Attentional bias towards supraliminal and subliminal smoking cues in smokers: Effects of cognitive load on attentional bias

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Abstract

This study attempted to replicate findings of an attentional bias towards supraliminal and subliminal smoking cues in the dot-probe task for smokers. Food-related cues were used as a control due to its natural reward properties. Further, the effects of cognitive load during the dot-probe task on attentional bias was explored. Smokers (n=43) and non-smokers (n=41) completed two versions (load and no load) of a dot-probe task containing smoking- and food-related cues, as well as subliminal smoking cues (16.7 ms presentation-time). In the smokers, attentional bias towards smoking cues was significant under cognitive load and approaching significance with no load. The bias in smokers was larger than that of non-smokers, significantly so in the load condition. Bias towards smoking cues was also larger than bias towards food cues, suggesting the attention-grabbing properties of smoking cues are stronger than that of a natural reward cue. Smokers' attentional bias towards subliminal smoking cues was negative, providing no evidence of attentional bias effects in subliminal conditions, however the size of the bias correlated significantly with self-reported urge to smoke. The limitations of methods using subliminally presented cues, the nature of non-conscious associations and individual differences in how cognitive load affected participants are discussed in relation to future research.

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INTRODUCTION

General introduction

According to the incentive sensitization model, drug-related stimuli becomes more salient and attention-grabbing for those addicted to the drug and craving is a result of hyper-sensitivity to cues associated with that substance (Robinson & Berridge, 1993). Through classical conditioning (Pavlov, 1927), a neutral cue can become associated with a substance if the cue is repeatedly presented simultaneously with the use of and effects of a substance. In this way the response to a cue can become automatic through fast activation of the associative network of the brain (Collins & Loftus, 1975). These conditioned cues can cause reactions related to the stimulus it is associated with and in addiction this reaction is usually a preparatory biological reaction. The preparatory reaction causes the nervous-system to begin counteracting the effects of the expected substance (which has not been ingested yet) resulting in a state opposite of the state induced by the drug which again results in withdrawal and craving.

In the biopsychological theory of addiction, a substance-related cue holds an "incentive salience", an attribution of being "wanted" (Robinson & Berridge, 1993). Drugs of abuse have also been found to activate the same areas of the brain that are activated in response to natural rewards like, i.e., food and sex (Childress et al., 2008). Drug-taking also increase, in the same was as food and sex does, release of chemicals that induce a sense of well-being (i.e., dopamine, serotonin). The area in the brain responsible for the release of these chemicals has therefore been dubbed "the reward circuitry". Based on this, the association of a cue with the effects of drug-taking likely means the cue is associated with activation of the reward circuitry of the brain, which makes the cue intuitively and automatically interesting to our perceptions.

This involuntary attentional bias towards drug-related cues and the processing of them have been hypothesised to play a role in creating and maintaining craving and addiction, as well as having a role in relapse after periods of abstinence (Fadardi and Cox, 2008; Franken, Rosso & van Honk, 2003; Waters, Shiffman, Sayette, Paty, Gwaltney & Balabanis, 2003; Marissen, Franken, Waters, Blanken, van den Brink & Hendriks, 2006). In opiate-users, an association between attentional bias towards drug-cues and level of dependence has been found (Bearre, Sturt, Bruce & Jones, 2007). Further, it has been suggested that cognitive control has an important role in cue-reactivity in addicts (Nestor, McCabe, Jones, Clancy & Garavan, 2009).

Field & Cox (2008) concluded their review of relevant evidence on the role of cue-reactivity and attentional bias in addiction, by suggesting that attentional bias is at least partly created by classical conditioning. The cues that are attended to cause subjective craving by creating an expectancy that the opportunity to use the drug is available. craving again increase attentional bias towards drug-related stimuli, and thus there is a reciprocal pattern between attending to cues and craving.

Based on the above-mentioned evidence and conclusions from previous studies, it seems research on attentional bias towards drug-related cues and the cognitive processes involved in this cue-reactivity is highly relevant for continued development and improvement of treatment therapies in addiction.

Introduction experiment 1

The dot-probe task has frequently been used to measure attentional bias. The simple location version of the task presents two stimuli simultaneously in different locations on a computer screen. The stimuli (i.e., pictures or words) disappear and a probe appears on the screen in one of the locations previously occupied by a stimulus. The task of the participant is to indicate where on the screen the probe is, usually through pressing keys to indicate "right"/"left", or "top"/"bottom". In a congruent trial the probe replaces a stimulus that is attention-grabbing (i.e. positively by being salient or negatively by being threatening). Responding to the location of the probe in congruent trials is expected to be faster as attention (overt or covert) is already allocated to the probe-location before the probe appears. If the probe replaces a neutral stimulus while an attention-grabbing stimulus was present in a different location of the screen (an incongruent trial), responding should be slower as attention needs to be reoriented from the location of the attention-grabbing stimulus to the probe-location. The difference in response time between an incongruent trial and a congruent trial then reveals the size of the attentional bias (the attentional bias score).

Attentional bias towards smoking cues

Attentional bias towards drug-related cues in drug-addicts has often been assessed through use of the dot-probe task. Significant attentional bias effects have been found in a number of studies and for a range of different substances. For instance, attentional bias towards smoking cues in a dot-probe task was found both in deprived and non-deprived smokers (Waters, Shiffman, Bradley & Mogg, 2003). The bias was small (3 ms), but reliable, and was more pronounced in lighter smokers compared to heavy smokers. Similarly a significant difference in attentional bias towards smoking cues (presented at 500 ms) between smokers and non-smokers was found in another dot-probe experiment (Ehrman, Robbins, Bromwell, Lankford, Monterosso & O'Brien, 2002).

Constantinou, Morgan, Battistella, O'Ryan, Davis & Curran (in press) found that current opiate-addicts showed an attentional bias towards opiate-related cues in a dot-probe task (2010). The bias was present both at long and short exposures to the cues (200 ms and 2000 ms), suggesting attentional bias is present both for automatic and controlled processes of attention. Constantinou et al found a negative correlation between duration of abstinence in ex-users and attentional bias levels, but this was only for the short-duration presentations of cues (200 ms), indicating automatic processes are important for succeeding in abstinence. However, it is not known whether the lower attentional bias was present before the period of abstinence and perhaps was the reason why the ex-addicts were managing so well, or whether the reduction in attentional bias was a result of the period of abstinence.

Similar attentional biases have also been found in research on other disorders than addiction, i.e., people diagnosed with mood-disorders show attentional bias towards stimulus relevant for mood states related to their disorder (Mogg & Bradley 2005; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2007). Another example is a bias towards food-relevant stimulus in people with eating disorders (Castellanos et al, 2009).

Based on the above findings of attentional bias effects caused by smoking-related cues (i.e., Waters et al.,2003; Ehrman et al., 2002) and the indications of the importance of attentional bias in maintenance of addiction, relapse and similar, this study will attempt to replicate findings of attentional bias towards smoking cues, comparing smokers with non-smokers on a dot-probe task.

Attentional bias towards food-cues

Using eye-tracking equipment, Castellanos et al (2009) found that both obese and non-obese participants showed an attentional bias towards food-related stimuli after an 8-hour fast. When satiated, non-obese participants showed no attentional bias while obese participants continued to have an attentional bias towards food-related stimuli. This was true for the measures taken with the eye-tracking equipment (a bias in initial orientation as well as a bias in gaze duration), but not for the measured attentional bias through response time to a classification dot-probe task. The lack of effect on the dot-probe task response time might be explained by the images being presented for 2000 ms, possibly giving participants time to strategically interfere with the bias and reorient towards the centre of the screen before the probe was displayed. In their conclusion, Castellanos and colleagues (2009) discuss the similarities of reactivity to food-related cues in obese individuals to cue-reactivity predicted by the incentive sensitization model (Robinson & Berridge, 1993) discussed earlier. The authors further compare the relationship some obese individuals have with food to the relationship an addict has to their substance. As food arguably can be considered a natural "addiction" present in most people, food-related cues can serve as a useful control when investigating a possible attentional bias towards smoking cues in smokers.

Participants in this study will have their attentional bias towards images of salient/desirable food investigated. Any differences for smokers in attentional bias towards smoking-images and towards other salient images (food-images) will be investigated. Food-images will be paired with neutral images and also smoke/food pairings will be made to explore the effect this has on attentional bias towards the stimuli. Possible interaction effects of urge to smoke and urge to eat with attentional bias in these trials will be investigated.

Attentional bias towards subliminal smoking-cues

As previously mentioned, an attentional bias towards a drug-related stimulus can be largely automatic and the processing of the cue can occur without conscious awareness. Several studies have found effects of subliminal drug-cue exposure (Childress et al, 2008; Ingjaldsson, Thayer & Laberg, 2003). Some evidence that motivation plays a part in the effect of subliminal stimuli has been found (Karreman, Stroebe & Claus, 2006), indicating that a motivational factor (thirst) influences whether subliminal presentation of a brand of drink affects the subsequent choice of brand made by the participant. For an addict, drug-seeking behaviour can be considered highly motivated and drug-related stimulus could therefore be expected to have an effect when presented subliminally.

Field & Cox (2008) concluded in their review that appetitive reactions (reactions towards “wanted” cues) are different from anxious reactions (reactions towards potentially dangerous/threatening cues) in that anxiety is associated with early attentional orienting (initial orienting), and could occur outside conscious awareness, while appetitive reactions are related to attentional disengagement occurring later in processing. Further, Hogarth, Dickinson, Hutton, Elbers and Duka (2006) concluded in their study that in nicotine-addicts an explicit awareness of the association between a cue and the drug was necessary for the cue to create an expectation of nicotine and drug-seeking behaviour. However, their methods of categorising participants as having explicit awareness did not actually make participants exhibit explicit awareness through verbalising their knowledge. Participants that performed well were categorised as “aware” and participants that did not perform well were categorised as “unaware”. This does not exclude the possibility that “aware” participants were only implicitly aware. A measure of ability to explicitly verbalise the contingencies of the task in the study by Hogarth et al. (2006) should have been included to strengthen the claim that participants were “aware” of associations between cues and the reward of nicotine.

A number of studies have found effects of subliminal drug-cues, however. The study by Castellanos et al. (2009) mentioned previously, found a bias in both types of both initial orienting and disengagement for salient food cues when using an eye-tracker. This goes against the suggestion that there is no initial orienting towards appetitive cues (made by Field & Cox, 2008), and attentional bias towards subliminal cues could seemingly be possible.

Indeed, Ingjaldsson and colleagues found an effect of subliminal cues for alcoholics reporting high levels of craving (2003). Leventhal, Breitmeyer, Tapia, Waters, Miller & Li (2008) found priming effects of subliminally presented smoking cues presented at 16.7 ms. Childress et al. (2008) presented cocaine-related images subliminally (33 ms) to cocaine-addicts and found fMRI activations of the limbic reward-circuitry in response to both these cues and to sexual cues. The activations anatomically overlapped with response to cues presented for longer periods of time. Based on this the authors suggest a continuity between conscious and non-conscious processing and point to the evolutionary survival-advantage of rapid responses to reward-cues like food and sex. The limbic reward-circuitry is activated in response to natural reward-cues (i.e. food and sex), but also in response to drugs of abuse which are then interpreted biologically as essential for survival.

Support for this continuity is found in dual-process models of addiction that usually base themselves on the core notion of two semi-independent systems for processing. One system has slow, controlled processing related to conscious thought ("reflective"), the other handles processing based on associations and automatic evaluation of emotional/motivational stimulus (i.e., Wiers & Stacy 2006). This means some cues are consciously processed while others are processed non-consciously leaving the cause of the reaction experienced unavailable to consciousness. Awareness of the source of experienced craving might be crucial for making use of cognitive coping-skills and tools taught in drug-rehabilitation therapies. If automatic processes have influences outside cognitive control they should be taken into consideration when working on treatment therapies for addictions (Wiers & Stacy 2006).

Other interesting points concerning cues and awareness of cues have been made in the literature; the ability to detect cues and their temptations might be important for self-regulation (Brownell, Marlatt, Lichtenstein & Wilson 1986, cited in Leander, Shah & Chartrand, 2009) and a lack of awareness of these cues might make self-regulation more difficult (Gaillot & Baumeister, 2007, cited in Leander et al., 2009); cue-exposure therapy does not generalise well to new cues and situations (Monti and Rohsenow 1999) and thus most likely does not generalise well to cues outside the conscious awareness of patients either; cognitive behavioural interventions decrease explicit arousal expectancies but do not affect implicit arousal associations (Wiers 2005). All of these points provide support that the concept of awareness in cue-reactivity deserves further attention, and that research in the area could be helpful in developing therapies for addiction or other disorders where cue-reactivity might play a part.

This study includes subliminally presented (16.7 ms) smoking cues in the dot-probe task to investigate the possibility that the subliminal cues could cause attentional bias without participants being consciously aware of having seen them. The presentations are based on previous studies with similar aims (i.e., Leventhal et al., 2008).

Summary of hypotheses for experiment 1

Replication of findings that smoking-related images in the dot-probe task cause an attentional bias in smokers (Waters et al., 2003; Ehrman et al., 2002) is expected (hypothesis 1). Similarly, food-related images will be used to compare any attentional bias effect towards smoking-stimuli with any attentional bias towards other stimuli that is generally considered salient. Food-related images are expected to cause a smaller attentional bias than smoking-related images in smokers (hypothesis 2). Finally, smoking-related images will be presented subliminally to check for attentional bias effects caused by pre-conscious processing of the images, based on effects found in other studies for subliminal cues (Leventhal et al., 2008; Childress et al., 2008; Ingjaldsson et al. 2006), an attentional bias towards the subliminal smoking-images is expected (hypothesis 3).

Experiment 2

There are a number of hypotheses concerning the underlying cognitive processes in addiction and in cue-reactivity and attentional bias, factors thought to play an important role are many, i.e. impulsivity and deficiencies in inhibition and cognitive control. Nestor et al (2009) registered fMRI activity in response to an attentional bias task. The authors suggested that the registered activity indicated that “bottom-up” control is increased and “top-down” control decreased in nicotine addiction and concluded that cognitive control might have a central role in responsitivity towards nicotine-related cues.

In another study using fMRI, Hester & Garavan (2004) found that cocaine-addicts' ability to inhibit their own behaviour was decreased under a working memory load. To perform better in the inhibition task, greater activation in areas of the brain associated with cognitive control was necessary for the cocaine-users.

Cognitive avoidance strategies might be used to help suppression of drug-related thoughts or involuntary attending to drug-related cues (Field & Cox, 2008). However, attempting to avoid distraction through suppression of thoughts could actually increase the distraction caused. In studies where participants have been instructed to suppress certain thoughts, i.e. been told to avoid thoughts of alcohol, the distracting effects caused by alcohol-related cues were exuberated (Klein, 2007). Then again, being told to suppress thoughts of alcohol in an experimental situation might differ from any “natural” suppression participants engage in, which is likely less compulsive – compare scenario one, concentrating hard on suppressing thoughts of alcohol which is more or less impossible, with scenario two, the thought “that beer looks good... but I have decided not to drink today”. That simple thought might be enough to start up the regulatory processes in the frontal regions and allow a defence against craving to be prepared. Thought suppression is only one type of cognitive coping-skill, and most likely not a very helpful one based on the effect described above, found by Klein (2007). Suppression is likely extremely difficult to engage in without involving at least one other cognitive skill, like distracting oneself. Other skills could include ability to identify a cue and disregard craving as an effect of the external cue and not an internal need, or even to identify the cue and simply prepare for the expected craving, perhaps by making a decision or plan of action for your behaviour before such decision-making is made more difficult by craving “kicking in”.

Further, avoidance strategies might not have the same effect for automatic, rapid attentional bias that it has for slower components of attentional bias (Field & Cox, 2008). The same level of attentional bias might be present for those who wish to use a substance and for those who wish to avoid it (Noël et al., 2006; Stormark et al., 1997, cited Field & Cox, 2008).

Assuming that a capacity like working memory is needed to perform regulatory functions like the cognitive coping mechanisms mentioned above, introducing a cognitive load to interfere with participants' working memory while performing the dot-probe task could provide some information in relation to the hypothesis suggested by Childress and colleagues (2008): If subliminal presentation of stimulus cause a larger attentional bias, and this effect is related to a late or lacking start of regulatory functions, it can be expected that interfering with the effectiveness of regulatory functions through a heavy cognitive load might have the same effect for stimulus presented supraliminally. Again, both supraliminal and subliminal smoking stimulus will be used in the dot-probe task while participants experience a heavy cognitive load (having to remember an 8-digit number throughout the entire block of trials – taken from Klein, 2007).

Summary of hypotheses for experiment 2

A cognitive load is expected to increase the attentional bias towards smoking-related images in smokers (hypothesis 4). There is no hypothesis in regard to effects on attentional bias towards subliminally presented smoking cues.

METHODS

Participants

Ninety participants were recruited on and outside the university campus through posters, emails to student mailing-lists, opportunistic approach, snowballing and use of social media like Facebook. All participants were given a scratch lottery-ticket (worth 10 NOK) as a reward for taking part. Out of these ninety, six participants were excluded from analysis (two due to incomplete participation, two due to human error on the researcher's part and two non-smokers due to reporting a too-high number of cigarettes smoked in their lifetime. Forty-three smokers (23 female and 20 male) and 41 non-smokers (26 female and 15 male) were left for analysis. Because Field et al. (2009) found that attentional bias might be more pronounced in lighter smokers and that the criterion of smoking every day was not necessary, the criterion for being labelled a "smoker" was having smoked a minimum of one cigarette per week over the last two years. The criteria for being labelled a "non-smoker" was never having smoked continuously over any period of time and not having smoked more than 100 cigarettes in their life-time. All participants reported normal or corrected to normal eyesight. Thirty-one of the smokers and 38 of the non-smokers were currently students. The mean age of the smokers was 30.6 years (range 19 to 59 years) and the mean age of the non-smokers was 25.4 years (range 19 to 57 years). The difference in age between smokers and non-smokers was significant, $t(82) = 2.55$, $p<.05$ (2-tailed). Smokers averaged 7.1 years of education after lower secondary school while non-smokers averaged 6.21 years. The difference in education was not significant, $t(82) = 1.21$, $p=.23$ (2-tailed).

Of the non-smokers, 20 reported never having smoked a single cigarette in their life. The remaining 21 participants all reported estimates of having smoked less than 100 cigarettes in their life (<5 cigarettes: 8 participants, <10 cigarettes: 6 participants, <20 cigarettes: 4 participants, <30 cigarettes: 1 participant and <100 cigarettes: 1 participant).

Smokers had on average smoked for 11.1 years and had on average attempted to quit smoking 0.9 times in the last two years. In the last four weeks before participation the average number of cigarettes smoked per day was 11.1 cigarettes. Two of the smoking participants had not smoked for over 24 hours when taking part due to illness, but were kept in the dataset because their response time data did not differ significantly from that of other participants. The reported time since last cigarette for these two participants (336 hours and 86 hours) were excluded before mean time since last cigarette was calculated for the remaining 40 participants: 2.8 hours. The average time from waking up in the morning until having their first cigarette was 1.6 hours, 22 of the smokers usually smoked before their first meal. Thirty-one of the smokers reported spending no time in smoke filled environments and only smoking outside. The remaining 12 smokers reported spending some time in smoke filled environments (<1 hour: 4 participants; <2hours: 2 participants; <3 hours: 4 participants; 4.5 hours: 1 participant; 12 hours: 1 participant).

Design

Experiment 1

A mixed between-participants and within-participants two-factor design was used, where the first factor was smoking-status (between-participants) and had two levels (smoking and non-smoking participants). The second factor was type of trials in the dot-probe task (within-participants) and had four levels (trials with smoking cues, subliminal smoking cues, food cues or smoke/food cues).

The dependent variables were the attentional bias scores (measured in milliseconds). The between-group independent-variables were whether or not a participant smoked. The within-group independent-variables were type of cues presented in the different trials (smoking cues, food cues, subliminal smoking cues and smoke/food cues).

Experiment 2

Experiment 2 had the same design as experiment 1 with the exception that there were only three levels on the second factor (type of trial). Trials with smoke/food cues were not presented in this experiment.

Materials

Hardware

An Intel Pentium 4 CPU 3.00 GHz PC with 512MB of RAM, running Windows XP Professional (Service Pack 1) was used to present the experiment in E-Studio 2.0. The CRT screen used was a 17" Eizo F730 with a Matrox Millenium G550 graphics card. The resolution was set to 1024 by 768 pixels, the colour quality to 32-bit and the refresh rate to 60 Hz.

Peripheral equipment connected to the computer was a keyboard, an optical mouse and a Cedrus response pad, model RB-420. This response pad had four keys. The two keys on the right side (key 3 and 4) had the labels "L" and "R" written clearly in black on a yellow background above them. The remaining two keys were not in use and pressing them would have no effect. The response pad was also fastened to the table to keep participants' distance from the screen fairly stable while simultaneously allowing some freedom to adjust distance to personal preference and comfort. The response pad was also moved to the left side of the desk for participants that preferred using their left hand.

Software

The presentation of the images was scripted into E-Studio 2.0 using inline objects. This was done to ensure the timing of the presentation of both supraliminal and subliminal images was optimal. The script created an offscreen canvas and loaded the images onto this canvas using the .Copy command. The program was instructed to wait for a vertical blank screen and then copy the images onto the onscreen canvas for the instructed refresh rates. This was done to avoid any lag in presentation time due to retrieval of the image from the hard drive.

The precision of the presentation was tested using an optical detector (The Black Box Toolkit) and its corresponding software (BBTK Real Time Log Analyzer), following the instructions for the hard/software (Plant, 2004). The toolkit was connected to a Dell Latitude D600 laptop, with 1GB RAM, 1.5 GHz Intel Pentium M Processor, running Windows XP

Service Pack 2. The optical detector was attached to the screen while running test-trials of the script, measuring how long the screen displayed images with more than millisecond precision.

The opto-detectors were placed on different locations on the screen and also two points of the screen were measured simultaneously. As the signal is not constant for one refresh-rate, but will fade and become too weak for the opto-detector to register, E-Studio 2.0 was programmed to alternately show a white square for one refresh-rate on the left and right side of the screen, meaning that there should be two refresh rates (33.4 ms) between onset-times in the same location, and one refresh rate (16.7 ms) between onset-times for each location.

Over 148 test-trials the mean time between each onset of an image registered by the opto-detectors was 16.67 ms. An opto-detector measures the “spikes” of the CRT-screen (the screen shows images by each pixel being “lit up” by electrons, the pixel then fades again). When the claim is made that the image is displayed for 16.7 ms, the image is actually detectable for the opto-detector for about 2.75 ms (probably longer for the human eye), but not “written over” by a new image until 16.7 ms have passed. The length of time an image is detectable for the opto-detector might also be affected by the means of which the detectors are fastened to the screen as well as level of illumination present from other sources than the screen under testing.

Images used in the dot-probe task and the visibility check

Images used were in JPG format, 600 by 400 pixels and 24-bit colour. Thirty smoking-related images and 40 neutral control-images were taken from the International Smoking Image Series (ISIS) provided by David Gilbert and validated by Gilbert & Rabinovich (1999). The smoking images in the ISIS have been shown to induce nicotine-craving (Gilbert & Rabinovich, 2005) and to cause different brain responses in smokers compared to the neutral images in the series (McClernon et al 2005). Twenty food-related images with matched controls were acquired from Ronald Cowen, previously used in the study by Castellanos et al. (2009). The food-images were rated on their desirability on a five point scale, by 10 independent raters (vegetarian and lactose-intolerant raters were part of the panel). The twenty images and their matched neutral counterparts used were chosen (out of 56 paired images) based on highest desirability-ratings and consensus among the raters, i.e. an image with a high overall rating, but with one extreme low rating would be discarded for an image with a lower overall rating but with no extreme low ratings, thus ensuring the images used were of foods that were generally accepted to be desirable by the panel. The images from Castellanos et al. (2009) were edited so that the food-related images and the neutral controls were separated from each other (they were originally paired in one file), and some editing to the background colour was done for the images with a white background, as the background colour for the presentation of the images was white in this study. Ten additional pairs of images of objects and landscapes used for the neutral subliminal condition were chosen from a database of neutral images available at the University of Oslo. These pairs were matched for content as well as possible.

The mask used in the subliminal conditions and the visibility check was created with a semi-random distribution of coloured shapes made in Photoshop CS4, later pixelized using Gimp 2.0 to create a blurred, but colourful image with no meaningful visual information present. The probe was a filled black circle made in Paint, with a diameter of 2.5 cm.

Interviews

An interview on participants' demographics (sex, age, working/student, years of education) was used. Additionally non-smokers were asked to estimate how many cigarettes they had smoked in their life.

The smoking-history and -habits questionnaire contained questions on duration of habit, quantity, time of last cigarette, attempts to quit, how long it usually took from participants woke in the morning until they had their first cigarette, the last as a measure of their level of craving (Waters & Feyerabend, 2000). Further questions were whether participants smoked before breakfast or after, again as a measure of craving and also to see whether food or a cigarette is what the participant craves the most in the morning (as food-related images were also used in the study). In addition, a question on how much time participants spend on average per day in a smoke-filled environment, either in their own smoke or in the smoke of others, as this could be a relevant additional measure of quantity.

On-screen Visual Analogue Scale (VAS) questionnaire

For smokers, the questionnaire included questions regarding wish and motivation to stop smoking, factors that could influence response time on the dot-probe task (i.e. high motivation towards quitting might lead to a different use of strategies, directing attention away from smoking-related stimuli). The response-scale went from “highly motivated” to “not at all motivated” and “strong wish to quit” to “do not wish to quit”. The other questions were “how strong is your urge to smoke right now?” (Field, Duka, Tyler and Schoenmakers, 2009) and “how strong is your urge to eat right now?”, with the values on the scales being “very strong urge”/”no urge at all”. Finally, questions on how participants were feeling *right now* on the scales of “very good”/”very bad” and “very energetic”/”very unenergetic” were used. For non-smokers the questions related to smoking were not included, leaving them with three questions to respond to versus six for the smokers.

The questions were scripted to appear on-screen using E-Studio 2.0 with a horizontal line representing the scale below the question. The ends of the scale were labelled with the corresponding values for each question. Whether a positive value on the scale was located on the left or right of the scale was counterbalanced as some of the questions were repeated at several points of the study to avoid effects of response-bias. The presentation order of these questions was also randomised for each participant.

Procedure

Participants received information that participation would take about 30 minutes, that the study was related to smoking and consisted of simple computer tasks and answering some questions on smoking-history and -habits. Participants were brought to a quiet, sound isolated room. Participants were informed of their anonymity in the study and their right to discontinue the experiment at any time without having to give a reason before signing the consent form.

After the brief demographic interview was concluded, half of the smokers were given the smoking-history and -habits interview while the other half were given this interview after completing the last computer-task to counterbalance any possible effect responding to the questions at the start of the experiment might have on performance. The above questions were asked in an interview instead of a questionnaire to ensure the questions were understood properly and to provide the possibility of asking follow-up questions if any answers were unclear.

The researcher instructed the participants on the dot-probe task, informing participants that all instructions would be displayed on the computer screen for participants to read in their own time, before verbally giving the instructions for the no-load task to ensure the basics of the task were understood. The on-screen instructions were identical to those in the main experiments described below. Participants first completed practice trials consisting of 10 no-load trials presented first followed by on-screen instructions for the load trials and a set of 10 practice trials for this condition. The images in the practice trials were all neutral and were not used again in the main experiment. practice trials with a cognitive load were included to familiarize participants with the concept and to reassure them that the task was within their capacity. When the practice trials were completed the questions from the VAS questionnaire were automatically presented on the screen, preceded by the instructions that these questions were part of the main study and not practice. The questions were shown one at a time, continuing to the next when a response was made. Participants responded to the questions by using the computer-mouse to navigate the marker across the visual scale and clicking the mouse when the marker was at the wanted location on the scale. After the practice trials participants were given the opportunity to ask any questions before the experimental trials began.

Whether the load or no load experimental condition was completed first by the participants was counterbalanced to even out any effects of fatigue, boredom or practice. After finishing each experimental condition, participants were again given the questions from the VAS questionnaire (except for the question on motivation and wish to quit for the smokers, leaving them answering four questions the second and third time). The questions were presented at three different points in time to control for any change in participants physical or urges to smoke/eat.

Procedure for experiment 1: Dot-probe task (without cognitive load)

The supraliminal dot-probe trials proceeded the same way as in Waters et al. (2003) and is illustrated in Figure 1 below. First a green fixation-cross was displayed in the middle of the screen, the duration of the inter-trial interval (the cross) was randomised to vary between 500 ms and 1500 ms. The fixation-cross preceding each experimental condition was presented for 3000 ms to allow participants to mentally prepare for the upcoming tasks. Participants had been instructed to rest their gaze on the cross between trials. The fixation-cross was followed by two images, one on the left side of the screen and one on the right. These images were 14 cm wide and 9 cm tall. There was 4 cm between the two images. The images remained on the screen for 500 ms (as in Duka & Townshend, 2004; Lubman, Allen, Peters & Deakin, 2008), when the images disappeared from the screen a probe appeared in one of the locations previously occupied by an image. The probe had a 2.5 cm diameter and was placed 8.5 cm from the left edge of the screen when presented on the left and 8.5 cm from the right edge of the screen when presented on the right. The probe remained on the screen until participants made their response to the probe (left or right) and the next trial automatically started.

The subliminal dot-probe trials were presented in the same way as Leventhal et al. (2008), as illustrated in Figure 2 below. The difference in presentation from the supraliminal trials was that the target images were first shown for 16.7 ms, immediately backwards-masked by the pixelized mask created for that purpose. The masking image remained on screen for 33.4 ms before an image matched to the target image replaced it for 450 ms (altogether 500 ms). The rest of the trial was identical to the supraliminal trial.

The types of trials were made up of the following image-pairings, with number of trials for each type in brackets: Neutral/neutral (20), smoke/neutral (40), food/neutral (40), subliminal neutral/subliminal neutral (20), subliminal smoke/subliminal neutral (40) and smoke/food (40), altogether 200 trials. The presentation was programmed in a way to present each image twice on the left side (once congruent with the probe location and once incongruent with the probe location) and twice on the right side (again once congruent and once incongruent with the probe location). This resulted in two congruent and two incongruent trials for each image, and altogether an image was present in four trials. The presentation-order of the different types of trials was individually randomised for all participants.

Figure 1: *Illustration of time-line for presentation of supraliminal dot-probe trials. This example shows a congruent food/neutral trial (the probe appears on the same side as the food cue).*

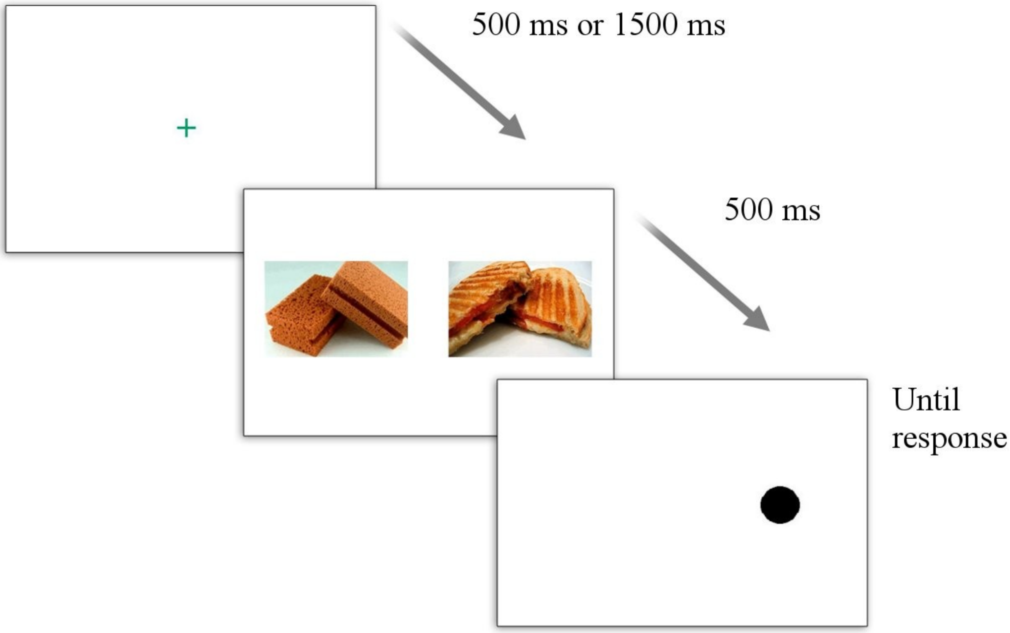
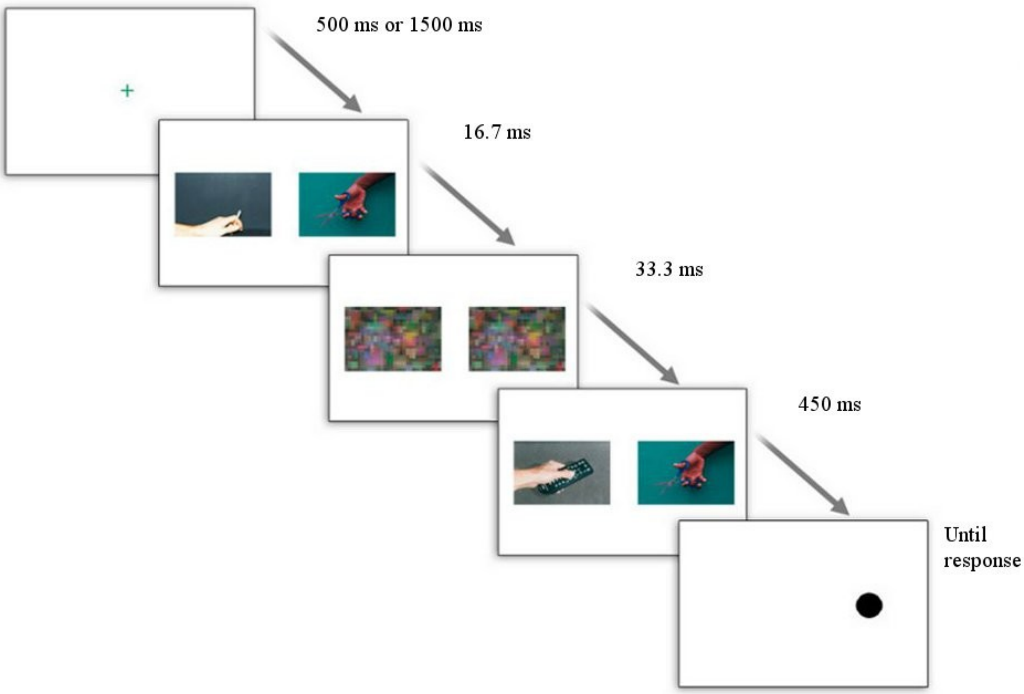


Figure 2: *Illustration of time-line for presentation of subliminal dot-probe trials. This examples is an incongruent subliminal smoke/subliminal neutral trial (the probe appears opposite of the smoke cue).*



Procedure for experiment 2: Dot-probe task with cognitive load

The procedure was the same as in the no load condition, with the exception that participants were shown an 8-digit number for 30 seconds before the dot-probe task began. Participants had to memorize this number (Klein et al., 2007) and type it into a box appearing on the screen (using the keyboard) after the set of trials had been completed. The exact same trials and procedures were used as in the no load condition, except for the smoke/food trials which was not included in this part, leaving altogether 160 trials.

Visibility check

Finally, all participants were asked to complete an additional task on the computer. Twenty images were shown for one refresh rate (16.7 ms), where half were smoking-related and half were neutral. All images had previously been used in the subliminal part of the dot-probe task already completed. The images were 14 cm wide (with 11 cm to the edge of the screen on both sides) and 9 cm tall (with 9 cm to the edge of the screen both below and above) shown one at a time in the middle of the screen. The images were immediately followed by the same pixelized mask used in the subliminal presentations in the dot-probe task. The mask was shown for 483.3 ms. Unlike the subliminal presentations in the dot-probe task no third image was shown following the mask. Another considerable difference in presentation was that one image was presented in the middle of the screen while in the dot-probe task two images were shown simultaneously and peripherally on the left and right.

After each image had been presented, participants were asked to categorise the image they had just been shown as either smoking-related or neutral (by using the response pad, right key for smoking-related, left key for neutral). Participants were told the distribution between the two categories were fifty-fifty and asked to follow their gut-feeling or make their best guess if they were uncertain of which category the image belonged to.

Upon completing this task, all participants were asked if they could see any of the twenty images they had just been presented. When participants said they had been able to see images, they were asked how many they had seen and encouraged to describe the content of the images they had seen. The half of the smokers that had not been given the smoking-history and –habits interview before completing the dot-probe tasks were given this interview at this point. Finally, all participants were debriefed and got the opportunity to ask any questions in relation to the study.

Preparation of response time data from the dot-probe task

In previous research various methods have been used to identify and exclude outliers (thought to be trials where other factors than the experimental factors have had an effect, i.e. finger slipping, thoughts wandering) from the dataset. Some studies have used fixed cutoff-points where response times below 100 ms or 200 ms and above 1000 ms are excluded (i.e. Townshend & Duka, 2001; Ehrman et al., 2002; Ribeiro & Fearon, in print). Ratcliff (1993) argues that standard deviations in the individual data of each participant should be used when identifying outliers in response time data, especially when there are large differences in participants' individual response time means. Ideally a cutoff that eliminates somewhere between 0% and 10-15% of the data should be used (Ratcliff, 1993). Ratcliff further recommends that researchers try a range of cutoff values as this will say something about the reliability of the data. Several studies using response time data from dot-probe tasks have indeed used cutoff criteria based on standard deviation, i.e. Harkness, Harris, Jones & Vaccaro (2009) excluded data 2 standard deviations above or below the individual mean. Other variations over the same theme have also been used (i.e. Waters et al., 2003; Salemink, van den Hout & Kindt, 2007; Lipp & Derakshan, 2005; Vanneste, Verplaetse, Van Hiel & Braeckman, 2007).

The chosen criteria for elimination of outliers in this study follows the method used by Harkness et al. (2009) and Waters et al. (2003). First any response times faster than 100 ms were removed as these are considered to be a result of a response initiated before the probe actually appears on the screen Ehrman et al. (2002). Any trials with response times above or below 2 standard deviations from the individual participant's mean were excluded. This was done separately for the load and no load experiments, as mean response times were significantly longer under load than with no load (paired samples t-test; $t(84) = 2.74$, $p< .01$).

RESULTS

Raw data

The raw data for the dot-probe task were recorded by E-Studio 2.0 and transferred into SPSS for exploration and statistical analysis. Error-trials were identified and excluded. In this experiment there was no upper limit for how long a participant could take to respond to a trial, therefore some extreme response times were present. Out of the overall 29.933 correct responses (divided over 84 participants), four trials had a response time over 3000 ms. These four trials were excluded along with the errors before standard deviations were calculated for the individual participants.

Raw data for the VAS questionnaire and the objective visibility check were also recorded by E-Studio 2.0 and transferred to SPSS. Data from the demographics interview and the smoking-history and -habits interview were entered manually into SPSS.

Dot-probe task

Data-properties

The response times for the trials where participants did not correctly identify the location of the probe were excluded, in all 1.02% of trials across all participants and conditions (137 error trials in the smokers and 170 error trials in the non-smokers). Of all trials, 3.38% were longer than 3000 ms or more than 2 standard deviations above the mean of the individual participant and were excluded as too-slow responses. Too-fast responses below 100 ms or more than 2 standard deviations below the mean of the individual participants were also excluded and made up 0.36% of the trials. In total 4.76% of the trials were excluded as errors or too-fast or too-slow responses.

After exclusions were made, the mean response time for all participants was 375.06 ms. There was no significant difference between smokers and non-smokers in mean response time. In the no load condition, the mean response time for all participants was 367.36 ms, while in the load condition the mean was 382.76 ms. This difference was significant in a paired samples t-test, $t(83) = 2.74$, $p<.01$ (two-tailed). The group mean response times for those that completed the load condition first and the no load condition last was longer in both conditions and significantly so in the load condition, $t(82) = 2.67$, $p<.05$ (equal variances not assumed).

Four participants had their response times for the subliminal conditions removed as they made more correct responses on the visibility-check task than would be expected due to chance (further details in the "objective awareness" section below).

Attentional bias scores were calculated by subtracting the mean response time on the congruent smoke, subliminal smoke, food and smoke/food trials from their incongruent counterparts. The resulting scores for the load and no load conditions for both smokers and non-smokers are shown in Table 1 below.

Table 1: *Table showing mean attentional bias scores for smokers and non-smokers across all trial types in the load and no load experimental conditions.*

Trial condition	Smoker		Non-smoker		Total
	Load	No load	Load	No load	
Smoking	8.79 ms	6.63 ms	-1.22 ms	-0.38 ms	3.46 ms
Subliminal Smoking	-3.58 ms	-2.80 ms	0.28 ms	3.48 ms	-0.66 ms
Food	-1.54 ms	4.60 ms	2.45 ms	4.51 ms	2.51 ms
Smoking/Food		14.86 ms		9.45 ms	12.16 ms

Experiment 1: Statistical tests no load condition

In the no load condition 1.01% of trials were error-trials, 3.29% were labelled too-slow and 0.44% as too-fast, all were excluded in total making up 4.74% of the trial in the no load condition. Non-smokers made significantly more errors in the incongruent food trials compared to smokers, $p<.05$ (equal variances not assumed). Non-smokers had significantly more congruent subliminal smoke trials excluded due to too-fast response times than smokers, p<.05 (equal variances not assumed). Smokers had significantly more smoke-incongruent smoke/food trials excluded due to too-long response times than non-smokers, p<.05 (equal variances not assumed).

One sample t-tests were performed, where attentional bias scores of smokers and non-smokers were tested for significance against zero (no attentional bias).

Non-smokers had a small negative attentional bias score (-0.38 ms) for smoking-related images in the no load condition and a positive attentional bias score (3.31 ms) for subliminally presented smoking-related stimuli. Neither of these were significant, $t(40) = -0.09$, p=.93 (two-tailed) and $t(39) = 0.95$, p=.36, respectively. A positive attentional bias score (4.51 ms) towards food-related images in the no load condition approached significance, $t(40) = 1.65$, p=.054 (one-tailed). Further, a significant attentional bias score (9.45 ms) towards smoking-images when these were paired with food-images in the no load condition, $t(40) = 2.14$, p<.05.

Smokers had a significant positive attentional bias score (6.63 ms) for smoking-related images in the no load condition, $t(42) = 2.09$, p<.05 (one-tailed). A negative attentional bias score (-3.75 ms) was found for subliminally presented smoking-cues, this was not significant, $t(39) = -1.10$, p=.28 (two-tailed). A positive attentional bias score (4.60 ms) for food-images approached significance, $t(42) = 1.67$, p=.052 (one-tailed), while a positive attentional bias score (14.86 ms) for smoking-related images paired with food-related images was highly significant, $t(42) = 4.13$, p<.001.

Individual groups t-tests were performed to compare attentional bias scores in smokers and non-smokers. Smokers had a higher attentional bias score towards smoking-related images than non-smokers in the no load condition, but this difference only approached significance, $t(82) = 1.29$, p=.10 (one-tailed). Smokers had a negative attentional bias score towards subliminal smoking-related images in the no load condition while non-smokers had a small positive attentional bias score towards these images. The difference between the groups was not significant, but approaching significance, $t(78) = -1.45$, p=.15 (two-tailed). Smokers attentional bias score towards food-related images paired with neutral stimuli in the no load condition was nearly identical to that of non-smokers (8 ms higher) and non-significant

($t(82) = 0.02$, p=.98). Smokers had a higher attentional bias score towards smoking-related images in the no load condition when these images were paired with food-related images, but only approaching significance, $t(82) = 0.95$, p=.17 (one-tailed).

Finally, attentional bias towards smoking cues in the smoke/food trials had a significant positive correlations with attentional bias towards smoking cues in the no load condition (r = .380, p<.001 (N=84)).

Experiment 2: Statistical tests load condition

In the load condition 1.02% of trials were error-trials, 3.49% were labelled too-slow and 0.28% as too-fast, all were excluded in total making up 4.79% of the trial in the load condition. Smokers had significantly more congruent subliminal-smoke trials removed due to too-fast responses than non-smokers, p<.05 (equal variances not assumed).

One-sample t-tests where attentional bias scores of smokers and non-smokers were tested for significance against zero (no attentional bias) were performed.

Non-smokers had no significant attentional bias scores in the load-condition. A negative attentional bias score (-1.22 ms) towards smoking-related images, a positive Attentional bias score (1.61 ms) towards subliminally presented smoking-related images and a positive attentional bias score (2.45 ms) towards food-related images were all non-significant ($t(40) = -0.42$, p=68 (two-tailed); $t(39) = 0.36$, p=.72 (two-tailed); and $t(40) = 0.62$, p=.27 (one-tailed), respectively).

Smokers had a significant positive attentional bias score (8.79 ms) towards smoking-related images in the load condition, $t(42) = 1.86$, p<.05 (one-tailed). Attentional bias scores for subliminal smoking-images and food were both negative (-4.15 ms and -1.54 respectively). Neither were significant, $t(39) = -1.10$, p=.28 (two-tailed) for subliminal smoking-related images and $t(42) = -0.38$, p=.71 (two-tailed) for food-images.

Individual groups t-tests were performed to compare attentional bias scores in smokers and non-smokers. Smokers had a significantly larger attentional bias score for smoking-related stimuli in the load condition than non-smokers, $t(82) = 1.78$, p<.05 (one-tailed). Smokers had a negative attentional bias score for subliminally presented smoking-related images while non-smokers had a score barely above zero, the difference between the two groups was non-significant, $t(78) = -0.98$, p=.33. Finally, smokers had a negative attentional bias score towards food-related images paired with neutral stimuli, while non-smokers had a positive attentional bias score towards the food-related images. The difference between the groups were non-significant, $t(82) = -0.70$, p=.49 (two-tailed).

Comparisons between attentional bias scores in the load and no load conditions were performed using **paired samples t-tests**. All comparisons, for both smokers and non-smokers had a negative t, meaning the attentional bias was smaller in the load condition, except for the bias towards smoking cues for smokers. Even though the latter bias was larger in the load condition (8.79 ms compared to 6.63 ms), it was not significant, $t(42) = 2.16$, p=.34 (one-tailed).

Effectiveness of cognitive load

During debriefing several participants reported that they thought completing the dot-probe task was more difficult when the cognitive load was introduced. However, some participants also reported that they felt their responses were faster in the load-condition compared to the no-load condition, holding that focusing on the number made it easier to ignore the pictures. Participants were not systematically asked which experimental condition they found most difficult, but when looking at the mean response times for each participant it is apparent that not all participants had their response times slowed by the introduction of cognitive load, but were actually faster in the load condition compared to the no-load condition.

Individual differences in the participants might be part of deciding whether or not the cognitive load task had the effect aimed for in this experiment. The analysis will look for possible explanations for this difference in participants by checking correlations with other factors and exploring the data for any implications that individual differences in influence from the cognitive load might have for the results. The load and no-load conditions were identical except for the introduction of cognitive load in the load condition. The only other factor that differed for the participants was which condition they completed first, a factor that was counterbalanced. Further, when looking at the data, about 70-75% of participants were slower in whichever dot-probe condition they completed first. This indicates there was no effect of fatigue as participants would then be expected to be slower in the second condition, not faster. However, it could indicate an effect of practice or that participants habituate to the images and their distracting effect disappears after a number of presentations.

Investigation of the data in relation to the effect of cognitive load on response-time in comparison to the no load condition was undertaken. Out of the 84 participants, there were 32 participants (38.1%) with longer response times in the no load condition. Nineteen of these were smokers and 13 non-smokers.

Smoking participants were divided into those who were slower in the load condition ("load effect" group, n=24) and those who were slower in the no load condition ("load no effect" group, n=19). Mean attentional bias scores for each of these groups for all types of trials are shown in Table 2 below). An identical table (Table 5) for non-smokers can be found in appendix 1, but the attentional bias scores for non-smokers in this context will not be discussed further in this report.

A significant difference between the two groups was a higher attentional bias towards food cues in the no load condition for the "load no effect" group, $t(41) = 2.56$, $p<.05$ (two-tailed).

Table 2*:* *Smokers: Mean attentional bias scores in ms for all dot-probe trials, dependent on effect of cognitive load (had slower response times in the load condition).*

Trial condition	"Load effect"		"Load no effect"		Total
	Load	No load	Load	No load	
Smoking	15.25 ms	7.08 ms	0.62 ms	6.05 ms	7.25 ms
Subliminal Smoking	-8.18 ms	-2.50 ms	0.77 ms	-5.29 ms	-3.80 ms
Food	0.77 ms	-1.29 ms	-4.46 ms	12.03 ms	1.76 ms
Smoking/Food		16.47 ms		12.83 ms	14.65 ms

The interaction of effect on load shows that for smokers in the "load no effect" group, the attentional bias towards smoking cues in the load condition is close to zero. However the attentional bias goes up to 6.05 ms for the same participants in the no load condition. When looking at the "load effect" group, the attentional bias towards smoking cues in the no load condition is similar to that of the "load no effect" group while the attentional bias towards smoking cues in the load condition for the "load effect" group is more than twenty times as large as that of the "load no effect" group. This difference between the groups approaches significance, $t(41) = 1.56$, $p = .13$ (two-tailed).

Individual t-tests found that in the "load effect" group attentional bias towards smoking cues in the load condition was significantly larger than zero, while the bias towards smoking cues in the no load condition approached significance, $t(23) = 2.02$, $p<.05$ (one-tailed) and $t(23) = 1.70$, $p = .051$ (one-tailed) respectively. In the same group the attentional bias towards smoking cues in the smoke/food trials was significantly larger than zero, $t(23) = 4.33$, $p<.001$ (one-tailed).

Individual t-tests for the "load no effect" group found a significant attentional bias towards smoking cues in the smoke/food trials, $t(18) = 1.92$, $p<.05$ (one-tailed) and a significant attentional bias towards food cues in no load condition, $t(18) = 3.77$, $p<.001$ (one-tailed).

Effect of habituation/fatigue

Using an individual samples t-test to compare the attentional bias scores for participants with the load condition first with those of the participants with the no load condition first no significant differences were found for any of the attentional bias scores, not for smokers or for non-smokers.

Visibility Check

Subjective awareness

Twenty-five out of 84 participants reported that they had been able to glimpse one or two images during the visibility-check. Seventeen were non-smokers and 8 were smokers. Out of the 25 that reported seeing images, 21 participants described the images they had seen when prompted, while 4 participants were not able to describe the content of the images. (Four participants claimed the same image had been repeated, which was not the case, indicating that there can be some sort of effect of expectation – when participants are expecting/trying to see something they imagine the image is repeating or even construct an image that is not presented.) Twelve participants correctly described one image while 9 participants correctly described two images.

Out of the 25 that reported some visibility of subliminal images, only one performed above chance in the objective awareness test described in the next section.

While it is surprising that such a proportion of participants were able to describe one or two images correctly from the presentation, one should bear in mind that the images in the awareness-check were not masked as heavily as the images in the actual experiment. In the actual experiment the target image was presented for one refresh rate, followed by the mask for two refresh rates and finally a neutral image for 27 refresh rates, meaning that the visual array changed twice and in the final image presented there was a meaningful motive. In the visibility-check the target image was shown for one refresh rate and then only the mask was shown for 27 refresh rates as it was preferred no other meaningful motive interfered with the target motive.

Objective awareness

Objective awareness of the subliminally presented smoking cues in the visibility-check was calculated by analysing responses on the visibility-check using signal detection theory. Out of 84 participants, 4 (3 smokers and 1 non-smoker) made more correct responses on the visibility check than can be expected to be a result of chance (see participants 1, 38, 55 and 82 in the table of d-prime scores in appendix 2). Out of these, only participant 38 had reported being able to see one of the images and made a (correct) description in the subjective awareness-check. The response times of these 4 participants were removed from the analysis of the responses towards subliminal cues in the dot-probe task.

VAS questionnaire

Means

The visual analogue scale responses were given by E-Studio 2.0 as a score on a range from -387.50 to 387.50. The responses on the individual presentations of the repeated items are shown overleaf in Figure 3 (smokers) and Figure 4 (non-smokers).

Figure 3: Smokers mean responses on the VAS questionnaire at three different points in time

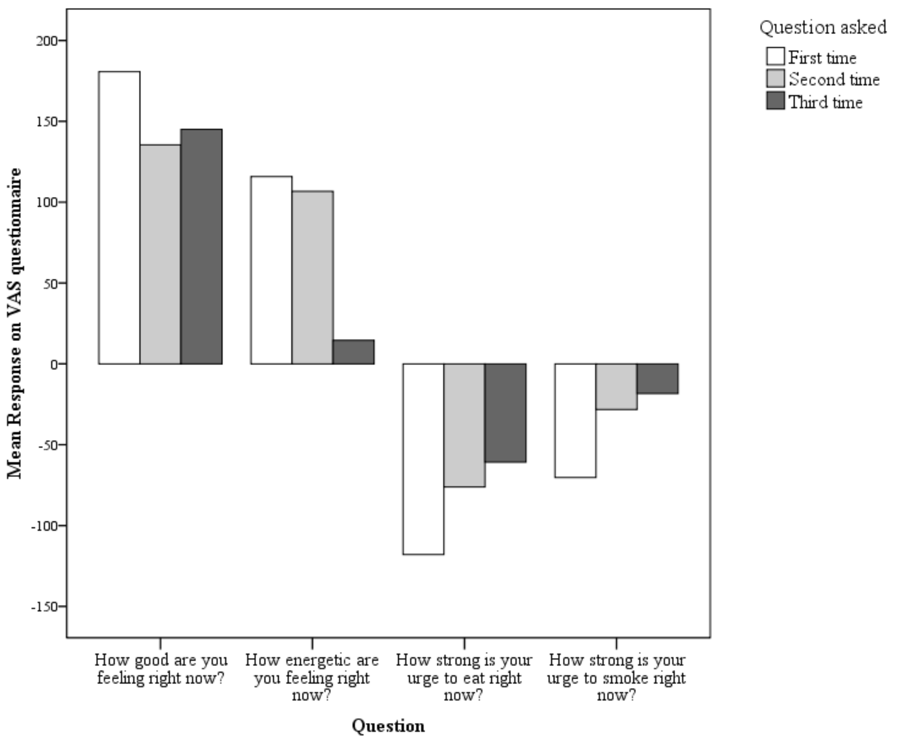
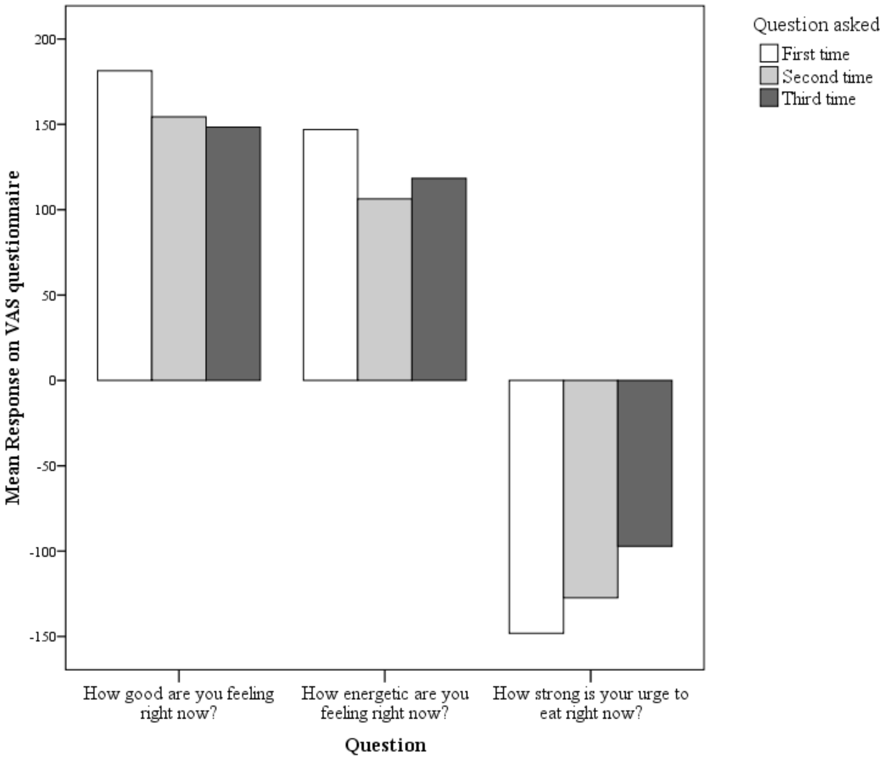


Figure 4: Non-smokers mean responses on the VAS questionnaire at three different points in time



The mean scores for smokers and non-smokers on the VAS items not related to smoking are presented in Table 3 below. Table 4 contains the VAS items exclusively presented to the smokers.

Table 3: Smokers and non-smokers: *Mean responses on the VAS questionnaire based on three presentation of each item (scale from negative to positive; -387.5 to 387.5).*

	How are you feeling? **Good/Bad**	How are you feeling? **Energetic/Unenergetic**	Urge to eat? **Very strong/Not at all**
Smokers	154	109	-85
Non-smokers	161	124	-124

Table 4: Smokers: *Mean responses on the VAS questionnaire on urge to smoke based on three presentations, motivation and desire to quit (scale from negative to positive; -387.5 to 387.5).*

	Urge to smoke? **Very strong/Not at all**	How motivated to quit? **Very strong/Not at all**	Desire to quit? **Very strong/No desire**
Smokers	-39	-10	19

Correlations

In smokers, how energetic participants were feeling significantly and positively correlated with how good they felt, $r(41) = .68$, $p<.001$ (two-tailed). Wish to quit smoking and motivation to quit smoking was positively correlated with each other, significantly so, $r(40) = .536$, $p<.001$ (two-tailed). Further, mean urge to smoke was significantly correlated with wish to quit smoking ($r = .248$, $p=.057$ [N=42])

The mean urge to smoke had a significant negative correlation with attentional bias towards smoking cues in the load condition ($r = -.328$, $p<.05$ [N=42]) and a significant positive correlation with attentional bias towards subliminal smoking cues in the no load condition ($r = .347$, $p<.05$ [N=39]).

Motivation to quit smoking had a significant positive correlation with attentional bias towards smoking cues in the no load condition ($r = .255$, $p=.052$ [N=42]).

How good smokers were feeling was significantly correlated with attentional bias towards smoking cues in the no load task, $r(38) = .314$, $p<.05$ (two-tailed).

DISCUSSION

Discussion experiment 1: No load condition

Smokers showed an attentional bias significantly larger than zero towards smoking cues, both when these were paired with neutral images and when they were paired with food cues. This is in line with findings by Waters et al. (2003) and Ehrman et al. (2002), and lends support to the idea that smoking cues can cause attentional bias in a dot-probe task (hypothesis 1). The biases in smokers towards the smoking cues were larger than that of non-smokers, but the difference between the groups only approached significance.

An attentional bias towards food cues found in both groups of participants were nearly identical in size, but the biases only approached significance. Together with a strong and significant bias towards smoking cues for the smokers in the smoke/food trials, this supports the idea that the attentional bias in smokers caused by smoking cues is stronger than that caused by naturally rewarding cues, in this case food (hypothesis 2). However, a significant attentional bias towards smoking cues in the smoke/food trials was also found in non-smokers, which was not predicted by any hypothesis; contrarily, the opposite effect would have been expected as chances are non-smokers would find food cues more salient and interesting than smoking cues. The bias was not as large as the bias in smokers and the difference between the groups was approaching significance. This smoking bias for non-smokers will be discussed further below, together with findings from experiment 2.

In the subliminal trials, smokers showed an attentional bias away from the subliminal smoking cues, while non-smokers had an attentional bias towards the subliminal smoking cues. Neither of these biases were significant and thus no support for hypothesis 3, that subliminal smoking cues can cause attentional bias, was found.

However, even though bias scores for the subliminal trials were overall negative in smokers, one interesting finding in relation to subliminal cues was made. There was a significant correlation between attentional bias towards smoking cues in the no load condition and self-reported urge to smoke on the VAS questionnaire. Being in a state of craving (here: Having an urge to smoke) can be assumed to lead to a heightened state of motivation to seek opportunities to smoke. The above correlation is therefore consistent with previous findings that motivational factors might be necessary for subliminal presentations to have an effect, i.e. thirst in participants being necessary for subliminal presentations of drink brands to influence them (Karreman et al., 2006). Though Field et al. (2009b) found that a state of nicotine-deprivation was unnecessary for smoking cues to cause attentional bias in their participants; this might not be so for subliminal cues. Perhaps the content of subliminal presentations must be highly relevant to current goals of a participant before sufficient processing resources to create craving (or an attentional bias) are allocated to the cue. A cue relevant to a current goal might receive priority in processing.

Further, the failure to find an attentional bias towards subliminally presented cues at 16.7 ms in this study, does not exclude the possibility that non-conscious cues and processes can be important in understanding addiction and designing treatment therapies for addiction. Subliminal flashes of images are not usually encountered in daily life and studies where non-conscious processes are investigated using this method do not necessarily carry much ecological validity. Arguably, these methods simply tap into effects of non-conscious visual perception and, possibly, different individuals may vary in how the signal of non-conscious visual information is processed and how these signals relate to the associative network or the reward circuitry of the brain.

A possible technical limitation of subliminal studies should be taken into consideration. When presenting images on a computer screen at such short intervals as one screen refresh rate it is crucial that the equipment used is capable of such short presentation times; the right hardware and software, as well as use of the correct settings on the PC is necessary to achieve precise presentation. Researchers making use of very short presentation times must take great care to ensure their equipment is actually showing the images as instructed by the software, otherwise presentation times might be longer than desired. Correct presentation times can be assured i.e. through testing with tools like the opto-detectors used in this study, or the use of thacistoscope equipment. Only when such measures have been taken, can the millisecond threshold for conscious processing be established. Findings of attentional bias at 16.7 ms presentation times could, if researchers are not careful, be due to presentation times actually being longer than 16.7 ms. This does not mean the presentations are not subliminal, they might still be and usually participants are subsequently tested for i.e. recognition of the stimuli as a control for awareness. Even though 33.4 ms is a very short presentation time, the increase in time from one refresh rate to two makes it possible that our processing mechanism can get twice as far in detecting content of a stimuli presented at 33.4 ms compared to when the stimuli is presented for 16.7 ms.

In relation to the nature of cues, non-conscious cues need not be visual; any stimulus can become an associated cue through classical conditioning; i.e. sounds, smells and internal states. If we were aware of all the associations we have at all times, with stimuli in our external and internal environments, we would be overwhelmed. It is necessary that not all of these associations and connections reach consciousness. This associative network is flexible in the sense that whether or not an association influences behaviour or reaches conscious awareness can be manipulated by context and recent priming of the contexts. In the study by Glautier & Spencer (1999) participants were cued for alcohol by tasting two drinks and making a judgement about which drink contained alcohol. After the tasting, participants were given a list of alcohol-ambiguous words and were instructed to write sentences for each of the words. In this way participants created a context for the word and revealed through this context which meaning of the word first sprang to mind (i.e. given the word "shot", sentences could be "I *shot* the sheriff" compared to "I want a *shot* of vodka"). Participants who drank more were found to write more alcohol-related sentences than participants who drank less.

It might be helpful in future studies to try to develop measures of non-conscious associations between less obvious drug-cues and the drug. This is more difficult than using subliminal presentations where obviously drug-related stimuli are used and can be assumed to lead to cue-reactivity in most individuals addicted to this drug. When looking at the more subtle cues, their identity and associative strength might be highly individual from one person to another, as they would be based on individual experiences. An example of such a personalised cue could be the smell of motor oil – an individual could have had their first experiences with a drug in a garage. The smell could cause craving but the link between the smell and the drug might not be consciously available for the addict. Even so, it might be possible to find some drug-cues that are common to most addicts without there being an obvious association, leaving the processing of the cue conscious but the presence of an association with the drug non-conscious. An example of such a cue could be the sound of two glasses clinking together. To heavy drinkers and alcoholics this sound might automatically be associated with consumption of alcohol, as toasts are often made with alcoholic beverages. However the association might not be conscious if the context the sound is heard in is not alcohol-related.

A study using exactly this kind of cue has previously been done by the current author (Skjaervo, unpublished), where social drinkers were shown a video-clip of either a scenario obviously related to alcohol (a pub scene) or a scenario where a toast was made (the actors were drinking orange-juice) in a household kitchen. After viewing the clips, participants were given the same sentence-generation task used in Glautier & Spencer (1999) described above. The findings revealed that participants made more alcohol-related sentences in both alcohol-prime conditions, compared to participants shown a video-clip with neutral content. The difference was significant in the subtle prime condition (clinking glasses) and approaching significance in the obvious prime condition (pub-scene).

Yet another approach using subtle cues was adapted by Stacy, Leigh & Weingard (1994) and Stacy, Ames, Sussman & Dent (1996) when investigating the associations of alcohol-cues with positive outcomes and implicit drug-related cognition in adolescents, respectively. Participants were given descriptions of different outcomes, i.e. positive/negative emotional states and subsequently asked to write down the associations the outcome evoked. High drinkers compared to low drinkers wrote down significantly more alcohol-related sentences in response to positive outcome descriptions. The outcome-primes, it could be argued, were not obviously alcohol-related in the same way as looking at alcohol-related images or tasting alcoholic drinks are, but were consciously accesible and could be described by participants. Investigation of these kinds of cues might be much more relevant for treatment-therapies than subliminally flashed images.

This criticism of subliminally presented cues used in attentional bias tasks, is not to say that these studies have no worth. Subliminally presented cues might well have much in common with supraliminally presented cues with a subliminal drug-association. It is simply important to be aware of the difference between the two and attempt to understand their relationship with each other and the relationship between the processing of the two – is the processing highly similar or very different? A level of processing that fails to bring the cue itself to conscious awareness might be different from a level of processing that fails to bring the cue's associations to consciousness. It is also worth noting that in this study there was a significant correlation between self-reported urge to smoke and attentional bias towards smoking cues in the no load condition, suggesting that even though there was no overall bias towards subliminal smoking cues, the hypothesised effect might have been present for participants experiencing craving, lending support to the idea that motivational state is important in subliminal processing (i.e. Karreman et al., 2006).

Discussion experiment 2: Load condition

In the load condition there was only one attentional bias score that was significantly larger than zero, and this was the bias towards smoking cues in smokers. This bias was also significantly larger than that of the non-smoking controls, which was not the case for the same trials in the no load condition. This is in accord with the hypothesis that attentional bias towards smoking cues would be larger in the load condition than in the no load condition (hypothesis 4), even though the difference between biases in load and no load within the group of smokers was not significant.

The lack of significant attentional biases towards food cues in both smokers and non-smokers, support, as in experiment 1, the third hypothesis which states that smoking cues were expected to be more salient than a naturally salient cue, i.e. food.

Again a bias score away from subliminal smoking cues were seen in smokers, larger than the negative bias seen in the no load condition, but not significant.

The significantly longer response times in the load condition compared to the no load condition indicates that the cognitive load imposed on participants while completing the dot-probe task has had an effect on their cognitive processing of this task. The exact nature of this effect and whether it is the same for all participants or individual differences might be present, is unclear. Investigations based on participants' feedback on the tasks revealed that a proportion of participants did not seem to be affected by the cognitive load, in the sense that their response times were actually lower in the load condition than in the no load condition. Though it is difficult to ascertain what this implies, the participants with longer response times in the load condition were tentatively labelled the ”load effect” group, while participants with shorter response times in the load condition were labelled the ”load no effect” group.

An interesting pattern of attentional bias towards smoking cues appeared. For smokers in which the load had no effect, the attentional bias in the load condition was barely above half a millisecond. For the same participants the attentional bias towards smoking cues in the no load condition was slightly above 6 ms, meaning the “load no effect” group seemed to avoid the bias towards smoking cues during cognitive load. This opposes the hypothesis that cognitive load increases attentional bias towards smoking cues (hypothesis 4), but is in accord with accounts from some participants that the load made it easier to ignore the distractor images compared to the no load condition. This pattern is inverted for the group of participants where the load caused a slower mean response time. Here the attentional bias towards smoking cues was over 15 ms and was reduced to slightly above 7 ms in the no load condition, lending support to hypothesis 4 and the reports from some participants that the added cognitive load made it more difficult to ignore the distractor images. In summary, the difference between the biases for “load effect” and “load no effect” participants in the load condition approached statistical significance, while the biases in the no load condition were fairly similar for the two groups.

It is difficult to draw any conclusions from comparisons of participants grouped as ”load effect” or ”load no effect” based on the trend in their response times. While it makes sense to investigate this difference in participants' performance based on the ambiguity of the feedback given by participants on the task, the point that seems to be illustrated is that cognitive load in the form of memorising an 8-digit number might not always result in the same effect in different individuals. What causes the task to have an effect on performance in the dot-probe task and which direction this effect has, is still unclear. Possibly individual differences in use of strategies (i.e. memorising the number to long-term memory) or how comfortable participants feel about numbers could cause the difference in whether or not the wanted effect of engaging the working memory was achieved. Other reasons could be differences in executive functions or working memory capacity. As reported in the results section there was no correlation between the effect of load and age of participants or the effect of load and number of years of education.

Reduction in attentional bias while under cognitive load might be seen as a positive effect of a distraction, participants are forced to concentrate on the number or risk failing at the task, and as a consequence the attentional bias towards salient stimuli is reduced. There might not be enough attention to be distracted by images and completing the dot-probe task and the memory task simultaneously. Instead of disrupting cognitive coping skills mentioned in the introduction (i.e., suppression and inhibition) the memory task might have simply added a distraction away from attentional bias and worked as a cognitive protection against attention-grabbing stimuli.

An alternative explanation for increased attentional bias towards smoking cues in the load condition might be provided by findings in a study by Hinsen, Jameson & Whitney (2003) where effects of working memory load on impulsivity was investigated. In this study it was found that during working memory load, while performing a secondary decision-task, participants made more decisions leading to immediate awards compared to decisions leading to larger delayed rewards. The authors concluded that this effect was a result of the working memory load increasing impulsivity.

Franco-Watkins, Pashler & Rickard (2006) performed a re-analysis of the data from the Hinsen et al study (2003), where it was suggested that the working memory load did not necessarily result in increased impulsivity but instead increased random responding. When looking at the effects of load on attentional bias towards smoking cues in this experiment, it does not seem the responding is random. Whether the bias is a result of increased impulsivity (which could be loosely paraphrased as decreased cognitive control) leading to an increase in attending to the smoking cues or an effect of some other process, is difficult to ascertain. Franco-Watkins et al. (2006) also suggest individual differences in working memory might be an important factor to take into consideration when looking at effects of working memory load on a secondary task, which is supported by the findings of individual differences in the effects of load in this experiment.

It does seem like further investigations of load on attentional bias and on decision-making in other fields could help shed some light on the underlying processes of attentional bias and cue-reactivity. Experimental designs that manage to separate and distinguish between effects caused by a tapped working memory (i.e. random responding) and effects caused by ability to inhibit or control attention being disrupted. In particular, studies using fMRI in combination with these kinds of tasks are exciting.

Finally, one more finding that was present in both the load and no load experiments deserve commenting upon. The increased attentional bias score towards smoking cues in the smoke/food trials might reflect a delay in response due to two salient cues competing for attention. The finding that both smokers and non-smokers showed significant attentional bias towards the smoking cues in these trials seems difficult to explain. If the reason for the increased bias in smokers in these trials compared to the smoke/neutral trials were due to two salient cues competing for attention, it does not make immediate sense that this effect should only be present in the incongruent smoke trials, or that the same effect is found in non-smokers, also there only in the incongruent smoke trials. A possibility is that smoking cues might cause an attentional bias in non-smokers simply because they are aware that the study they are participating in is related to smoking. This knowledge might make the smoking stimuli more relevant to them and cause the attentional bias effects. Indeed, the purpose of including the non-smoking group is an attempt to control for effects on the trials caused by other factors than being a nicotine-addict, knowledge of the general topic of the study seems to be such a factor. However, as participants likely grow aware of the food-theme in the study as well (they are asked about urge to eat and shown food-related images), this explanation does not seem to suffice completely.

General summary and conclusion

In summary, the attentional bias effects caused by smoking cues previously found in the dot-probe task (Waters et al., 2003; Ehrman et al., 2002) were replicated and shown to be significantly larger than bias effects in the control group of non-smokers, supporting hypothesis 1. The bias in smokers towards smoking cues were also larger than bias towards food cues, supporting hypothesis 2, that smoking cues are more salient than other natural reward cues. Smoking cues presented subliminally at 16.7 ms did not cause an attentional bias, but instead showed a pattern of negative bias away from the smoking cues, this effect only approached significance, still no support was found for hypothesis 3 where it was proposed that subliminal smoking cues would cause an attentional bias in smokers. There was some support for the hypothesis that a cognitive load while performing the dot-probe task might increase the attentional bias towards smoking cues, but the pattern of the findings was complex and the exact effects and causes were difficult to discern. Further research on the meaning of ”awareness” in cue-reactivity is encouraged, as it might be very important in understanding the underlying processes of addiction and the reasons why relapse is so common.

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Appendix 1: Table 5

Table 5: *Non-smokers: Mean attentional bias scores in ms for all dot-probe trials, dependent on effect of cognitive load (having slower or faster response times in the load condition).*

Trial condition	”Load effect”		“Load no effect”		Total
	Load	No load	Load	No load	
Smoking	-4.91 ms	-5.15 ms	6.73 ms	9.89 ms	7.25 ms
Subliminal Smoking	6.01 ms	3.83 ms	-7.53 ms	2.24 ms	-3.80 ms
Food	4.86 ms	5.22 ms	-2.75 ms	2.98 ms	1.76 ms
Smoking/Food		7.90 ms		12.77 ms	14.65 ms

Appendix 2: Table 6

Table 6: *Table of d-prime (d') scores from the objective awareness check for each participant, with corresponding C-value(test for response-bias)***,** *confidence intervals for d'. N.s. indicates awareness of the subliminal cues was not above-chance.*

Participant	**d'**	**C**	**95% C.I. d'**	**p<0.05 d'**
1	2,123	-0,220	1,381	Significant
2	0.778	-0.136	1.134	n.s.
3	0.253	0.127	1.105	n.s.
4	0.507	0.000	1.111	n.s.
5	0.253	-0.127	1.105	n.s.
6	-1.366	0.159	1.205	n.s.
7	0.524	-0.262	1.127	n.s.
8	0.000	-1.282	1.498	n.s.
9	0.000			Only "no"-responses
10	0.440	1.062	1.381	n.s.
11	0.000	-0.842	1.252	n.s.
12	0.000	-0.253	1.111	n.s.
13	0.271	-0.389	1.134	n.s.
14	0.253	-0.127	1.105	n.s.
15	0.000	0.000	1.099	n.s.
16	-0.842	-0.421	1.178	n.s.
17	0.588	0.547	1.184	n.s.
18	0.000			Only "no"-responses
19	0.000			Only "no"-responses
20	-1.095	-0.294	1.184	n.s.
21	0.000	0.253	1.111	n.s.
22	0.507	0.000	1.111	n.s.
23	0.253	0.127	1.105	n.s.
24	0.524	-0.262	1.127	n.s.
25	-0.507	0.000	1.111	n.s.
26	-0.842	-0.421	1.178	n.s.
27	0.507	0.000	1.111	n.s.
28	-0.507	0.000	1.111	n.s.
29	0.000	0.000	1.099	n.s.
30	0.000	0.000	1.099	n.s.
31	-0.842	0.421	1.178	n.s.
32	0.000			Only "no"-responses
33	0.524	-0.262	1.127	n.s.
34	0.507	0.000	1.111	n.s.
35	-0.524	0.262	1.127	n.s.
36	0.842	0.421	1.178	n.s.
37	-0.253	0.127	1.105	n.s.
38	1.535	0.514	1.319	Significant
39	-0.778	-0.136	1.134	n.s.

40	0.803	1.243	1.581	n.s.
41	0.588	0.547	1.184	n.s.
42	0.000	-0.253	1.111	n.s.
43	-0.440	1.062	1.381	n.s.
44	0.000	0.000	1.099	n.s.
45	0.000	-0.524	1.155	n.s.
46	0.253	0.127	1.105	n.s.
47	1.282	0.641	1.314	n.s.
48	0.000	0.000	1.099	n.s.
49	0.524	-0.262	1.127	n.s.
50	-0.271	0.389	1.134	n.s.
51	0.000	-0.253	1.111	n.s.
52	-0.524	-0.262	1.127	n.s.
53	0.271	0.389	1.134	n.s.
54	0.000	0.000	1.099	n.s.
55	1.366	0.159	1.205	Significant
56	0.524	-0.262	1.127	n.s.
57	0.253	0.127	1.105	n.s.
58	0.778	0.136	1.134	n.s.
59	0.000			Only ”yes”-responses
60	0.507	0.000	1.111	n.s.
61	0.000			Only ”no”-responses
62	0.253	0.127	1.105	n.s.
63	0.000	0.842	1.252	n.s.
64	-0.36			19 ”no”-responses
65	0.317	0.683	1.205	n.s.
66	0.507	0.000	1.111	n.s.
67	0.803	1.243	1.581	n.s.
68	-0.36			19 ”no”-responses
69	-0.317	-0.683	1.205	n.s.
70	-1.095	-0.294	1.184	n.s.
71	0.524	0.262	1.127	n.s.
72	-0.778	-0.136	1.134	n.s.
73	-0.253	-0.127	1.105	n.s.
74	-0.524	0.262	1.127	n.s.
75	0.363	1.463	1.685	n.s.
76	-0.507	0.000	1.111	n.s.
77	-0.440	1.062	1.381	n.s.
78	0.507	0.000	1.111	n.s.
79	1.049	0.000	1.155	n.s.
80	0.363	1.463	1.685	n.s.
81	0.253	0.127	1.105	n.s.
82	1.366	0.159	1.205	Significant
83	0.253	-0.127	1.105	n.s.
84	0.000	0.253	1.111	n.s.