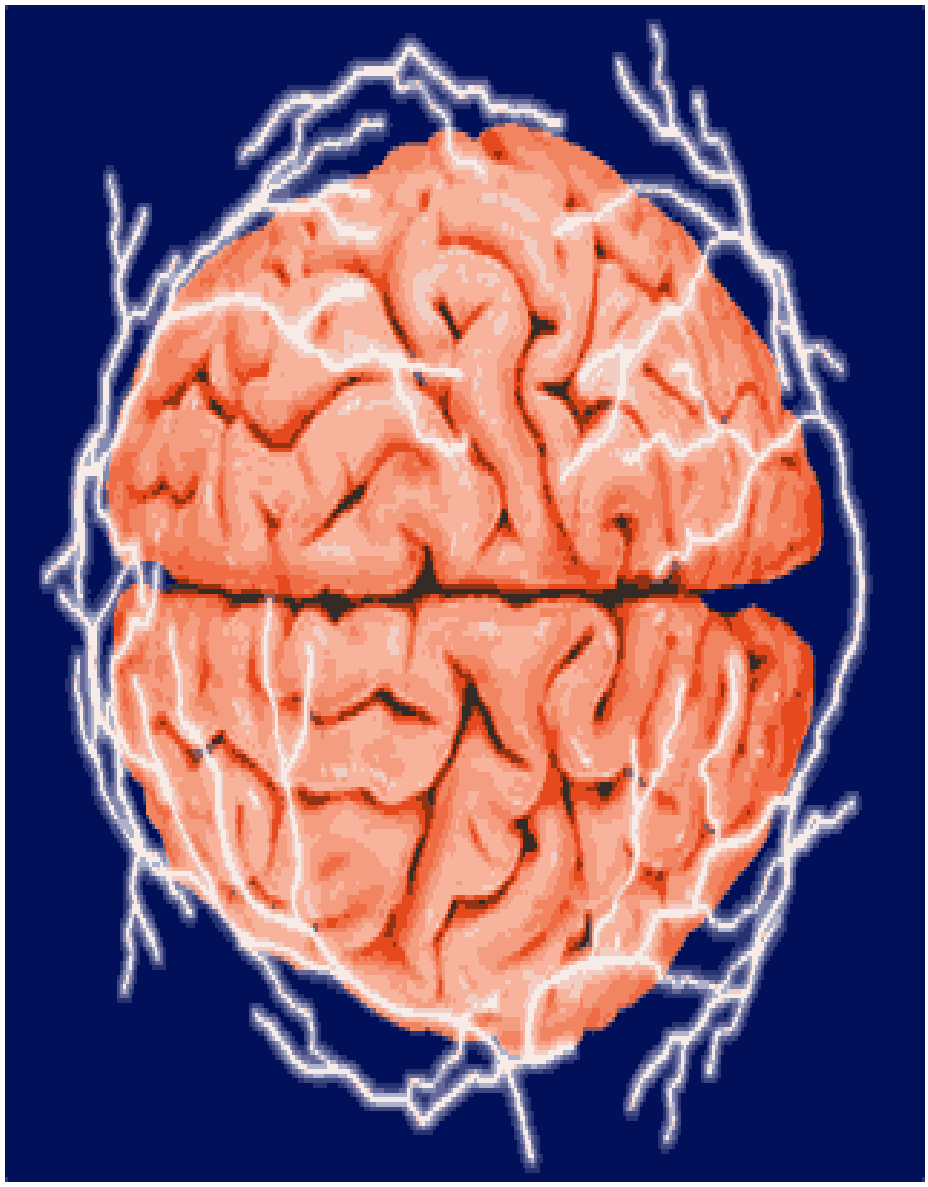
Cue-reactivity and attentional bias in smokers and non-smokers: an ERP study



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Cue-reactivity and attentional bias in smokers and non-smokers: an ERP study

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In the period of

02-2006 till 09-2006

at

Erasmus University Rotterdam

Abstract

This thesis discusses enhanced cue-reactivity in smokers as a result of an attentional bias. Cue-reactivity is tested by means of event-related potentials using a passive viewing task and a dot-probe attentional task. Twenty smoking subjects and twenty-one non-smoking subjects were included in the analysis. Results of the passive task showed that smoking-related cues elicited an enhanced P3, which is a marker of cue-reactivity in smokers. This was not the case in non-smokers. However, evidence for an attentional bias was not present in behavioral results of the dot-probe task. The accompanying ERPs showed no such results either. This was probably caused by the inhibition of return effect, which causes subjects to perform an additional attention shift. The occurrence of this effect was due to too large cue-target onset asynchronies. A feasible combination of ERP and dot-probe tasks therefore seems difficult to obtain.

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http://www.morphonix.com/software/education/science/brain/game/specimens/electric_brain.gif

1. Introduction

1.1. Anecdote

Watching the World Cup 2006 Soccer finale on television with several friends I only realized afterwards how much they smoked during the match. It appeared they smoked more than they usually did and more interestingly they seemed to smoke in "cycles". Either nobody smoked or they all did. So why did they smoke as much as they did? Was the match we were watching that stressful? I doubt it, because the dutch squad wasn't competing anymore and none of us had a strong emotional connection with either one of the playing teams, so there was not much at stake. Perhaps Sunday evening is an evening in which they are used to smoke a lot and therefore during the match they coincidentally happened to smoke a lot as it was on Sunday as well. Reflecting back on the Sunday a week earlier in which all of us were together as well, having a drink at the beach, they did not smoke that much. And how would Sunday smoking explain the somewhat cyclic pattern of smoking? This therefore seems an unlikely explanation as well. Perhaps it was the abundance of smoking related objects in the room. There were ashtrays, lighters, several packs of cigarettes and of course there were other people who started to smoke. In this way perceiving this smoking-related information could have led to a higher smoking urge and in turn to more frequent smoking. This may sound reasonable, but engaging in speculation does not really provide a solid explanation in the first place. So what does scientific literature have to say on smoking behavior? Which theories are available and what do they say? Of course it would be wise to figure out why people engage in this kind of smoking behavior and what addiction has to do with it. And what addiction is and what kind of behaviors it entails.

Firstly, a prominent theory in the field of addiction will be outlined, followed by the role of attention. Subsequently, ways of measuring attention and attentional bias will be discussed, followed by research questions and hypotheses and what will be done in this study.

1.2. The incentive-sensitization theory

Robinson & Berridge (1993, 2000) have proposed a theory which is based on the incentive value of a certain drug and on the sensitization of the addict towards cues associated with the (use of the) drug. They suggest that addictive behaviors are made up of three features, which every theory needs to explain. Firstly, addicts experience craving, which can be seen as an intensive desire to use drugs Robinson & Berridge (1993). Note that craving can also be experienced for

food or sex (Franken, 2003). Craving can divert attention away from the usual daily activities. This time is then spent searching for or taking drugs. A viable theory has to be able to explain this behavior, this craving. Secondly a theory has to explain that former drug addicts easily relapse (for instance: Weiss, 2005). Craving can persist even long after addicts have become detoxified and finally it has to be able to explain the fact that drugs become more wanted if drug use becomes elongated, whereas drug liking diminishes (Robinson & Berridge, 1993). Simply put, addicts seem to want their drug more and more, although they simultaneously experience less and less pleasure of using it. So how does their theory comply with these features?

The incentive-sensitization theory (Robinson & Berridge, 1993) states that drug use causes persistent neuroadaptations. The involved neural system becomes particularly sensitive towards drug-related cues or stimuli. These stimuli elicit a response of craving, provided that they are salient enough. Initial drug taking causes pleasurable effects which leads the subject to repeat usage. When doing so, the user learns the associated stimuli together with the pleasurable experience in a Pavlovian conditioning manner. These drug-related stimuli become more salient and more potent behavior controlling cues. The neural system becomes sensitive to these incentive cues (Robinson & Berridge, 2000).

An important note which has to be made here is that Robinson & Berridge (1993, 2000) suggest that wanting is not the same as liking. Hence, the neural system responsible for wanting should be different than the neural system responsible for liking. Common sense would point out that addicts want drugs because they like them. This line of reasoning however, can prove to be elusive. The theory posits that only the neural system responsible for wanting is sensitisized. This sensitization is quite persistent, which can account for the high number of relapsing addicts.

The above discussed neural system, which is active in drug wanting, is thought to be the dopaminergic system. More precisely, several addictive substances activate mesotelencephalic dopamine neurotransmission (Di Chiara & Imperato, 1988). Brain areas involved herein are the ventral (i.e. nucleus accumbens) and dorsal striatum. Drugs which trigger this system are among others: methylenedioximethamphetamine (MDMA, Ecstasy), morphine, cocaine, alcohol and of interest for current research nicotine (Robinson & Berridge, 1993). Another important factor in addiction is attention and its relation to craving. This will be discussed subsequently, followed by methods of measuring attention and especially attentional bias.

1.3. Craving & attention

As said before craving is an intense desire for, in this case, drugs. Franken (2003) argues that craving can be seen as an emotion which coincides with approaching behavior. Consider again the incentive value of drug-related cues. These cues elicit craving in addicts, which can in turn lead to drug-taking behavior. Franken (2003) refers to this as a conditioned appetitive motivational state. These drug-related cues can thus be seen as emotional cues. In case of a smoker this could be illustrated as follows: Upon entering a bar in which the smoker often comes, a conditioned response is triggered. The bar, the people there, the sounds, the smell can all contribute to trigger this response. The smoker wants to have his/her cigarette at that time and will engage in behavior to fulfill this desire.

Attention plays an important role in the process of craving, elicited by emotional cues, and the actual drug taking. Franken (2003) states that attention is a cognitive selection mechanism, which we use to select information. In any kind of situation an abundance of information is present. Not all of this information is useful and attention helps us filter out the unwanted or unnecessary information. He continues that it is of evolutionary value to divert attention to pleasant and unpleasant stimuli. Pleasant stimuli deserve attention in order to survive. One has to eat and drink in order to survive and one has to reproduce in order to pass on genes. Similarly, unpleasant stimuli need attention for survival purposes. If one, for instance, fails to recognize danger in an approaching predator, this would probably lead to a shorter life expectancy and a lowered chance of passing on genes. So these stimuli have attention-grabbing properties. If stimuli are unexpected, unusual, or remarkable they can also grab ones attention involuntary (Franken, 2003). Emotional stimuli seem to have similar attention grabbing properties compared with neutral stimuli (Vuilleumier 2005). This can be seen using several attentional tasks (for instance: Williams, Mathews & MacLeod 1996). So, if drug-related cues can trigger a conditioned appetitive motivational state and emotional stimuli can grab attention involuntary, addicts should experience drug-related cues as emotional cues. That is in case of a smoker, a cigarette is able to grab attention and to instill smoking urge. Note of course that in this case the smoker has to be addicted at least instead of just being a “recreational” smoker. Evidence for this line of reasoning comes from research using EEG (for instance: Warren & McDonough ,1999; McDonough & Warren, 2001) or research using attentional tasks (Waters & Feyerabend (2000); Franken, Kroon & Hendriks (2000); Waters, Shiffman, Bradley & Mogg (2003); Ehrman, Robbins, Bromwell et al. (2002).

It is clear that addicts are subject to an attentional bias, considering the above described evidence. But how exactly is this evidence obtained? How can one measure an attentional bias? Several methods can be employed. Two of them will be discussed next. Firstly, attentional tasks, then event-related potentials (ERPs).

1.4. Measuring attention

Vuilleumier (2005) states that our sensory systems are of limited processing capacity and that the brain needs to make a selection of relevant information. Franken (2003) reports that this limited capacity should be used in measuring an attentional bias. That is, more attention is directed towards certain salient stimuli compared to neutral stimuli. In this way attention from a primary task can be drawn away and performance will be influenced.

1.4.1. Dot-probe task & other attentional tasks

Pourtois, Grandjean, Sander & Vuilleumier (2004) used a classical paradigm originated from a covert orienting task (Posner, Snyder & Davidson, 1980). In this task the subjects have to react to targets which are preceded by a cue. Subjects have to indicate in which location the target is (left vs. right or up vs. down). Cues can differ on validity and on valence. A cue is valid if it appears in the same place in which the target appears. In this case the cue would correctly predict the location of the target. Invalid cues appear on the opposite side of the target and therefore incorrectly predicting the location of the target. Valence can differ in each experiment. When testing healthy subjects one can use positive, neutral and negative stimuli. When testing addicts one can use drug-related versus non drug-related stimuli. In this case the drug-related stimulus would correspond with a positive stimulus and the non drug-related would correspond with a neutral stimulus. Different variants of the task exist in that some experiments give two cues (Ehrman et al, (2002); Waters et al., (2003); Franken et al., (2000)), one on each side. One is then an emotional cue, whereas the other is a neutral cue. Other variants use only one cue at a time (Li, Li & Luo, 2005). Performance is enhanced when the valid cue is emotional and the invalid cue is neutral in dot-probe tasks using two cues. When only one target is used a similar pattern can be seen, namely that performance on the valid trials is better when cues are emotional.

There are other tasks, that can be used to measure the attentional bias. Firstly one can make use of an emotional Stroop task. Williams et al. (1996) used it in their study and describe it as a way of measuring attentional bias in emotionally disturbed people. In a normal stroop task the primary

goal of the subject is to name the color of a word as fast as possible. Words used are color-words like red, green and blue. They are then printed in red, green or blue and subjects have to name the printed color. Interference arises because subjects automatically start to read the word, which results in a competition of two colors which want to be reported, namely the color the word is printed in and the color which the word describes. In an emotional stroop task only the words used differ from a normal stroop task. Words here have emotional value to the subjects taking the test. For a smoker words could be: cigarette, lighter, matches and so on. These words grab the subjects' attention and direct it away from the task at hand, which is naming the color the word is printed in. Williams et al. (1996) reviewed evidence that subjects with a certain clinical condition had longer reaction times (RTs) when naming an emotional word's color compared to a control group. They were not slower on naming the color of neutral words however. Secondly there are visual search tasks. In these tasks the subject has to search for a specific target among distractors. Subjects show an enhanced performance if the target has an emotional value (Vuilleumier, 2005), either positive or negative. Finally there are attentional blink tasks. The subject undergoes a course of quickly succeeding stimuli, in which the target has to be detected. When a target is presented shortly after another it is usually missed. Performance improves when the second target is of emotional value (Vuilleumier, 2005).

Next to attentional tasks, physiological measures can be used as well to determine whether someone has heightened attention for certain stimuli. Warren & McDonough (1999) outline several of these: tonic heart rate, systolic and diastolic blood pressure and vasoconstriction. ERPs can be used as well. These will be discussed next.

1.4.2. Event-related Potentials and cue-reactivity

In ERP research an important factor is cue-reactivity. Basically it is the term for the above described ability of cues to grab one's attention. In case of a smoker this would be his or hers enhanced reactivity towards smoking-related cues (McDonough & Warren, 2001). This cue-reactivity can be seen using ERPs. There are several ERP components which can reflect cue-reactivity. Luck (2005) summarizes some major ERP components. Of interest for the current study are the following: P1, N1, P2, N2, P3 and a late positive potential (LPP). In figure 1 these components can be seen.

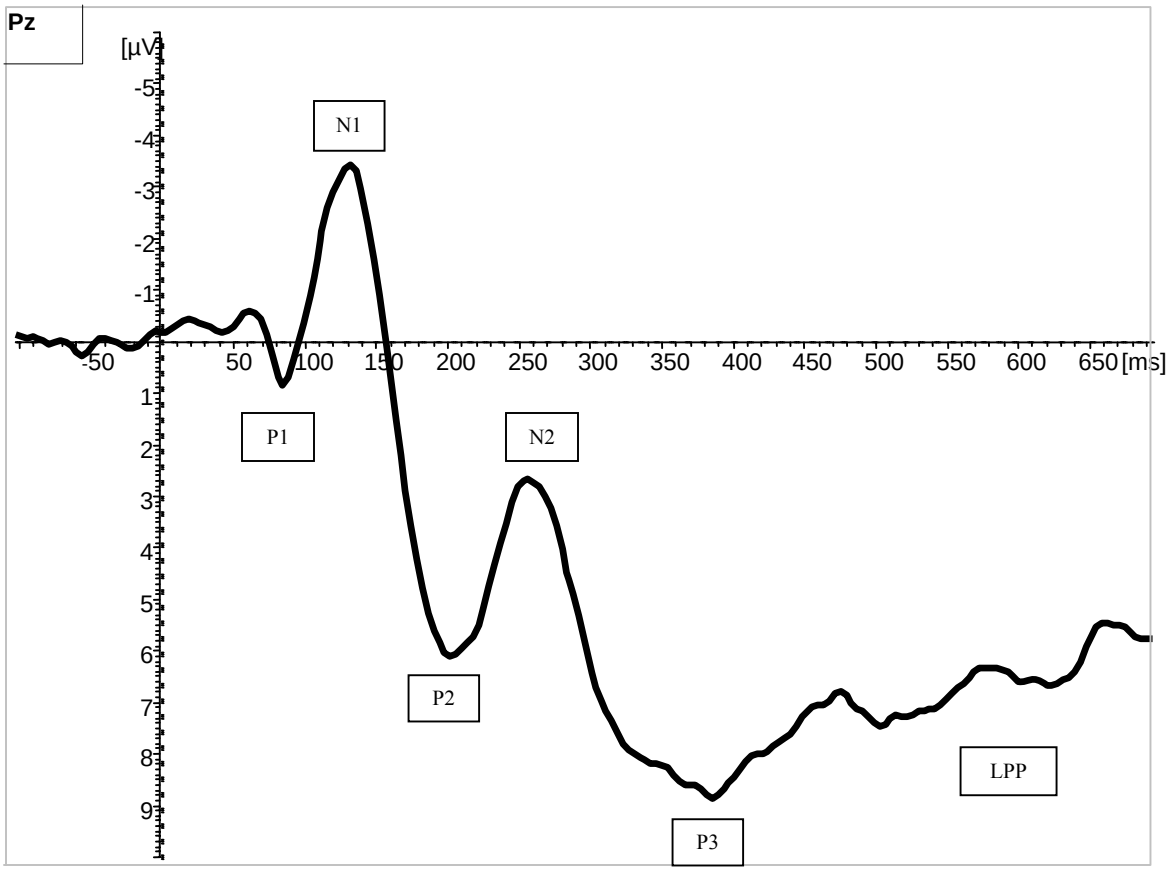

Figure 1. ERP components elicited in smokers viewing smoking-related stimuli (pictures)

1.4.2.1. Components

The first downward peak, usually starting 60 to 90 seconds following stimulus presentation and peaking at 100 to 130 ms is the P1 wave. Di Russo, Martinez, Sereno, Pitzalis and Hillyard (2002) localize this peak in posterior regions of the brain. More precisely, the early part of this peak originates in the dorsal extrastriate cortex, whereas the later part originates more ventrally from the fusiform gyrus. Caution is needed here however in that the preceding C1 wave (not discussed here and not strongly pronounced in figure 1) overlaps with the P1 wave. Furthermore, at least thirty separate visual areas show activity within 100 ms after stimulus onset (Luck, 2005). The P1 wave is thought to be influenced by location of the stimulus with respect to the subject's spatial attention. When the stimulus appears within the attentional spotlight a P1 wave can be seen (Mangun & Hillyard, 1996).

The following upward peak is the N1 wave. This negative wave peaks around 100 to 200 ms poststimulus. It is made up of two components of which the first arises 100 to 150 ms after

presentation in anterior regions. The second component originates in the parietal cortex and in the lateral occipital cortex at around 150 to 200 ms poststimulus. Similar to the P1 wave the N1 wave is involved in spatial attention (Luck, 2005). Moreover, the portion originating in the lateral occipital cortex is enlarged in discriminating activities in comparison with detection activities (Luck, 2005). The following downward peak is known as the P2 wave. It originates in central and anterior sites and it is enlarged when subjects perceive fairly simple target stimuli. Difficulties in interpretation occur as a result of frequent overlap with N1, N2 and P3 waves (Luck, 2005).

Subsequently, the N2 wave can be seen. Ritter, Simson and Vaughan (1983) regard this component to reflect automatic and deliberate stimulus evaluation as well as classification processes. Wijers, Okita, Mulder et al. (1987) found that the N2 wave only appeared in targeted stimuli. Irrelevant stimuli did not generate a N2 wave. This therefore can be interpreted as higher-level processing, since the N2 only seems to be elicited in attended locations.

Following the N2 wave is the P3 or P300 wave, arising at around 300 ms poststimulus. Linden (2005) states that the P3 is usually found in oddball paradigms, in which subjects have to detect a target among a majority of non-targets. The P3 wave has two subcomponents, namely the P3a and the P3b. The P3a, also known as novelty P300 is evoked when subjects perceive an unique, novel or salient stimulus. For smokers this could be a picture of a smoking-related object. The P3b is elicited when subjects perceive a deviant task-relevant stimulus, which they are attending to. Of both these subcomponents interest goes out to the P3a. The more general term P3 will however be used.

Finally a late positive potential (LPP) can be seen. Cuthbert, Schupp, Bradley, Birbaumer & Lang (2000) suggest that this slow wave reflects selective processing of emotional stimuli. Using IAPS pictures they found an enhanced LPP was present when pictures were of higher emotional value. This LPP is thought to reflect prolonged processing, because of the motivational significance of emotional stimuli.

1.5. Current study

In current study two tasks will be used. Firstly, cue-reactivity in smokers and non-smokers will be measured using a passive viewing task, by means of EEG-recordings. Secondly, behavioral data will be obtained using a dot-probe task. During this dot-probe task EEG-recordings will be taken as well. Furthermore several questionnaires will be administered. The research question concerning the first task are as follows:

"Do smokers show a larger amplitude in P3 than non-smokers when viewing smoking-related cues?" In doing this the P3 on smoking-related cues is compared to the P3 on neutral cues. It is hypothesized that smokers show a larger P3 amplitude compared to non-smokers when viewing smoking-related cues. When viewing neutral cues, no differences in P3 amplitude between the two groups are expected. When investigating this research question the P1 wave, the N1 wave, the P2 wave, the N2 wave and the LPP will be investigated as well. There are no expected differences in the P1 and N1 components since stimulus location is not manipulated to show differences in these early waves. The P2 and N2 wave are more likely to show differences. These later components are related to initial higher level processing. The P3 component, however, is of more interest, since stimuli used are quite complex and more robust differences in processing are expected in these components. The same is true for the LPP. Finally, wave amplitudes of the components P1, N1, P2, N2, P3 and mean activity in LPP are expected to correlate with smoke status, smoking severity, smoking urge and valence and arousal ratings. Higher smoking severity, smoking urge, valence and arousal rating are expected to correlate with higher peak amplitudes in P2, N2, P3 and higher mean activity in LPP.

Concerning the dot probe task the following question can be posed:

"Does ERP provide a similar pattern of results, concerning the attentional bias, as a dot-probe task?" Put simply, are the behavioral data in accordance with the physiological data? Behavioral data encompass RT and accuracy and physiological data reflect the accompanying ERPs. It is expected that this would be the case. Smokers should show an decreased RT (i.e. faster) compared to non-smokers on valid smoking-related trials. In ERP this would be reflected in a higher amplitude in P1 and N1 in smokers in valid trials, measured after target onset. If smoking-related trials are invalid, smokers attention should be shifted towards the wrong location and RTs would therefore increase (i.e. slower). On neutral trials there should be no difference between groups, regardless of validity and valence. This should be accompanied by no difference in P1 and N1 amplitude between smokers and non-smokers. Finally, performance and P1/N1 amplitude are expected to correlate with smoke status, smoking severity, and valence and arousal ratings. It should be noted that wave latencies might show differences as well, but this will not be investigated in current study. Furthermore all statistical analyses will be performed using for scalp locations, namely only the midline sites (Oz, Pz, Cz and Fz).

2. Method

2.1. Participants

Two groups of a total of 46 psychology students participated in the current study in return for course credits. The first group contained people who smoked, the second group contained non-smokers. Recruiting was done through an online advertisement, after which screening by phone took place (smoke status and general information). Groups were matched on sex.

A total of five subjects had to be excluded due to noisy EEG-signal. The final smokers group (N = 20) consisted of 12 females and 8 males. Age varied from 18 to 25 years with an average of 21.20 (SD = 2.19). Smokers were defined as people who smoked on a regular basis for at least half a year. Average smoking length was 5.17 years (SD = 2.21), ranging from 8 months to 10 years. The final nonsmokers group (N=21) consisted of 13 females and 8 males. Age ranged from 18 to 22 years with an average of 19.57 (SD = 1.25). Nonsmokers were defined as people who haven't smoked more than twenty cigarettes in their lifetime. Ten had actually never smoked at all. One subject only tried one drag. Eight subjects had finished one entire cigarette and only two subjects had smoked more than one cigarette. One of them had an estimated total of ten cigarettes and the other estimated a total of twenty.

Comparing means of both groups using an independent t-test reveals a significant difference in age ($t(30) = 2.91$, $p = .007$). Smokers in this sample were significantly older in this sample. See table 1 for a summary of sample characteristics.

	Smokers (N = 20)		Non-smokers (N = 21)	
	M	SD	M	SD
Age	21.20	2.19	19.57	1.25
Smoking duration	5.17	2.21		
Cessation duration	.44	.60		

Table 1. Main demographics for smokers and non-smokers

2.2. Stimuli

Stimuli of the passive task were photos which were either smoking-related or non smoking-related. The first category contained pictures of people engaging in smoking activities, packs of cigarettes, a cigarette in an ashtray and so on. The second category included pictures of equal complexity was made up of pictures of people holding a pen, people making a call, or just someone without a cigarette. A total of 32 pictures were used (16 smoking-related and 16 not smoking-related) four times resulting in a total of 128 trials. Stimuli of the dot-probe task were a total of 20 picture pairs. All of these pairs were made up of a picture in which the person is smoking and one in which the person is not. Pictures within a pair were constructed in a way that they were as identical as possible.

2.3. Procedure

Prior to testing subjects were informed about the nature of the experiment. Signed informed consent was obtained from all subjects. At first, some personal information and information about smoking status was obtained. Then smokers had to fill one more questionnaire, the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker & Fagerström, 1991) measuring subjects' smoking dependence. The FTND and other questionnaires named in this section will be discussed later on. Next, participants were seated in a comfortable chair at a 90 cm viewing distance from the screen and electrodes were attached. A cushion was placed behind the head after completion of electrode placement in order to relax neck muscles. Subjects were instructed to relax and to hold their eyes as motionless as possible. That is not looking left or right, up or down and minimizing eye blinks. Instructions for the first task were given in which subjects passively had to view pictures. These pictures were presented on a computer screen. In order to stimulate attention for these, instructions included that questions about the pictures could be posed afterwards. Smokers received a shortened version of the Questionnaire for Smoking Urge (QSU-Brief; Cox, Tiffany & Christen, 2001) when the first task was completed. Subsequently instructions for the dot-probe task were given. After completion of this task electrodes were disconnected and subjects were asked to rate all pictures (i.e. of both tasks) using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). Ratings of arousal and valence were obtained in this way.

2.4. Measurement instruments

2.4.1. Fagerström Test for Nicotine Dependence

Successive to the Fagerström Tolerance Questionnaire (FTQ; Fagerström, 1978) the FTND was developed as a revision in 1991 (Heatherton et al.). It contains 6 items resulting in a total score ranging from 0 to 10 with the lower end reflecting low dependence and the higher end high dependence. Four of the six items offer two answering choices scored by either a 0 or a 1. The remaining two questions have four answering options with scores ranging from 0 to 3. A total score is calculated by simply adding up all item scores. Administration of the test takes approximately 5 minutes.

Pomerleau, Carton, Lutzke, Flessland & Pomerleau (1994) tested the FTQ and FTND on reliability and validity using a sample of moderate smokers as well as a group of smokers suffering from a major depression. They had their subjects fill in the tests at different points of time. The resulting test-retest correlation on the total score of the FTND was .88 ($p < .001$). Cronbach's alpha was .64. Correlating it with other measures of smoking addictiveness such as Classification of Smoking by Motives (CSM; Russell, Peto & Patel, 1974) revealed similar results as the FTQ which were satisfactory.

2.4.2. Questionnaire for Smoking Urge

Different versions of the QSU exist, mostly distinguished by the number of items used. Originally the QSU contained 32 items measuring four different aspects of smoking urges (Tiffany & Drobes, 1991). These are: 1. the desire to smoke, 2. Anticipation of positive outcome from smoking, 3. Relief of withdrawal or negative affect, 4. the intention to smoke. Using Factor Analysis two factors were found when item structure was further examined. The first factor contained items relating to intention and desire to smoke and anticipation of positive outcomes. The second factor contained items relating to an overwhelming desire to smoke and anticipation of relief of negative affect and withdrawal. Both factors showed high internal consistency with a Cronbach's alpha of .95 for factor 1 and .93 for factor 2.

In this study, the QSU-brief, a shortened version containing 10 items, was used. Cox et al. (2001) evaluated this questionnaire in laboratory and clinical settings. In their study they found the same two factors as were found in the full questionnaire. Both factors showed high internal consistency, when tested in a laboratory setting. Cronbach's alpha amounts to .96 for factor 1 and .93 for factor 2. QSU-brief also showed good general reliability with a Cronbach's alpha of .97. Finally QSU-brief showed significant correlations with the original QSU ($r = .51$, $p < .001$). Testing in a clinical setting revealed similar results. Administration of the QSU-brief takes

approximately 5 minutes. Scoring is done by adding up all ten seven-scaled items and then dividing the total score by ten.

2.4.3. Self-Assessment Manikin

The SAM used in the present study (Bradley & Lang 1994) measures emotional value of pictures, words, events or any other kind of stimuli on two dimensions, namely Arousal and Valence. Arousal is how much excitement a certain stimulus triggers. High arousal corresponds with much excitement, whereas low arousal corresponds with relaxedness or sleepiness. Valence is how positive or negative a stimulus is. It can either make the subject feel happy or it can make the subject feel unhappy, disgusted or even afraid. Reliability was measured by comparing the SAM with the semantic differential (Mehrabian & Russel, 1974). Results showed high correlations on the arousal and valence dimensions. Subjects had to place a small mark on a dashed line, corresponding with their feelings of arousal and valence. These were measured in millimeters, which resulted in two scores per picture. A total of 72 pictures had to be rated, of which 32 were of the first experiment and 40 of the second. Collection of all ratings took approximately 15 minutes.

2.5. Computerized tasks

2.5.1. Passive viewing task

After connecting subjects to the EEG, they received instructions for the first task. They had to view smoking-related and neutral pictures passively. Each trial was made up of one picture, lasting 3000 ms, followed by an empty black screen, lasting either 800, 900, 1000 or 1200 ms. A total of 32 pictures was shown four times, resulting in a total of 128 trials. No behavioral responses were recorded, only EEG recordings were made.

2.5.2. Dot-probe task

In this task each trial consisted of the following: a central fixation cross with two rectangles (15.1 cm x 12.6 cm) placed left and right of it. This lasted for 500 ms. Hereafter, one picture, the cue, was presented in one of the rectangles for 600 ms followed by a short interval lasting randomly between 100 and 300 ms. Finally, the target, a small square appeared, remaining on screen until

the participant responded or when 2000 ms had elapsed. Between trials a 1000 ms interval was built in. A total of 240 trials were presented this way. After 120 trials subjects were given an intermission for how long they needed. Ten of twenty picture pairs were used in the first half, the remaining ten were used in the second half. Subjects were instructed to remain fixated at the fixation cross and to react to the probe as quick as possible, but without making too much errors. They were encouraged to use only their two index fingers to respond. For this a response box was used. RTs and response accuracy were recorded automatically by a computer during the dot-probe task.

2.6. Apparatus

ERP measures were obtained by using a BIOSEMI active-two system at 32 sites. Two additional electrodes served as a reference and a ground electrode. To control for vertical eye movements a vertical electro-oculogram (VEOG) was recorded. For this Ag/AgCl electrodes were placed closely above and below the left eye. Horizontal eye movements were measured by a horizontal electro-oculogram (HEOG). Ag/AgCl electrodes were placed at the outer canthus of each eye. Finally two more electrodes were placed at both mastoids. EEG-signals were digitized at a 512 HZ sampling rate and were analyzed using BrainVision Software (Brain Products, Germany).

2.7. Data reduction and statistical analysis

2.7.1. Self-report measures

To check for group equality an independent t-test at an alpha of .05 was conducted with smoke status as grouping variable. The testing variable was age. SAM ratings were analyzed using two 2 (stimulus category) x 2 (group) ANOVAs at an alpha of .05. One ANOVA tested valence, the other tested arousal.

2.7.2. Reaction Time and Accuracy

Only correct trials of the dot-probe task were used for analysis. RTs below 200 ms and above 1000 ms were excluded from analysis as well. Four total scores were computed. These are scores on each stimulus category (smoke-related and neutral) and on each validity level (valid and

invalid) resulting in a 2 (validity) x 2 (cue) repeated measures ANOVA with smoke status as between-subjects factor with an alpha of .05.

2.7.3. ERP-data

EEG recordings were segmented into 2000 ms epochs, starting 101.56 ms before stimulus onset. Ocular artifacts were removed according to the Gratton & Coles algorithm (Gratton & Coles, 1983; Gratton, 1998). Remaining segments with an EEG activity exceeding +/- 100 μV were removed from further analysis. Following baseline correction, segments were averaged for each stimulus category. In the passive task these were either reactions to neutral pictures or to smoking-related pictures. In the dot-probe task the categories were: 1. Smoking-related and valid, 2. Smoking-related and invalid, 3. Neutral and valid and 4. Neutral and invalid. In the first task a total of six components could be identified. These are P1, N1, P2, N2, P3 and LPP. P1 was defined as a positive peak occurring between 130 and 220 ms. N1 is a negative peak in the 80-150 ms time range. The positive P2 ranges from 300 to 400 ms. The N2 was captured in a 220-300 ms time window. The P3 was measured from 500 to 750 ms and finally the LPP is mean activity in the 750-1500 time range. Of all peaks mean amplitude was used for analysis. For the passive task a 2 (cue) x 4 (site) repeated measures ANOVA was conducted at an alpha of .05. Post-hoc bonferonni tests were conducted to reveal specific differences. In the second task only two components of interest were found, the P1 and N1. Here the P1 ranged from 110 to 150 and the N1 from 150 to 190. A 2 (cue) x 2 (validity) x 4 (site) repeated measures ANOVA was conducted with an alpha of .05. In both repeated measures ANOVAs smoke status acts as between-subjects factor. When needed Greenhouse-Geisser corrections were applied. Finally, Spearman correlation coefficients were calculated between difference scores of (e.g. P3smoke – P3 neutral) ERP components of both tasks and SAM ratings, QSU-score, FTND and smoking and cessation duration, between RT and P1 & N1 amplitudes and between RTs and SAM ratings, QSU-score, FTND and smoking and cessation duration. All correlations were interpreted at an alpha of .01 in order to correct for multiple testing. For all statistical testing SPSS-12 was used.

3. Results

3.1. Passive task

The results section is divided into two parts. The first part covers the passive task and all the results related to this task. The second part will describe every result associated with the dot-probe task. Furthermore, only significant results will be reported. However, if an effect is expected, but turns out to be non-significant, it will also be reported.

3.1.1. ERP effects

Statistical analysis of the P1 and N1 component revealed expected effects (Figure 2). Investigating the P2 waveform several effects were found. First of all a main effect of Cue was present ($F(1,39) = 21.55$, $p < .000$). Peak amplitude on smoking-related cues were higher ($M = 5.74$, $SD = .67$) than amplitudes on neutral cues ($M = 3.91$, $SD = .70$). Secondly, a Cue x Smoke status interaction effect was found ($F(1,39) = 6.76$, $p = .013$). Post-hoc tests revealed that this effect was due to a significant difference in response to cues in the smokers group ($F(1,39) = 25.60$, $p < .000$). In this group, peak amplitudes on smoking-related cues were higher (see table 2). Thirdly, a cue x site interaction effect was found ($F(2.11,82.24) = 11.95$, $p < .000$). Post-hoc tests revealed that smoking related cues elicited higher responses than neutral cues in three locations: Pz (respectively, $M = 9.46$, $SD = .90$, $M= 7.71$, $SD = .97$; $F(1,39) = 12.01$, $p = .001$), Fz (respectively, $M = .57$, $SD = .80$, $M = -2.36$, $SD = .80$; $F(1,39) = 31.29$, $p < .000$) and Cz (respectively, $M = 3.648$, $SD = .85$, $M = 1.33$, $SD = .82$; $F(1,39) = 18.87$, $p < .000$). Finally, a cue x site x smoke status effect ($F(2.11,82.24) = 4.008$, $p = .02$) was found. Post-hoc tests showed that smokers reacted more strongly on smoking-related cues than on neutral cues in the locations Pz (respectively, $M = 10.05$, $SD = 1.28$, $M = 7.38$, $SD = 1.39$; $F(1,39) = 13.63$, $p = .001$), Fz (respectively, $M = .630$, $SD = 1.14$, $M = -3.78$, $SD = 1.14$; $F(1,39) = 34.54$, $p < .000$) and Cz (respectively, $M = 4.13$, $SD = 1.22$, $M = .25$, $SD = 1.17$); $F(1,39) = 25.63$, $p < .000$). This effect was not present in non-smokers.

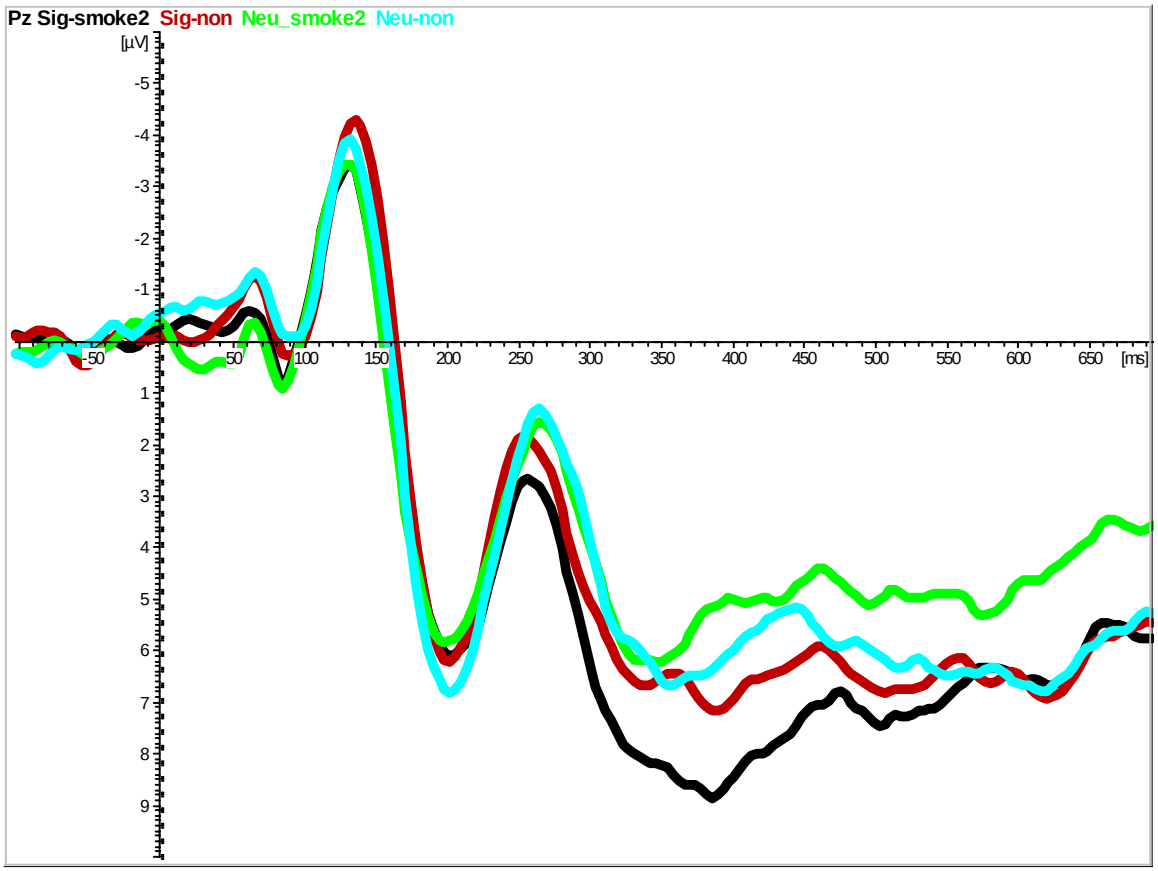

Figure 2. Average event-related potentials at Pz site for smokers (smoke2) and non-smokers (non) in response to neutral (Neu) and smoking-related (Sig) stimuli in the passive task.

	Smokers		Non-smokers	
	M	SD	M	SD
Neutral stimuli	3.11	1.01	4.71	.98
Smoke stimuli	5.98	.95	5.51	.93

Table 2. Mean amplitudes of P2 component in µV averaged over Pz, Oz, Fz and Cz for both groups on both cues

Analyzing N2 component revealed three effects. Firstly a main effect of cue was visible ($F(1,39) = 7.50$, $p = .009$). Neutral cues produced a more negative (M = -2.19, SD = .525) peak than smoking-related cues did (M = -1.01, SD = .561). Secondly a cue x site interaction effect was observed ($F(2.07,80.84) = 14.36$, $p < .000$). Post-hoc tests revealed this effect was due to a more negative peak on neutral cues (M = -8.34, SD = .81) than to neutral cues (M = - 6.05, SD = .87) at location Fz ($F(1,39) = 17.88$, $p < .000$). On location Cz neutral cues (M = -5.52, SD = .78) were more negative than smoking-related cues (M = -3.63, SD = .84) as well ($F(1,39) = 10.47$, p

= .002). Finally a cue x site x smoke status effect (see table 3) was found (F(2.07,80.84) = 19.09, p = .032). Post-hoc tests pointed out that neutral cues elicited a more negative peak than smoking-related cues in smokers on Fz (F(1,39) = 21.33, p < .000) and Cz (F(1,39) = 9.16, p = .004).

	Smokers		Non-smokers	
	M	SD	M	SD
Pz				
Neutral stimuli	.57	1.08	.334	1.06
Smoke stimuli	1.51	1.07	.761	1.04
Oz				
Neutral stimuli	4.35	1.01	4.95	.98
Smoke stimuli	4.20	.95	4.78	.92
Fz				
Neutral stimuli	-9.50	1.16	-7.18	1.13
Smoke stimuli	-5.92	1.25	-6.18	1.22
Cz				
Neutral stimuli	-6-25	1.11	-4.78	1.09
Smoke stimuli	-3.72	1.20	-3.53	1.17

Table 3. Mean amplitudes of N2 component in μV for both groups on both stimuli separated for all four locations

Analysis of the P3 component revealed four effects. A main effect of cue was found (F(1,39) = 6.82, p = .013). A higher P3 amplitude was found in response to smoking-related cues (M = 7.13, SD = .50) in comparison with neutral cues (M = 5.46, SD = .64). A cue x smoke status interaction effect was present (F(1,39) = 4.29, p = .045). Post-hoc analyses showed that smoking-related cues (M = 7.35, SD = .72) elicited a stronger response than neutral cues (M = 4.36, SD = .92) in smokers. Thirdly a cue x site interaction effect was present (F(2.25,87.86) = 11.52, p < .000). Further analyses pointed out that smoking-related cues elicited a stronger response compared to neutral cues in locations Fz (F(1,39) = 13.59, p = .001; M = 4.99, SD = .53 and M = 2.37, SD = .71) and Cz (F(1,39) = 11.02, p = .002; M = 7.83, SD = .66 and M = 5.38, SD = .81). Finally a cue x site x smoke status interaction effect was found (F(2.25,87.86) = 32.01, p = .003). Analysis of means (table 4) revealed at the Fz location smokers exhibited a reduced response to neutral cues compared to non-smokers. Furthermore, smokers react significantly stronger to smoking-

related cues than to neutral cues in locations Pz ($F(1.39) = 4.41$, $p = .042$), Fz ($F = 23.28$ (1,39), $p < .000$) and Cz ($F = 13.51$ (1,39), $p = .001$).

	Smokers		Non-smokers	
	M	SD	M	SD
Pz				
Neutral stimuli	6.77	1.06	8.55	1.04
Smoke stimuli	9.12	.93	9.01	.91
Oz				
Neutral stimuli	5.84	.89	7.01	.87
Smoke stimuli	6.69	.87	6.58	.85
Fz				
Neutral stimuli	.79	1.02	3.94	1.00
Smoke stimuli	5.71	.75	4.27	.74
Cz				
Neutral stimuli	4.02	1.17	6.74	1.14
Smoke stimuli	7.90	.95	7.76	.93

Table 4. Mean amplitudes of P3 component in μV for both groups on both stimuli separated for all four locations

Looking at LPP results, the same four effects present in P2 and P3 were found. Firstly a main effect of cue ($F(1,39) = 5.55$, $p = .024$). Higher mean activity was found in response to smoking related stimuli ($M = 4.06$, $SD = .42$) compared to neutral stimuli ($M = 2.73$, $SD = .51$). Secondly a cue x smoke status effect was found ($F(1,39) = 4.80$, $p = .035$). Post-hoc analysis revealed smokers ($M = 1.63$, $SD = .73$) showed a reduced mean activity in response to neutral cues ($F(1,39) = 4.65$, $p = .037$) compared to non-smokers ($M = 3.84$, $SD = .72$). Furthermore smoking-related pictures ($M = 4.19$, $SD = .61$) evoke a higher mean activity than neutral pictures ($M = 1.63$, $SD = .73$) do in smokers ($F(1,39) = 10.92$, $p = .003$). Thirdly a cue x site interaction effect was found ($F(2.26,88.38) = 70.55$, $p < .000$). Post-hoc tests showed that this effect was due to higher mean activity on smoking-related cues compared to neutral cues in locations Fz ($F(1,39) = 11.34$, $p = .002$; $M = 2.05$, $SD = .53$ and $M = -.13$, $SD = .66$) and Cz ($F(1,39) = 12.66$, $p = .001$; $M = 5.02$, $SD = .62$ and $M = 2,82$, $SD = .66$). Finally a cue x site x smoke status effect was found ($F(2.26,88.38) = 19.20$, $p = .025$). Further analysis revealed that on the Fz location smokers showed a decreased mean activity compared to non-smokers on neutral cues ($F(1,39) = 4.44$, $p =$

.042). Furthermore smokers showed an increased mean activity on smoking-related cues compared to neutral cues on the Fz ($F(1,39) = 20.30$, $p < .000$) and Cz ($F(1,39) = 15.51$, $p < .000$) location. A similar effect was marginally significant at the Oz location ($F = 3.81$ (1,39), p .058).

	Smokers		Non-smokers	
	M	SD	M	SD
Pz				
Neutral stimuli	3.78	.86	5.81	.84
Smoke stimuli	5.71	.76	5.82	.74
Oz				
Neutral stimuli	2.64	.74	4.25	.72
Smoke stimuli	3.32	.78	3.52	.76
Fz				
Neutral stimuli	-1.51	.94	1.26	.92
Smoke stimuli	2.67	.75	1.44	.73
Cz				
Neutral stimuli	1.60	.94	4.04	.92
Smoke stimuli	5.08	.88	4.95	.86

Table 5. Average activity of LPP component in μV for both groups on both stimuli separated for all four locations

3.1.2. Self-report effects

Analysis of SAM-ratings was done by two repeated measures ANOVAs. One covering valence, the other covering arousal (see table 6). Inspection of valence ratings revealed several significant effects. In the first place there was a significant main effect of stimulus category ($F(1,39) = 23.93$, $p < .000$). Further inspection showed that smoking-related pictures ($M = 891.41$, $SD = 38.20$) were generally judged as less appealing than neutral pictures ($M = 724.53$, $SD = 26.63$). In the second place there was a significant stimulus category x smoke status interaction effect ($F(1,39) = 14.45$, $p < .000$). Post-hoc analysis showed that there was a significance difference ($F(1,39) = 10.39$, $p = .003$) in ratings on smoking-related stimuli between smokers and non-smokers, with smokers rating smoking-related as more positively valenced. Also, there is a significant difference ($F = 38.73$ (1,39), $p < .000$) in how non-smokers rated neutral pictures compared to smoking-related pictures. Analysis of arousal revealed only a main effect of stimulus category

(F(1,39) = 23.96, $p < .000$). Smoking-related pictures (M = 642.19, SD = 57.35) proved to cause more arousal than neutral pictures (M = 460.09, SD = 37.94).

	Smokers		Non-smokers	
	M	SD	M	SD
Valence				
Neutral stimuli	731.05	38.11	718.00	37.19
Smoke stimuli	768.25	54.68	1014.57	53.37
Arousal				
Neutral stimuli	487.05	54.31	433.14	53.00
Smoke stimuli	724.90	82.09	559.48	80.11

Table 6. Average rating score for valence and arousal for both groups on both stimuli. A high score in valence reflects a negative judgment. A low score in valence reflects a positive judgment. A high score in arousal reflects high arousal and a low score reflects low arousal.

3.1.3. Correlations

Correlating FTND, SAM, QSU, smoking duration (for smokers), smoking cessation duration (for smokers), amount of cigarettes smoked (for non-smokers) and time of last cigarette (non-smokers) revealed no significant results. Correlating these variables with difference scores (e.g. P1 on smoking-related cues – P1 on neutral cues for all four locations) off all components revealed no significant effects as well.

3.2. Dot-probe

3.2.1. ERP effects

Visual inspection of the P3 component on the cues, was not possible due to high overlap with other components. No expected waveform pattern could be distinguished. Examining the analysis of the P1 component evoked by the targets revealed only one significant effect. This is a validity x site x smoke status interaction effect (F(3,117) = 17.73, $p = .019$). Post-hoc tests revealed a significant difference between smokers and non-smokers in both valid and invalid trials on locations Pz and Oz. More specifically, on location Pz, on valid trials, smokers (M = 3.78, SD = .60) showed an enhanced P1 amplitude (F(1,39) = 4.27, $p = .036$) compared to non-smokers (M =

1.97, SD = .58). Furthermore, on location Pz, on invalid trials, smokers (M = 4.17, SD = .72) showed an enhanced P1 amplitude (F(1,39) = 4.39, *p* = .043) compared to non-smokers (M = 2.07, SD = .70) as well. Similarly, on location Oz, on valid trials, smokers (M = 2.69, SD = .43) showed an increased P1 amplitude (F(1,39) = 6.93, *p* = .012) in comparison with non-smokers (M = 1.12, SD = .42). Finally, on location Oz, on invalid trials, smokers (M = 3.16, SD = .50) showed an increased P1 amplitude (F(1,39) = 8.87, *p* = .005) in comparison with non-smokers (M = 1.08, SD = .49). Next to the above described interaction effect, there is a marginally significant validity x cue x smoke status interaction effect (F(1,39) = 3.77, *p* = .063) appeared. Further inspection shows a significant difference (F(1,39) = 11.61, *p* = .002) between smokers (M = 2.12, SD = .46) and non-smokers (M = -.08, SD = .45) on a valid trial cued by a neutral stimulus. On invalid trials, cued by a smoking-related stimulus, smokers (M = 2.30, SD = .55) show an increased P1 amplitude (F(1,39) = 6.94, *p* = .012) in comparison with non-smokers (M = .26, SD = .54).

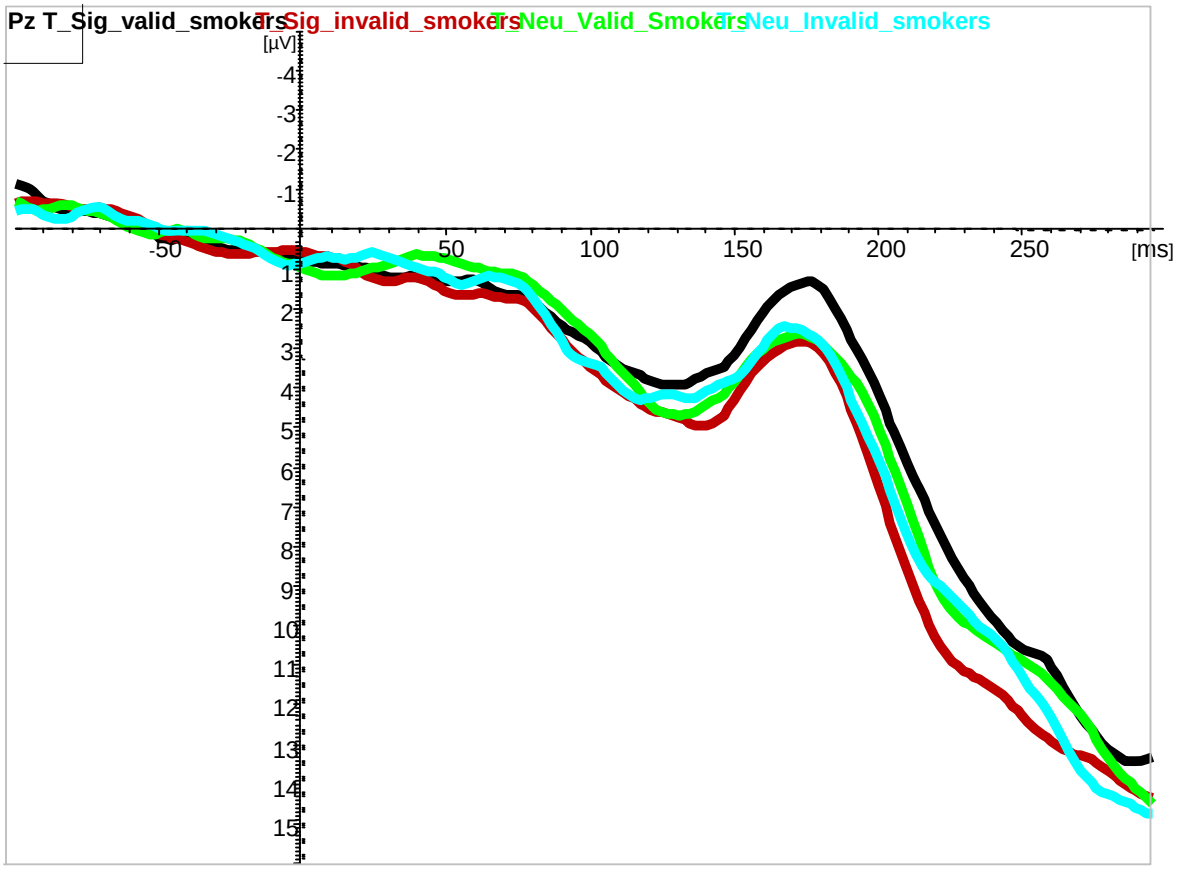

Figure 3. Average event-related potentials at Pz site for smokers in response to neutral valid, neutral invalid, smoking-related valid and smoking-related invalid trials in the dot-probe task

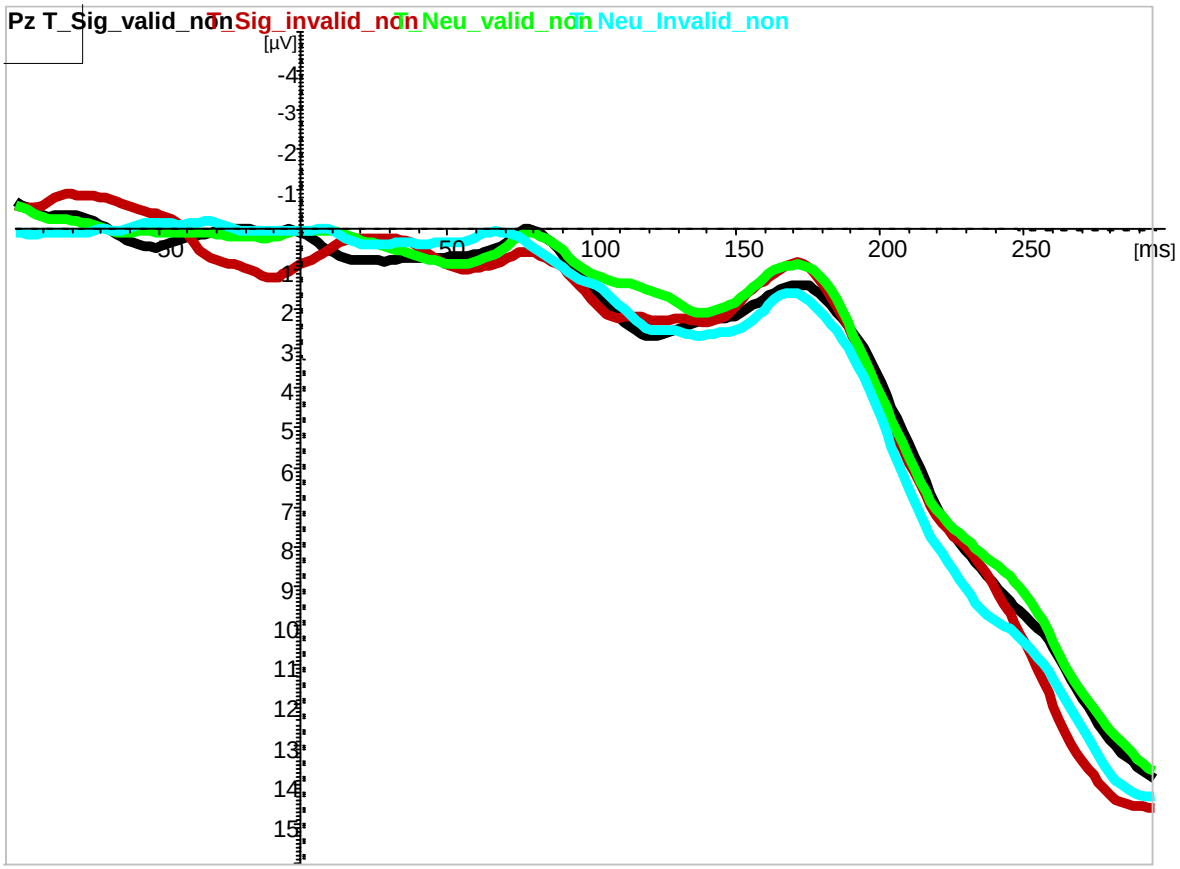

Figure 4. Average event-related potentials at Pz site for non-smokers in response to neutral valid, neutral invalid, smoking-related valid and smoking-related invalid trials in the dot-probe task

Investigating N1 results a significant validity x cue x site x smoke status interaction effect was found ($F(3,117) = 11.01$, $p = .049$; see table 7). Post-hoc testing showed that this effect was due to several effects. Firstly, a significant difference ($F(1,39) = 5.12$, $p = .029$) was found between responses on neutral ($M = .25$, $SD = .61$) and on smoking-related cues ($M = -.091$, $SD = .55$) on invalid trials at the Oz location in non-smokers. Secondly, a significant difference ($F(1,39) = 4.41$, $p = .042$) was found in smokers between valid ($M = 1.49$, $SD = .97$) and invalid trials ($M = 2.93$, $SD = 1.02$) at the location Cz, on smoking-related cues. Thirdly, a significant difference ($F(1,39) = 4.92$, $p = .033$) between smokers ($M = 1.51$, $SD = .53$) and non-smokers ($M = -.13$, $SD = .52$) at the Oz location on valid trials initiated by neutral cues. And finally a significant difference ($F(1,39) = 8.68$, $p = .005$) exists between smokers ($M = 1.41$, $SD = .56$) and non-smokers ($M = -.91$, $SD = .55$) at the Oz location on invalid trials initiated by smoking-related cues.

		Smokers		Non-smokers	
		M	SD	M	SD
Pz					
Valid	Neutral cue	2.86	.90	1.24	.88
	Smoke cue	1.85	1.02	1.59	.99
Invalid	Neutral cue	2.89	.94	1.86	.92
	Smoke cue	3.27	.90	.94	.88
Oz					
Valid	Neutral cue	1.51	.53	-.13	.52
	Smoke cue	.821	.57	-.03	.55
Invalid	Neutral cue	1.55	.63	.25	.61
	Smoke cue	1.41	.56	-.91	.55
Fz					
Valid	Neutral cue	.69	.77	.59	.76
	Smoke cue	1.43	.77	.37	.75
Invalid	Neutral cue	.88	.96	1.33	.94
	Smoke cue	1.38	.84	.38	.82
Cz					
Valid	Neutral cue	2.14	.87	1.23	.85
	Smoke cue	1.49	.97	1.63	.95
Invalid	Neutral cue	1.97	1.02	2.08	.97
	Smoke cue	2.93	1.02	.84	1.00

Table 7. Mean amplitude of N1 component in μV for both groups on valid and invalid trials cued by neutral and smoking-related stimuli for all four locations

3.2.2. Reaction Times

A main effect of validity was found ($F(1,39) = 17,23$, $p < .000$). RTs on valid trials (M = 290. 87, SD = 6.61) were higher than RTs on invalid trials (M = 283.83, SD = 6.37). In addition, a marginally significant validity x smoke status interaction effect ($F(1,39) = 3.51$, $p = .069$) was further investigated. Pairwise comparisons indicated that smokers were faster ($F(1,39) = 17.71$, p

< .000) on invalid trials (M = 277.97, SD = 9.12) than on valid trials (M = 289.63, SD = 9.46). No expected validity x cue x smoke status effect was observed (F(1,39) = .005, p = .942).

3.2.3. Self-report effects

Analyzing SAM arousal ratings for dot-probe stimuli revealed a main effect for stimulus category (F(1,39) = 5.37, p = .026). Further inspecting this effect showed a higher score for smoking-related stimuli (M = 639.40, SD = 70.80) than for neutral stimuli (M = 550.96, SD = 58.24), meaning smoking-related stimuli were rated more arousing (see table 8).

	Smokers		Non-smokers	
	M	SD	M	SD
Neutral cues	605.15	83.37	496.76	81.36
Smoke cues	695.75	101.34	583.05	98.90

Table 8. Average arousal rating scores for both groups on both stimuli

Investigating SAM valence ratings, a main effect of stimulus category was found (F(1,39) = 14.14, p = .001). Comparison of means showed that smoking-related pictures (M = 1121.49, SD = 40.85) were rated higher than neutral pictures (M = 962.98, SD = 32.11), meaning smoking-related pictures were judged more negatively. Furthermore, for valence ratings a stimulus category x smoke status interaction effect was found (F(1,39) = 5.95, p = 0.19). Post-hoc inspection pointed out that this effect was due to a significance difference (F(1,39) = 6.10, p = .018) between smokers (M = 1020.60, SD = 58.47) and non-smokers (M = 1222.38, SD = 57.06) in rating smoking-related stimuli. In addition a significance difference (F(1,39) = 19.70, p < .000) between ratings on smoking-related pictures (M = 1222.38, SD = 57.06) and neutral pictures (M = 961.00, SD = 44.85) in non-smokers (see table 9).

	Smokers		Non-smokers	
	M	SD	M	SD
Neutral cues	964.95	45.96	961	44.85
Smoke cues	1020.60	58.47	1222.38	57.06

Table 9. Average valence rating scores for both groups on both stimuli

3.2.4. Correlations

Correlations between RTs and difference scores (smoke-related – neutral) of valid and invalid ERP components were computed. All self-report variables were included as well. Again no expected significant correlations emerged.

4. Discussion

4.1. Passive task and cue reactivity

The results of the passive task in the current study replicated results other studies (Warren & McDonough, 1999; McDonough & Warren, 2001) have found in that smokers show enhanced cue-reactivity towards smoking-related stimuli, reflected mostly by an enhanced P3 component. These effects can also be found in other substance-related addictions, for instance in alcohol (Herrman, Weijers, Wiesbeck, Boning & Fallgatter, 2001) and in heroin (Franken, Stam, Hendriks & Van den Brink, 2003). These results are further supported by behavioral data using dot-probe and emotional stroop tasks. Waters & Feyerabend (2000) used an emotional stroop task to display an attentional bias in smokers. Using a dot-probe task Franken et al. (2000) found an attentional bias in cocaine abuse patients. Using a dot-probe Waters et al. (2003) and Ehrman et al. (2002) found an attentional bias in smokers. Clearly, there is enough evidence to support the presence abnormal attentional processes in substance dependent individuals. The same appears to be true for the smokers, who participated in the present study.

Other ERP components were analyzed as well. The P1 and N1 component revealed no significant effects in the passive task. This was to be expected since they reflect spatial attention or attentional shifts, which was not relevant in current task. Franken et al. (2003) found no effects in N1 component either. They make no mention the P1 component. On the other hand however, Hermann et al. (2001) did find a significant effect on the N1 component, which was decreased in heavy drinkers, but not in light social drinkers. It is unclear how this discrepancy can be

explained. In their study they did not find an effect on the P1 component, which is concordance with this study.

Current results show significant differences for P2 and N2 components. An increased P2 and an decreased N2 were observed. Franken et al. (2003) only report findings for P2, which resulted in no significant effects. Similarly Herrman et al. (2001) found no results for both the P2 and N2 component. A possible explanation for these contradictory results could be that in current study pictures were shown several times, whereas in both other studies pictures were only viewed once. Perhaps viewing a picture more than once could lead to faster recognition. This then would be visible in the components P2 and N2, preceding the P3.

In conclusion, the postulated hypotheses were mainly confirmed. The cue x smoke status interaction effect, which is interesting for answering the research questions, was present in the P2 component, in the P3 component, and in the LPP.

4.2. Dot-probe and attentional bias

Results of the dot-probe task were more difficult to reconcile with existing literature. As described above an attentional bias was found in substance dependent individuals, using either a dot-probe task (Waters et al. 2003; Ehrman et al. 2002; Franken et al. 2000) or an emotional stroop task (Waters & Feyerabend, 2000). In the current study smokers should have been faster on valid smoke trials. Since their attention is drawn towards that location by the preceding smoke stimulus. This should not be the case for non-smokers and on invalid trials. On invalid trials smokers should perform worse than non-smokers when a smoke cue is preceded. Results show exactly the opposite, however. Smokers were faster on invalid trials than on valid trials, even though overall interaction effect was marginally significant. These results would mean that smokers would avoid smoking-related cues. ERP results of the first task however, show that smokers show an enhanced cue-reactivity. Klein (2000) provides a possible explanation for these conflicting results. One important difference between this study and the above described studies using a dot-probe task is that in this study an interval, randomly lasting between 100 and 300 ms, is present between the cue and the target. The found discrepancy can be explained by a so called inhibition of return (IOR) effect, as described by Klein (2000). When subjects attend to a certain location, processing of information in that location is facilitated. However, if the location attended to is irrelevant and if ample time is available for disengaging attention, an inhibitory after effect will arise on that location (Klein, 2000). Posner & Cohen (1984) were the first to discover this effect and they experimented with cue-target onset asynchronies. Cue-target onset

asynchronies can be seen as interval between cue and target and the duration of the cue together. Their results showed that RT was faster to targets on cued locations in comparison with uncued locations when these onset asynchronies were short. The opposite was true when onset asynchronies were longer. The crossover point they found lay around 200-300 ms after cue onset. Recall that the interval in this study randomly lasted between 100 and 300 ms and that cues were presented for 600 ms. So there is a cue-target onset asynchrony of at least 700 ms, which is well beyond the crossover point. This would explain the results found in current study and why it is discrepant with previous research using dot-probe tasks.

Examining the results of the P1, it becomes clear that on the locations Pz & Oz, smokers display an enhanced P1 irrespective of validity. This neither supports nor contradicts the presence of an altered ERP pattern. In correspondence with the IOR effect only invalid trials on smoke-related cues should now elicit an enhanced P1 in smokers. Indeed, smokers show an enhanced P1 compared to non-smokers on invalid smoke trials. This is exactly what would be expected in the presence of IOR. Consider now the results of the N1 component. On the location Cz, smokers showed an decreased N1 on invalid trials in comparison with valid trials when preceded by a smoking-related cue. Furthermore, on location Oz on invalid smoke trials smokers show a decreased N1 compared to non-smokers. Expectations on these trials would be that smokers would show an increased N1. Now, however the same situation occurs as the P2 and N2 on the passive task. The P1 component shows a marginally significant validity x cue x smoke status effect, whereas the N1 does not.

In conclusion, ERP-measurements are difficult to combine with a dot-probe task using comparable stimuli used here. One has to create an interval between cue and target in order to receive uncontaminated components of interest, on the one hand. On the other hand, one has to make sure the cue-target onset asynchrony does not exceed 200-300 ms in order to prevent the occurrence of IOR. This is difficult since cue presentation time then will have to be extremely short. Probably too short for subject to distinguish between smoking-related and neutral pictures. Furthermore the interval should not be set at a fixed length since subjects would then be invited to predict the onset of the target and thereby influencing RTs. It would therefore seem difficult to combine a pictorial dot-probe task with EEG, taking into account the above discussed issues. Picture valence might play an important role in this matter as well. Pourtois et al. (2004) presented emotional faces for 100 ms followed by a black screening lasting between 100-300 ms. They found enhanced performance when the target replaced a fearful face. When the target was replaced by a happy or a neutral face the effect was not present however. These results indicate the presence of a neural mechanism for rapid, exogenous spatial orienting towards fearful stimuli.

Current study used only positive and neutral stimuli. It seems a pictorial dot-probe and EEG can be combined using fear-related stimuli. Future research should is needed to determine this more precisely.

4.3. Questionnaire effects and correlations

SAM ratings of both tasks were according to expectations. For the stimuli of the passive task non-smokers rated smoking-related stimuli significantly more negative than smokers did. Moreover, non-smokers rated smoking-related stimuli significantly more negative than they rated neutral stimuli. Results of the stimuli rating of the dot-probe task revealed a similar pattern. Non-smokers rated smoking-related cues more negative than neutral cues. Suitably, smoking-related stimuli were judged more negatively by non-smokers in comparison with smokers. For both tests arousal showed only a main effect of stimulus category. Smoking-related pictures elicited more arousal in both smokers and non-smokers. Non-smokers can probably feel a bit disgusted by seeing the smoking-related cues. This would coincide with feelings of higher arousal. Concluding, results of SAM ratings are according to what would be expected. This means that this measurement instrument proves to be a good instrument to have subjects judge stimuli.
In contrast to the hypotheses no correlations were found between QSU-total score and ERP-components. It was expected that when subjects experience higher craving (i.e. higher QSU score), this would correlate with some of the main ERP components (P3 and LPP in the passive task and P1 and N1 in the dot-probe task).

4.4. Limitations

A limitation of this study concerns the stimuli used. Conklin (2006) investigated proximal and distal cues of smoking and their ability to elicit craving. Proximal cues are cues which lie closely to actual drug administration. These are among others lighting cigarettes, someone smoking and a pack of cigarettes. Distal cues are environmental cues, in which the drug is used. For smokers this could be pictures of for instance a bar. Her investigation showed that proximal cues elicited the strongest craving, but that smoking environmental context elicited craving as well. So an environment, without proximal cues, is also able to elicit sufficient craving. Hence, these type of cues could have been used in current study as well to broaden the stimulus range.

5. Conclusion

Even though it was not the objective of this study to test the incentive-sensitization theory (Robinson & Berridge 1993, 2000), the results can fit nicely in the framework provided by it. Cue-reactivity was found in smokers when viewing smoking-related stimuli. Non-smokers did not show an enhanced response. Furthermore, subjective ratings showed that smokers favored smoking-related pictures and non-smokers favored neutral pictures.

In the dot-probe task no expected results were found due to the presence of the inhibition of return effect. The interval between the cue and the target provided enough time for an attentional shift. This shift resulted in no enhancement in performance on smoking-related trials for smokers.

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APPENDIX

Vragenlijst

Leeftijd:…….

Geslacht: □ man □ vrouw

Hoogst genoten opleiding:…….

Ik rook: □ ja □ nee

Voor rokers:

Hoe lang rook je al?..... maanden / jaar

Ben je wel eens gestopt met roken? □ ja □ nee

Zo ja, tel alle periodes dat je ooit gestopt bent geweest bij elkaar op

Hoe lang ben je in totaal gestopt geweest?..... maanden / jaar

Voor niet rokers:

Heb je wel eens gerookt? □ ja □ nee

Zo ja, hoe lang is dat geleden?..... maanden / jaar

Om hoeveel sigaretten/haaltjes ging het toen? □ 1 haaltje □ 1 sigaret □ meerdere sigaretten

Indien je meerdere sigaretten hebt gerookt, hoeveel sigaretten waren dit?

……. sigaretten

De handvoorkeurvragenlijst

Instructie: In de volgende lijst staan vragen met betrekking tot de diverse aspecten van links- en rechtshandigheid. Beantwoord ze a.u.b. zo nauwkeurig en volledig mogelijk.

Schrijfhand

Omcirkel met welke hand je schrijft.

Links / Rechts / Op school gedwongen rechts te schrijven

Handvoorkeur

Hieronder staat een aantal activiteiten die je met je linker- of rechterhand kunt uitvoeren. Omcirkel welke hand je gewoonlijk gebruikt voor elk van deze activiteiten. Indien je het antwoord niet meteen weet, voer dan de betreffende handeling in gedachten uit. Heb je geen duidelijke voorkeur, omcirkel dan pas 'beide'.

1. Met welke hand teken je?	Linker	Rechter	Beide
2. Welke hand gebruik je om met een tandenborstel te poetsen?	Linker	Rechter	Beide
3. In welke hand houd je een flesopener vast?	Linker	Rechter	Beide
4. Met welke hand gooi je een bal ver weg?	Linker	Rechter	Beide
5. In welke hand heb je een hamer vast als je ermee op een spijker moet slaan?	Linker	Rechter	Beide
6. Met welke hand houd je een (tennis-)racket vast?	Linker	Rechter	Beide
7. Welke hand gebruik je om met een mes een touw door te snijden?	Linker	Rechter	Beide
8. Welke hand gebruik je om met een lepel te roeren?	Linker	Rechter	Beide
9. Welke hand gebruik je om met een gummetje iets uit te vlakken?	Linker	Rechter	Beide
10. Met welke hand strijk je een lucifer aan?	Linker	Rechter	Beide

FTND vragenlijst
Rokers

Kruis het antwoord aan dat het beste bij je past.

1. Hoe snel nadat je bent opgestaan, rook je meestal je eerste sigaret?

- ☐ Binnen 5 minuten
- ☐ Ongeveer 6 tot 30 minuten na het opstaan
- ☐ Ongeveer 31 tot 60 minuten na het opstaan
- ☐ Meer dan 1 uur na het opstaan

2. Vind je het moeilijk om niet te roken op plaatsen waar roken verboden is?

- ☐ Ja
- ☐ Nee

3. Welke sigaret zou je **het minst graag** op willen geven?

- ☐ De eerste sigaret/ shaggie (’s ochtends) nadat ik ben opgestaan
- ☐ Iets anders

4. Hoeveel sigaretten rook je ongeveer gemiddeld per dag?

- ☐ 1-10 sigaretten/ shaggies per dag
- ☐ 11-20 sigaretten/ shaggies per dag
- ☐ 21-30 sigaretten/ shaggies per dag
- ☐ 31 of meer sigaretten/ shaggies per dag

5. Rook je meer sigaretten gedurende de ochtend dan gedurende de rest van de dag?

- ☐ Ja
- ☐ Nee

6. Rook je ook wanneer je ziek bent en het grootste deel van de dag in bed moet liggen?

- ☐ Ja
- ☐ Nee

QSU vragenlijst

Geef voor onderstaande stellingen aan in hoeverre ze op jou van toepassing zijn.
1 = Volledig mee **on**eens 7 = Volledig mee eens

1. Op dit moment wil ik niet roken

1 2 3 4 5 6 7

2. Als ik nu mocht roken, zou ik me minder depressief voelen

1 2 3 4 5 6 7

3. Wanneer mij nu een sigaret aangeboden werd, zou ik deze direct oproken

1 2 3 4 5 6 7

4. Als ik nu aan het roken was zou ik scherper kunnen nadenken

1 2 3 4 5 6 7

5. Ik heb op dit moment ontzettende trek in een sigaret

1 2 3 4 5 6 7

6. Ik zou alles beter onder controle hebben als ik nu mocht roken

1 2 3 4 5 6 7

7. Ik zou me lichamelijk niet beter voelen als ik nu mocht roken

1 2 3 4 5 6 7

8. Ik heb een sterke drang om te roken

1 2 3 4 5 6 7

9. Op dit moment heb ik geen plannen om een sigaret te gaan roken

1 2 3 4 5 6 7

10. Als ik nu mocht roken, zou ik me minder vermoeid voelen

1 2 3 4 5 6 7

SAM vragenlijst

Tijdens het eerste experiment heb je 32 verschillende foto's gezien. Deze zijn in bijgaand boekje nog eens op een rijtje gezet.
Geef voor elke foto op onderstaande lijnstukken aan hoe aangenaam je hem vind. Geef tevens aan hoeveel de foto je doet.
Let op: Alle foto's in bijgaand boekje evenals alle lijnstukken in deze vragenlijst zijn genummerd. Zorg dat de nummers met elkaar overeen komen.

Foto 1

Ik vind deze foto……

zeer aangenaam ---------- zeer onaangenaam

't doet me niets ---------- 't doet me veel

Foto 2

Ik vind deze foto……

zeer aangenaam ---------- zeer onaangenaam

't doet me niets ---------- 't doet me veel

Foto 3

Ik vind deze foto……

zeer aangenaam ---------- zeer onaangenaam

't doet me niets ---------- 't doet me veel

Examples of stimuli of the passive task

Example of a picture-pair used in the dot-probe task