Subliminal Understanding of Negation: Unconscious Control by Subliminal Processing of Word Pairs

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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.

Keywords: Subliminal priming, Subjective thresholds, Guessing criterion, Contrast masking, Unconscious cognition

1. 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, 1983; 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) 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 (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. 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.

[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).

2. 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.

2.1. Method

2.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependant 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).

2.1.2. 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. Each screen display was centrally presented in lower-case, black, bold Courier New font, and point size 18 on a white background. 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.

2.1.3. Procedure

Participants were tested individually in a small quiet space 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. All trials consisted of four separate components: a fixation cross presented for 350ms, 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 150ms, 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.

2.1.3.1. Conscious Trials. Having read the instructions, the procedure began with a set of 6 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 subliminal 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 6 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.

2.1.3.2. 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 speed 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 6 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.

2.1.3.3. 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. Eimer, Kiss, Press & Sauter, 2009), creating two blocks of 50 trials.

2.1.3.4. 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 speed 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.

2.2. Results

2.2.1. SOA Setting.

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

2.2.2. 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 1, 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, $M = .60$, $SE = .11$, $t(24) = 5.62$, $p < .001$, $d = 2.29$.

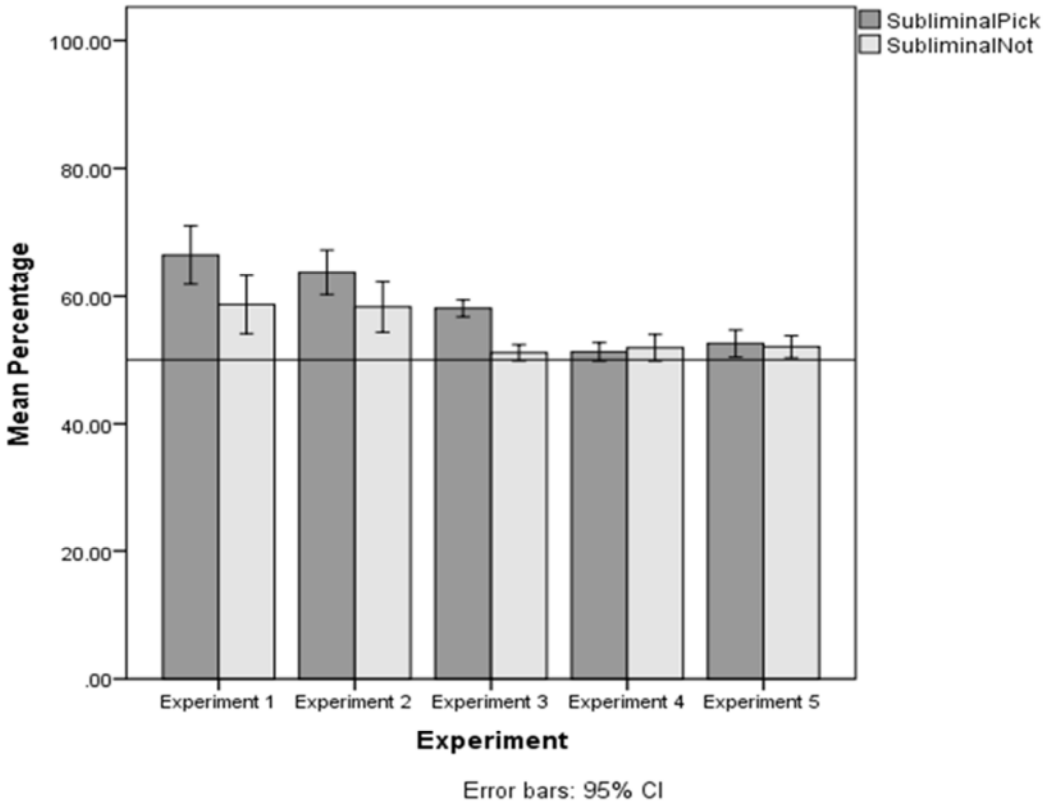

Figure 1. Mean percentage values for correct identification of the noun in subliminal *pick* and *not* conditions for Experiments 1, 2, 3, 4 and 5 with a 50% reference line.

2.2.3. 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) than in '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, $t(24) = -2.27$, $p = .03$, $d = 0.93$).

2.2.4. Threshold Drift.

Data from the threshold drift phase reveals that subjective threshold durations ranged from an SOA of 32 ms to 80 ms, with a mean experimental subliminal presentation speed 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.

2.2.5. 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. 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. Discussion

Participants in the subliminal ‘pick’ condition correctly identified the noun on an average 66% of the trials, whilst correct noun identification 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 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".

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 of 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 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.

3. 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.

3.1. Method

3.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependant 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).

3.1.2. 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.

3.1.3. 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.

3.2. Results

3.2.1. SOA Setting.

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

3.2.2. 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 1 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).

3.2.3. 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 are unable to determine whether this implies that there is evidence for the null hypothesis, that there would be no difference in response times between subliminal 'pick' and 'not' conditions, or that there is 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.

3.2.4. Threshold Drift.

Data from the threshold drift phase reveals that subjective SOA durations ranged from an SOA of 16 ms to 80 ms, with an average experimental subliminal presentation speed 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.

3.2.5. 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).

3.3. Discussion

The accuracy data from the conscious trials in Experiment 2 replicates 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’ conditions, 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, 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 was explored further in Experiment 3.

4. 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, 1983, 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.

4.1. Method

4.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependant 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).

4.1.2. Apparatus and Materials

Replicated Experiment 2.

4.1.3. Procedure

Replicated Experiment 2. Participants were also asked to rate their confidence in choosing the correct noun on a scale of 50-100%. 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.

4.2. Results

4.2.1. SOA Setting.

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

4.2.2. 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 1, 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. 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%, was 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.

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 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.

4.2.3. 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

[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. 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.

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

4.3. 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 to 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 were 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.

5. 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 has 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.

5.1 Method

5.1.1. Design & Participants

In a repeated measures design with the number of correct identifications being the dependant 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).

5.1.2. Apparatus and Materials

Replicated that used in Experiments 2 and 3.

5.1.3. Procedure

5.1.3.1. Conscious Trials. The stimulus instruction was presented within a rectangular box of the same size as used for the fixation. The background of the rectangle was filled with grey at a contrast level set by equally altering the red, green and blue (RGB) channels to 212 on the computer monitor. The stimulus instruction was presented within this box in grey at an RGB contrast level of 108 (see figure 2 for an example). 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.

5.1.3.2. SOA Setting. In an attempt to block conscious perception of the prime instruction, each stimulus instruction was presented at an RGB level of 208 against a background RGB contrast of 212 (see figure 3 for an example).

Figure 2. Example of a conscious contrast contrast mask

Figure 3. Example of an unconscious contrast mask

5.1.3.3. 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, at an RGB level of 208 against a background RGB contrast of 212). The presentation time 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 (with the stimulus instruction at an RGB of 108 against a background RGB contrast of 212, presented for 300 ms) to prevent rhythmic pressing of the "1" and "2" keys, and to remind participants of the task required (cf. Eimer, Kiss, Press & Sauter, 2009).

5.2. Results

5.2.1. SOA Setting.

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

5.2.2. 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 1, with a 50% reference line indicating chance performance. On subliminal trials, overall d’ values significantly differed from zero (*M* = .07, *SE* = .03, $t(21) = 2.60$, $p = .02$, $d = 1.13$). Although, 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'.

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.

5.2.3. 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 suggests 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.

5.3. 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, 1983). 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.

6. 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, 1983; 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.

6.1. Method

6.1.1. Design & Participants

One problem with the previous study was low power. The dz for the accuracy on not trails 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 dependant 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).

6.1.2. Apparatus and Materials

Replicated Experiments 2, 3 and 4.

6.1.3. 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.

6.2. Results

6.2.1. 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 speed of 64 ms (SD = 35, with a cumulative mean presentation speed of 192 ms).

6.2.2. 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 1, 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.

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.

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 suggests 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).

6.3. Discussion

Participants in the subliminal 'pick' condition correctly identified the noun at an average rate of 53%. Similarly, the results suggest that participant's 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.

7. 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 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 suggest 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 needs 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 the task. 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, 1983; 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,

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

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 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. A meta-analysis of the overall ZCC indicated an overall non-significant relationship 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 1 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

[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 $B = 0.36$.

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 towards 50%. 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, 1983, 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. Additional research using subjective measures of unconscious have similarly demonstrated unconscious cognitive control in grammar studies (Dienes, Altmann, Kwan, & Goode, 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). 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 other hand, according to Wordly Discrimination Theory, 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, Timmermans, Overgaard, and Cleeremans (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, Mudrik and Deouell (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 speeds 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) indicate 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 (submitted) 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.

7.1. 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.

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