiety-congruent and incongruent items in the supraliminal group than they were in the control group. In addition, participants in the control condition made significantly more errors in categorising anxiety-congruent items than either supraliminal or subliminal groups. However, whilst the supraliminal priming effects were clear, the data were insensitive for indicating whether or not there was subliminal priming of specific relationship anxieties.

4.2. Introduction

Anxiety is an unpleasant psychological state that develops in order to allow us to effectively perform in difficult situations (Davey, 2008). As well as a number of somatic symptoms, anxiety often involves a number of significant cognitive characteristics including a lack of concentration, intrusive thoughts, affective fear

experienced as a result of threat anticipation, and excessive worry and concern regarding the negative consequences connected to the perceived threat. In addition to these cognitive characteristics of anxiety, highly anxious individuals often go on to develop cognitive biases which aid in the identification of possible threats (Mathews, Mackintosh, & Fulcher, 1997; Mathews & MacLeod, 1985). These cognitive biases involve the rapid detection of, and diversion of attention to, perceptual cues that may be related to the associated threat. Moreover, the cognitive resources required to rapidly detect and divert attention to potential threats often inhibits the cognitive processing of additional and less vital information.

A modified version of the Stroop paradigm (Stroop, 1935) is perhaps the most common approach to demonstrating the cognitive biases that can develop as a result of anxiety activation (Mathews et al., 1997). The Emotional Stroop task employs both emotive and neutral words presented in differing ink colours and requires the individual to respond to the ink colour. Research has often shown that individuals high in anxiety respond quicker to the ink colour of neutral words as opposed to threatening or unpleasant words (Becker, Rinck, Margraf, & Roth, 2001; De Ruiter & Brosschot, 1994; Williams, Mathews, & MacLeod, 1996). It is proposed that the anxiety that is elicited upon presentation of the threatening words initially prevents cognitive resources from focusing on the required task, which subsequently delays the response to ink colour of the emotive words. Interestingly, evidence suggests that these anxiety driven cognitive bias effects evidenced in the Emotional Stroop task are similarly exhibited even when the threatening stimuli is presented outside of conscious awareness (Fox, 1996; Li, Zinbarg & Paller, 2007; MacLeod & Hagan, 1992; Manguno-Mire, Constans, & Geer, 2005; Mogg, Bradley, Millar, & White, 1995; Mogg, Bradley, Williams, & Matthews, 1993; Öhman, 1999; Van Honk, Peper, & Schutter, 2005). Despite a lack of

conscious access to the semantic content of the words, response times indicate that individuals scoring highly on a trait anxiety scale nevertheless continue to display the attentional bias to threatening and unpleasant words when compared to neutral words. Therefore, this delay in response to threatening words suggests that anxiety can be induced through subliminal priming.

Further corroboration for the claim that anxiety can be elicited outside of conscious awareness is provided by a number of empirical studies. For example, Tyrer, Lewis, and Lee (1978) presented participants with a series of anxiety inducing words such as ‘hatred’, ‘cruel’, and ‘mutilate’ under either subliminal or supraliminal conditions. The results indicated that following priming, subjective ratings of anxiety significantly increased under both subliminal and supraliminal conditions. Similarly, Kemp-Wheeler and Hill (1987) subliminally presented a group of participants with a set of emotionally unpleasant words, and a control group with a set of emotionally neutral words. When measured across a series of psychological and physiological variables relating to stress, the results indicated that the group that had been subliminally presented with emotionally unpleasant words rated subjective levels of sweating, anxiety, perceived shaking and muscular tensions as higher when compared to the control group. Bargh and Pietromonaco (1982) subliminally presented participants with a series of words that connoted hostility. Their results indicated that when subsequently required to pass judgment on an individual engaging in neutral behaviours, hostile and negative judgements were directly related to the number of hostile words the participant had been subliminally exposed to.

Using imagery to demonstrate the activation of anxiety, Yiend and Mathews (2001) supraliminally presented high and low anxious participants with pairs of images, one portraying a threatening image and the other a non-threatening image, before asking

the participant to respond to target locations. The results suggested that participants scoring high in anxiety were faster to respond to targets replacing the location of threatening images compared to targets replacing non-threatening images when compared to the responses of participants scoring low in anxiety. These results further support the contention that the activation of anxiety leads to a preferential attention to threat related stimuli. Furthermore, the activation of anxiety has similarly been demonstrated using images presented subliminally. For example, Robles, Smith, Carver, and Wellens (1987) embedded positive, negative or neutral images into a two-minute video of a woman walking through a forest. Despite being presented at a speed that rendered the image unconscious, subjective anxiety ratings following presentation were highest for those in the negative condition, followed by neutral and positive conditions respectively.

Whilst many of the above studies appear to have successfully induced anxiety on a general or global level through supraliminal or subliminal presentation, very few studies have attempted to prime specific anxieties. For example, whilst Kemp-Wheeler and Hill (1987) measured psychological and psychical variables to demonstrate successful anxiety activation, the anxiety induced was a generalised state-type anxiety rather than the activation of a specific anxiety or fear. One such area regarding the priming of more specific anxieties relates to adult attachment. Adult attachment can be conceptualised as a continuum with anxious attachment at one end of the scale and avoidant attachment at the other, with secure attachment being somewhere in the middle (Mikulincer & Shaver, 2010). Wilkinson, Rowe, and Heath (2013) supraliminally primed participants with either attachment anxiety or attachment security and measured the participants' subsequent consumption of food. Their results indicated that participants consumed more food following the anxiety prime than they did following

the secure prime, with the authors concluding that the food served the purpose of comforting and alleviating the attachment anxiety activated.

With regards to subliminal priming and adult attachment, Barabi, Mikulincer, and Shaver (2006, as cited in Mikulincer & Shaver, 2010) investigated the differential effects of subliminal sexual imagery on secure and insecure adult attachment. After measuring independent adult attachment styles, Barabi et al. subliminally presented a group of male participants with erotic oedipal and control images and subsequently required them to rate the sexual attractiveness and allure of a series of female targets. As adult attachment insecurity is believed to impede upon sexual maturity, it was hypothesised that the oedipal imagery would interact with the immature sexuality and anxiety regarding child-mother relationships of anxiously attached males leading to an increase in their perception of target women as attractive when compared to the control images. Conversely, it was hypothesised that oedipal imagery would lead to disgust and distaste in securely attached males and thus lead to lower ratings of attractiveness when compared to control images. The results supported these hypotheses in that males scoring highly in anxious attachment rated target females as more attractive and alluring following oedipal images when compared to erotic control images, whilst securely attached males rated target females as more attractive following control images when compared to oedipal. Interestingly, males scoring highly in avoidant attachment also rated females as more attractive following oedipal images when compared to control images.

As a result of the success of studies presented here and elsewhere, it has been argued that it is possible to affectively and cognitively alter the emotional state of an individual through the emotive content of supraliminal and subliminal primes. However, many researchers have found that the emotional effects and anxiety induced

through subliminal priming are both limited and minimal (Mayer & Merckelbach, 1999a, 1999b; Smith, 1993). In fact, there still remains a considerable controversy regarding whether or not the semantic comprehension of stimuli presented subliminally even occurs (Abrams & Greenwald, 2000; Damian, 2001; Hutchison et al., 2004; Kouider & Dupoux, 2004; Loftus & Klinger, 1992), with successful priming often being attributed to factors such as the retrieval of stimulus-response links, sublexical processing, or partial conscious awareness. However, the adherence to strict objective thresholds (i.e., that any response accuracy above chance performance is indicative of conscious knowledge) may account for the failure of many of these studies to demonstrate successful subliminal priming effects (Dienes, 2004, 2008). On the other hand, subjective methods provide a more sensitive method of measuring subliminal perception (e.g., Cheesman & Merikle, 1984, 1986). That is, subjective methods assume that if a participant believes themselves to be guessing and yet accuracy exceeds chance performance, then this should be considered evidence of unconscious knowledge (cf. Dienes, 2008). Indeed, Armstrong and Dienes (2013) showed that using subjective thresholds, a subliminal two word prime to either pick or not pick a certain word influenced word choices.

In addition to supraliminal priming, the current study aimed to utilise subjective methods of assessing subliminal perception to explore the full extent of prime processing by attempting to prime relationship anxieties. More specifically, we investigated whether it was possible to induce very specific relationship anxieties using both supraliminal and subliminal primes relating to one of four specific relationship threats; the fear of being close, far, controlled or controlling. Birtchnell's (1996) relating theory suggests that within a relationship, there are four important and necessary states of relatedness that all individuals endeavour to balance with their partners, and these are

closeness, distance, upperness and lowerness (Birtchnell, Voortman, DeJong, & Gordon, 2006). The concept of closeness refers to the degree to which an individual is involved and committed to a relationship, whilst distance refers to the degree to which an individual is separate and detached from the relationship. Within the relationship context, upperness and lowerness refer to the notion of power and control; whilst upperness refers to the level of control an individual exerts over their partner, lowerness refers to the level of control and power exerted over them. According to relating theory, romantic relationship anxiety will ensue if disparity exists within any of these four relationship states (Brennan & Shaver, 1995; Holmes & Johnson, 2009; Tucker & Anders, 1999).

4.2.1. Current study

This study attempted to induce one of the following four specific relationship anxiety types; a) the fear of being close to a partner, b) the fear of being far from a partner, c) the fear of being controlled by a partner, or d) the fear of being controlling with a partner. To prime relationship anxiety, participants were continuously presented either supraliminally or subliminally with a series of three emotive adjectives relating to the specific relationship threat whilst participating in a neutral classification task. Once the participant had been primed with one of the four anxieties, they were required to read a short passage about a fictitious character named 'Joanna', who was experiencing a relationship anxiety congruent with the primed anxiety. Having read the passage, participants completed a single category implicit association test (IAT) which required the participant to classify a series of emotional adjectives as something that Joanna would be fearful of or not fearful of. In addition to these emotive items, there were a series of items relating to the concept of 'self' (i.e., *me, myself,* and *I*), which the participants were required to classify with the same response as something Joanna

would be fearful of on 50% of occasions, and non-fearful on the other 50% of occasions. After completing the IAT classification task, participants were required to rate their current levels of anxiety relating to the fear of being close, far, controlled, and controlling. Lastly, participants completed the Experience in Close Relationships Scale (ECR; Brennan, Clark, & Shaver, 1998) to measure adult attachment levels across two dimensions; avoidant attachment and attachment anxiety. The responses of those participants that had been supraliminally and subliminally primed were then compared to the responses of a control group that had received no priming.

4.2.1.1. Predictions based on the IAT emotive items

As indicated previously, past research suggests that anxiety can increase response time to threat related items (Byrne & Eysenck, 1995; MacLeod & Mathews, 1988; Muris, Merckelbach, & Damsma, 2000). Therefore, our first prediction proposed that the participants that had been supraliminally and subliminally primed with anxiety would be quicker to classify the emotive/anxiety items that were congruent with the anxiety induced when compared to the response times of the control group. In addition to anxiety increasing the response time to threat related items, research also suggests that increased levels of anxiety are associated with preferential attention to cues relating to threat (Mathews et al., 1997; Neumann, Seibt, & Strack, 2001). Therefore, our second prediction regarding the anxiety items proposed that participants in supraliminal and subliminal conditions would make fewer errors in classifying congruent and incongruent anxiety items when compared to the errors made by the control group.

Further support for these predictions is provided by Bower's (1981) network theory, which suggests that external emotional stimuli activates emotion nodes within memory upon entering perception. This activation of an emotional node then leads to an increase in activation with associated emotional nodes through the spreading activation

phenomenon. That is, the inducement of a specific anxiety state through priming should then increase the salience of information congruent with that anxiety state (De Ruiter & Brosschot, 1994), leading to a quicker response to congruent anxiety items and fewer errors in classifying congruent and incongruent items when compared to the control group that had received no such priming.

4.2.1.2. Predictions based on the IAT self-related items

The purpose of including self-related items within the IAT was in an attempt to measure the strength of association between the anxiety induced and concepts of the 'self'. For example, past research has demonstrated that anxiety may speed up responding to self-related items when required to categorise the items into anxiety and calmness categories (Egloff & Schmukle, 2002). We attempted to extend this finding by investigating whether the activation of anxiety would speed up responding to self-related items when required to classify 'self' items as something to be fearful of when compared with classifying 'self' items as something not to be fearful of. More specifically, we hypothesised that the inducement of anxiety would lead to an association between the specific anxiety induced and the concept of the 'self'. Therefore, our third prediction was that this association between the anxiety and the 'self' in supraliminal and subliminal conditions would lead to a quicker response time when required to classify self-related items as fearful when compared to non-fearful. Furthermore, our fourth prediction was that participants in supraliminal and subliminal conditions would make fewer errors in classifying self-related items as fearful when compared with non-fearful. If correct in these predictions, this may provide an implicit measure of the self being related to a particular anxiety. Whilst we propose that the self-related items within the current framework of the IAT would measure the extent to

which the participant feels the anxiety, alternative possibilities remain open and are explored in more detail in the discussion.

4.2.1.3. Predictions based on current anxiety ratings

Our predictions regarding self-reported anxiety levels remain open. On the one hand, traditionally, psychologists have argued that the conscious experience of affect is a necessary and vital component of emotion, whether that emotion is pleasure, guilt, or anxiety (Berridge & Winkielman, 2003). According to this perspective, participants in supraliminal and subliminal conditions should rate higher levels of anxiety congruent with the anxiety induced when compared to participants in the control condition. On the other hand, Winkielman and Berridge (2004) propose that under certain conditions, the processing of emotion which can effect both behavioural and physiological reactions can remain entirely unconscious. According to this unconscious emotion perspective, the lack of a participant's conscious experience of anxiety does not mean that the anxiety does not exist. The mode of information processing may be globally changed such that it is sensitive and focused on threat without the person being aware of the change. Thus, an interesting dissociation would be if the IAT showed threat-relevant speeded information processed without corresponding changes in self-reported anxiety; such a pattern would constitute evidence for the induction of unconscious anxiety.

4.2.1.4. Predictions based on the ECR Scale

As well as attachment style impeding sexual maturity as previously mentioned (Barabi et al., 2006, as cited in Mikulincer & Shaver, 2010), research also suggests that the quality of parent-child relationships in childhood can have a direct influence on the quality of romantic relationships in adulthood (Brennan & Shaver, 1995; Collins & Read, 1990; Hazan & Shaver, 1987; Mikulincer & Shaver, 2010). Whilst avoidant attachment refers to individuals that prefer to distance themselves from close romantic

relationships and prefer to view themselves as independent (i.e., fear being close to partner), attachment anxiety refers to individuals who seek closeness in a relationship and tend to depend on their partners' for personal validation (i.e., fear being far from partner) (Mikulincer & Shaver, 2010). Therefore, we predict that primes relating to the fear of being far from their partner may have a stronger effect on participants scoring highly on anxious attachment rather than participants low in anxious attachment. Conversely, primes relating to the fear of being close to their partner may have a stronger effect on participants scoring highly on avoidant attachment. This prediction is supported by a study by Birnbaum, Svitelman, Bar-Shalom, and Porat (2008), who found an interaction effect between specific relationship threats and attachment styles.

4.3. Method

4.3.1. Participants

One hundred and twenty undergraduate and Masters students studying psychology at the University of Sussex voluntarily took part in this study in exchange for course credits. Ninety nine of the participants were female and twenty one male, with ages ranging from 18 to 50 years (M = 22.03, SD = 5.16). Participants were told that the study looked at the influence of anxiety on classifying emotional adjectives but did not mention anything regarding priming, either subliminal or supraliminal.

4.3.2. Design

In a mixed design, the between subjects variables were condition (3 levels; supraliminal, subliminal, control) and anxiety group (4 levels; the fear of being close, far, controlled, controlling). The within subjects variables were anxiety congruence (2 levels; whether the anxiety items classified were congruent with the induced anxiety, or

incongruent), self-related fear (2 levels; whether the self-related items were to be rated as fearful, or non-fearful), current ratings of subjective anxiety consistency (2 levels; whether the anxiety ratings were consistent with the anxiety induced, or inconsistent), and attachment style (2 levels; anxious attachment, avoidant attachment). Of the 120 participants that took part in this study, 40 participants took part in the supraliminal condition, 40 participants took part in the subliminal condition, and 40 participants took part in the control condition. Within each condition, 10 participants completed the fear of being close experiment, 10 participants completed the fear of being far, 10 participants completed the fear of being controlled, and 10 completed the fear of being controlling experiments.

4.3.3. Apparatus and Materials

The experiment was created using E-Prime version 2.0. The study used a grey scale contrast method of masking established by Lamy et al., (2008) to render the prime subliminal. This involved presenting the prime in grey lettering within a rectangular box filled in grey at a differing contrast level to the prime. The experiment was presented on a Dell laptop with a 60Hz screen refresh rate, limiting minimum stimulus presentation speed to 16 ms. The format for subliminal, supraliminal and control conditions followed the same structure and included the same word lists, passages and materials.

4.3.4. IAT Emotional Adjective Norming

Within each experiment, there were 36 IAT emotional adjective items; nine relating to the fear of being close (e.g., *intimate, clingy*), nine relating to the fear of being far (e.g., *neglected, deserted*), nine relating to the fear of being controlled (e.g., *hampered, submissive*), and nine relating to the fear of being controlling (e.g., *forceful, assertive*) (all IAT items can be found in Appendix E). Subliminal and supraliminal conditions contained an additional 12 items designed to elicit anxiety (three items

relating to the ‘close’ anxiety group, etc.) (the anxiety inducing items can be found in Appendix F).

Ten participants that did not take part in the subliminal, supraliminal or control conditions were required to rate the extent to which each of the 48 items related to the fear of being close, far, controlled, and controlling on a Likert scale from 1(‘not at all related’) to 7 (‘very related’). These relatedness ratings were consequently grouped into anxiety consistent (e.g., ‘close’ anxiety items rated as relating to *close*, ‘far’ anxiety items rated as relating to *far*, etc.) and anxiety inconsistent (e.g., ‘far’, ‘controlled’ and ‘controlling’ anxiety items rated as relating to *close*, etc.) ratings. Paired sample t-tests comparing close, far, controlled and controlling anxiety consistent and inconsistent ratings were significant (all *p*s < .001), indicating that anxiety items were more strongly related to their consistent anxiety than they were to inconsistent anxieties (means and t values can be found in Appendix G).

As well as rating relatedness, the same ten participants were asked to rate the 48 items on the extent to which each word positively or negatively related to being close, far, controlled and controlling on a Likert scale from 1 (very positive) to 7 (very negative). As with the relatedness scores, the emotional valence ratings were grouped into anxiety consistent and inconsistent. The valence ratings confirmed that, as expected, participants rated anxiety consistent items as negative. Furthermore, paired sample t-tests comparing close, far, controlled and controlling anxiety consistent and inconsistent valence ratings were significant (all ps < .001), indicating that anxiety consistent items were more strongly rated as negative when compared to anxiety inconsistent items (means and t values can be found in Appendix G).

4.3.5. Experimental Conditions

4.3.5.1. Subliminal Condition

The subliminal experiment consisted of eight sections: a stimulus onset asynchrony (SOA) setting phase to achieve individual thresholds for subliminal presentation, an objective threshold test, an anxiety priming phase, passage reading, an IAT task, a measure of current anxiety, an adult attachment measure (the ECR Scale), and an anxiety eliminating task.

4.3.5.1.1. SOA Setting: For the SOA setting, participants were presented with a masked word and required to indicate which of two subsequent words had been presented (word pairs used in the SOA setting were either *illuminate* and *highlight,* or *decorated* and *patterned,* see figure 12 for an example of the contrast between prime and background). The contrast between prime and background was measured in terms of luminance using a Cambridge Research Systems ColorCal colorimeter defined in terms of CIE 1931 coordinates. The luminance of the grey text in SOA setting and subliminal trials was $Y = 57.89$ cd/m^2 ($x = 0.292$, $y = 0.265$) against a grey background luminance of $Y = 61.04$ cd/m^2 ($x = 0.293$, $y = 0.268$). From a viewing distance of 60 cm, the dimensions of the rectangular box subtended 2.39° of visual angle (height), and 11.31° of visual angle (width). The primes used in the SOA setting stage ranged from 1.43° of visual angle (height), and a range of 4.67-5.33° of visual angle (width). Each trial began with a fixation cross at the centre of the rectangular box, presented on the screen for 350 ms. Immediately after the fixation followed the prime, which consisted of one word (e.g., *illuminate* or *highlight*). On each trial, the prime was presented three times, with a 150 ms pause between each presentation. Participants were then presented with the word pair (e.g. both *illuminate* and *highlight*) and were required to indicate which of the two words had just been presented.

Figure 12: Example of a masked prime used in the SOA setting phase, contains the word ‘illuminate’

Once the participant had made their word choice, they were required to rate, on a scale of 50-100%, how confident they were that they had chosen the correct word. The participants were instructed that they could choose any value between 50-100%, with 100% indicating that they absolutely knew which word to choose, and 50% indicating that they were purely guessing. During this part of the experiment, stimulus duration was reduced by 16 ms (one screen refresh for each of the three presentations) after each trial, from a starting point of approximately 500 ms. Once a participant had rated confidence to be at 50%, the SOA remained at that same presentation duration for subsequent presentations. Once a participant had rated confidence to be at 50% (chance performance) for five successive trials, the SOA phase of the experiment concluded. If during any of these five trials participants rated confidence to be above 50%, SOA was again reduced until five successive trials at 50% confidence had been completed. If a participant were to reach minimum stimulus presentation duration (16 ms) whilst still rating confidence to be above 50%, they would be excused from the experiment and their data removed from further analysis. The two pairs of words used in the SOA setting phase were of both similar length and semantic meaning.

4.3.5.1.2. Objective Threshold Test: An objective threshold test aimed to measure whether participants were performing above the objective threshold whilst still below the subjective threshold (for a review see Cheesman & Merikle, 1984, 1986). Using the

same two word pairs used in the SOA setting phase to create an additional 24 trials, the trial format mirrored that of the SOA task. Prime presentation duration was determined by the point at which participants rated confidence to be at 50% for five successive trials. Confidence ratings were taken after each trial.

4.3.5.1.3. Anxiety Priming Phase: Participants were required to complete an animal/shape categorisation task to mask the real purpose of this phase, which was to subliminally prime the participant with a specific relationship anxiety. At the top left hand corner of the screen appeared the word '*Animal*', and at the top right hand corner of the screen appeared the word '*Shape*'. Participants then viewed a centrally presented word (either an animal or shape) and were required to press the '1' key on the keyboard if the word was an animal and '0' if the word was a shape. A total of five animal words (*monkey, horse, antelope, koala,* and *elephant*) and five shape words (*rhombus, square, triangle, hexagon,* and *rectangle*) were used, with each word appearing three times to create a total of 30 trials. Once the participant had categorised the word as either shape or animal, a new word would appear. Before each animal or shape word was presented, a contrast masked prime was flashed up three times in succession at a duration determined by the point at which participants rated confidence to be at 50% for five successive trials during the SOA setting phase. The contrast masked primes each contained one of three words designed to induce anxiety relating to either the fear of being close (e.g., *suffocated*), the fear of being far (e.g., *abandoned*), the fear of being controlled (e.g., *weak*) or the fear of being controlling (e.g., *dominating*). From a viewing distance of 60 cm, the primes used in the priming task ranged from 1.43° of visual angle (height), and a range of 3.91-4.86° of visual angle (width). Each of the three words was presented ten times in random order so that each participant viewed a subliminal prime 30 times.

4.3.5.1.4. Passage Reading: Once the anxiety priming phase had concluded, participants were required to read a passage about two fictitious characters; 'Joanna' and 'David'. The passage described a situation in which Joanna was experiencing relationship problems relating to the anxiety induced (i.e., the passage the participant read depended upon whether they were in the close, far, controlled or controlling anxiety groups; all four passages can be found in Appendix H). For example, participants in the fear of being close anxiety group read the following passage:

> "Joanna has been in a romantic relationship with David for just over six months. They live in different towns and Joanna is happy with the way the relationship works. She sees David at weekends, and the rest of the time she can see her friends or do whatever she likes. Recently, David has been calling on the phone more often, wanting to spend more time together, and has begun to suggest that they move in together. The idea of living together and spending so much time with each other scares Joanna. She likes the current situation; that she can see David when she wants but gets to keep her own identity and have her own space, she doesn't want to have to give up her independence and answer to someone else. Joanna is going to have to come up with a way of keeping David at arm's length or she is going to have to finish the relationship."

4.3.5.1.5. IAT Task: Once the participant had read the passage, they were told that they would see a series of words appear on the screen and that their task was to decide whether these words would make Joanna fearful or not (e.g., in the fear of being close

anxiety group, Joanna would be fearful of being confined and intimate but not fearful of being apart or single, whereas the opposite would be true for the fear of being far anxiety group). There were 240 trials, divided into four blocks of 60 trials. Within each block, there were nine randomly placed items relating to the fear of being close, nine relating to far, nine relating to controlled, and nine relating to controlling. In addition to these 36 items, there were 24 randomly placed trial items relating to the self; eight instances of '*I*', eight instances of '*me*', and eight instances of '*myself,* creating a total of 60 trials within each block. The items the participants were required to classify were the same in close, far, controlled and controlling conditions. Emphasis was placed on speed as opposed to accuracy.

Block 1: In block 1, '*Fears*' appeared at the top left of the screen and '*Doesn't fear*' appeared at the top right. In the centre of the screen appeared the words '*Afraid of being...*' followed by one of the 60 instances of experimental items. Participants were required to press '1' if the item represented something that Joanna would be fearful of, and '0' if it represented something she would not be fearful of. Participants were told that when an item relating to the self appeared, they were to press the '1' key (i.e., 'fears') as quickly as possible.

Block 2: In block 2, '*Fears*' again appeared at the top left of the screen and '*Doesn't fear*' on the right. When an item relating to the self appeared, participants were required to press the '0' key (i.e., 'doesn't fear') as quickly as possible.

Block 3: In block 3, '*Doesn't fear*' then appeared at the top left of the screen and '*Fears*' appeared at the top right. Participants were required to press '1' if the item did not represent something that Joanna would be fearful of and '0' if it did represent something she would be fearful of. When an item relating to the self appeared,

participants were required to press the '1' key (i.e., 'doesn't fear') as quickly as possible.

Block 4: In block 4, '*Doesn't fear*' again appeared at the top left of the screen and '*Fears*' on the right. When an item relating to the self appeared, participants were required to press the '0' key (i.e., 'fears') as quickly as possible.

4.3.5.1.6. Current Anxiety Measure: Following the IAT task, participants were given 16 statements that aimed to measure current anxiety levels, four statements related to the fear of being close (e.g., *I am afraid of getting close to my partner*) (α = .13), four related to the fear of being far (e.g., *I enjoy having a separate identity from my partner*) (α = .52), four related to the fear of being controlled (e.g., *I am afraid of being owned by my partner*) (α = .42), and four related to the fear of being controlling (e.g., *I am afraid that my partner is weak and can't stand up to me*) (α = .27) (The full set of questions to measure current levels of anxiety can be found in Appendix I). Participants were required to rate the degree to which they agreed with the statements on a 7 point Likert scale, with 1 indicating that they completely disagreed with the statement, and 7 indicating that they completely agreed with the statement. Therefore, high scores would indicate higher levels of subjective anxiety. For each of the four anxiety groups, two of the statements were reverse phrased.

4.3.5.1.7. Adult Attachment Measure (the ECR Scale): Participants were given 36 statements relating to adult attachment, 18 of which measured anxious attachment (e.g., '*When I don't have close others around, I feel somewhat anxious and insecure*') (α = .90), and 18 of which measured avoidant attachment (e.g., '*Just when someone starts getting close to me, I find myself pulling away*') (α = .87) (the ECR-Scale items can be found in Appendix J). Participants were again required to rate the degree to which they agreed with the statements on a scale of 1 (completely disagree) to 7 (completely agree).

4.3.5.1.8. Anxiety Eliminating Task: In an attempt to eliminate any primed anxiety, the same categorisation task used in the anxiety priming phase was used, with participants categorising words as animal or shape. During the anxiety eliminating phase, the contrast masked primes contained words designed to alleviate the anxiety induced. For example, if the participant had been primed with the fear of being close, three positive words relating to being close to a partner were used (e.g., *liberated, carefree* and *independent*) (anxiety eliminating words can be found in Appendix K). Each of the three words were presented ten times so that each participant viewed a subliminal prime 30 times. The stimulus presentation duration replicated that used in the anxiety priming phase.

4.3.5.2. Supraliminal Condition

The supraliminal experiment consisted of six sections: An anxiety priming phase, passage reading, an IAT task, a measure of current anxiety, an adult attachment measure (the ECR Scale), and an anxiety eliminating task.

4.3.5.2.1. Anxiety Priming Phase: The supraliminal anxiety phase used the same animal/shape categorisation task and materials used in the subliminal condition, participants were required to categorise the same 30 trials as either an animal or a shape. In addition, the anxiety inducing words for all four anxiety groups matched those used in the subliminal experiment. However, the luminance values for the grey text in the supraliminal condition was $Y = 14.35$ cd/m^2 ($x = 0.277$, $y = 0.216$) against a grey background luminance of $Y = 61.04$ cd/m^2 ($x = 0.293$, $y = 0.268$) (see figure 13 for an example). Each of the three prime presentation durations were held at 150 ms.

Figure 13: Example of a prime to induce anxiety in supraliminal conditions; 'Confined' aimed to induce the fear of being close to partner.

4.3.5.2.2. Passage Reading, IAT Task, Current Anxiety Measure & Adult Attachment Measure (the ECR Scale): The passages for close, far, controlled and controlling experiments replicated those used in subliminal conditions. Similarly, the IAT task, the measure of current anxiety and the adult attachment measure (ECR) replicated the same format and materials as that used in the subliminal condition.

4.3.5.2.3. Anxiety Eliminating Task: Using the same prime/background luminance levels and presentation durations described in the current categorisation task, the supraliminal anxiety eliminating task replicated that used in the subliminal condition.

4.3.5.3. Control Condition

The control experiment consisted of five sections: A categorisation task, passage reading, an IAT task, a measure of current anxiety, and an adult attachment measure (ECR Scale).

4.3.5.3.1. Categorisation Task: The categorisation task used in the control condition replicated the anxiety priming phase used in the subliminal and supraliminal conditions, with participants categorising the same set of 30 words as either animal or shape. However, before each word appeared, participants were exposed to three presentations of a blank grey rectangular box of the same background luminance described in subliminal and supraliminal conditions. Each of the three presentation durations of the blank mask were presented for 150 ms.

4.3.5.3.2. Passage Reading, IAT Task, Current Anxiety Measure & Adult Attachment Measure (ECR Scale): The passage the participants read for close, far, controlled and controlling experiments replicated those used in subliminal and supraliminal conditions. Furthermore, the IAT task, the measure of current anxiety and the adult attachment measure (ECR) replicated the same format and materials as that used in the subliminal and supraliminal conditions.

4.3.6. Procedure:

Participants were randomly assigned to either subliminal, supraliminal, or control conditions and anxiety groups. All participants were tested individually in a private room in which they sat before a laptop such that their eyes were approximately 60 cm from the monitor screen. All participants had normal or corrected to normal vision, and English was the first language for all participants. Once the participant had followed the instructions presented on the screen and had completed all sections of the experiment, they were fully debriefed and thanked for their participation. Each participant received an information sheet providing some background information on the study, which condition and anxiety group they took part in, and experimenter contact details.

4.4. Results

4.4.1. SOA setting phase for subliminal condition:

For those in the subliminal condition, subjective threshold durations ranged from an SOA of 32 ms to 528 ms, with an average experimental subliminal presentation duration of 240 ms (*SD* = 219.51).

4.4.2. Objective threshold test for subliminal condition:

The objective identification threshold test aimed to assess whether participant performance was above the objective threshold whilst remaining below the subjective (cf. Cheesman & Merikle, 1984, 1986). Correct responses ranged between 29% and 67%, with a mean of 50% correct (*SE* = 1). For all statistical tests, we used an alpha level of .05 to determine significance. Using chance level as the test value (50%), a one-sample t-test confirmed that participants did not perform significantly above chance level performance ($t(39) = 0.14$, $p = .89$, $d = 0.04$). Thus it may be that not only was the subjective threshold reached, but unfortunately also the objective threshold. To determine whether there was evidence for the objective threshold (i.e., in this case, that accuracy was at chance performance), we used a Bayes Factor. Whilst values over 3 are seen as substantial evidence in support of the experimental hypothesis (that objective performance was above chance), values under 1/3 are seen as substantial evidence in support of the null hypothesis (i.e., in this case, that the objective threshold was reached) (Dienes, 2011). A Bayes Factor of 1 indicates the evidence is exactly neutral between the two theories, values between 1/3 and 3 indicate data insensitivity and no conclusions should be drawn. Armstrong and Dienes (2013; experiment 5) used a procedure under the same presentation conditions that involved objective classification and produced a reliable effect 3% above baseline performance. Thus, to represent the

plausibility of different possible population effects, we used a half-normal with a standard deviation of 3% (following the recommendation of Dienes, 2011, Appendix). A sample mean of .21% above baseline (*SE* = 1.4), led to a Bayes Factor of B = 0.47, indicating that the data were insensitive and did not provide strong support for the null hypothesis that performance was at chance. It remains open as to whether or not the objective threshold was reached.

4.4.3. IAT anxiety and non-anxiety related item reaction times:

A 2 (congruence) × 3 (condition) mixed ANOVA was conducted to compare the overall effect of condition on the reaction time (RT) to classifying anxiety congruent and incongruent items. The anxiety congruence of an item was determined by anxiety group. For example, the congruent items in the close groups related to the anxiety close whilst the incongruent items related to the anxieties far, controlled and controlling, and so on. Table 1 provides the mean RTs for anxiety congruent and incongruent items across all conditions. There were significant main effects of congruence on RTs to classifying IAT items ($F(1, 117) = 18.38$, $p < .001$, $\eta_p^2 = .136$), and of condition ($F(2, 117) = 8.85$, $p < .001$, $\eta_p^2 = .131$). Importantly, these effects were moderated by a significant interaction effect between congruence and condition ($F(2, 117) = 5.28$, $p = .006$, $\eta_p^2 = .083$).

This 2-df interaction was broken into two 1-df interactions, one to test for supraliminal and the other for subliminal priming. When comparing supraliminal and control conditions, there was a significant interaction between congruence and condition ($F(1, 78) = 7.16$, $p = .01$, $\eta_p^2 = .084$)[10]. However, when the main interaction effect was

[10] When this interaction was explored separately for each anxiety group, the interaction effect was only significant for participants in the controlled anxiety group ($F(1, 18) = 14.13$, $p = .001$, $\eta_p^2 = .440$), and not for close ($F(1, 18) = .03$, $p = .87$, $\eta_p^2 = .002$), far ($F(1, 18) = 3.31$, $p = .09$, $\eta_p^2 = .155$) or controlling ($F(1, 18) = .33$, $p = .57$, $\eta_p^2 = .018$) anxiety groups. The latter non-significant results were interpreted with a Bayes Factor, calculated for each anxiety group using a half-normal with a standard deviation equal to the

explored further using paired sample t-tests, there was a significant difference between RTs to classifying congruent and incongruent items, with participants being faster to classify anxiety congruent items in supraliminal conditions ($t(39) = -5.38$, $p < .001$, $d = 1.72$), but not for the control conditions ($t(39) = -1.1$, $p = .28$, $d = 0.35$). When comparing subliminal and control conditions, there was a non-significant interaction between congruence and condition ($F(1, 78) = .01$, $p = .93$, $\eta_p^2 = .000$).

Was there any subliminal priming? The subliminal priming effect (difference in congruency effect between primed and control groups) was 33 ms (*SE* = 53 ms). The sort of priming effect that could be expected is provided by the supraliminal priming effect (87 ms). A Bayes factor with the hypothesis of subliminal priming modelled as a half-normal with an SD of 87 ms was 0.84, indicating that the data were insensitive and so we were unable to draw any conclusions as to whether or not there was subliminal priming.

Table 1: Reaction time means with standard error for classifying both anxiety congruent and incongruent items across subliminal, supraliminal and control conditions.

Classification	Condition	Mean RT (ms)	*SE*
Anxiety Congruent		1716	51
	Subliminal	1479	65
	Supraliminal	1790	81
	Control	1877	103
Anxiety Incongruent		1829	49
	Subliminal	1549	73
	Supraliminal	2025	87
	Control	1933	79

interaction effect evidenced in the controlled anxiety group (423 ms). For close (*M* = 18 ms, *SE* = 103 ms) B = 0.27; for far (*M* = 210 ms, *SE* =116 ms) B = 2.33; and for controlling (*M* = 101 ms, *SE* = 176 ms) B = 0.62, Bayes factors indicated that the data were insensitive for these specific anxieties taken separately. However, when sensitivity is increased by averaging over anxieties, the overall interaction effect indicates an overall match between priming and the specific anxiety elicited.

4.4.4. IAT anxiety and non-anxiety related item errors:

A 2 (congruence) × 3 (condition) mixed ANOVA was conducted to compare the overall effect of condition on the error rates (ER) in classifying anxiety congruent and incongruent items. All subliminal, supraliminal, and control experiments consisted of 240 trials; 96 of these trials were self-related items, 36 of these trials were anxiety congruent items, and 108 trials were anxiety incongruent items. Therefore, ERs were converted to percentages to make them directly comparable. Table 2 provides the mean ERs for classifying anxiety congruent and incongruent items for supraliminal, subliminal and control conditions. There was a significant main effect of congruence on ER in classifying IAT items ($F(1, 117) = 18.37$, $p < .001$, $\eta_p^2 = .136$). That is, across all conditions, participants made significantly more errors when classifying anxiety incongruent items ($M = 29\%$, $SE = 1$) when compared to anxiety congruent items ($M = 20\%$, $SE = 2$). Whilst there was a significant main effect of condition on classification ERs ($F(2, 117) = 3.47$, $p = .03$, $\eta_p^2 = .056$), post hoc comparisons using a Bonferroni adjustment indicated that ER differences between supraliminal, subliminal, and control conditions were non-significant ($ps > .05$). The interaction between congruence and condition was non-significant ($F(2, 117) = 1.31$, $p = .27$, $\eta_p^2 = .022$).

As before, supraliminal and subliminal priming effects were analysed separately. When comparing supraliminal and control conditions, there was a significant main effect of condition ($F(1, 78) = 5.26$, $p = .03$, $\eta_p^2 = .063$), with participants making approximately 8% ($SE = 4$) fewer errors in supraliminal conditions ($M = 22\%$, $SE = 3$) when compared to the control condition. There was a non-significant interaction between congruence and condition ($F(1, 78) = 3.40$, $p = .07$, $\eta_p^2 = .042$). Looking at subliminal and control conditions, there was a significant main effect of condition ($F(1, 78) = 4.50$, $p = .04$, $\eta_p^2 = .055$), with participants making approximately 8% ($SE = 4$)

fewer errors in subliminal conditions (M = 22%, SE = 3) when compared to the control (M = 29%, SE = 3) condition. Thus, there is evidence for some subliminal processing, but not for subliminal processing of the precise anxiety content: There was a non-significant interaction between congruence and condition ($F(1, 78) = .70$, $p = .41$, $\eta_p^2 = .009$).

Table 2: Mean percentage of errors with standard error made in classifying anxiety congruent and anxiety incongruent items across subliminal, supraliminal, and control conditions.

Classification	Condition	Mean ER (%)	*SE*
Anxiety Congruent		20	1
	Subliminal	17	2
	Supraliminal	15	2
	Control	27	3
Anxiety Incongruent		29	2
	Subliminal	26	4
	Supraliminal	28	3
	Control	32	3

4.4.5. IAT self-related items as fearful and non-fearful reaction times:

A 2 (fear) × 3 (condition) mixed ANOVA was conducted to compare the overall effect of condition on the RTs of classifying self-related items as fearful and non-fearful. Table 3 provides the mean RTs for classifying self-related items as fearful and non-fearful for supraliminal, subliminal and control conditions. There was a significant main effect of fear on RTs to classifying self-related items ($F(1, 117) = 5.73$, $p = .02$, $\eta_p^2 = .047$), with participants across all conditions being significantly quicker to categorise self-related items as non-fearful (M = 902 ms, SE = 25) when compared to fearful (M = 947 ms, SE = 32, $p = .02$). However, there was a non-significant main effect of condition on RTs to classifying self-related items ($F(2, 117) = .19$, $p = .83$, η_p^2

= .003), and a non-significant interaction between fear and condition ($F(2, 117) = 2.09$, $p = .13$, $\eta_p^2 = .034$).

Despite the non-significant omnibus interaction, we tested specifically for supraliminal priming and for subliminal priming as in the last section. When comparing supraliminal and control conditions, there was a significant interaction between fear and condition ($F(1, 78) = 3.96$, $p = .05$, $\eta_p^2 = .048$). However, when the main interaction effect was explored further using paired sample t-tests, there was a significant difference in RTs to classifying self-related items as fearful and non-fearful in that participants were significantly faster to classify self-related items as non-fearful in the control condition ($t(39) = 2.3$, $p = .03$, $d = 0.74$). Whilst participants in the supraliminal condition were faster to categorise self-related items as fearful, this RT difference was not significant ($t(39) = -.34$, $p = .73$, $d = 0.11$). However, when comparing subliminal and control conditions, there was a non-significant interaction between fear and condition ($F(1, 78) = .25$, $p = .62$, $\eta_p^2 = .003$).

A Bayes Factor was conducted to determine whether there was evidence of a subliminal priming effect. The subliminal priming effect (difference in categorising self-related items as fearful and non-fearful effect between primed and control groups) was 26 ms ($SE = 53$ ms). Again, the sort of priming effect that could be expected is provided by the supraliminal priming effect (66 ms). A Bayes factor with the hypothesis of subliminal priming modelled as a half-normal with an SD of 66 ms was 0.88, indicating that the data were insensitive and so we were unable to draw any conclusions as to whether or not there was subliminal priming.

Table 3: Reaction time means and standard error for classifying self-related items as fearful and non-fearful across subliminal, supraliminal, and control conditions

Classification	Condition	Mean RT (ms)	*SE*
Self as Fearful		947	32
	Subliminal	984	79
	Supraliminal	926	38
	Control	932	37
Self as Non-Fearful		902	25
	Subliminal	899	52
	Supraliminal	933	40
	Control	873	35

4.4.6. IAT self-related items as fearful and non-fearful errors:

A 2 (fear) × 3 (condition) mixed ANOVA was conducted to compare the overall effect of condition on the ERs in classifying self-related items as fearful and non-fearful. Supraliminal, subliminal, and control experiments each contained 96 trials containing self-related items. Of these 96 items, participants were required to classify 48 of these items as fearful, and 48 as non-fearful. Again, ERs were converted to percentages and Table 4 provides the mean ERs for classifying self-related items as fearful and non-fearful for supraliminal, subliminal and control conditions. There was a non-significant main effect of fear ($F(1, 117) = .49$, $p = .49$, $\eta_p^2 = .004$) or condition ($F(2, 117) = 1.04$, $p = .36$, $\eta_p^2 = .017$) on the ERs for classifying self-related items. However, there was a significant interaction between fear and condition ($F(2, 117) = 3.37$, $p = .04$, $\eta_p^2 = .054$).

Two 1-df interactions explored this effect further. When comparing supraliminal and control conditions, there were non-significant main effects of fear ($F(1, 78) = 3.33$, $p = .07$, $\eta_p^2 = .041$) and condition ($F(1, 78) = .59$, $p = .45$, $\eta_p^2 = .007$), and a non-significant interaction between fear and condition ($F(1, 78) = 3.19$, $p = .08$, $\eta_p^2 = .039$). When comparing subliminal and control conditions, there were non-

significant main effects of fear ($F(1, 78) = .60$, $p = .44$, $\eta_p^2 = .008$) and condition ($F(1, 78) = .46$, $p = .50$, $\eta_p^2 = .006$) on classifying self-related items, and a non-significant interaction between fear and condition ($F(1, 78) = .65$, $p = .42$, $\eta_p^2 = .008$). However, as demonstrated in Table 4, participants made significantly more mistakes in classifying self-related items as fearful when they were meant to classify as non-fearful in supraliminal conditions ($M = 10\%$, $SE = 3$, $t(39) = -3.0$, $p = .01$, $d = 0.96$), but not for subliminal ($M = 5\%$, $SE = 5$, $t(39) = 1.1$, $p = .28$, $d = 0.35$) or control ($M = 0\%$, $SE = 4$, $t(39) = -.02$, $p = .98$, $d = 0.01$) conditions.

A Bayes Factor was again conducted to determine whether there was evidence of a subliminal priming effect. The subliminal priming effect (difference in fearful and non-fearful ERs between primed and control groups) was 5% ($SE = 6$). Again, the sort of priming effect that could be expected is provided by the supraliminal priming effect (10%). A Bayes factor with the hypothesis of subliminal priming modelled as a half-normal with an SD of 10% was 1.01, indicating that the data were insensitive and so we were unable to draw any conclusions as to whether or not there was subliminal priming.

Table 4: Mean percentage of errors with standard error made in classifying self-related items as fearful or non-fearful across subliminal, supraliminal, and control conditions.

Classification	Condition	Mean ER (%)	*SE*
Self as Fearful		11	2
	Subliminal	16	4
	Supraliminal	4	1
	Control	12	4
Self as Non-Fearful		12	2
	Subliminal	11	3
	Supraliminal	14	3
	Control	12	3

4.4.7. Current anxiety measure:

Current relationship anxiety levels for the fear of being close, far, controlled and controlling were measured on a 7 point Likert scale, with higher values indicating higher levels of anxiety. Relationship anxiety ratings were divided into those consistent with the anxiety manipulated in the group (and also measured by IAT in that group) or inconsistent. For example, in the Far groups, the rating of far anxiety was consistent, and all other anxieties (close, controlled, controlling) inconsistent. Figure 14 shows the summary data for all explicit ratings in each cell. A 2 (consistency: consistent, inconsistent) × 3 (condition: supraliminal vs. subliminal vs. control) mixed ANOVA indicated a non-significant main effect of consistency ($F(1, 117) = .06$, $p = .81$, $\eta_p^2 = .001$) (ratings of consistent ($M = 3.40$, $SE = .09$) and inconsistent ($M = 3.38$, $SE = .06$) anxiety), and of condition ($F(2, 117) = .09$, $p = .92$, $\eta_p^2 = .002$). In addition, there was a non-significant interaction between consistency and condition ($F(2, 117) = 1.71$, $p = .19$, $\eta_p^2 = .028$). Again, the individual effects of supraliminal and subliminal priming were analysed individually. For supraliminal priming, there was a non-significant interaction between consistency and condition ($F(1, 78) = 1.27$, $p = .26$, $\eta_p^2 = .016$) on supraliminal consistent ($M = 3.39$, $SE = .17$) and inconsistent ($M = 3.33$, $SE = .12$), control consistent ($M = 3.26$, $SE = .17$), and inconsistent ($M = 3.50$, $SE = .12$) anxiety ratings. Similarly, in terms of subliminal priming, there was a non-significant interaction between consistency and condition ($F(1, 78) = 3.40$, $p = .07$, $\eta_p^2 = .042$) on subliminal consistent ($M = 3.55$, $SE = .17$) and inconsistent ($M = 3.30$, $SE = .11$), control consistent ($M = 3.26$, $SE = .17$), and inconsistent ($M = 3.50$, $SE = .11$) anxiety ratings.

On the face of it there appears to have been implicit priming of anxiety on the IAT, but not on explicit anxiety ratings. But are the anxiety ratings just insensitive? It is

hard to directly compare the implicit and explicit priming effects because they are measured on different scales. Nonetheless, the standardized effect sizes can be compared. The F for the supraliminal priming effect for congruent versus incongruent RTs was $F(1, 78) = 7.16$, giving a standardized effect size r of sqrt(7.16/(7.16 + 78)) = 0.29 (Fisher's *z* also 0.29, *SE* = 0.11). The corresponding standardized effect for supraliminal priming for explicit anxiety ratings is sqrt(1.27/(1.27 + 78)) = .13 (Fisher's *z* also 0.13, *SE* = 0.11). These effects are not significantly different ($z = 1.13$), so we cannot claim that the implicit measure was more sensitive than the explicit. Further, a Bayes Factor testing the hypothesis that there was explicit priming using a half-normal with an SD of 0.29 is 1.13, indicating no conclusion can be drawn as to whether there was or was not explicit priming.

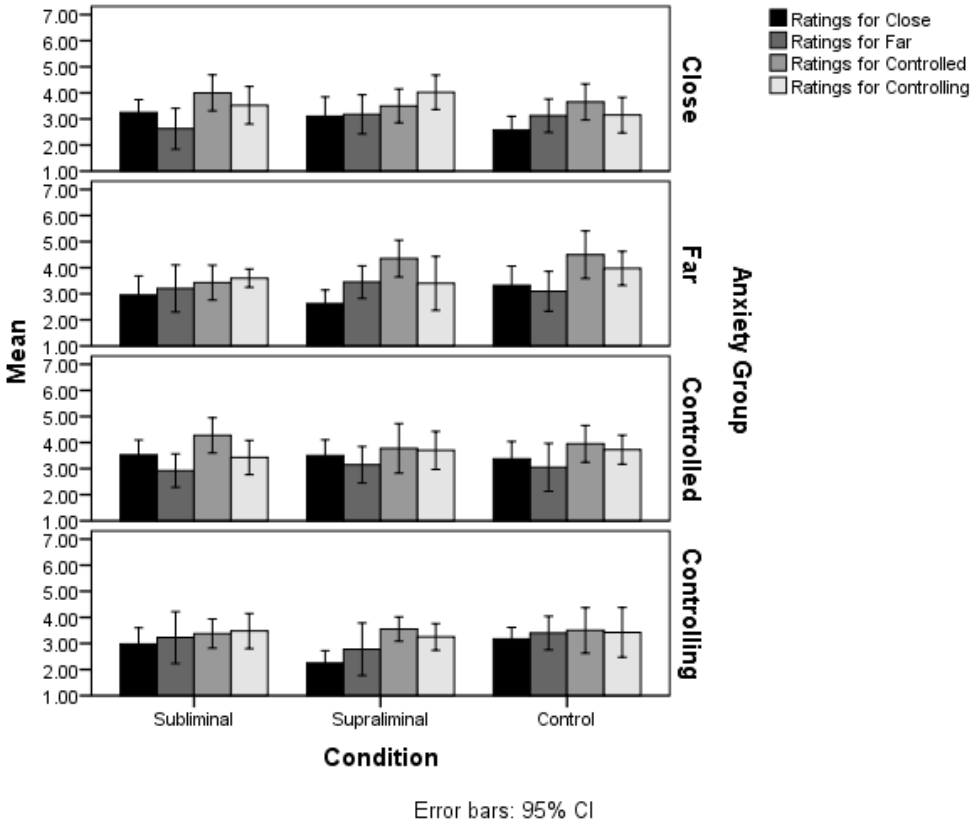

Figure 14: Mean close far, controlled and controlling current subjective anxiety ratings on a scale of 0-7 (7 indicating high anxiety) for supraliminal, subliminal and control conditions and close, far, controlled and controlling anxiety groups.

4.4.8. Adult Attachment levels and the ECR Scale:

The ECR scale measured levels of adult attachment on a 7 point Likert scale, with higher values indicating higher levels of attachment. From this scale, an attachment anxiety and avoidant attachment score was computed for each participant. A 4 (anxiety group; close, far, controlled, controlling) × 3 (condition; supraliminal, subliminal, control) × 2 (attachment; attachment anxiety, avoidant attachment) mixed ANOVA was conducted to compare whether the fear of being close, the fear of being far, the fear of being controlled, or the fear of being controlling anxiety groups and subliminal, supraliminal, or control conditions had an effect on attachment anxiety and avoidant attachment. Table 5 provides the mean attachment scores across anxiety group and condition. There was a significant main effect of attachment ($F(1, 108) = 41.18$, $p < .001$, $\eta_p^2 = .276$) in that participants scored significantly higher in anxious attachment ($M = 4.1$, $SE = .1$) than they did for avoidant attachment ($M = 3.3$, $SE = .1$). There were no other significant effects, consistent with the random assignment of participants to groups.

Table 5: Mean and standard error for avoidant attachment and attachment anxiety scores across anxiety group and condition.

Anxiety Group	Condition	Anxious Mean	*SE*	Avoidant Mean	*SE*
Close		3.8	.2	3.3	.2
	Subliminal	3.7	.4	3.5	.4
	Supraliminal	3.6	.2	3.5	.3
	Control	4.1	.4	2.9	.2
Far		4.3	.2	3.1	.2
	Subliminal	4.2	.3	2.9	.3
	Supraliminal	4.5	.3	3.2	.4
	Control	4.4	.3	3.3	.3
Controlled		4.4	.2	3.6	.2
	Subliminal	4.0	.3	3.8	.4
	Supraliminal	4.6	.2	3.6	.3
	Control	4.5	.4	3.3	.2
Controlling		4.0	.2	3.3	.2
	Subliminal	3.9	.3	3.3	.3
	Supraliminal	3.7	.4	3.4	.3
	Control	4.4	.4	3.3	.3

A set of multiple regressions were conducted on the subliminal and control data to determine whether priming (primed versus control group), anxious attachment and avoidant attachment variables predicted the reaction time difference between responding to anxiety congruent and incongruent items. Regressions were conducted separately for close, far, controlled and controlling groups. The results indicated no significant overall regressions for the close ($F(3, 19) = .51$, $p = .68$, $f^2 = .10$), far ($F(3, 19) = .48$, $p = .70$, $f^2 = .10$), controlled ($F(3, 19) = 1.1$, $p = .38$, $f^2 = .02$) or controlling ($F(3, 19) = .02$, $p = .99$, $f^2 = .00$) anxiety groups. The values of individual predictors are presented in Table 6. A further set of multiple regressions were conducted using the same predictor variables and included an interaction between priming and anxious attachment variable and an interaction between priming and avoidant attachment

variable. No interactions were significant; values of the new variables are presented in Table 6.

Table 6: Standardized betas, their associated standard errors, and unstandardized betas for the close, far, controlled and controlling multiple regressions.

Anxiety Group	Predictors	*B*	*SE B*	*ß*
Close	Priming	57.90	88.84	.17
	Anxious	.16	38.14	.00
	Avoidant	-51.14	48.80	-.30
	Anxint	-140.29	81.09	-.76
	Avoidint	145.51	134.55	.72
Far	Priming	-103.37	161.51	-.16
	Anxious	77.80	82.38	.23
	Avoidant	-2.89	92.34	-.01
	Anxint	239.37	178.12	.53
	Avoidint	-145.29	208.36	-.25
Controlled	Priming	-19.70	58.10	-.08
	Anxious	31.76	25.89	.30
	Avoidant	-22.46	33.18	-.17
	Anxint	31.06	68.48	.18
	Avoidint	88.75	86.06	.57
Controlling	Priming	5.68	117.25	.01
	Anxious	13.02	62.60	.06
	Avoidant	-9.51	69.48	-.04
	Anxint	-89.94	135.61	-.24
	Avoidint	104.23	146.65	.26

Note; All *p*s > .05. Close first regression R^2 = .09, second regression R^2 = .25; Far first R^2 = .08, second R^2 = .19; Controlled first R^2 = .02 second R^2 = .23; Controlling first R^2 = .00, second R^2 = .05.

4.5. Discussion

The current research aimed to extend upon previous work on the supraliminal and subliminal priming of anxiety by investigating whether it is possible to supraliminally and subliminally prime specific relationship anxieties relating to the fear of being close to partner, far, controlled and controlling with partner.

Past research has suggested that an increased level of anxiety leads to a preferential attention to cues relating to threat and threatening stimuli (Mathews & Mackintosh, 1998; Mathews et al., 1997; Neumann, Seibt, & Strack, 2001). Therefore, we predicted that participants that had been supraliminally and subliminally primed with anxiety would be quicker and make fewer errors in classifying items that were congruent with the anxiety induced when compared to a control group that had not been primed. In regards to reaction times, we found evidence only for a supraliminal priming effect. Although, participants in the subliminal condition were approximately 398 ms quicker to classify anxiety congruent items when compared to the control condition, and approximately 384 ms quicker to classify anxiety items that were incongruent with the anxiety induced when compared to the control. In regards to error rates, priming effects were evidenced for both supraliminal and subliminal priming conditions in that participants in the control condition made more errors in classifying congruent and incongruent items. However, whilst this result does indeed indicate a degree of anxiety inducement activated through subliminal priming, the anxiety induced need not necessarily have been a content-specific one. That is, this result may instead indicate the activation of a generalised relationship anxiety as opposed to, for example, the specific activation of the fear of being close to a partner.

In relation to the classification of self-related items, it was proposed that the priming of relationship anxieties would lead to the anxiety activated and *self* concepts becoming more cognitively salient. It was further believed that this salience would in turn lead to a quicker reaction time when required to classify self-related items as fearful when compared to the occasions participants were required to classify self-related items as non-fearful. However, contrary to this prediction, the results indicated that participants across all conditions were significantly slower to classify self-related

items as fearful when compared to classifying self items as non-fearful. We further predicted that participants in supraliminal and subliminal priming conditions would be more likely to make errors when required to classify self-related items as non-fearful when compared to the control condition. Again, we found evidence only for a supraliminal priming effect in that participants that had been supraliminally primed made more mistakes in classifying self-related items as fearful when they were meant to classify as non-fearful when compared to subliminal and control conditions. Whilst we propose that the self-related items would measure the extent to which the participant felt the induced anxiety, other possibilities remain open. For example, it could be argued that the self-related items would actually measure the extent to which the participant was afraid of themselves, or had affect-neutral beliefs concerning the relation between that anxiety and the self.

Current research focusing on the supraliminal priming of anxiety has tended to concentrate on the inducement of anxiety on a global level (e.g., Williams, Mathews, & MacLeod, 1996; Yiend & Mathews, 2001). That is, the anxiety induced is generalised as opposed to being directly related to a specific concept. However, very little research has attempted to investigate whether it is possible to consciously prime content-specific anxieties. Therefore, we attempted to extend research in this area by demonstrating the activation of four very specific anxieties relating to relationships. The supraliminal reaction time and error rate results for anxiety congruency and self-related items provides support for the possibility of priming more specific anxieties than previously demonstrated.

Whilst the supraliminal priming effects are relatively clear, the current research has thus far demonstrated insensitive evidence regarding the subliminal priming of specific anxieties in the form of reaction times and error rates to classifying anxiety

congruent and incongruent items, and self-related items. Did the priming produce conscious or unconscious anxiety? The explicit anxiety ratings for the specific anxiety induced were compared with the ratings of the relationship anxieties that were inconsistent with the anxiety induced. Whilst the implicit results demonstrated a degree of successful supraliminal and subliminal priming of relationship anxiety, explicit ratings of current anxiety were insensitive in indicating a priming effect (despite running 120 participants). It would be interesting to collect more data to make this result sensitive. What could be concluded if we sensitively show no priming of explicit anxiety?

Many researchers believe that emotion, of which anxiety is an example, is a necessarily conscious experience (e.g., Clore, 1994; Hatzimoysis, 2007; James, 1884); that an emotion without a degree of conscious awareness of how one feels does not exist. Scherer's (2005) component processing definition of emotion consists of five elements that must be present for an emotion to qualify as an emotion; these components include a cognitive component, a neurophysiological component, a motivational component, a motor expression component, and a conscious subjective feeling component. Therefore, by Scherer's definition, the current research has failed to elicit any demonstrative anxiety as evidenced by the lack of a subjective feeling component. In accordance with the emotion as a conscious experience point of view, there may be a number of reasons why subjective ratings of anxiety have failed to demonstrate an anxious priming effect. For example, the anxiety manipulation in this study was subtle; it may be that the manipulation was too subtle to have influenced conscious appraisals of emotion. It may be that using short sentences or emotive pictures that require a greater depth of cognitive processing may in turn have had more of an effect on conscious perceptions of anxiety. In addition, it may be that our measure

of subjective anxiety was not sensitive enough to have detected any differences between primed and no priming conditions. Furthermore, although the lack of pre-experimental anxiety ratings was a deliberate effort to avoid demand characteristics, it may have been interesting to have had these ratings in order to compare self-reported pre- and post-experimental anxiety levels.

However, whilst the small subliminal anxiety priming effects evidenced may be accurately reflected in the subjective anxiety ratings, the implicit anxiety measures have clearly demonstrated a supraliminal priming effect of anxiety and yet not on the subjective experience of anxiety. Therefore, the lack of a measurable difference in explicit anxiety between primed and control conditions may instead be indicative of unconscious emotion (e.g., Berridge & Winkielman, 2003; Winkielman & Berridge, 2004). Proponents of the unconscious emotion perspective believe that not only can an individual be unconscious as to the underlying cause of a specific emotion, but that they can also be unconscious of their own emotional reaction. Winkielman and Berridge (2004) argue that evolutionary reasons may account for unconscious emotions in that the primary function of an emotion is to enable an individual to react accordingly to an external event. Therefore, to be conscious of that emotion is neither necessary nor functionally or cognitively efficient. An example of a study demonstrating the existence of emotion in the absence of conscious introspection is provided by Winkielman, Berridge, and Wilbarger (2005). In their study, the authors investigated the influence of subliminally primed happy or angry faces on mood and the pouring and consumption of a beverage. Despite there being a lack of difference in self-reported mood and thirst measures, participants that had been primed with happy faces both poured more and consumed more beverages than those primed with angry faces. Thus, although participants failed to report changes in conscious mood, the effects of subliminal

priming were nevertheless able to alter subsequent behaviours. Therefore, in relation to the current research, the lack of a statistical difference between subjective anxiety ratings for primed and non-primed conditions does not necessarily negate anxiety activation, as demonstrated by the supraliminal priming effects. Instead, the priming results evidenced in IAT classification are consistent with the existence of unconscious emotion (e.g., Bornemann, Winkielman, & van der Meer, 2012).

The IAT has often been criticised as a poor measurement of the strength of implicit associations between concepts. However, many criticisms of the IAT appear to revolve around its use as a diagnostic tool. That is, the IAT is often used to confer personality characteristics, or to measure implicit biases that are subsequently used to demonstrate subtle discrimination or prejudice. Therefore, many researchers have questioned what it is the IAT is actually measuring. Fiedler, Messner, and Bluemke (2006) claim that the need to conform to social desirability leads individuals to fake their responses by adopting strategies that make themselves look good. However, in the current research, it is unlikely that participants felt the need to fake their responses. Our implicit measure was designed to measure the strength of associations between the anxiety activated and concepts relating to the anxiety induced, and also the association between the anxiety induced and concepts of the 'self', therefore lacking an element of social desirability. Furthermore, similarly using the IAT to measure implicit anxiety, Egloff and Schmukle (2002) found that giving participants a faking instruction led to very small and non-significant implicit effects whilst having a greater effect on explicit measures. The IAT has also been criticised for measuring salience as opposed to associations. Rothermund and Wentura (2004) claim that a faster response to pairs of concepts merely measures the similarity in salience between the two concepts rather than pairs of concepts having stronger associations with the individual. In the current

research, whether the IAT is measuring the strength of associations or salience, a faster response time to congruent items in priming conditions when compared to the control indicates a degree of anxiety activation, and semantic processing of the prime in subliminal conditions.

In addition to looking at current levels of explicit relationship anxiety, we also measured adult attachment styles using the Experience in Close Relationships Scale (ECR; Brennan, Clark, & Shaver, 1998) to measure levels of anxious and avoidant attachment. In the same way that Barabi, Mikulincer, and Shaver (2006, as cited in Mikulincer & Shaver, 2010) demonstrated a differential subliminal priming effect between attachment styles, we investigated whether anxious and avoidant attachment variables would predict reaction time differences in responding to anxiety congruent and incongruent items. Avoidant attachment refers to individuals that prefer to distance themselves from close romantic relationships and view themselves as independent and individual, and so it seemed likely that this attachment style would have some relation with the primed fear of being close to a partner. Conversely, anxious attachment refers to individuals who seek closeness in a romantic relationship and tend to depend upon their partners' for personal validation, and so it seemed likely that this would have some relation with the fear of being far from their partner. The results demonstrated that there was an overall effect of attachment in that scores on anxious attachment were significantly higher than for scores on avoidant attachment. However, we did not detect a moderating effect of attachment insecurity on relationship anxiety priming.

There are some criticisms to this study. For example, we would have benefitted from tailoring the specific anxiety priming experiments to the fears of specific individuals. That is, it would have been beneficial to have pre-selected for participants who had specific relationship anxieties relating to the fear of being close and so on, and

also for extreme scores on the attachment questionnaire. This would have likely resulted in stronger subliminal priming effects than those evidenced here. In addition, whilst the current research utilised a method of multiple prime presentation, Wentura and Frings (2005) found maximum priming effects when a prime was presented 10 times in quick succession. Furthermore, Marcel (1983b) found an increasing priming effect with up to 20 prime presentations. Therefore, whilst the current method of three prime presentations may have taken advantage of the increase in prime presentation duration without increasing prime awareness, this advantage could have been maximised with further repeated presentations (as found by Armstrong & Dienes, 2013, using a similar subliminal methodology as used here).

In addition, for the subliminal condition, the objective threshold data indicated that whilst we were successful in priming below the subjective threshold of awareness, we were also at, or at least very near to, the objective threshold. Previous research has frequently demonstrated that being below the subjective threshold whilst also being *above* the objective threshold is vital in achieving maximum likelihood of demonstrating subliminal priming effects (for a review, see Cheesman & Merikle, 1984, 1986; Dienes, 2004, 2008; contrast Snodgrass, Bernat, and Shevrin, 2004). In relation to subjective thresholds, the current research was also hampered by the necessity of being presented on a 60 Hz laptop with a screen refresh rate of 16 ms, limiting presentation duration decrements during the SOA setting phase of the experiment to intervals of 16 ms. Therefore, the likelihood of bypassing the necessary spot between subjective and objective thresholds was relatively high. Whilst the IAT measures have demonstrated small subliminal priming effects, future research would benefit from investigating subliminal anxiety activation using more subtle and sophisticated methods of subliminal

presentation, such as through the use of a tachistoscope or by using continuous flash suppression.

4.6. Conclusion

To conclude, we present a study that attempted to supraliminally and subliminally prime content-specific anxieties. Previous research demonstrating the priming of anxiety has predominantly focused on the activation of a generalised or global level of anxiety. Instead, we demonstrated the supraliminal priming of very specific relationship anxieties relating to the fear of being close, far, controlled or controlling with a partner. However, the evidence regarding whether or not there existed subliminal priming effects remains insensitive.

5. Discussion and Conclusions

5.1. Theoretical Basis of Research

The current research set out to investigate the power of subliminal priming and the extent of unconscious cognitive processing. The status of existing empirical research regarding subliminal perception remains varied and controversial: Whilst many researchers have demonstrated successful subliminal priming of some fairly complex unconscious analyses, including the comprehension of sentences (e.g., Palumbo & Gillman, 1984; Silverman et al., 1978; Sklar et al., 2012; Talbot et al., 1991) and arithmetic computations (e.g., García-Orza et al., 2009; Sklar et al., 2012; Sklar & Hassin, 2011), further research presents evidence demonstrating a far more limited and unsophisticated interpretation of unconscious cognition (e.g., Damian, 2001; Greenwald, 1992; Kouider & Dupoux, 2004). However, the lack of empirical parity regarding what can and cannot be subliminally primed is in part due to individual interpretations as to what constitutes 'unconscious', and consequent measurements of subliminality.

In relation to measuring thresholds of subliminal perception, objective methods assume that any trial accuracy beyond chance level performance is indicative of conscious knowledge (Seth et al., 2008). However, there are currently two broad approaches to explaining the conscious status of mental states, namely integration/global access theories and higher order theories (Dienes & Seth, 2010d), and neither would accept classification accuracy as indicative of the perception being conscious. Most global access theories claim that conscious seeing involves extensive integration of information in higher frontal areas, implying a flexible ability to use the

information for arbitrary purposes – and that would include reporting awareness of seeing, if probed. (Other integration theories, like Lamme's, 2010, do not have this feature, but then Lamme's theory has no special connection to any behavioural measure, subjective or objective, because it states the necessary and sufficient condition for mental state consciousness is recurrent feedback at a local neural level, whatever the behavioural consequences.) The other approach to consciousness, the higher order one, makes awareness of seeing definitional of the seeing being conscious. That is, the two main approaches to consciousness both motivate subjective measures: On both accounts, if seeing is conscious, a relevant higher order thought (HOT) should be elicited when probed. For integration theories, the HOT is contingent yet still diagnostic of the mental state being conscious; for HOT theories the presence of the HOT, at least when probed, constitutes the mental state being conscious.

The current research adopted subjective methods as a measure of individual subliminality thresholds. With this in mind, the current series of three articles attempted to address a number of issues identified in the literature to demonstrate an intelligent interpretation of unconscious cognition. The next section will briefly summarise the objectives and main findings of each study before moving on to look at the particular research questions the studies have addressed, as well as providing a review of the limitations and recommendations for further research.

5.2. Objectives and Empirical Findings

5.2.1. Article I - Subliminal Understanding of Negation: Unconscious Control by Subliminal Processing of Word Pairs

In Article I, a series of five experiments aimed to determine whether participants that had been primed with a subliminal instruction to either *pick* or *not* pick

an accompanying noun (e.g., ‘pick yard’ and ‘not yard’) would identify the correct word when presented with a choice of two nouns (e.g., ‘1. yard, 2. baby’). Participants first completed a set of conscious trials, which were then followed by a subjective threshold setting phase and a set of subliminal trials. In each of the five experiments, it was predicted that participants would identify the correct noun beyond chance level expectations for both subliminal ‘pick’ and ‘not’ instructions. It was further predicted that a response time difference between ‘pick’ and ‘not’ trials would reflect the relative differences in cognitive task difficulty for both conscious and subliminal trials. That is, it was predicted that participants would be faster to identify the noun in ‘pick’ trials when compared to ‘not’ trials under both conscious and subliminal conditions.

Experiment 1 aimed to maximise the likelihood of priming by taking advantage of research demonstrating the superior subliminal priming effects of items that have been previously rehearsed as conscious items by using the same prime-target noun pairs in conscious and subliminal trials. Subliminal stimuli were masked using backward masks in the form of a series of ampersands. The results revealed a significant subliminal priming effect in that participants identified the correct noun beyond chance performance for both ‘pick’ and ‘not’ trials. In addition, when compared to ‘not’ trials, participants were significantly faster to identify the noun in both conscious and subliminal ‘pick’ trials.

Experiment 2 replicated Experiment 1 in terms of prime masking and procedure, but aimed to avoid the assumption that the results could be attributable to the retrieval of S-R links, as opposed to successful priming, by using separate noun pairs in conscious and subliminal conditions. As evidenced in Experiment 1, the results demonstrated a significant subliminal priming effect in that participants identified the correct noun beyond chance performance for both ‘pick’ and ‘not’ trials. Whilst

participants were again faster to identify the noun in ‘pick’ trials when compared to ‘not’ for both conscious and subliminal conditions, this response time difference was only significant for the conscious condition.

Experiment 3 attempted to avoid the assumption that the positive subliminal priming effects evidenced in Experiments 1 and 2 could be attributable to conscious awareness by taking subjective confidence ratings after each experimental subliminal trial. In Experiment 3, masking and materials replicated those used in Experiment 2, however only trials in which participants rated confidence to be at 50% (i.e., guessing) were included in the analysis. Whilst the results indicated that participants did not perform significantly above chance expectations for subliminal ‘not’ trials, there was a significant difference between the number of occasions a participant simply chose the primed noun between ‘pick’ and ‘not’ trials. That is, only if *pick* and *not* instructions were differentially and appropriately processed would there be a difference between ‘pick’ and ‘not’ trial accuracy. As evidenced in Experiment 2, although participants were faster to identify the noun in ‘pick’ trials when compared to ‘not’ for conscious and subliminal trials, this response time difference was only significant for the conscious condition.

Experiment 4 attempted to demonstrate successful priming of negation by employing a more sensitive method of delivering subliminal stimuli in the form of a grey scale contrast method of masking. Materials and procedure replicated those used in Experiment 3, with confidence ratings again taken after each subliminal trial. The results indicated that participants did not perform significantly above chance expectations for either subliminal ‘pick’ or ‘not’ trials. However, as evidenced in Experiment 3, there was a significant difference between the number of occasions participants chose the primed noun between ‘pick’ and ‘not’ trials, again demonstrating

appropriate processing of the subliminal prime instruction. As similarly evidenced in Experiments 2 and 3, participants were faster to identify the noun in ‘pick’ trials when compared to ‘not’ for both conscious and subliminal conditions, with this response time difference being significant only for the conscious condition.

Experiment 5 attempted to improve upon the priming results evidenced in Experiment 4 by adopting a repeated presentation method of subliminal priming. Therefore, materials and procedure replicated that of Experiment 4: However, rather than one presentation of the conscious and subliminal prime, each trial consisted of three presentations, with each presentation lasting for the same duration. The results indicated that participants performed significantly above chance performance for both subliminal ‘pick’ and ‘not’ trials. In addition, participants were significantly faster to identify the noun in ‘pick’ trials when compared to ‘not’ for both conscious and subliminal conditions.

Therefore, Article I demonstrated unconscious processing of the logical function of negation in two-word primes in the form of performance accuracy and reaction times. Furthermore, this subliminal priming effect was evidenced in the absence of partial awareness and without this effect being attributed to S-R links.

5.2.2. Article II - Subliminal Understanding of Active vs. Passive Sentences

In Article II, a series of three experiments subliminally primed participants with short sentences that informed the participant which of two characters were active or passive within the sentence (e.g., ‘A is injecting B’, ‘A is injected by B’ etc.). When subsequently presented with two schematic images (one depicting character A as the active agent whilst B is passive, and the other depicting character B as the active agent whilst A is passive), the participants’ task was to indicate which of the two images best represented the prime sentence. Participants first completed a set of conscious trials,

which were then followed by a subjective threshold setting phase and finally a set of subliminal trials. It was predicted, in each of the three experiments, that participants would identify the correct schematic image beyond chance performance for both subliminal active and passive sentences. It was further predicted that a response time difference in image identification would be evidenced between active and passive trials, with participants being significantly faster to identify the image for active trials when compared to passive in both conscious and subliminal conditions.

Experiment 1 attempted to demonstrate subliminal priming effects in the absence of partial conscious awareness and without any effects being attributable to the retrieval of S-R links. As such, confidence ratings were recorded after each trial and separate lists of verbs were used in conscious and subliminal conditions. Subliminal stimuli were masked using backward masks in the form of a series of ampersands, and only trials in which the participant rated confidence to be at 50% were included in the analyses. The results indicated that participants did not correctly identify the image beyond chance expectations for either subliminal active or passive sentences. However, participants were significantly faster to identify the image for active trials when compared to passive trials in both conscious and subliminal conditions.

Experiment 2 employed the same grey scale contrast method of masking subliminal stimuli utilised in Experiments 4 and 5 of Article 1. Materials and procedure replicated that of Experiment 1, with confidence ratings recorded after each subliminal trial. The results indicated that performance on subliminal active trials was significantly above chance level performance, but not for subliminal passive trials. However, when performance on active and passive trials was directly compared according to image identification based on the lead in character, there was a significant difference in accuracy between trials. That is, only if verb voice was appropriately processed would

there be a difference in active and passive trial accuracy. As evidenced in Experiment 1, participants were significantly faster to identify the image in active conditions when compared to passive in both conscious and subliminal conditions.

Experiment 3 replicated Experiment 2 but included three presentations of the prime sentences. The results again indicated that participants performed significantly above chance expectations for subliminal active trials but not for passive trials. However, a meta-analysis over all three experiments revealed an overall significant priming effect for accuracy in passive trials. Furthermore, when active and passive trial accuracy was compared according to image identification based on the lead in character, there was a significant difference in accuracy between trials suggesting differential processing of verb voice. As evidenced in Experiments 1 and 2, participants were significantly faster to identify the image in active conditions when compared to passive in both conscious and subliminal conditions.

Therefore, Article II demonstrated unconscious processing of verb voice in multiple-word primes in the form of performance accuracy and reaction times. Furthermore, Article II demonstrated that participants were able to draw sufficient semantic information from a textual prime to translate into a pictorial representation. As demonstrated in Article I, this subliminal priming effect was evidenced in the absence of partial awareness and without the effect being attributable to S-R links.

5.2.3. Article III – Supraliminal and Subliminal Priming of Specific Relationship Anxieties

In Article III, participants were supraliminally and subliminally primed (using the grey scale contrast method of masking employed in Articles I and II) with a set of emotive words that were designed to activate one of four specific relationship anxieties (i.e., the fear of being close to partner, far, controlled or controlling) whilst being

engaged in a neutral classification task. Participants were subsequently required to classify two sets of items; a set of emotive items to be classified as either congruent or incongruent with the specific anxiety induced, or a set of self-related items in which the participant was instructed to classify as either fearful or non-fearful. These classification response times and error rates were then compared to a control group that had received no anxiety priming.

It was predicted that participants in priming conditions would be faster to classify emotive items that were congruent with the anxiety induced when compared to the control condition, and that participants in priming conditions would make fewer errors in classifying congruent and incongruent emotive items than the control. It was further predicted that participants in priming conditions would be faster to classify self-related items as fearful, and make fewer errors in classifying self-related items as fearful, when compared to the control condition.

The results indicated that participants in both priming conditions were faster to classify anxiety congruent and incongruent items when compared to the control group, but that this response time difference was only significant for supraliminal priming. In regards to error rates, we found evidence for supraliminal and subliminal priming effects in that priming lead to fewer errors in classifying anxiety congruent and incongruent items when compared to the control group. In regards to the self-related items, it was revealed that participants in all conditions were actually faster to categorise items as non-fearful when compared to fearful. Furthermore, participants in priming conditions did not make significantly fewer errors in classifying self-related items as fearful when compared to the control condition. Post experimental self-reported anxiety ratings failed to demonstrate a measurable difference in conscious anxiety levels congruent with the primed anxiety between primed and control conditions.

Therefore, Article III demonstrated the activation of specific relationship anxieties through supraliminal priming, but not through subliminal priming. Whilst the subliminal priming effects demonstrated the activation of a generalized level of anxiety, we were unable to conclude whether the anxiety activation evidenced specifically related to the fear of being close to a partner, far from a partner, controlled by a partner, or controlling with a partner. In addition, these supraliminal and subliminal priming effects were evidenced in the possible absence of subjective anxiety, indicating that an emotion (i.e., anxiety) can potentially be unconscious, though this remains to be confirmed.

5.3. Current Research in Context

In the past, successful subliminal priming effects have often been attributed to the retrieval of S-R links, established during conscious rehearsal of prime-target combinations to be later presented as subliminal primes, as opposed to the semantic activation of subliminal stimuli (e.g., Damian, 2001; Draine & Greenwald, 1998; Eimer & Schlaghecken, 1998). These S-R links then remain in short term memory and lead to an accelerated response when they are later reactivated upon encountering the prime and target on a further occasion. Therefore, subliminal primes that have previously been consciously practiced merely rely on the retrieval of these mappings without necessitating the semantic analysis of subliminal stimuli. However, the current research supports additional empirical evidence demonstrating successful priming using unpractised and novel stimuli (e.g., Klauer, Eder, Greenwald, & Abrams, 2007; Kunde et al., 2003; Naccache & Dehaene, 2001). The final experiments in both Articles I and II demonstrated a level of subliminal priming in which the prime and target combinations never appeared as conscious targets. Therefore, a link between the stimulus and its

associated motoric response could not have been formed, thereby negating S-R mappings as an appropriate criticism in the current case and instead indicating semantic processing of subliminal stimuli.

In addition to S-R links, further research has attributed subliminal priming effects to letter or sublexical level processing (e.g., Abrams & Greenwald, 2001; Greenwald & Abrams, 2002; Hutchison et al., 2004). Whilst not directly investigated here, it is difficult to attribute the current priming effects evidenced to a sublexical processing explanation. In Article I, to have chosen the correct noun, following the subliminal instruction to either *pick* or *not* pick a given noun, indicates successful semantic processing of the instructional word. In Article II, participants were required to identify the image that best represented the subliminal prime sentence. Due to the inability to derive phonological form from an image (Dell'Acqua & Grainger, 1999), a semantic interpretation of subliminal stimuli can more appropriately account for successful priming as opposed to a sublexical interpretation. That is, the participant needed to extract sufficient information from the prime sentence to translate this knowledge into a pictorial representation in order to identify which character was active or passive. Although the results failed to demonstrate a significant above chance priming effect for passive sentences in individual experiments, a significant difference between active and passive accuracy according to the lead in character further indicated differential processing of verb voice as opposed to word fragments. Furthermore, in Article III, the IAT classification task demonstrated subliminal priming effects of a generalised level of anxiety. This in turn indicates semantic activation of subliminal stimuli at the whole-word level as opposed to sublexical processing, as it is unlikely that processing word fragments would have led to the activation of anxiety.

A further significant criticism often directed at subliminal priming studies revolves around the issue of partial conscious awareness of stimuli designed to be subliminal (cf. Holender, 1986). Issues regarding partial conscious awareness were addressed throughout the current research. As mentioned previously, much of the controversy regarding subliminal perception appears to revolve around individual interpretations of the term 'unconscious'. In accordance with higher order thought theory (cf. Rosenthal, 2005), we defined consciousness as the presence of higher order thoughts (i.e., being aware of seeing the prime). Therefore, to claim successful subliminal priming, it was necessary to search for the presence or absence of conscious awareness of the prime. This was achieved by adopting subjective measures of assessing subliminality in the form of confidence ratings (CRs) to search for the presence of conscious knowledge (cf. Cheesman & Merikle, 1984, 1986). Therefore, if a participant was not *aware* that they had seen the prime, then whether they had or had not *seen* the prime was irrelevant in determining whether the stimuli was subliminal or not. In both Articles I and II, subliminal priming effects were directly evidenced when participants believed themselves to be guessing. A meta-analysis of the zero-correlation criteria (ZCC) results in Article I further indicated a non-significant relation between confidence and accuracy; further supporting the proposition that participants lacked conscious awareness of the subliminal stimuli. However, whilst CRs indicated a lack of conscious knowledge in Article II, a meta-analysis of the ZCC results indicated a positive relation between confidence and accuracy, suggesting the potential for conscious awareness. In Article III, an objective threshold test (i.e., a more stringent measurement of conscious knowledge) indicated potential performance at the objective threshold as opposed to the subjective (though the evidence was insensitive). However,

a subliminal priming effect in the form of the activation of generalised anxiety was evidenced.

Nevertheless, one could argue that participants in Article I were able to consciously perceive fragments of the prime to the extent that they could distinguish between ‘pick’ and ‘not’ instructions, and that it was this awareness that lead to the priming effects evidenced rather than unconscious processing. The same argument could be applied to the active and passive sentence priming in Article II. However, if this were the case, the participants’ knowledge would have been reflected in their confidence ratings. Participants were provided with an explicit definition of what constituted a ‘guess’ and were actively encouraged to give an above 50% confidence rating if they believed that they saw anything at all. Furthermore, in Article I, if the participant saw fragments of the presented noun and chose the primed noun accordingly, this would lead to a correct response for ‘pick’ trials, but an incorrect response for ‘not’ trials. So, the participant would have needed to have consciously seen informative fragments of both the instructional word and the noun. In Article II, the participant would have needed to have consciously seen at the very least the lead in character or the final character, as well as the presence or absence of ‘by’. However, if the participants had had informative conscious experience of these fragments to that extent in both articles, there would have been no reason not to have reflected this experience in the confidence ratings, just as they were instructed to.

In Greenwald’s (1992) somewhat critical summation of subliminal perception and its consequent potential, he concluded that unconscious cognition is often exaggerated in its analytical abilities, and unsophisticated and limited in its processing capabilities. He further issued a challenge regarding sentence priming in which he asserted that no one word in a multiple word prime should individually impart sentence

level meaning. The research presented here demonstrated not only the priming of multiple words, but also demonstrated that a set of rather sophisticated analyses needed to be completed in order to successfully fulfil task requirements.

In Article I, the first word in each prime informed the participant of the subsequent task to be completed. To successfully indicate the correct word, the participant must first recognise and comprehend the semantic meaning of *pick* and *not* instructions. The next cognitive task would require the participant to analyse the noun word to the extent that they could recognise the word when presented again. Whether this analysis of the noun was completed at the semantic or letter level is disputable. However, it seems likely that if the instructional word was analysed at the semantic level, then so was the noun. When subsequently presented with a choice of two nouns, the primed noun and an accompanying noun, the participant must have known whether the instruction was to include or to exclude, and thus recognised which noun to include or exclude. An average error rate of 4% for conscious trials illustrates the relative difficulty in identifying the correct noun without the constraints synonymous with subliminality. The successful priming results evidenced in Article I are in direct contrast with Jacoby et al. (1992), who argue that the ability to control cognition by excluding responses is a uniquely conscious ability. Not only could participants exercise control over excluding items, they could do so when the instruction to exclude was itself subliminal. These results support additional research which demonstrates the cognitive control of unconscious knowledge (e.g., Capa, Bustin, Cleeremans, & Hansenne, 2011; Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Perner, 2007; Fu, Dienes, & Fu, 2010; Norman, Price, & Jones, 2011; van Gaal, Ridderinkhof, Scholte, & Lamme, 2010; Wan, Dienes, & Fu, 2008).

Naccache and Dehaene (2001) have previously commented on the lack of empirical research attempting to demonstrate manipulations of material presented outside of conscious awareness. Therefore, Article II subliminally presented participants with short four word (e.g., ‘A is injecting B’) and five word (e.g., ‘A is injected by B’) sentences, portraying two characters activity or passivity within the sentence, in an attempt to demonstrate the manipulation of semantic textual information into a pictorial representation. The wording of the sentences ensured that the only difference between *A is injecting B* and *A is injected by B* was verb voice, and the presence or absence of ‘by’, whilst the meaning of both sentences was quite different. In the first example, the lead character is active whilst the second character is passive. However, in the second example, the lead character is now passive whilst the second character is active. If the participant was able to correctly identify the image representing the prime sentence, this would indicate that the participant had inferred sufficient semantic information to create a visual schematic representation from the prime. To do that, the participant must first know who the lead in character was, before moving on to process verb voice in order to determine whether the lead character was active or passive. At that point, if the lead in character (or even the final character) and verb voice were understood, then the participant had the information necessary to translate that knowledge into a pictorial representation to identify the correct image.

As similarly evidenced in Article I, the difficulty in completing such a task in Article II was demonstrated by an average 7% error rate for trials in which the prime sentence was presented consciously. The subliminal priming results indicated that participants were able to identify the correct image beyond chance level performance for trials in which the lead in character was active, but not for trials in which the lead in character was passive. Although, a meta-analysis across all three experiments

demonstrated a significant priming effect for passive trials also. This variation in priming effects is highlighted by research demonstrating the relative difference in cognitive difficulty between understanding and processing active versus passive sentences (Chomsky, 1965; Miller, 1962). The simplest way of identifying the image without necessitating a full syntactic analysis of the active and passive sentences would have been for the participant to have searched for the lead in character and the presence or absence of 'by'. The absence of 'by' would mean the lead in character (or final character) was active; whilst its presence would mean the lead in (or final) was passive, thus allowing a semantic analysis. Nevertheless, if participants were able to correctly identify image without processing verb voice, this would still demonstrate processing of the syntactic functioning of two words (lead in character/final character, and 'by'). However, a significant difference in response times between active and passive trials reflects the additional processing time required to comprehend passive sentences (similarly demonstrated by Gough, 1965, 1966). If subjects were using "by" and the lead word, to conclude the sentence was active requires determining "by" was not there. In general, determining the absence of a search target takes longer than determining the presence (e.g., Treisman, 1988). Thus, on the theory that people search specifically for "by", active sentences would take longer than passive sentences, which is opposite to our results.

Whilst there are many studies successfully demonstrating the activation of anxiety through the presentation of subliminal stimuli (e.g., Naccache et al., 2005; Soares & Öhman, 1993; Tyrer et al., 1978; Williams et al., 2006), the type of anxiety induced tends to be a general and non-specific level of anxiety. Therefore, Article III explored the extent of subliminal priming by attempting to activate very specific relationship anxieties relating to the fear of being close to a partner, far from a partner,

controlled by a partner, or controlling with a partner. That is, rather than the activation of a general relationship anxiety (which is in itself distinct from other anxieties such as phobias), we attempted to specifically prime the fear of being close to a partner rather than the fear of being far, the fear of being far from a partner rather than the fear of being controlled, etc. The results of Article III suggested that participants that had been subliminally primed with a specific relationship anxiety were both quicker (although not significantly quicker) and made fewer errors in classifying items as congruent and incongruent with the induced anxiety when compared to a control group that had not been primed. However, the evidence was insensitive for showing whether specific anxieties rather than generalised anxiety could be subliminally primed. As well as extending previous research into the activation of anxiety through supraliminal and subliminal manipulation, the results also argue for a semantic interpretation of subliminal material, which may or may not be semantically finely resolved. Furthermore, the subliminal priming of anxiety evidenced in Article III was not associated with significant conscious subjective anxiety. The null result for conscious anxiety was not sensitive however; thus the issue of whether an emotion can be unconscious is not directly addressed by the current data. Article III does however provide a paradigm by which the issue could be further explored.

5.4. Limitations and Recommendations for Future Research

Past research has demonstrated that backward masks in the form of letter strings and symbols can adversely interfere with the subsequent processing of textual primes (Di Lollo et al., 2000; Grainger et al., 2003; Walley & Weiden, 1973), as evidenced in Experiment 3 of Article I, and Experiment 1 of Article II. Therefore, within the current research, we adopted a grey-scale contrast method of masking

subliminal stimuli established by Lamy et al. (2008) in an attempt to successfully demonstrate subliminal semantic priming effects. However, whilst successful in increasing performance accuracy, the subliminal priming effects evidenced were relatively small. For example, in Articles I and II, correct noun choice and image identification on subliminal trials ranged from just 2% to 4% above an expected baseline chance performance of 50%. Furthermore, an overall meta-analysis comparing accuracy in subliminal trials from backward masking and contrast masking experiments in Articles I and II revealed that performance did not significantly increase in contrast masking experiments, mean increase in accuracy of .03%, SE = .71, $t(193)$ = -.03, p = .97, d = 0.06, 95% CI (-1.38, 1.42) (to eliminate any potential confounding effects of conscious awareness, only experiments including trial by trial confidence ratings were included). In the current research, we reduced prime presentation speeds whilst keeping the contrast between text and background constant to achieve subliminality. However, Lamy et al. (2008) kept prime presentation at 500 ms whilst reducing the contrast between text and background until the prime was rendered subliminal. It is possible that this procedure adopted by Lamy et al., and the longer prime presentation durations afforded, would have resulted in a higher percentage of correct responses to noun choice and image identification in Articles I and II, and anxiety priming in Article III. Therefore, future research may benefit from further investigation into the benefits of contrast masking, and additional more sensitive methods of masking subliminal stimuli.

In addition to issues regarding methodological masking procedures, further research may benefit from exploring the priming effects evidenced from multiple prime presentations. In Articles I, II, and III, we produced small priming effects using three presentations of each subliminal prime as opposed to just one single presentation. However, a comparison of experiments 4 (using one presentation) and 5 (using three

presentations) in Article I did not reveal a significant increase in priming effects using repeated presentations. Furthermore, an overall meta-analysis comparing priming effects from one and three presentations in Articles I and II revealed that three presentations did not significantly increase performance, mean increase in accuracy of .44%, *SE* = .82, *t*(139) = -.53, *p* = .59, *d* = 0.10, 95% CI (-2.06, 1.19). However, Wentura and Frings (2005) investigated multiple priming by comparing the effectiveness of a standard single prime presentation with a repeated priming procedure in which the prime was presented 10 times in quick succession. Their results demonstrated a significant subliminal priming effect only in the repeated priming condition. Furthermore, performance in the repeated priming condition was comparable to performance in a further visible priming condition. Whilst Atas et al. (2012) attribute repeated priming effects to the progressive emergence of conscious visual awareness, Wentura and Frings argue that the cumulative duration of prime presentations increase access to the semantic content of the prime whilst continuing to remain below the threshold of conscious perception. Similarly, Marcel (1983b) demonstrated an increasing priming effect by using up to 20 repetitions of the subliminal prime. Therefore, it may be that more than three presentations of the prime were necessary to significantly boost subliminal priming. As such, future research may benefit from exploring the extent of subliminal priming in conjunction with adopting a repeated priming procedure.

The use of computers to present subliminal stimuli can lead to further methodological issues regarding presentation durations. For example, the current research utilised a 60 Hz laptop with a screen refresh rate of 16 ms for the presentation of experimental material. That is, when assessing subjective thresholds of subliminality, we were limited to decrements in presentation durations of 16 ms (i.e., one screen

refresh). As the millisecond difference between subjective and objective thresholds is often relatively small, it is quite likely that participants fell far below the threshold of subjective conscious awareness to the objective threshold or perhaps below. This limitation was aptly demonstrated by Article III, whereby despite measuring conscious perception using subjective methods, a subsequent discrimination task indicated performance at the objective threshold. Furthermore, performance at this OIT threshold is believed to correspond to minimal unconscious processing according to Snodgrass and colleagues (2004). Therefore, it would be beneficial to utilise alternative methods of presenting subliminal stimuli such as through the use of a tachistoscope. A tachistoscope allows for millisecond precision in manipulating presentation speeds, thus making it more likely to lead to performance below the subjective threshold whilst continuing to remain above the objective. Additional methods of prime presentation include continuous flash suppression (CFS). As discussed previously, CFS involves the presentation of a rapidly moving stimulus to one eye so as to prevent the conscious perception of a static stimulus presented to the other eye (Tsuchiya & Koch, 2005). Using this method, stimuli can be presented for periods of time in excess of one second whilst remaining outside of conscious awareness, thereby increasing subliminal processing time. For example, Sklar et al. (2012) demonstrated subliminal sentence priming using CFS. Therefore, further research may benefit from investigating subliminal priming, and in particular sentence priming, using either a tachistoscope or CFS.

Within the current research, we used confidence ratings (CR) to measure subjective awareness of subliminal stimuli. Both in the instructions and on each screen in which the participant was required to rate confidence, the participants were given a definition of what ‘guessing’ and ‘know’ means. The participants were told to give a

value of 50% if they believed that they were purely guessing; that they had no idea which word/image to choose and that they may as well have tossed a coin. They were told to give a value of 100% if they knew which word/image to choose, that is if they saw the prime. They were also told that if they had any confidence at all, if they believed they saw something even if they did not know what it was, they were to give a value above 50. In Articles I and II, it is possible that participants consciously saw fragments of the prime and could distinguish between pick and not instructions or active and passive sentences; but if this were the case it would be reflected in their confidence ratings as participants were actively encouraged to give an above 50% confidence rating if they believed that they saw anything. On the conscious trials that were interspersed within the subliminal trials, participants did in fact use confidence accurately. Further, there was no incentive to say one was completely guessing if one felt one was not. Therefore, if a participant stated that confidence was at 50% (guessing) whilst identifying the correct word or image, we assumed that they possessed unconscious knowledge. Nevertheless, a different way of defining subliminality is when a subject regards themselves as having no visual experience whatsoever, not even visual experience that is irrelevant to the judgment (Sandberg et al., 2010). As such, Ramsøy and Overgaard (2004) constructed the perceptual awareness scale (PAS) as a measure of subjective conscious awareness, requiring the participant to rate visual perception on a scale of no visual experience to clear visual experience. When PAS, CR and post decision wagering (PDW) were directly compared based on their effectiveness at measuring subjective conscious awareness, Sandberg et al. (2010) found that when subjects believe they are guessing they may be having some visual experience, and this experience is associated with objective accuracy in classification. Therefore, future

research may benefit from investigating the extent of subliminal priming using the PAS to address different definitions of subliminality.

Using a definition of subliminal perception and unconscious processing as determined by higher order thought theories of consciousness (i.e., the primes were subliminal as the participants were unaware of having seen what the primes were), we argue that we have successfully demonstrated subliminal priming of negation, active versus passive sentence priming, and anxiety priming relating to relationship anxiety. Our results show the unconscious has a power previously denied it, perhaps because of a tendency in the field to use a methodology ill-suited to showing just what the unconscious can do.

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APPENDICES

Appendix A: Noun pairs employed in Experiment 1 of Article I

Table A1: Noun Pairs

Conscious and SOA Practice Trial Pairs:	SOA Setting and Threshold Drift Trial Pairs:	Conscious and Subliminal Trial Pairs:	Conscious Trial Pairs in Subliminal Blocks:
lost - home tank - pool	fog - hat top - vet mask - tree shoe - mail	cup - jar fan - pie map - fly sun - cat frog - cave game - lake nest - jail spoon - horse light - coach judge - water	fog - hat top - vet man - pod

Appendix B: Noun pairs employed in Experiment 2, Experiment 3, Experiment 4 and Experiment 5 of Article I

Table B1: Noun Pairs

Conscious and SOA Practice Trial Pairs:	SOA Setting and Threshold Drift Trial Pairs:	Conscious Trial Pairs:	Subliminal Trial Pairs:	Conscious Trial Pairs in Subliminal Blocks:
lost - home	fog - hat	cup - jar	ant - sky	fog - hat
tank - pool	top - vet	fan - pie	bat - sea	top - vet
	mask - tree	map - fly	bed - oil	man - pod
	shoe - mail	sun - cat	box - pen	
		frog - cave	baby - yard	
		game - lake	camp - page	
		nest - jail	ball - vein	
		spoon - horse	apple - steam	
		light - coach	brick - space	
		judge - water	plant - train	

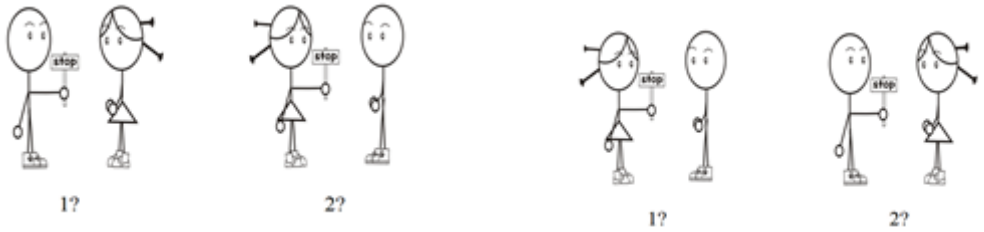
Appendix C: Verbs used in Experiment 1, Experiment 2 and Experiment 3 of Article II

Table C1: Verbs in their Simple Present Form

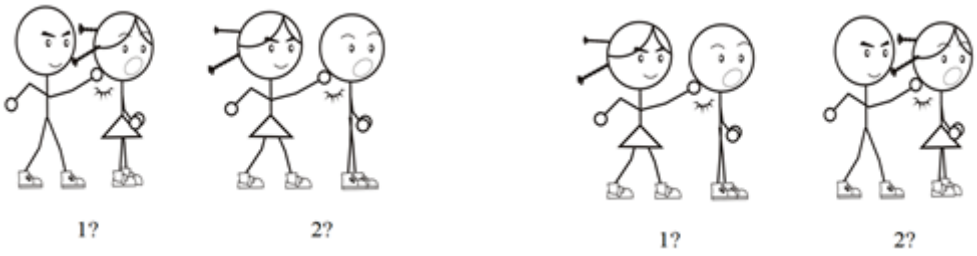
Conscious and SOA Practice Trial Verbs:	SOA Setting Trial Verbs:	Conscious Trial Verbs:	Subliminal Trial Verbs:	Conscious Trial Verbs in Subliminal Blocks:
stops punches follows	stops punches follows	pokes burns whips kisses	protects kills washes feeds films injects fans pushes measures carries brushes chases	stops punches follows

Appendix D: Schematic images employed in Experiment 1, Experiment 2, and Experiment 3 of Article II

Stops



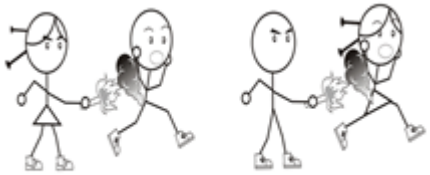
Punches



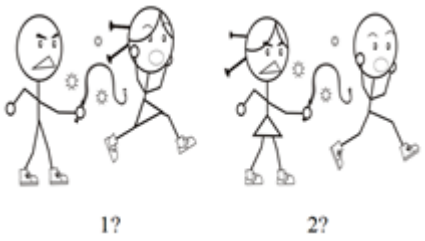
Follows

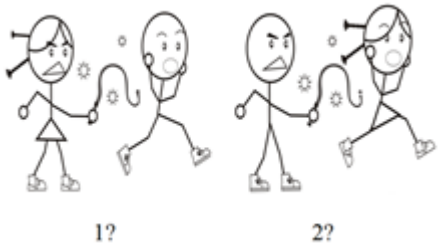
Pokes

Burns

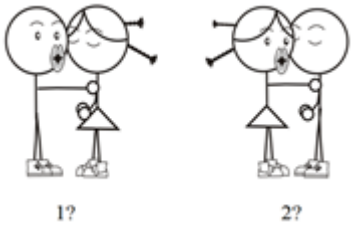


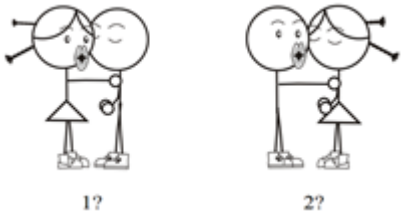
Whips



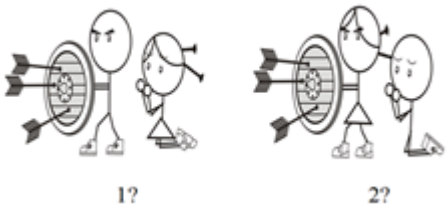


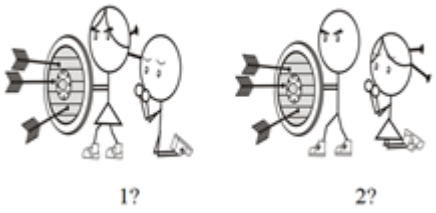
Kisses



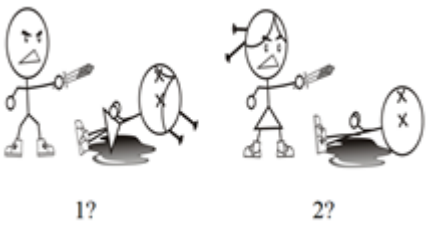


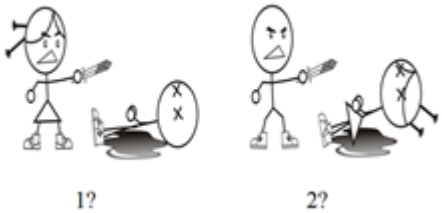
Protects





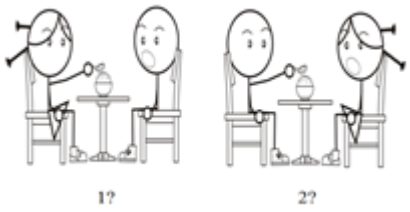
Kills

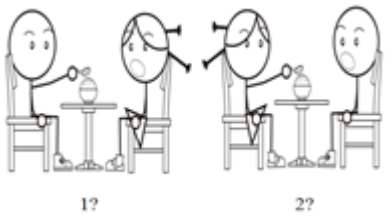




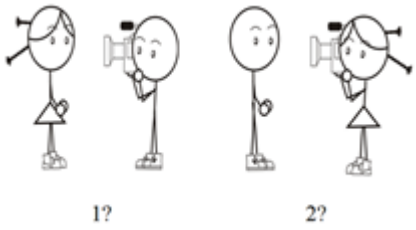
Washes

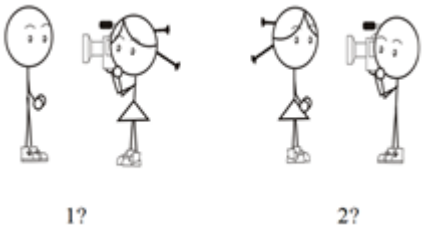
Feeds





Films





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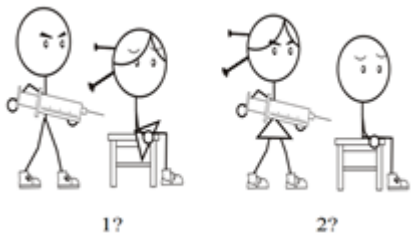
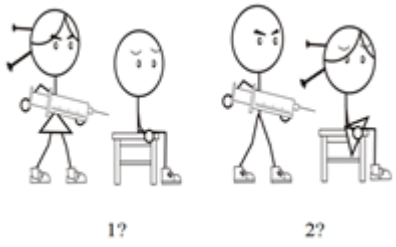
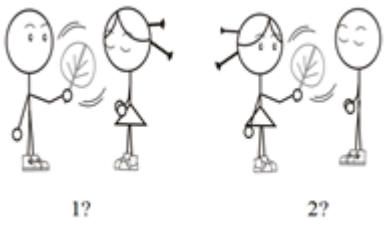
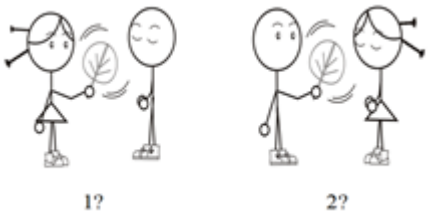




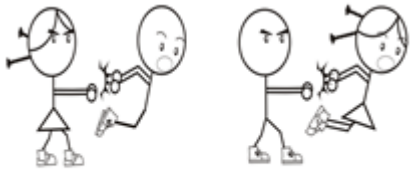
Fans





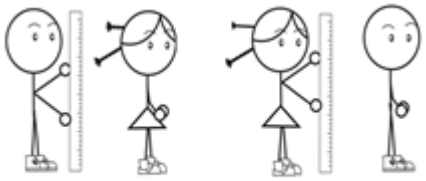
Pushes

1? 2?



1? 2?

Measures



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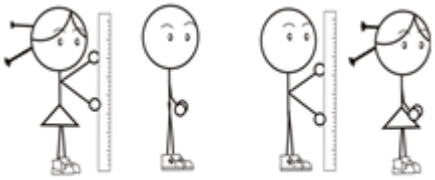
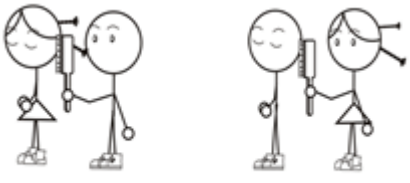


1? 2?

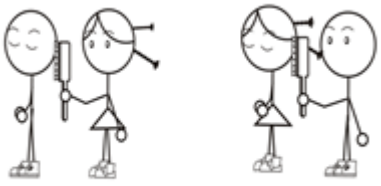
Carries

1? 2?

Brushes

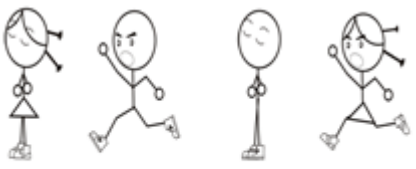


1? 2?



1? 2?

Chases



1? 2?

1? 2?

Appendix E: IAT items employed in Article III

Related Relationship Anxiety:	IAT Classification Items:	Related Relationship Anxiety:	IAT Classification Items:
Close	Couple	Controlled	Restrained
	Restricted		Bossed
	Intimate		Surrendered
	Devoted		Hampered
	Clingy		Commanded
	Affectionate		Submissive
	Obliged		Coerced
	Bored		Repressed
	Conform		Constrained
Far	Unloved	Controlling	Demanding
	Apart		Assertive
	Deserted		Decisive
	Single		Overwhelming
	Isolated		Compelling
	Lonely		Persuasive
	Cold		Strong
	Individual		Bully
	Solitary		Offensive

Appendix F: Words used to induce anxiety in Article III

Relationship Anxiety:	Anxiety Inducing Words:
Close	Suffocated
	Trapped
	Confined
Far	Abandoned
	Alone
	Neglected
Controlled	Weak
	Powerless
	Controlled
Controlling	Dominating
	Powerful
	Forceful

Appendix G: Results of the IAT Emotional Adjective Norming in Article III

Table G1: Means, standard error and t values of the relatedness ratings

Anxiety:	Consistent Anxiety *M*:	*SE*	Inconsistent Anxiety *M*:	*SE*	*t*:
Close	5.19	.09	3.31	.09	13.60***
Far	5.97	.13	3.26	.11	16.03***
Controlled	5.51	.12	3.64	.07	12.21***
Controlling	5.68	.19	3.56	.11	7.58***

*** $p < .001$

Table G2: Means, standard error and t values for the emotional valence ratings

Anxiety:	Consistent Anxiety *M*:	*SE*	Inconsistent Anxiety *M*:	*SE*	*t*:
Close	5.59	.11	3.38	.05	16.64***
Far	5.68	.19	3.48	.06	10.08***
Controlled	5.42	.20	3.45	.06	8.04***
Controlling	5.78	.15	3.54	.02	16.93***

*** $p < .001$

Appendix H: Passages relating to the fear of being close, far, controlled and controlling employed in Article III

Fear of being Close:

Joanna has been in a romantic relationship with David for just over six months. They live in different towns and Joanna is happy with the way the relationship works. She sees David at weekends, and the rest of the time she can see her friends or do whatever she likes. Recently, David has been calling on the phone more often, wanting to spend more time together, and has begun to suggest that they move in together. The idea of living together and spending so much time with each other scares Joanna. She likes the current situation, that she can see David when she wants but gets to keep her own identity and have her own space, she doesn't want to have to give up her independence and answer to someone else. Joanna is going to have to come up with a way of keeping David at arm's length or she is going to have to finish the relationship.

Fear of being Far:

Joanna has been in a romantic relationship with David for just over six months. She loves being in a relationship but she isn't happy with the way the relationship is currently working. She and David live in different towns and Joanna only gets to see David at weekends and she wants to spend far more time with him. Joanna and David spend a lot of time during the week talking on the phone and Joanna has suggested that they move in together. Living apart from each other and only getting to speak on the phone during the week upsets Joanna and makes her worry. However, the idea of seeing him every day, spending the evenings and every spare minute together sounds ideal. The sooner they move in together the better.

Fear of being Controlled:

Joanna has been in a romantic relationship with David for just over six months. They live in different towns but get to spend quite a lot of time together. David has recently begun suggesting that they move in together. Although she loves David, Joanna worries about living together. If they are going out anywhere together, David decides where they go. If they get a takeaway, David decides what it will be. If they go to see a movie, David decides what they will see. If there is any decision to make, David will make it and Joanna feels as though she is completely under the thumb and unable to choose anything for herself. Joanna worries that if they were to move in together, David may become more controlling.

Fear of being Controlling:

Joanna has been in a romantic relationship with David for just over six months. They live in different towns but get to spend quite a lot of time together and there has been talk recently of moving in together. However, Joanna worries that she is too controlling for David. If there is a decision to be made, on where to go out, on what to eat, on what to watch, Joanna makes the decision. She knows that if they move in together, then she will be the one to decide where they will live and how they will decorate. She can't seem to help herself and Joanna worries that it will be too much for David.

Appendix I: Questions used to measure current anxiety levels employed in Article III

Close

1. I enjoy having a familiar routine with my partner
2. I am afraid of getting close to my partner
3. I am afraid of losing my own identity and becoming part of my partner's
4. I enjoy feeling committed to my partner

Far

1. I enjoy having a separate identity from my partner
2. I am afraid of being alone without my partner
3. I enjoy having my own space away from my partner
4. I am afraid of my partner being distant

Controlled

1. I am afraid of being owned by my partner
2. I enjoy not having responsibility in our relationship
3. I am afraid of being controlled by my partner
4. I am happy to accept guidance from my partner

Controlling

1. I am happy taking charge for our plans because I know I can make things work out OK
2. I know my partner is strong and can thus happily take any demand I might make of them
3. I am afraid of being too controlling with my partner
4. I am afraid that my partner is weak and can't stand up to me

Appendix J: ECR Scale employed in Article III

The ECR Scale: Even numbered items measure Anxious Attachment; Odd numbered items measure Avoidant Attachment.

1. I prefer not to show others how I feel deep down
2. I worry about being rejected or abandoned
3. I am very comfortable being close to other people
4. I worry a lot about my relationships
5. Just when someone starts getting close to me, I find myself pulling away
6. I worry that others won't care about me as much as I care about them
7. I get uncomfortable when someone wants to be very close to me
8. I worry a fair amount about losing my close relationship partners
9. I don't feel comfortable opening up to others
10. I often wish that close relationship partners' feelings for me were as strong as my feelings for them
11. I want to get close to others but I keep pulling back
12. I want to get very close to others, and this sometimes scares them away
13. I am nervous when another person gets too close to me
14. I worry about being alone
15. I feel comfortable sharing my private thoughts and feelings with others
16. My desire to be very close sometimes scares people away
17. I try to avoid getting too close to others
18. I need a lot of reassurance that close relationship partners really care about me
19. I find it relatively easy to get close to others

20. Sometimes I feel that I try to force others to show more feeling, more commitment to our relationship than they otherwise would

21. I find it difficult to allow myself to depend on close relationship partners

22. I do not often worry about being abandoned

23. I prefer not to be too close to others

24. If I can't get a relationship partner to show an interest in me, I get upset or angry

25. I tell my close relationship partners just about everything

26. I find that my partners don't like to get as close as I would like

27. I usually discuss my problems and concerns with close others

28. When I don't have close others around, I feel somewhat anxious and insecure

29. I feel comfortable depending on others

30. I get frustrated when my close relationship partners are not around as much as I would like

31. I don't mind asking close others for comfort, advice, or help

32. I get frustrated if relationship partners are not available when I need them

33. It helps to turn to close others in times of need

34. When other people disapprove of me, I feel really bad about myself

35. I turn to close relationship partners for many things, including comfort and reassurance

36. I resent it when my relationship partners spend time away from me

Appendix K: Words used to eliminate anxiety in Article III

Relationship Anxiety:	Anxiety Eliminating Words:
Close	Supportive
	Warm
	Loving
Far	Liberated
	Carefree
	Independent
Controlled	Assertive
	Dominant
	Powerful
Controlling	Compliant
	Humble
	Agreeable