The effects of self-expansion in relationships on nicotine craving in deprived smokers:

fMRI and behavioral evidence

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Abstract of the Dissertation

The effects of self-expansion in relationships on nicotine craving in deprived smokers: fMRI and behavioral evidence

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fMRI studies have found that brain areas associated with the reward of relationship self-expansion are also the same areas that are associated with the reward of cigarettes (e.g. Aron et al., 2005; Ikemoto et al., 2006; Xu et al., 2011). This raises the possibility that one reward may be able to substitute for another, allowing self-expansion to aid in smoking abstinence and cessation. One recent study found that successful quitters experienced significantly more self-expanding experiences immediately prior to their quitting, and even unsuccessful quitters were able to abstain longer as a function of how many self-expanding experiences they had prior to their quit attempt (Xu, Floyd, Westmaas, & Aron, 2010).

The current studies build upon the idea of reward replacement by experimentally manipulating self-expansion and using fMRI to investigate whether craving attenuation is the mechanism behind this effect. In Study 1, smokers in a new romantic relationship abstained from smoking overnight and then viewed pairs of photographs in the scanner. Each pair consisted of one headshot and one object image. Headshots were either self-expanding (an image of their romantic partner) or not self-expanding (images of a friend or neutral acquaintance). Object images were either a pencil (control) or a cigarette (craving cue). When smokers viewed cigarette images alongside a photo of their partner, they exhibited less activation of areas in the brain associated with craving (cuneus, precuneus, insula, postcentral gyrus, middle occipital gyrus, and anterior cingulate) than when the cigarette image was alongside the non self-expanding photos. In Study 2, smokers in long-term relationships (at least 2 years) abstained from smoking overnight and then, while in the scanner, played a series of cooperative two-player games with their partner. Games were randomized to be either self-expanding (novel, exciting, and challenging) or merely pleasant but not self-expanding, and some versions of the games contained smoking cues. Smokers showed less craving area activations (middle occipital gyrus, amygdala, and anterior cingulate) when viewing smoking cues during self-expanding games as opposed to non self-expanding games. These studies provide evidence that self-expansion rewards can undermine craving for cigarettes. Implications for interventions and future studies are discussed.

Dedication Page

To my dad, who taught me that great science is driven by curiosity, hard work, open-mindedness, compassion and an enthusiastic willingness to admit when you're wrong.

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The effects of self-expansion in relationships on nicotine craving in deprived smokers: fMRI and behavioral evidence

Cigarette smoking is the number one preventable cause of death in the United States and health complications from smoking are responsible for one in five (438,000) deaths every year (Centers for Disease Control and Prevention [CDC], 2005). This health issue is also extremely relevant globally, and it is projected that 175 million deaths will be attributed to smoking by 2030 (World Health Organization, 2008). In the United States, roughly 21% of adults (45.3 million people) are smokers (CDC, 2006), and the prevalence of smoking is particularly high among those below the poverty line and/or with less formal education (CDC, 2009). Those who smoke are at increased risk for a large variety of illnesses including 15 cancers, lung disease, coronary heart disease, stroke, cerebrovascular disease, chronic bronchitis, acute myeloid leukemia, gastric ulcers, and emphysema (CDC, 2005; US Department of Health and Human Services, 2004). Smokers and the children of smokers (who are exposed to harmful second-hand smoking) also use significantly more healthcare services and have longer hospital stays than non-smokers and children of non-smokers (McBride, Lozano, Curry, Rosner, & Grothaus, 1998; Vogt & Schweitzer, 1985). In addition to being a health crisis, smoking is also a severe financial problem, costing $96 billion per year in the U.S. in medical expenditures and an additional $97 billion in lost productivity (CDC, 2008).

Luckily, most adult smokers in the U.S. report a desire to quit smoking completely (CDC, 2002). There are many clinical and pharmacologically based smoking cessation treatments and interventions that are available for those seeking to quit (for reviews see Fiore et al., 2008; Rose, 1996). Some commonly useful treatments include antidepressants (see Hughes, Stead, & Lancaster, 2004 for review), individual behavioral counseling (see Lancaster & Stead, 2002 for review), and nicotine replacement therapy (see Silagy, Lancaster, Stead, Mant, & Fowler, 2004 for review). Although these interventions and treatments have been shown to be effective, many smokers still do not use them (Ferguson, Shiffman, Gitchell, Sembower, & West, 2009). Part of the issue is that many treatments are costly due to the expenses required for clinical professionals, treatment centers, and/or pharmaceutical aids including nicotine replacement products. In addition to the financial cost, interventions may also be costly in terms of the time that is necessary to participate in programs. Therefore it would be extremely valuable to develop additional cost- and time effective strategies that could be used either alone or in conjunction with existing treatments for a synergistic effect.

Particularly of interest would be any interventions that could tap into behavioral phenomenon that already exist naturalistically as this would be widely accessible to all smokers (including those of low socioeconomic status and/or education level) and may also be more agreeable to smokers, which could lead to less attrition and more success in terms of smoking cessation. Additionally, interventions that could tap into behaviors that smokers already engage in, or behaviors that are pleasant (rather than aversive) may also lead those who quit to remain abstinent for longer, as these behaviors could be utilized indefinitely to help with long-term maintenance.

Reward Replaceability

The most straightforward replacement intervention has been direct nicotine replacement therapy (NRT) which replaces nicotine from smoking cigarettes with nicotine via a smokeless transporter such as transdermal patches, nasal sprays, gums, and lozenges. NRT is effective for smoking cessation and abstinence partly because smokers can slowly taper down the amount of nicotine they have in their system and thus avoid withdrawal symptoms associated from quitting smoking “cold turkey.” NRT can also be used in conjunction with other smoking cessation therapies, for higher levels of effectiveness (Silagy, Lancaster, Stead, Mant, & Fowler, 2004). However, although NRT is no more harmful than smoking cigarettes, there are health consequences associated with non-smoking nicotine use, particularly in terms of cardiovascular and immune functions (Benowitz & Gourlay, 1997; Benowitz, Porchet, Sheiner, & Jacob, 1988; McAllister-Sistilli et al., 1998). NRT therefore follows a harm-reduction model and is appropriate in cases where the harm from smoking outweighs the harm of NRT. Because of this, NRT is not recommended for long-term use (typically beyond 3 months), nor for light smokers, pregnant women, adolescents, and smokeless tobacco users (Fiore et al., 2008). NRT also carries risks in that a significant number of smokers misuse NRT by concurrently using NRT and smoking cigarettes and/or using NRT for longer than the intended period, although only a small minority of smokers develop clinical dependence on NRT (Hughes, 1989; Hughes, Pillitteri, Callas, Callahan, & Kenny, 2004). Finally, smokers also suffer from an increased risk of relapse when they cease with NRT (Medioni, Berlin, & Mallet, 2005).

Since direct simple replacement of nicotine has many limitations and risks, what about replaceability in terms of a different type of reward substituting, at least partly, for nicotine? The idea of reward substitution is not new, particularly in the context of drugs of abuse. Covariation in addictive behaviors (sometimes known as cross-addiction) occurs when the common addictive dynamics (e.g., hedonics) of certain drugs or behaviors substitute for one another (e.g., Donovan, 1988; Marks, 1990; Haylett, Stephenson, & Lefever, 2004). For example, the physiological effects of alcohol and marijuana are similar, and efforts to prevent alcohol use (including reducing perceived or real access) leads to increases in marijuana use (e.g., Alter, Lohrmann, & Greene, 2006; DiNardo & Lemieux, 2001). On the other hand, tobacco and marijuana smoking are complementary and do not act as natural substitutes, so restricting access to tobacco leads to decreases in marijuana usage (Farrelly, Bray, Zarkin, & Wendling, 2001).

Substitution and replacement occurs not only with addictive substances but also with other forms of reward such as high-fat foods. For example, Wellman, Nation, and Davis (2007) observed that rats maintained on a high-fat diet (compared to a low-fat diet) demonstrated decreased acquisition of cocaine self-administration. Additionally, Carr (2007) found that chronic food restriction increased behavioral sensitivity to drugs of abuse in animal models. This apparent substitutability may have long term effects as well, as obese people (for whom food reward may be particularly salient) are 25% less likely to develop substance abuse problems (Simon et al., 2006).

Another replaceability method is contingency management, which utilizes prizes (e.g., raffles, monetary rewards) to reward reduction in usage and/or abstinent behavior. Contingency management can effectively help with addictions associated with alcohol, tobacco, and drugs such as methamphetamines, opiods, and cocaine (Corby, Roll, Ledgerwood, & Schuster, 2000; Petry & Martin, 2002; Petry, Martin, Cooney, & Kranzler, 2000; Petry, Martin, & Simic, 2005; Roll et al., 2006; Schumacher et al., 2007; Shoptaw, Jarvik, Ling, & Rawson, 1996). Unfortunately, contingency management is mainly effective only as long as the treatment continues, and rates of relapse are high after contingency management ceases (e.g., Crowley et al., 1995; Rand et al., 1989; Stoptaw et al., 2002).

The mechanism through which the reward from substances such as nicotine can be replaced involves the neurotransmitter dopamine, which is strongly linked to the experience of reward and motivation (e.g., Woolverton, Goldberg, & Ginos, 1984) as well as the reinforcing effects of drugs (for review see Volkow, Fowler, Wang, Swanson, Telang, 2007). The brain's mesolimbic dopaminergic pathway is comprised of the ventral tegmental area (VTA), nucleus accumbens (N Acc), pre-frontal cortex (PFC), and dorsal striatum (Breiter et al., 1997; David, Segu, Buhot, Ichaye, & Cazala, 2004; Kalivas & Duffy, 1998; Ikemoto, Qin, & Liu, 2006; McBride et al, 1999; Wise & Hoffman, 1992), and plays a key role in addiction (e.g., Pierce, 2003) including the reinforcing qualities of nicotine (Corrigall, Franklin, Coen, & Clarke, 1992; Pontieri, Tanda, Orzi, & Di Chiara, 1996; Sziraki, Sershen, Hashim, & Lajtha, 2002). The hedonic effect of drugs are proportionally related to the amount of dopamine released in the striatum (e.g., Barrett, Boileau, Okker, Pihl, & Dagher, 2004) and when the dopamine response is blocked, a corresponding decrease in substance use is observed (e.g., Thomsen, Hall, Uhl, & Caine 2008). One smoking intervention utilizes bupropion (an anti-depressant widely prescribed to combat cravings in smokers attempting to quit), which inhibits neuronal dopamine uptake and thus renders nicotine much less rewarding (Brody et al. 2004; Hayford et al., 1999; Hays et al., 2001; Jamerson et al., 2001; Shiffman et al., 2000).

It is important to note that although the mesolimbic dopaminergic pathway is involved with reward, this is not simply a matter of pleasure and satiety, which are more associated with the opiod and serotonergic systems of the brain. Instead, the dopaminergic system of the brain is tied to motivation and incentive salience (e.g., Berridge & Robinson, 1998), how much we want something and will actively pursue it. This is partly the reason why addictive substances can be so difficult to resist – not just because they offer us hedonia, but because they activate a very strong sense of desire above and beyond the actual pleasure that is experienced. The dopaminergic response to addictive substances taps into the SEEKING system proposed by Panksepp (1998) and also is part of the larger Approach Coordinator Module of addiction (which includes non-dopaminergic regions of the brain such as perceptual areas) summarized by Ikemoto (2010).

When dealing with addictive substances such as nicotine that are rewarding and motivating due to dopaminergic responses, it is crucial to use replacement that is dopaminergic in nature rather than providing reward from a different system (e.g., opioids).Therefore, replaceability models need to tap into the effect of dopamine either by a direct replacement with dopamine, as when dopamine is used to replace cocaine (e.g., Goeders, & Smith, 1985) or when one addictive drug is used to replace another. Because certain behaviors and non-drug rewards may also tap into the mesolimbic dopaminergic system, it is possible that a non-drug reward may substitute for a drug award (such as monetary reward via contingency management). For example, Wilson, Sayette, Delgado, and Fiez (2008) found decreased activation of the caudate nucleus in response to monetary gains or losses among heavy smokers who were able to smoke during their study as opposed to those who could not, suggesting that the salience of monetary reward was lessened when reward was also present from nicotine.

Self-Expansion

Although there is some research on replaceability via other substances and rewards from contingency management, very little research has been done on naturalistic non-substance rewards that people are driven to pursue. This context is especially important as it is highly accessible, cost-effective, has a potential for low levels of harm, and can be easily maintained in the long term. One potential area that could be fruitful for beneficial replacement in smokers is that of self-expansion (Xu, Floyd, Westmaas, & Aron, in press).

The self-expansion model posits that people seek to expand the self to increase their physical, informational, and social resources (Aron, Aron, & Norman, 2001). It further posits that the process of attaining these resources at a rapid rate generates high levels of aroused positive affect and feelings of reward (e.g., Strong & Aron, 2006), an idea consistent with the notion proposed by Carver and Scheir (1990) that rapid progress towards a goal yields high positive affect. Thus, for example, Aron and Aron (1986) argued that the rapid formation of a new relationship is often an exhilarating experience because the partners gain access to new social circles and statuses, new information, and, most important, the perspectives and identities of their partner. The partner is "included in the self" and this inclusion of the other in the self leads to increased closeness (for review see Aron, Mashek, & Aron, 2004).

In two longitudinal studies, Aron et al. (1995) showed that from before to after beginning a new relationship there was a significant increase in the diversity of the content of the spontaneous self-concept, in self-esteem, and in self-efficacy. In a conceptually parallel series of studies, Lewandowski et al., (2006), showed reductions in the diversity of the content of the spontaneous self-concept following relationship breakup as a function of how much self-expansion was being provided by the lost relationship. Other research (e.g., Aron. Steele, Kashan, & Perez, 2006) suggests that under conditions in which a relationship is likely, people prefer partners who are dissimilar to the self (and thus offer greater opportunities for self-expansion).

Social self-expansion also appears to play a significant role in the vitality of long-term relationships. A number of surveys, laboratory, and field experiments have demonstrated that married couples who engage together in self-expanding (novel, exciting, and/or challenging) activities, show substantial increases in positive affect related to the partner, as well as increases in marital quality, compared, for example, to those assigned to pleasant, but not self-expanding activities (Aron, et al., 2000; Reissman et al., 1993; Graham, 2008). Self-expanding activities that have been effective in this way consist of activities that both members of a couple are enthusiastic about and in which they can participate jointly (e.g., hiking, attending an art class, gardening, learning to tango). Couples who engage in these types of activities experience an increase in positive affect that is associated with the partner, which also leads to greater relationship satisfaction.

Self-expansion has been studied extensively in the context of romantic relationships, both newly formed and more long term (e.g., Aron, Norman, Aron, McKenna, & Heyman, 2000; Aron, Paris, & Aron, 1995; Graham, 2008; Tsapelas, Aron, & Orbuch, 2009). But what does it have to do with drug addiction? Until recently very little has been done to show this connection. The first formal suggestion that self-expansion might substitute for an addictive substance came from Vaillant (1983), who investigated patterns of abstinence among a group of inner-city male alcoholics. Among those men in the study who ever experienced a period of abstinence, 32% happened to be in the process of beginning a new romantic relationship.

The connection became much clearer recently when self-expansion was investigated using neuroimaging techniques. Aron et al. (2005) found that persons experiencing intense attraction to a new partner, when viewing images of the partner (as compared to images of a familiar acquaintance), showed substantial activation in the mesolimbic dopaminergic system, the same brain regions involved in response to addictive drugs such as nicotine. Thus, the self-expansion of an initial intense attraction may yield such strong reward-related experiences because it activates the same neural systems as do addictive drugs. This could explain why persons who have recently begun romantic relationships report feeling a need to be with the partner -surrounding themselves with images or reminders of the person, and constantly thinking about the partner when he or she is absent (Tennov, 1999). Other studies of romantic love have also found activation of the mesolimbic dopaminergic system (especially the VTA, caudate, and ventral striatum/nucleus accumbens), although the effects (particularly for the VTA) seem to be stronger for individuals who are “madly” in love (Acevedo, Aron, Fisher, & Brown, 2011; Bartels & Zeki, 2000; Fisher, Brown, Aron, Strong, & Mashek, 2010; Ortigue, Bianchi-Demicheli, Hamilton, & Grafton, 2007; Xu et al., 2011; for review see Ortigue, Bianchi-Demicheli, Patel, Frum, & Lewis, 2010).

Self-expansion may be especially effective as it not only provides reward and activates the mesolimbic domapinergic system, but has also been shown to mitigate physical pain (through a system different from that of distraction), which potentially could help with the discomfort associated with nicotine withdrawal (Younger, Aron, Parke, ChatterJee, & MacKey, 2010).

Self-expansion also works on a more broad level by changing a person’s sense of self and identity. In the context of close relationships, as people fall in love and develop bonds they become closer and include the other in their sense of self (Aron, Mashek, & Aron, 2004). In non-relationship contexts, as people become immersed in a sport, hobby, spiritual way of thinking etc., their sense of self grows and their identity shifts to include those aspects. This process by which self-expansion changes one’s sense of identity can be quite useful in dealing with an addiction, as successful quitters often change their sense of identity from that of a drug-user to something more healthy, an idea that is part of something termed Gradualism (see Kellogg & Kreek, 2005 for review).

Past research on self-expansion as an aid in smoking abstinence and cessation by Xu, Floyd, Westmaas and Aron (2010) found that smokers who successfully quit experienced significantly more self-expanding events in their lives prior to their quit attempt than smokers who tried to quit but ultimately failed. Even among the smokers who attempted to quit but failed however, self-expansion was beneficial in that there was a significant positive correlation between number of self-expanding events prior to the quit attempt and how long smokers were able to abstain.

Finally, because self-expansion is something that naturalistically occurs and that people pursue in their daily lives, an intervention utilizing self-expansion could be quite appealing to smokers seeking to quit (encouraging a low attrition rate), could be highly cost-and-time efficient, could be utilized with other smoking interventions for a synergistic effect, and could be used safely in the long-term to help with maintenance. Therefore self-expansion research in the context of smoking cessation and abstinence is highly important and with the potential to be extremely useful.

The Present Research and Hypotheses

Although many effective interventions for smoking exist, none are fully effective and many have severe limitations including not being suitable for all smokers, being extremely time and/or financially costly, being unpleasant for smokers to participate in, not suitable for long-term use, and having a high risk of relapse after the completion of the intervention. The present project sought to investigate a new method for addressing smoking abstinence and cessation via a replacement model that aims to circumvent some of the limitations of currently available interventions by utilizing naturally occurring self-expanding events/activities that are fairly universal, extremely cost effective, inherently pleasurable, and potentially maintainable indefinitely.

The current research examined addiction and social self-expansion in relation to both reward and craving for reward (e.g. desire for a cigarette). Although self-expansion can consist of activities/events that do not involve another person, since the majority of self-expansion research has been conducted with individuals intensely in love, we sought to keep the context similar for the current research.

Previous research distinguishing brain regions involved specifically in craving have noted involvement of the anterior cingulate, orbitofrontal cortex (OFC), occipital cortex, superior frontal gyrus, ventral striatum/nucleus accumbens (NAcc), thalamus, amygdala, posterior cingulate, cuneus, precuneus, fusiform gyrus, cerebellum and insula (Brody et al., 2002; Brody et al., 2004; David et al., 2005; Due, Huettel, Hall, & Rubin, 2002; Franklin et al., 2007; Goldstein & Volkow, 2002; Lee, Lim, Wiederhold, & Graham, 2005; Lim et al., 2005; Maas et al., 1998; McBride, Barrett, Kelly, Aw, & Dagher, 2006; McClernon, Hiott, Huettel, & Rose, 2005; McClernon, Kozink, Lutz, & Rose, 2009; Naqvi, Rudrauf, Damasio, & Bechara, 2007; Wang et al., 2007; Wilson, Sayette, Delgado, & Fiez, 2005; Zubieta et al., 2005). These areas overlap somewhat with reward regions (e.g., Aron et al., 2005; Ikemoto, Qin, & Liu, 2006), but mostly are quite distinct. Central to our predictions is the idea that the craving and reward areas of the brain, although distinct, are intrinsically connected, such that an increase in reward should correspond to a decrease in craving (e.g., Breiter et al., 1997).

The similarity of responses to reward from nicotine and social self-expansion in the brain's mesolimbic dopamine pathway prompts investigation as to the substitutability of one reward for the other, in this case, substituting a social self-expansion reward to satisfy a nicotine craving. If successful, this could lead to inexpensive and appealing intervention programs to aid smokers in their cessation attempts that may be especially effective if combined with drug therapy that can target negative effects of quitting such as withdrawal symptoms and/or behavioral and cognitive therapy that can help identify and deal with motives for smoking. It may also be extremely helpful in targeting a time-frame for quit-attempts, such that it may be easier to attempt to quit when a person is experiencing high levels of self-expansion.

The current research aimed to investigate how reward from self-expansion could replace the reward from smoking, potentially through a mechanism of craving reduction. The research also aimed to expand understanding of the brain's reward and craving systems in the context of social relationships. We predicted the following:

Hypothesis 1: The self-expansion experienced with the onset of a romantic relationship will undermine cravings for nicotine as measured via self-reported levels of craving as well as activation in brain areas associated with craving (tested in Study 1).

Hypothesis 2: This same pattern will be found with long-term romantic partners: Reward from the self-expansion of participating in a shared novel and exciting activity will undermine nicotine cravings such that there will be lower levels of reported craving and less neural activation in brain areas associated with craving (tested in Study 2).

In sum, the specific aims of the present research were to determine (a) whether the reward from nicotine engages the same neural systems as the reward from social self-expansion in the context of a new romantic partner or of shared novel/challenging activities with a long-term romantic partner, and (b) whether social self-expansion rewards can undermine craving for nicotine. This research advances our general understanding of reward and craving processes in the context of addiction, self-expansion and relationship processes. This research also advances our understanding a dramatically different and entirely novel approach to undermining addiction to nicotine.

Study 1

Method

Participants. Participants were 18 male Han-Chinese smokers who smoked at least eight cigarettes per day, had been smoking at least six months, and who reported being in a non-long-distance romantic relationship with a non-smoking partner for whom they felt intense passionate love (partner's non-smoker status was to ensure that partner did not act as a smoking cue). We were interested in recruiting smokers in relationships with non-smokers, and since rate of daily smoking is quite high for men in China (48.9%) and extremely low for women (3.25%), we recruited men for this study (Qian et al., 2010). Participants reported smoking on average 15.78 cigarettes per day (*SD* = 7.83), and that they had been smoking between six months and ten years with a mean of 4.42 years (*SD* = 2.70). We originally aimed to only recruit participants who were in the early stage of their relationship (roughly one year or less), but due to the difficulty of recruiting participants who met this criteria, six participants were accepted into the study who met all other criteria but had been with their partner for more than fourteen months (but no more than three years). Overall, participants were with their partner for an average of 14.22 months (*SD* = 10.97). All participants reported being intensely in love with their partner and completed the Passionate Love Scale (PLS; Hatfield & Sprecher, 1986; see Measures subsection).

Participants scored an average of 108.5 (*SD* = 11.49) on the PLS (possible scores range from 15-135), which is indicative of extreme passionate love, and there was no statistically significant difference in terms of PLS score for those who had been with their partner for fourteen months or less and those who had been with their partner between fifteen months and three years, $F(1, 16) = 1.66$, $p = .22$. Although, as expected and common in the relationship literature, there was an overall negative correlation between PLS and relationship length, $r(18) = -.47$, $p = 0.049$.

Participants were recruited from campuses of various Beijing colleges and universities including Beijing Normal College, Peking University, and China Agricultural University by flyers and emails sent to student listservs seeking participants who met the above inclusion criteria as well as through word of mouth and by asking participants to refer their friends who might qualify for the study. Students were targeted for recruitment since they report a high rate of beginning new romantic relationships (e.g., Aron et al., 1995) and because this population has been used in previous fMRI studies on early-stage romantic love (e.g., Aron et al., 2005), including one study conducted in China with very similar participants (Xu et al., 2011). The study was approved by the IRBs at the Chinese Academy of Sciences and Stony Brook University. Participants ranged in age from 21-33 years (M = 25.11, SD = 3.03). Since we were interested in current smokers, participants were screened out of the study if they reported current attempts to quit smoking including the use of nicotine replacement products. Participants were also screened to ensure that they met the safety protocol for entering the MRI (e.g., no embedded metals), that they were not taking psychoactive medications and did not have a history of claustrophobia, head trauma, or severe alcohol and/or drug use (with the exception of nicotine). All but one participant in the study preferred their right hand.

It is important to note that while we chose to run Study 1 and 2 in different countries (China and the U.S.) for pragmatic reasons, there were no expected differences in our hypotheses based on culture. Study 1 was carried out in China in part because we recently ran a successful and related study (Xu et al., 2011) there, have an outstanding collaborative group in Beijing, and also because multi-cultural research is particularly important on a subject such as smoking, which affects global health and is an extremely serious problem in China as an estimated 34.1% of China's 1.4 billion population smoke (Yang et al., 1999). Multi-cultural research also enhances generalizability of research findings and limits the chances of results being unique to a particular cultural context.

General procedure. We screened participants who contacted us expressing interest in the study to ensure that they met the inclusion criteria and that they did not meet any of the exclusion criteria. We set up a time for participants to come into the lab at the Chinese Academy of Sciences in Beijing (participants were told to smoke normally so that a baseline measurement of carbon monoxide could be assessed). When participants arrived, they were given and completed informed consent and any questions that participants had were answered. Participants then filled out a series of questionnaires (see Measures section below). Finally, we assessed participants' baseline (normal smoking) carbon monoxide levels with a breath CO monitor. Participants had a mean CO measure in parts per million (ppm) of 14.22 (SD = 8.77) which ranged from 4 ppm to 32 ppm. These baseline measures verified that participants were smokers (cutoff was 3ppm as recommended by Cropsey, Eldridge, Weaver, Villalobos, & Stitzer, 2006). We set up a time with participants to return to the lab and complete the scanning portion of the study (this was typically done within the next couple of weeks). We asked participants to provide us with three digital photographs via email of a) their romantic partner, b) a familiar acquaintance (same sex as their partner), and 3) a same-sex close friend. Previous studies of early-stage intense romantic love did not use a same-sex close friend condition, however we thought it would be beneficial for us to include this condition as we would have a positive control condition and would be able to determine if partner effects were merely due to pleasant feelings (e.g., for a close friend) or went above and beyond this.

Participants were asked to select photographs of friends and acquaintances who were non-smokers, whom they knew for at least as long as they had dated their partner (to ensure at least similar levels of familiarity) and for whom they did not have any romantic feelings or history.

Photographs were cropped to show only the head and to ensure all head-shots were the same size.

Seven Han Chinese volunteers rated all photographs on picture quality on a 1 (extremely bad) to 7 (extremely good) scale. There were no significant differences between any of the photograph types (partner, friend, acquaintance) in terms of picture quality. Four male volunteers (a subset of the original seven) further rated the photographs of the female partners and acquaintances on physical attractiveness on a 1 (absolutely unattractive) to 7 (absolutely attractive) scale. There were no significant differences between partner photographs and acquaintance photographs in terms of physical attractiveness.

We asked participants to refrain from smoking and using any other product with nicotine (e.g., cigars, chewing tobacco, nicotine patches/gums etc) overnight for at least eight hours prior to the scanning session and informed them that this would be verified with another breath CO measure.

Participants arrived for the scanning portion of the study and were asked to change into scrubs and remove all jewelry to ensure that they did not carry any metal into the scanner. Participants who wore glasses were given a pair of plastic scanner-safe glasses in their prescription (participants who did not know their prescription tried on several pairs until they found one they were comfortable with). All participants were scanned between 2pm and 6pm. Prior to entering the scanner, participants were asked to recall memories of their romantic partner, their same-sex friend, and their neutral acquaintance. They were told to think of those memories when they saw the corresponding photographs (this is consistent with the procedures used by Aron et al., 2005 and Xu et al., 2011). We also instructed participants on a count-back task that they would be doing in the scanner. This was a task where they saw a four-digit number appear on the screen and mentally counted-back starting from that number in increments of sevens. Following the scanning, participants verbally confirmed that they followed all and that they did not experience distress in the scanner. Participants also completed a few final scales (see Measures section below). Participants were then debriefed on the study and given payment of 150 RMB (roughly $23 USD).

Scanning stimuli and procedure. Participants' data were obtained using a 3T Trio MRI scanner at the Beijing MRI Center for Brain Research. During scanning participants viewed images of people and objects in a 3 (partner vs. friend vs. acquaintance) x 3 [high craving-inducing cigarette cue (cighigh) vs. moderate craving-inducing cigarette cue (cigmod) vs. pen] block design. Images were always viewed in pairs of one person and one object together side-by-side (left-right order was randomized). A fixation point was presented at the center of the screen prior to each image pair appearing. We chose to use two different cigarette craving cues so that we could look at intensity of craving cue in our analyses. The moderate craving-inducing cue was an image of a person holding a cigarette, cropped so only the hands and cigarette were visible (see Figure 1A); the high craving-inducing cue was an image of a person lighting a cigarette, cropped so only the hands, lighter, and cigarette were visible (see Figure 1B). An image of a person holding a pen, cropped so only the hands and pen were visible (see Figure 1C) was chosen to be the control counterpoint for the cigarette images because the object is fairly similar in size, shape, and image complexity.

Each pair of stimuli images stayed on the screen for 30 seconds, and was interspersed with a serial count-back task (mentally counting backwards in increments of sevens starting from a random four-digit number) for 26 seconds (to prevent spillover of response to viewing the image stimuli). Immediately before each count-back task, participants were asked to report using their button-box how much they currently craved a cigarette, their romantic partner, and how much stress they were currently experiencing (see Measure section below). Our 3x3 design yielded nine pairs of distinct stimuli, and these were each repeated three times throughout the scanning session, yielding a total of 27 blocks (order was randomized). Due to the length of the experiment, the 27 blocks were broken down into three sets of nine blocks each, and participants were given the opportunity to take a short break (typically around a minute) between each set.

Participants viewed photographs in the scanner via an angled mirror mounted on the RF coil, allowing the photographs to be projected on a screen placed directly outside the MRI tube. Blood oxygen level-dependent (BOLD) responses and in-plane anatomical data were recorded for each participant. Images were (a) anatomical, axial T2-weighted Spin-Echo Scans: 93-ms TE, 3700ms TR, 160° flip angle, 24-cm FOV, 3-mm slice thickness, 0-mm gap, 256 X 256 matrix size, 30 slices; and (b) functional, T2* Gradient-Echo EPI scans: 30-ms TE, 2000-ms TR, 90° flip angle, 24-cm FOV, 3-mm slice thickness, 0-mm gap, 64 X 64 matrix size (0 filled into 128 X 128 before FFT and the resulting 128 X 128 images were averaged into 64 X 64 before analysis), 30 slices. Voxel size for functional images was 3.8 X 3.8 X 3.0 mm.

Measures. For all measures, questions were originally in English and were translated into Chinese by a bilingual translator and back-translated by a different bilingual translator with any discrepancies (often from idiomatic items) resolved by a third bilingual translator. Prior to scanning, participants filled out demographic information and rated the physical attractiveness of their romantic partner and their neutral acquaintance (same sex as their partner) on a 1 (not at all) to 7 (extremely) scale. Participants also rated how pleasantly they felt about their romantic partner and their close same-sex friend on a 1 (not at all) to 9 (extremely) scale. Participants also answered the question “Is your smoking a source of conflict in your relationship with…” for their romantic partner, their same-sex friend, and their neutral acquaintance on a 0 (not at all) to 5 (very much so) scale.

Next, participants filled out a series of highly reliable relationship and mood questionnaires that have often been used in the relationship literature. Participants reported how close they felt to their partner, same-sex friend, and neutral acquaintance by completing the Inclusion of Other in the Self Scale (IOS; Aron, Aron, & Smollan, 1992) for each of the three target persons in their life. The IOS is a one-item pictorial measure of closeness that is commonly used to assess closeness in relationships. The scale is scored from 1 (least amount of closeness) to 7 (most amount of closeness).

Participants also completed the Experiences in Close Relationships measure (ECR; Brennan, Clark, & Shaver, 1998), a 36-item scale that assesses attachment style dimensions, variables that consistently account for substantial variance in relationship-related behaviors. Each item is scored on a 1 (disagree strongly) to 7 (agree strongly) scale. Sample items include “I am nervous when partners get too close to me” (avoidant insecure attachment), “I often want to merge completely with romantic partners, and this sometimes scares them away” (anxious insecure attachment), and “I am very comfortable being close to romantic partners” (secure attachment).

Participants also completed the Passionate Love Scale (PLS; Hatfield & Sprecher, 1986), which assesses subjective levels of passionate love for the romantic partner. This is a 15-item measure scored on a 1 (not at all true) to 9 (definitely true) scale. Participants are told to think about their romantic partner and rate how true various statements are, for example “I have an endless appetite for affection from my partner” and “I would rather be with my partner than anyone else.”

Participants also completed Watson, Clark, and Tellegen’s (1988) Positive and Negative Affect Schedule (PANAS) which measures affect and mood. Participants were asked to think about how they felt during the past week and to rate how much they experienced a list of 20 affective adjectives (10 positive and 10 negative) on a 1 (very slightly or not at all) to 5 (extremely) scale. Example affective adjectives include “interested”, “inspired”, “proud” (positive) and “distressed”, “irritable”, “afraid” (negative).

Then participants completed a series of smoking related measures that are highly reliable and commonly used in the field. Participants completed the Cigarette Dependence Scale (CDS; Etter, Le Houezec, & Perneger, 2003), a 12-item measure that assesses subjective dependence on cigarettes. The CDS asks participants to rate their own addiction to cigarettes on a 0 to 100 scale, to report their average daily consumption of cigarettes, how soon after waking they have their first cigarette, and their agreement (from 1 totally disagree to 5 fully agree) on a series of nine questions related to smoking such as “the idea of not having any cigarettes causes me stress” and “I smoke all the time”. Participants also completed The Contemplation Ladder (TCL; Biener & Abrams, 1991), a 1-item pictorial scale used to assess participant’s current quitting stage.

Participants also completed the Wisconsin Inventory of Smoking Dependence Motives (WISDM-68; Piper et al., 2004), a 68-item measure which assesses 13 separate motives for smoking by having participants respond to statements about possible motives for smoking with a 1 (not true of me at all) to 7 (extremely true of me) scale. Of the 13 motives, four are primary dependence motives: Automaticity (e.g., “I often smoke without thinking about it”), Craving (e.g., “I frequently crave cigarettes”), Loss of Control (e.g., “Sometimes I feel like cigarettes rule my life”) and Tolerance (e.g., “I can only go a couple hours between cigarettes”), while the rest (affiliative attachment, behavioral choice/melioration, cognitive enhancement, cue exposure/associative processes, negative reinforcement, positive reinforcement, social/environmental goads, taste/sensory processes, and weight control) are secondary dependence motives (Piasecki, Piper, & Baker, 2010). Since we were interested in using the WISDM-68 to assess motives of smoking to better understand how addicted to nicotine our participants were, we only used the primary dependence motives sub-scores in our analyses.

During scanning, participants used their button-box to rate levels of craving for cigarette ("how much are you craving a cigarette right now?"), craving for partner ("how much are you craving your partner right now?"), and overall stress ("how stressed do you feel right now?") on a 1 (not at all), 2 (a little), 3 (somewhat) and 4 (extremely) scale. These assessments were taken once per block immediately after the paired-image stimuli but prior to the count-back task. This 1-4 scale was used since the button-box had four buttons. For the first participant scanned, we used a 1-10 scale via a program we created which allowed participants to use the two most lateral buttons to shift the selection on the scale on screen and one of the center buttons to make the selection. However this program had a tendency to glitch and we abandoned it for all subsequent (17) participants, and reverted to the 1-4 scale (rating results are presented only for the 17 participants who utilized the 1-4 scale).

After the scanning session, participants were asked to rate each pair of stimuli (order of presentation was randomized) that they had seen while in the scanner in terms of valence and arousal via the pictorial Self Assessment Manikin (SAM; Lang, Bradley, & Cuthbert, 1999). We chose this measure as it was pictorial and would be less prone to translational issues, and because it is a highly reliable and valid measure. These ratings were done after scanning as there was not enough time during scanning for these evaluations and we did not want to prime participants with the stimuli prior to the scanning session. Participants also rated their craving towards the two images of the cigarette and the pen (order of presentation was randomized) on a 0-9 scale.

Analyses and Results for Behavioral Data

Questionnaires and cigarette abstinence. Participants answered the question "Is your smoking a source of conflict in your relationship with…" for their romantic partner, their same-sex friend, and their neutral acquaintance on a 0 (not at all) to 5 (very much so) scale. Participants reported smoking being a significantly greater source of conflict with their partner (M = 2.33, SD = 1.71, range from 0 to 5) than with their same-sex friend (M = 1.39, SD = 1.58, range from 0 to 5), $t(17) = 2.58$, $p = .019$, as well as their neutral acquaintance (M = 1.00, SD = 1.18, range from 0 to 3), $t(17) = 4.76$, $p < .001$. There was no statistically significant difference between smoking being a source of conflict with the same-sex friend vs. the neutral acquaintance, $t(17) = 1.33$, $p = .202$.

Participants also reported how close they felt to their partner, same-sex friend, and neutral via the IOS scale (Aron et al., 1992). Participants reported being significantly closer to their romantic partner (M = 5.89, SD = 1.02, range from 3 to 7) than their friend (M = 4.39, SD = 1.29, range from 2 to 7), $t(17) = 4.92$, $p < .001$, as well as to their neutral acquaintance (M = 2.44, SD = 1.20, range from 1 to 5), $t(17) = 9.72$, $p < .001$. Participants also reported being significantly closer to their friend than their neutral acquaintance, $t(17) = 4.86$, $p < .001$.

On average, current smokers scored 38.22 (SD = 6.66) on the CDS-12, which is comparable to average nicotine dependence levels of general population samples of smokers (e.g., Etter, LeHouezec, Huguelet & Etter, 2008). For the WISDM-68 motives for smoking, participants scored on average 5.07 (SD = 1.22) for Automaticity, 3.08 (SD = 1.20) for Loss of Control, 4.74 (SD = 1.26) for Craving, and 4.52 (SD = 1.39) for Tolerance (recall ranges were from 1-7).

Prior to scanning, participants were asked to abstain from smoking overnight (for at least eight hours). Participants had a mean CO measure of 14.22 ppm (*SD* = 8.77) at baseline. After the abstinence period and immediately prior to scanning, participants had a mean CO measure of 5.83 ppm (*SD* = 2.75), which was a statistically significant drop in ppm from baseline to after abstinence $t(17) = 9.00$, $p < .001$. The difference in ppm on average was 8.39 (*SD* = 8.13) and all but one participant showed a decrease in ppm. The one participant who did not show a decrease in ppm (instead an increase from 6ppm to 9ppm) reported abstaining for 12 hours (mostly sleeping) and explained that prior to those hours he had chain-smoked 15 cigarettes in preparation for his abstinence. This high level of chain-smoking (especially as it was something he did not typically do) might explain the increase in ppm, especially as his baseline was not especially high for our sample (which ranged from 4ppm to 32ppm). As the participant reported high levels of craving due to the abstinence we decided to keep him in the study.

Scanning stimuli ratings. Participants rated the physical attractiveness of their romantic partner and their neutral acquaintance (same sex as their partner) on a 1 (not at all) to 7 (extremely) scale. Romantic partners averaged a score of 6.31 (*SD* = .60) with a range from 5 to 7. Acquaintances averaged a score of 3.38 (*SD* = 1.50) with a range of 1 to 6. Participants viewed their romantic partners as significantly more physically attractive than their neutral acquaintances, $t(15) = 8.18$, $p <.001$.

Participants rated how pleasantly they felt about their romantic partner and their close same-sex friend on a 1 (not all all) to 9 (extremely) scale. Romantic partners averaged a score of 7.56 (*SD* = 0.86) with a range from 6 to 9. Same-sex friends averaged a score of 6.22 (*SD* = 1.06) with a range from 5 to 8. Participants reported feeling significantly more pleasant about their romantic partners than their same-sex friend, $t(17) = 6.73$, $p <.001$.

Participants rated all 18 pairs of stimuli for arousal and valence. There was not a significant interaction with order (which picture was on the right vs. left), and there were no statistically significant differences based on order for any of 18 pairs, so for ease of interpretation, ratings were combined to the nine distinct pairs.

Participants' ratings for arousal (see Table 1, Figure 3) were highest for pairs of images including the partner, then for pairs of images including the close same-sex friend, and finally pairs of images including the neutral acquaintance. For partner pairs, there was no significant difference between cighigh and cigmod, however cighigh was rated marginally significantly higher in arousal than pen, $t(279) = 1.69$, $p = 0.092$. For friend pairs, there were no significant differences between cighigh, cigmod, and pen. For neutral pairs, cighigh was rated significantly higher than pen $t(279) = 2.00$, $p = 0.047$ and cigmod was rated marginally significantly higher than pen, $t(279) = 1.84$, $p = 0.067$. Across object images, partner-cighigh was rated significantly higher than both friend-cighigh, $t(279) = 5.22$, $p < 0.001$, and neutral-cighigh, $t(279) = 6.75$, $p < 0.001$. Partner-cigmod was rated significantly higher than both friend-cigmod, $t(279) = 4.15$, $p < 0.001$, and neutral-cigmod, $t(279) = 5.83$, $p < 0.001$. Friend-cigmod was also rated as marginally significantly higher than neutral-cigmod, $t(279) = 1.69$, $p = 0.092$. Partner-pen was rated significantly higher than both friend-pen, $t(279) = 5.07$, $p < 0.001$, and neutral-pen, $t(279) = 7.06$, $p < 0.001$. Friend-pen was also rated significantly higher than neutral-pen, $t(279) = 2.00$, $p = 0.047$.

Participants' ratings for valence (see Table 1, Figure 4) were highest (most positive) for pairs of images including the partner, then for pairs of images including the close same-sex friend, and finally pairs of images including the neutral acquaintance. For partner pairs, there was no significant difference between cighigh and cigmod, however cighigh was rated significantly higher in valence than pen, $t(279) = 2.00$, $p = 0.047$. For friend pairs, there were no significant differences between cighigh, cigmod, and pen. For neutral pairs, cighigh was rated significantly higher than pen, $t(279) = 2.36$, $p = 0.019$. Across object images, partner-cighigh was rated significantly higher than both friend-cighigh, $t(279) = 6.00$, $p < 0.001$, and neutral-cighigh, $t(279) = 6.96$, $p < 0.001$. Partner-cigmod was rated significantly higher than both friend-cigmod, $t(279) = 5.45$, $p < 0.001$, and neutral-cigmod, $t(279) = 8.00$, $p < 0.001$. Friend-cigmod was also rated significantly higher than neutral-cigmod, $t(279) = 2.55$, $p = 0.021$. Partner-pen was rated significantly higher than both friend-pen, $t(279) = 4.73$, $p < 0.001$, and neutral-pen, $t(279) = 7.82$, $p < 0.001$. Friend-pen was also rated significantly higher than neutral-pen, $t(279) = 3.09$, $p = 0.002$.

Participants also rated, after scanning, how much they craved a cigarette (on a 0-9 scale) while viewing each of the three object images (cighigh, cigmod, and pen). This was done so that we could assess the overall craving effect of these stimuli and check that the cigarette cues were in fact eliciting higher levels of craving than the control (pen) image. Craving ratings for the cighigh image ($M = 6.31$, $SD = 2.18$) were significantly higher than for the pen image ($M = 3.38$, $SD = 2.39$), $t(15) = 5.19$, $p < .001$. Craving ratings for the cigmod image ($M = 6.13$, $SD = 1.71$) were also significantly higher than for the pen image, $t(15) = 6.09$, $p < .001$. However, craving ratings for cighigh did not differ significantly from craving ratings for cigmod, $t(15) = 0.48$, $p = 0.637$. These ratings reflect that cigarette craving cues elicited significantly more craving than our control (pen) image. The difference in elicited craving between cighigh and cigmod, although in the right direction, did not reach significance suggesting that there may have been no difference in craving perception between these two stimuli.

Self-report during scanning. Due to glitches in the program and button-box, we could collect only very partial self-report data from the first two participants in the study. The analyses therefore were done only on the responses of the remaining 16 participants. We compared self-reported cigarette craving, romantic partner craving, and overall stress between the 9 distinct pairs of images. For cigarette craving (Table 2, Figure 5) there was no overall significant difference among the image pairs, $F(8, 401) = 1.10$, $p = 0.361$. We next ran contrast analyses between all cighigh and cigmod, cighigh and pen, and cigmod and pen combinations to assess whether craving cues were eliciting self-reported higher levels of craving. To our surprise, only for the friend pairs did cighigh ($M = 2.62$, $SD = 0.91$) significantly elicit higher craving ratings than pen ($M = 2.24$, $SD = 0.74$), $t(401) = 2.04$, $p = 0.042$, and cigmod ($M = 2.55$, $SD = 0.78$) also elicited marginally significantly higher craving ratings than pen, $t(401) = 1.68$, $p = 0.093$. For partner pairs and neutral pairs, there were no significant differences in reported cigarette craving among cighigh, cigmod, and pen images. Finally we ran contrasts for reported cigarette craving between partner-cighigh & friend-cighigh, partner-cighigh & neutral-cighigh, partner-cigmod & friend-cigmod, and partner-cigmod & neutral-cigmod. Unlike what we predicted, partner-cighigh and partner-cigmod did not exhibit significantly lower levels of reported craving than either friend-cighigh and friend-cigmod or neutral-cighigh and neutral-cigmod.

For partner craving (Table 2, Figure 6) there was a significant difference among the image pairs, $F(9, 401) = 8.79$, $p < 0.001$. Specifically, participants reported significantly higher levels of partner craving during all partner pairs (averaged across the three pairs) compared to all friend pairs (averaged across the three pairs), $t(399) = 7.08$, $p < .001$, and neutral pairs (averaged across the three pairs), $t(399) = 6.72$, $p < .001$. Partner craving across all friend pairs was not significantly different from partner craving across all neutral pairs, $t(399) = 0.32$, $p = 0.75$. This was unsurprising as when participants were viewing images of their partners, an eliciting of partner craving could be expected. Individual contrasts yielded the same pattern of results (e.g.,partner-cighigh showed significantly higher partner craving than friend-cighigh and neutral-cighigh) at the $p < .001$ level. Interestingly, neutral-pen ($M = 1.98$, $SD = 0.95$) showed marginally higher rates of partner craving than neutral-cighigh ($M = 1.76$, $SD = 0.79$), $t(399) = 1.19$, $p = 0.080$.

For stress (Table 2, Figure 7) there was no overall significant difference among the image pairs, $F(8, 401) = 0.87$, $p = 0.546$. We ran all the same contrasts as we had for cigarette craving analyses above. The only contrast of note was that partner-cighigh yielded significantly higher reports of stress than neutral-cighigh, $t(405) = 1.96$, $p = 0.050$.

Analyses and Results for fMRI Data

We analyzed functional data within the framework of the general linear model in the Analysis of Functional Neuroimages program (AFNI, http://afni.nimh.nih.gov/afni). Due to a glitch during scanning, the protocol for one participant suffered from timing issues (e.g., conditions ran for amounts of time different from what was programmed). We dropped this participant and conducted fMRI analyses on the remaining 17 participants. We performed the following preprocessing steps: For each participant, we used 3dToutcount and 3dDespike to check images for quality (both visual and automatic) and cut off outliers. We then used 3dvolreg for slice timing correction and volume registration. After motion correction, we smoothed images with 5 mm full width at half maximum (FWHM) isotropic Gaussian kernal, masked out non-brain parts of the images (using 3dAutomask and 3dcalc), and normalized the time series baseline to 100 (using 3dTstat and 3dcalc). Magnitude estimates for effects of interest were computed for each subject based on an implementation of the general linear model (3dDeconvolve in AFNI). The set of regressors were a) partner+cighigh, b) partner+cigmod, c) partner+pen, d) friend+ cighigh, e) friend+cigmod, f) friend+pen, g) neutral+cighigh, h) neutral+cigmod, i) neutral+pen, and seven additional regressors for subject head motion. The first nine regressors were then convolved with hemodynamic response function before being entered into the model. Functional images were aligned to the anatomical images using the @auto_tlrc script in AFNI. Anatomical and functional images were then projected into standard stereotaxic space (Talairach and Tournoux 1988) using the auto_tlrc function in AFNI with the ColinN27 brain in Talairach space (TT_N27) as the reference anatomical template.

We first ran whole brain analyses using a cutoff of $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels), as these were the parameters used by Xu et al. (2011). Next we reran whole brain analyses using a more stringent criterion and also after reorganizing some of our data. Specifically, since five of our participants rated the moderate cigarette cue as being more craving inducing than the high cigarette cue, for these participants we treated their moderate cigarette condition data as high cigarette and vice versa so that their data would be in line with those of the other participants. Based on our experimental design (two-way within-subject), group analyses were analyzed statistically using 3dANOVA3 .To determine cluster size significance, we performed Monte Carlo simulations of null hypothesis data using the AFNI program AlphaSim. In order to account for spatial correlation among voxels, each randomly generated image was smoothed by a Gaussian kernel corresponding to the smoothness of the residual image left over from the group analysis. We then used the program AlphaSim to determine the distribution of cluster sizes defined by a voxelwise-threshold of $p < .005$. Whole brain simulations revealed that less than 5% of null clusters exceeded 1188 mm (44 voxels), which we therefore used as our cutoff for significance.

For region of interest (ROI) analyses we were interested primarily in two regions associated with self-expansion reward in past literature, namely parts of the caudate (Aron et al., 2005) and VTA (Aron et al., 2005; Xu et al., 2011), as well as six regions associated with cigarette cue induced craving from past literature, namely the posterior cingulate (McBride et al., 2006; McClernon et al. 2009; Wilson et al., 2005), anterior cingulate (Brody et al., 2002; David et al., 2005; Lee et al., 2005; Lim et al., 2005; McBride et al., 2006; McClernon et al, 2005; Wang et al., 2007; Wilson et al., 2005; Zubieta et al., 2005), insula (Franklin et al., 2007; McBride et al., 2006; Naqvi et al., 2007; Wang et al., 2007), precuneus (McClernon et al., 2009; Lee et al., 2005; McBride et al., 2006), medial frontal gyrus (Lee et al., 2005), and superior frontal gyrus (David et al., 2005; Lee et al., 2005; McClernon et al., 2005; McClernon et al., 2009 ; Wilson et al., 2005). It is important to note that there is some overlap between these regions in terms of function, for example anterior cingulate was also anticipated by Aron et al. (2005) to be a region that may be active in early-stage intense romantic love (as people often crave their romantic partner). ROIs were defined by activation, and we focused on clusters that were prominent in our contrasts of interest. We also converted regression coefficients to percent signal change for each ROI for each condition, and used SPSS to run t-tests to compare percent signal change in our contrasts of interest.

Finally, we conducted correlation analyses between brain response and behavioral data using 3dRegAna. The statistics (p <0.005, uncorrected) were displayed as maximum intensity projections in Talairach space.

Whole brain analyses. We first ran whole brain group analyses for all our contrasts of interest [recall that we have a 3 (partner, friend, neutral) x 3 (cighigh, cighmod, pen) design]. As noted above, we accepted $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels). For the partner-cighigh vs. friend-cighigh contrast, we found activations in the left posterior cingulate, left precentral gyrus and two separate clusters in the right posterior cingulate (Table 3, Figure 13). For the partner-cighigh vs. neutral-cighigh contrast, we found activation in the right posterior cingulate and right caudate tail and deactivation in the left cuneus (Table 3, Figure 14). For the partner-cigmod vs. friend-cigmod contrast we found deactivation in the right precuneus (Table 3, Figure 15). For the partner-cigmod vs. neutral-cigmod contrast we found deactivation in the right insula and right postcentral gyrus, the right precuneus, and the left insula (Table 3, Figure 16). We also ran contrasts with cigarette cues averaged, and for the partner-cigaveraged vs. neutral-cigaveraged contrast, we found deactivations in the left middle occipital gyrus, right postcentral gyrus and right insula, right inferior parietal lobule and right angular gyrus, and right precuneus (Table 3, Figure 17).

Since there were several regions of activation/deactivation with large clusters, we were interested to see which would remain significant after more stringent analyses. We first defined cluster sizes by a voxel-wise threshold of $p < 0.005$ (uncorrected). Then we conducted Monte Carlo simulations of null hypothesis data using AlphaSim, which revealed a cluster size cutoff of 44 voxels (we then used as our threshold). We accepted whole brain analyses with $p <.05$ significance, family-wise error (FWE) corrected. For the partner-cighigh vs. friend-cighigh contrast, we found white matter activation (Table 4, Figure 18). For the partner-cighigh vs. neutral-cighigh contrast, we found activation in white matter regions and deactivation in the left middle occipital gyrus/cuneus (Table 4, Figure 19). For the partner-cigmod vs. friend-cigmod contrast we found activation in the right anterior cingulate and white matter (Table 4, Figure 20). For the partner-cigmod vs. neutral-cigmod contrast there were no significant activations or deactivations. We also ran contrasts with cigarette cues averaged, and for the partner-cigaveraged vs. neutral-cigaveraged contrast, we found deactivation in the left cuneus (Table 4, Figure 21). Partner-cigaveraged vs. friend-cigaveraged did not yield significant clusters of activation and/or deactivation at the $p < .05$ FWE corrected level. Exploratory contrasts comparing friend pairs to neutral pairs (e.g.,friend-cighigh vs. neutral-cighigh) did not yield significant activations or deactivations.

ROI analyses. We ran a series of ROI analyses of craving-related regions focusing on averaged cigarette conditions vs. pen conditions in each of the pairs (partner, friend, neutral) to confirm that cigarette cues were working. For partner-cig vs. partner-pen, we found activation in both the anterior and posterior cingulate (see Table 5). For friend-cig vs. friend-pen, we found activation in the superior frontal cortex (see Table 5). For neutral-cig vs. neutral-pen, we found activation in the medial frontal cortex as well as deactivation in the precuneus (see Table 5). The precuneus deactivation was surprising as we expected activation in this region. However, upon further review, this seems to be a separate area of the precuneus than those typically associated with craving. The precuneus is a fairly large structure and functional connectivity studies suggest that there are distinct functions and regions within the precuneus (e.g.,Margulies et al., 2009). Our deactivation cluster consisted of precuneus as well as superior/inferior parietal lobule, regions associated with somatosensory functions (e.g.,Wolpert, Goodbody, & Husain, 1998). Recall that for whole-brain analyses, we found significant inferior parietal lobule deactivation in the partner-cigaveraged vs. neutral-cigaveraged contrast.

For percent signal change analyses (we conducted t-tests for each of our contrasts of interest), we found significant differences in caudate (central Talairach coordinates 14, 18, 19), in partner-cigmod vs. friend-cigmod, $p = .028$, as well as partner-cigmod vs. neutral-cigmod, $p = .034$, and in both cases partner-cigmod had more caudate activation, suggesting that partner condition was more rewarding than the corresponding friend and neutral condition. Interestingly, we did not find any significant VTA activations differences between partner conditions and friend and neutral conditions, suggesting perhaps that the replacement paradigm works both ways and that although partner images can help attenuate cigarette craving, cigarette cues may also decrease the reward of partner images. For craving-related regions, t-tests yielded significant percent signal change in the superior frontal cortex (central Talairach coordinates -7, 52, 26) for partner-cighigh vs. neutral-cighigh contrast such that there was significantly less SFC activation in the partner condition, $p = .045$ (1-tailed).

Correlational analyses. Finally we ran correlational analyses to investigate potentially important differences based on individual variables. Specifically, we focused on two contrasts: partner-cigaveraged vs. friend-cigaveraged and partner-cigaveraged vs. neutral-cigaveraged. For all correlations, we accepted $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

In the partner-cigaveraged vs. friend-cigaveraged contrast, there were no significant correlations for length of relationship with partner or level of addiction (based on CDS scores). There were a series of significant negative correlations for partner smoking conflict (how much smoking was a source of conflict in the relationship with the partner), such that those who had higher conflict scores also showed less activation in certain regions associated with craving, including the insula, medial frontal gyrus, cuneus and bilateral precuneus (Table 6, Figure 22).

For the partner-cigaveraged vs. neutral-cigaveraged contrast there was a significant negative correlation for partner smoking conflict in the right middle frontal gyrus (Table 7, Figure 23) such that those who had higher conflict scores showed less activation in this region. There were significant negative correlations for relationship length with partner (Table 7, Figure 24) in the right inferior frontal gyrus, pons, right superior temporal gyus, left precuneus, and left middle frontal gyrus such that those with longer relationships showed less activation in these regions. There were also significant negative correlations for CDS score (Table 7, Figure 25) in left insula and right precentral gyrus such that those with higher CDS scores also showed less activation in these regions.

Discussion

Self-report responses. Arousal and valence analyses showed us that the target person (partner, close friend, or neutral) in the stimuli pair affected ratings quite strongly, with partner pairs yielding the highest arousal ratings as well as the highest (most positive) valence ratings. This was followed by close-friend pairs and then neutral-acquaintance pairs. Pairs that included cigarette cues (particularly cighigh) yielded higher ratings of arousal, which suggests that craving (from looking at the cue) may illicit a higher sense of arousal, although this effect only existed for partner and neutral pairs. Interestingly, although partner-cighigh was rated as highest among all the pairs on positive valence and arousal, it was rated to also be more stressful than neutral-cighigh suggesting perhaps that the stress associated with the stimuli may not be all negative.

Unexpectedly, pairs that included cigarette cues (particularly cighigh) also yielded higher (more positive) valence ratings, although this effect only existed for partner and neutral pairs. Also unexpectedly, our cigarette cues overall did not yield significantly higher levels of self-reported craving compared to the control images, nor did pairs containing cighigh images elicit more self-reported craving than pairs containing cigmod images. We speculate that the reason behind these unexpected results was due to methodological issues. Particularly, we asked people to assess cravings on a momentary basis (roughly every 30 seconds), which may be difficult to do accurately. Additionally, participants were only given 4 options for assessing their craving and these four options were categorized as not at all, a little, somewhat and extremely (the average response was between “a little” and “somewhat”). The low number of options and the way the options were categorized might have led to there not being enough variance for significant results to emerge. It is worth noting that past fMRI research using craving-inducing cigarette cues typically do not include a self-report component during scanning, so we could not anticipate these methodological issues.

fMRI data. Unlike the self-report responses, we got much more consistent results in line with our hypotheses when looking at brain activations. Whole-brain analyses showed us that as we hypothesized, there was less craving (more deactivation of craving) in the self-expanding image pairs (when the image of the partner was present) compared to non self-expanding image pairs. Specifically, there were significant deactivations in contrasts of partner conditions with cigarette cues vs. friend and neutral conditions with cigarette cues in regions associated with cigarette-cue craving including the cuneus, precuneus, insula, postcentral gyrus, and the middle occipital gyrus. There were also a couple of activations of note. One was the right caudate tail (for partner-cighigh vs. neutral-cighigh), a region associated with the reward of early-stage intense romantic love (Xu et al., 2011). The other was posterior cingulate, which appeared for both partner-cighigh vs. friend-cighigh as well as partner-cighigh vs. neutral-cighigh. Although the posterior cingulate is associated with craving and has been shown to be active in past research on cigarette craving cue, it is also a region that reacts to the presentation of both positive and negative emotion words (Maddock, Garret, & Buonocore, 2003). Future research would be necessary to determine if posterior cingulate activation in these contrasts were due to increased emotion in the partner-cighigh condition and/or increased craving (and whether this was craving from the cigarette cue, from the partner, or some combination). Although we cannot say definitively, it is most likely that posterior cingulate activation occurred due to craving for the partner and/or more emotion processing for the partner image, as it is unlikely that the friend image produced a higher craving attenuation effect than the partner image, as there was no other evidence of friend image leading to the effect (e.g., compared to neutral).

When we used more stringent analyses with FWE correction, we still found some significant craving deactivations for our contrasts of interest. Specifically, when contrasting partner-cighigh to neutral-cighigh, we found deactivation in left middle occipital gyrus/cuneus, a region associated with cigarette craving (e.g., Wilson et al., 2005). We also found this for partner-cigaveraged compared to neutral-cigaveraged, with deactivation in the left cuneus. Interestingly, we did not find this effect for partner-cigmod compared to neutral-cigmod, perhaps suggesting that the higher craving induction of cighigh images was necessary for the effect to show up in corrected whole-brain analyses. Similarly, we did not find our hypothesized effect when comparing partner to friend or when comparing friend to neutral, perhaps suggesting that a greater amount of self-expansion is necessary (i.e., the reward of friend over and above neutral is not enough for the effect, nor is the reward of partner over and above friend). We did however find right anterior cingulate activation for partner-cigmod compared to friend-cigmod contrast, suggesting that the partner-cigmod stimuli were associated with more craving than friend-cigmod. This may be because the positive association of the friend is leading to less craving than the partner, however this is unlikely as friend does not yield any benefits above and beyond neutral (although partner does). It is possible that this anterior cingulate activation is a function of craving for the partner (as participants report significantly greater amounts of partner craving when viewing the partner picture as opposed to viewing the friend picture) rather than craving for cigarettes, and the ACC was an area identified by Aron et al. (2005) as a region associated with early-stage intense passionate love.

Overall our whole-brain analyses showed us that there was more deactivation in regions associated with craving in partner-paired conditions vs. friend or neutral-paired conditions, although this effect was strongest (i.e., still significant after FWE-correction) when comparing partner conditions to neutral conditions. For partner-cighigh vs. friend-cighigh and partner-cigmod vs. friend-cigmod contrasts we found activations in regions associated with craving, particularly the anterior cingulate and posterior cingulate. We cannot be sure if these activations are a product of participants craving cigarettes more in partner conditions vs. friend conditions or a product of participants craving their partner more in partner conditions vs. friend conditions. However, since friend conditions did not yield a craving attenuation effect compared to neutral conditions (although partner conditions did), it is unlikely that the friend conditions are more rewarding and more craving attenuating than partner conditions.

From our ROI analyses, we found that pairs of images containing cigarette cues elicited more response in craving regions of the brain than images containing control images, suggesting the effect of our cues. ROI analyses also verified our hypothesis that there would be less craving region activation when a cigarette cue was presented alongside an image of the partner as opposed to a neutral acquaintance, suggesting that self-expansion reward can attenuate craving. ROI analyses also verified that even when cigarette images were present, partner conditions exhibited more reward activation (via caudate, although not VTA) than either friend or neutral conditions.

We also examined if different relationship and individual variables were associated with our effect. For the partner-cigaveraged vs. friend-cigaveraged contrast, smoking conflict score was significantly negatively correlated with activation in regions associated with craving (cuneus, precuneus, medial frontal gyrus and insula), suggesting that our replacement effect was more successful for those for whom smoking was a greater source of conflict in the relationship. There are a couple of potential reasons for this correlation. Perhaps smokers for whom smoking is a large source of conflict in the relationship value their relationship more and thus the image of the partner is more salient/rewarding. Another potential explanation is that smokers for whom smoking is a large source of conflict in the relationship may be primed to recall this when they view the image of their partner and may think less about smoking (and/or spend more time focusing on the image of the partner rather than the cigarette cue). Future studies would be needed to examine which (if either) of these potential reasons is the cause of this correlation, or perhaps some mixture (or perhaps an alternative explanation entirely).

For the partner-cigaveraged vs. neutral-cigaveraged contrast, smoking conflict score was also associated with our effect, being negatively correlated with activation in the left middle frontal gyrus, an attention and memory area that has been shown to be associated with cigarette craving (Brody et al., 2007). So for this contrast as well, it seems that smoking related conflict in the relationship increases the replacement effect.

Relationship length was significantly negatively correlated with activation in left precuneus and left middle frontal gyrus, as well as right inferior frontal gyrus, a region associated with craving (McClernon et al., 2005), suggesting that our replacement effect was more successful for those who had been in a relationship longer. It is important to remember that participants were all in relatively early stages of their relationships (with an average relationship length of 14 months, and no more than 3 years), so this correlation with relationship length is still in the rewarding context of relatively new relationships (recall that all participants reported intense romantic love as measured by the PLS and that there were no significant differences in PLS scores or other pertinent measures between those who were together fewer than 14 months and those who were together 15months to 3 years). It is possible that this seeming benefit of relationship length may be due to relationships becoming more stable and less volatile (e.g., obsessive) as time passes, with those who are still intensely in love but no longer in the very early stages of relationships benefiting from both early-stage relationship reward as well as the stability and attachment benefits (e.g., reduction in anxiety and stress) of longer-term relationships (Acevedo et al., 2011).

CDS was also significantly negatively correlated with activation in regions associated with craving such as the insula, suggesting that our replacement effect was more successful for those who were more heavily addicted to cigarettes. CDS was not significantly correlated with smoking conflict score, relationship length, or PLS, and we had no a priori theoretical reasons for why higher CDS would be related to a stronger attenuation effect. However, CDS was significantly negatively correlated with number of hours abstained (all participants abstained for at least eight hours), $r = -.53$, $p = .024$, so it is possible that higher CDS was related to a stronger attenuation effect mainly because higher CDS was associated with lower craving/lower cigarette cue effect (due to significantly less abstinence prior to scanning).

Study 2

Method

Participants. Couples were recruited via flyers posted on and off Stony Brook University's campus, emails to listservs and online advertisements on Craigslist and other website advertising the study. Participants were 20 couples (19 heterosexual couples, 1 lesbian couple) who were in long term relationships (at least 2 years). Each couple had at least one member who currently smoked at least eight cigarettes per day and was not attempting to quit (10 couples had both members as smokers). The smoker in the couple was the one who was scanned (if both members of the couple were smokers who met inclusion criteria and scanner screening requirements, the couple decided who entered the scanner). We were interested mostly in the scanned smoker and so unless otherwise noted; all data and results reflect only the partners who were scanned.

Participants ranged in age from 19-42 years (*M* = 24.10, *SD* = 6.17). Overall, couples' relationship length ranged from 2 years to 24 years (*M*= 3.89, *SD* = 4.84), and 4 of the 20 couples were either engaged or married, 4 were dating and living together and 12 were dating and living separately. Smokers who entered the scanner (12 men, 8 women) smoked an average of 13.25 cigarettes per day (*SD* = 8.59). Smokers began smoking on average at age 15.85 (*SD* = 3.31, range was 8 to 21) and had been smoking on average 7.97 years (*SD* = 7.59, range was 2 to 30 years). Four of the 20 participants who were scanned preferred their left hand.

General procedure. When participants contacted us expressing interest in the study, we scheduled a phone screening session. During screening, we verified that couples met all inclusion criteria and made sure the smoker was willing and able to enter the scanner safely (no history of claustrophobia, head trauma, drug use, embedded metals etc). If both members of the couple were smokers who were safe to enter the scanner, we allowed the couple to decide who would be in the scanner and who would be outside. Participants were made aware that the study consisted of two in-person sessions (where they would both have to come in to Stony Brook University), with the scan taking place during the second session (and that abstinence from smoking for at least eight hours would be required only for the scanning session). Once participants agreed to the study, we scheduled their initial session and asked that they smoke normally.

During the initial session, after informed consent, both members of the couple filled out questionnaires (see Measures subsection below) and we assessed smokers' baseline breath carbon monoxide (CO) utilizing the Bedfont Smokerlyzer. Couples then scheduled their scanning session and were sent updates and reminders that the smoker entering the scanner needed to abstain from cigarettes and all other nicotine products for at least eight hours prior to the scan.

When participants came into the lab for the second (scanning) session, they were given a pre-scan questionnaire (see Measures), a reassessment of CO level to verify abstinence, and both members of the couple played a practice round of the two-player game on a desktop with two screens (one cloned) and were given an opportunity to ask questions. The couple was then brought over to the SCAN (Social, Cognitive, and Affective Neuroscience) Center at Stony Brook University where the scanning took place (see Scanning Stimuli and Procedures below). After the scanning session was complete, participants were debriefed, thanked and compensated for their time ($60 for each member of the couple).

Scanning stimuli and procedure. The SCAN Center at Stony Brook University is equipped with a Siemens MAGNETOM Trio Tim (Total imaging matrix technology) 3 Tesla system scanner. Scanner participants viewed the program in the scanner via an angled mirror mounted on the RF coil. Blood oxygen level-dependent (BOLD) responses and in-plane anatomical data were recorded for each participant. We acquired function images via T2* Gradient-Echo EPI scans: 30ms TE, 2500ms TR, 80° flip angle, 220mm FOV, 4mm slice thickness, 64 X 64 matrix, 34 slices. Voxel size for functional images was 3.4 X 3.4 X 4.0 mm.

Non-scanner participants (the romantic partners of those in the scanner) completed their part of the two-player game outside the scanner on a desktop computer whose screen was a clone of the screen the scanner participant was viewing.

While in the scanner participants viewed 24 blocks of stimuli split up into four conditions (six blocks of each condition) presented in random order. The four conditions were a) self-expanding with cigarette cue (SECig), b) self-expanding without cigarette cue (SEnoCig), c) non self-expanding with cigarette cue (NSECig), and d) non self-expanding without cigarette cue (NSEnoCig).

Conditions a and b (both self-expanding conditions) each contained 15 trials (1.5 seconds per trial) per block and a total of 6 blocks. Conditions c and d (both non self-expanding conditions) each contained 9 trials (2.5 seconds per trial) per block and a total of 6 blocks. Thus all conditions each totaled 135 seconds (2.25 minutes) for all blocks.

Each block consisted of a series of trials where 4 black-and-white images appeared horizontally on the screen (see Figure 2A-2D for example stimuli for each condition). Images were easily recognizable everyday objects (e.g., toothbrush, pencil, screwdriver etc.). The goal of the two-player game was for each member of the couple to select as many feather images as possible by pressing corresponding buttons on a button-box (for the participant in the scanner) or the 1-4 keys on a keyboard (for the non-scanner participant). The game was cooperative such that participants each got 1 point for every feather image they correctly selected. If both members of the couple got a correct feather image, 2 points were added to their team score (which appeared at the top of the screen throughout the game). Each participant got a point subtracted for every incorrect selection of a non-feather image.

For conditions a and c (both containing cigarette cues), an image of a cigarette with smoke coming out of it appeared in at least half of the trials for those blocks. The cigarette picture never appeared more than once per trial. The self-expanding conditions (conditions a and b) had shorter trials than the non self-expanding conditions (conditions c and d) to increase the challenge and excitement (and thus self-expansion) of the blocks. In addition, self-expanding conditions contained anywhere from 0-4 feather images per trial whereas non self-expanding conditions never contained more than 1 feather image in any trial. To enhance self-expansion in conditions a and b, aside from the feather and cigarette images, images appearing in these self-expanding conditions were all novel, while images appearing in the non self-expanding conditions (c and d) were all non-novel (participants had seen these images during the practice round prior to scanning). The practice round did not contain any cigarette cues and trials were 2 seconds in length.

Immediately following each game block, participants rated their cigarette craving, how exciting and pleasant the game was, and how positive and negative they felt (see Measures section below). This was followed by a 5 second rest where the words "The next game will begin in a few seconds…" appeared on the screen.

The entire protocol contained 24 blocks of the game (six of each condition) totaling 540 seconds (nine minutes). In addition to the 24 rests (totaling two minutes), the entire protocol took 11 minutes plus however much time participants spent responding to the questions in between each block.

Measures. During the initial session (prior to the scanning session), participants filled out several questionnaires. All participants, regardless of smoking status completed demographic questions, and the PANAS (Watson, Clark, & Tellegen, 1988), as in Study 1. Participants also filled out a short form of the ECR (ECR-S; Wei, Russell, Mallinckrodt, & Vogel, 2007), a 12-item version of the 36-item ECR, using the same 1 (strongly disagree) to 7 (strongly agree) rating system. Participants also completed a short form of the Passionate Love Scale (PLS-10; Sprecher & Regan, 1998), a 10-item version of the 15-item PLS, utilizing a smaller 1 (untrue) to 6 (true) scale. Participants also completed Hendrick's (1988) Relationship Assessment Scale (RAS), a 7-item measure which examines overall relationship satisfaction using questions on a 1-7 scale including items like "How well does your partner meet your needs" and "How often do you wish you hadn't gotten in this relationship?", with dissatisfaction items reverse-scored. Participants also completed the Self-Expansion Questionnaire, a 14-item measure which examines how much the partner is a source of self-expansion by asking participants to answer questions such as "How much does your partner provide a source of exciting experiences?" and "How much does your partner help to expand your sense of the kind of person you are?" on a 1 (not very much) to 7 (very much) scale (Lewandowski & Aron, 2002). Additionally, all participants completed the Self-Expansion Satisfaction Questionnaire (White, Lewandowski, Aron, & Aron, 2004), a seven-item measure which assesses how much the need for self-expansion in general (not just in a relationship context) has been satisfied by asking participants to rate their satisfaction with various needs (e.g., "the need to gain knowledge", "the need to discover new identities") on a 1 (not at all satisfied – I would still like to do a lot more in this area) to 7 (completely satisfied – I don't need to do more in this area) scale. All participants also completed the the Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003), which asks participants how much they see themselves characterized by 10 pairs of characteristics (e.g., “extraverted, enthusiastic” and “critical, quarrelsome”) on a 1 (disagree strongly) to 7 (agree strongly) scale. Finally, all participants completed the depression subscale of the Brief Symptoms Inventory (BSI, Derogatis, & Melisaratos, 1983), which asks participants to report how much distress they experienced from six separate potential problems (e.g., “feeling lonely” and “feelings no interest in things”) during the past week on a 0 (not at all) to 4 (extremely) scale.

Also during this initial session, smokers completed an additional set of questionnaires including the Wisconsin Inventory of Smoking Dependence Motives (WISDM-68; Piper et al., 2004), the Contemplation Ladder (TCL; Biener & Abrams, 1991), and questions about how often smoking is a source of conflict in the relationship (these were the same as those used in Study 1). Additionally, smokers completed a questionnaire assessing nicotine addiction with two items (“please rate your addiction to cigarettes on a scale of 0 to 100” and “on average, how many cigarettes do you smoker per day”) pulled from the Cigarette Dependence Scale (CDS; Etter, Houezec, & Perneger, 2003) and six items (e.g., “do you smoke more during the first hours after the waking than during the rest of the day? Yes/no” and “do you smoke even when you are very ill? Yes/no”) pulled from the Fagerstrom Tolerance Questionnaire (Fagerstrom & Schneider, 1989).

Finally, baseline breath CO for smokers was assessed using the Bedfont Smokerlyzer (participants were told to smoke normally for the initial session). This was done to verify smoking status and also to obtain a baseline level to compare to for the scanning session (where the smoker in the scanner was asked to abstain for at least eight hours). Although the Smokerlyzer does not provide exact ppm data, it does give an assessment on a 1 (non-smoker) to

7 (very heavy smoker) scale, with scores of 2-3 representing low dependence levels, 4-5 medium dependence levels, and 6-7 high dependent levels. This measure was accurate enough for us to determine whether or not participants abstained from smoking by noting whether or not there was a drop from baseline CO measure to scan-session CO measure. Furthermore, the use of the Smokerlyzer helped to induce better compliance as participants believed that it could accurately gauge whether or not they abstained for the required eight hours.

During the scanning session, both members of the couple completed both a pre and post-scan questionnaire that consisted of the Inclusion of Others in the Self Scale (IOS; Aron et al., 1992), and questions asking participants to rate on a 1 (not at all) to 7 (completely) scale how happy they are generally, how happy they are in the relationship, and how committed they feel towards their partner.

During the actual scanning protocol, both members of the couple engaged in the two-player cooperative game. In between each block of the game, participants responded to five questions (always in the same order) on a 1 (not at all) to 4 (extremely) scale (scanner participants responded using their button box, non-scanner participants responded using the keyboard): a) How much are you craving cigarettes RIGHT NOW?; b) How pleasant was the game you JUST PLAYED?; c) How exciting was the game you JUST PLAYED?; d) How positive do you feel RIGHT NOW?; e) How negative do you feel RIGHT NOW?

Analyses and Results for Behavioral Data

Questionnaires and cigarette abstinence. Smokers' passionate love scores (via the PLS-10) ranged from 37 to 59 and averaged 49.30 (*SD* = 6.00) out of a maximum score of 60. Self-expansion in the relationship (via the Self-Expansion Questionnaire) ranged from 58 to 84 and averaged 71.95 (*SD* = 7.58) out of a maximum of 98. Self-expansion satisfaction ranged from 7 to 45 (out of a maximum of 49) with a mean of 30.05 (*SD* = 10.28). Depression scores via the BSI ranged from 0 to 15 (out of a maximum of 24) with a mean of 4.85 (*SD* = 4.33).

Smokers reported on whether smoking was a source of conflict in the relationship, with scores averaging 1.15 (*SD* = 1.27, recall ratings could range from 0-5).

Immediately prior to scanning, smokers' closeness to their partner (via the IOS) averaged 3.84 (*SD* = 1.34) out of 6. After the scanning (during which they played the two-player game), closeness averaged 4.45 (*SD* = 1.36), which was a marginally significant increase, $t(18) = 2.04$, $p = .056$. Smokers' general happiness (rated on a 1-7 scale) rose from an average of 4.89 (*SD* = 1.45) prior to the two-player game to an average of 5.75 (*SD* = 0.85) after the two-player game, which was a significant increase, $t(18) = 2.45$, $p = .025$. Smokers' relationship happiness (rated on a 1-7 scale) rose from an average of 5.84 (*SD* = 0.96) prior to the two-player game to an average of 6.00 (*SD* = 0.92) after the game, although this was not statistically significant.

Finally, smokers' commitment (rated on a 1-7 scale) rose from an average of 6.58 (*SD* = 0.77) to an average of 6.80 (*SD* = 0.41) after the game, although this was not statistically significant. This trend in improvements to relationship and happiness variables testifies to the two-player game being a self-expanding activity, as self-expansion leads to these sorts of increases (Aron, et al., 2000; Reissman et al., 1993; Graham, 2008). It is surprising that we find these improvements after a simple 15-20 minute two-player game, even though smokers are suffering from cigarette craving and potentially even withdrawal during the game. It is possible however that pre-to-post test differences, particularly in general happiness, are due in part to participants being tense prior to entering the scanner (as many had never been in an MRI before) and relieved at the end of the scanning session.

On average, smokers rated their level of addiction at a 70 (*SD* = 23.56) on a 0-100 scale (the first item of the CDS-12). Smokers scored on average 4.35 (*SD* = 2.18) on the Fagerstrom items (possible scores were 0-10). Baseline Smokerlyzer scores ranged from 2 to 6 (recall that possible scores ranged from 1 to 7 with 1 indicating non-smoker status) with a mean of 3.45 (*SD* = 1.36). For the WISDM-68 motives for smoking, participants scored on average 3.60 (*SD* = 1.82) for Automaticity, 3.73 (*SD* = 1.63) for Loss of Control, 4.35 (*SD* = 1.27) for Craving, and 4.19 (*SD* = 1.64) for Tolerance (recall ranges were from 1-7).

All participants reported abstaining for at least eight hours from initial session to scan session. Smokerlyzer scores from initial session (*M* = 3.45, *SD* = 1.36) to scan session (*M* = 1.40, *SD* = 0.68) decreased on average by 2.05 (*SD* = 1.19).

Self-report during scanning. After each block participants reported on current cigarette craving, how pleasant they thought the game they had just played was, how exciting they thought the game they had just played was, their current positive mood and their current negative mood (see Table 8). For each of these variables we ran four contrast analyses: a) self-expansion with cigarette cue (SECig) vs. self-expansion without cigarette cue (SEnoCig), b) self-expansion with cigarette cue (SECig) vs. no self-expansion with cigarette cue (NSECig), c) self-expansion without cigarette cue (SEnoCig) vs. no self-expansion without cigarette cue (NSEnoCig), and d) no self-expansion with cigarette cue (NSECig) vs. no self-expansion without cigarette cue (NSEnoCig).

For cigarette craving (Figure 8), unlike our hypothesis, self-expansion conditions did not yield significantly less craving than non self-expansion conditions.

For game pleasantness (Figure 9) ratings were significantly higher for the SEnoCig condition (*M* = 2.32, *SD* = 0.94) than the NSEnoCig condition (*M* = 2.05, *SD* = 0.84). For game excitement (Figure 10) there were significant differences between self-expansion conditions and non self-expansion conditions. Game excitement ratings for the SECig condition were significantly higher (M = 2.34, SD = 0.97) than the NSECig condition (M = 2.06, SD = 0.88), and excitement ratings for SEnoCig condition were significantly higher (M = 2.42, SD = 0.99) than the NSEnoCig (M = 2.03, SD = 0.93). These results support the idea that the self-expansion conditions were in fact more self-expanding than the non self-expansion conditions.

For both positive mood (Figure 11) and negative mood (Figure 12), there were no significant differences in ratings in any of our contrasts.

Analyses and Results for fMRI Data

We used Statistical Parametric Mapping software (SPM8; Wellcome Trust Center for Neuroimaging, UCL, London, UK) for fMRI data analyses. Functional images were spatially normalized to the SPM EPI template brain using SPM8's automatic re-alignment procedure and smoothed with a Gaussian kernel of 6mm, allowing for comparisons across participants of common regions. Out of 20 participants, four exhibited excessive motion during the protocol (our cutoff for XYZ movement was 4mm, reflecting our voxel size, and 3 degrees for rotation movement), and were dropped from all further fMRI analyses (these four participants were significantly older, had been smoking longer, had started smoking earlier, and were more addicted based on Fagerstrom and CDS scores than participants who did not exhibit excessive motion – it may be that the withdrawal was more intense for these 4 participants and thus they had more difficulty staying still in the scanner). We treated each condition (SECig, SEnoCig, NSECig, NSEnoCig) as a separate regressor, modeled as a boxcar function convolved with the canonical hemodynamic response function. We created contrast images for each participant for each comparison and analyzed across participants using a mixed-effects general linear model, treating participants as a random effect and conditions as a fixed effect and removing low frequency signal components (high-pass filter cut-off of 128s).

Whole brain analyses. We first ran whole brain group analyses for our contrasts of interest: a) self-expansion with cigarette cue vs. self-expansion without cigarette cue (SECig-SEnoCig; to test the effect of the craving cue); b) no self-expansion with cigarette cue vs. no self-expansion without cigarette cue (NSECig-NSEnoCig; to test the effect of the craving cue); c) self-expansion with cigarette cue vs. no self-expansion with cigarette cue (SECig-NSECig; to test the effect of self-expansion); d) self-expansion without cigarette cue vs. no self-expansion without cigarette cue (SEnoCig-NSEnoCig; to test the effect of self-expansion); and e) no self-expansion with cigarette vs. self-expansion with cigarette (NSECig-SECig; to test our craving difference hypothesis) . We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels) and used xjView toolbox (http://www.alivelearn.net/xjview) to help us label regions of activation. We used $p < 0.001$ (uncorrected) instead of $p < 0.005$ (uncorrected) (as was used in Study 1) since these were the parameters that Bartels and Zeki (2000) used for their study on romantic love (not just in early-stage participants) and our sample for Study 2 better matched Bartels and Zeki's study as opposed to Aron et al. (2005) or Xu et al. (2011).

For the first contrast (SECig-SEnoCig), we found activations in putamen, precentral gyrus, postcentral gyrus, and Brodmann Area 6 (see Table 9, Figure 26). For the second contrast (NSECig-NSEnoCig), we found activations in several areas of the cerebellum as well as the fusiform gyrus (see Table 9, Figure 27). For these two contrasts, some of these activated regions are associated with craving, specifically the putamen, precentral gyrus, postcentral gyrus (McClernon et al., 2009), cerebellum (McClernon et al., 2009; Zubieta et al., 2005), and fusiform gyrus (David et al., 2005; Wilson et al., 2005; Zubieta et al., 2005) . These results support the effect of the craving cue.

For the third contrast (SECig-NSECig), we found activations in the cerebellum, inferior occipital gyrus, Brodmann Area 9, lateral globus pallidus, thalamus, superior parietal lobule, Brodmann Area 6, and cingulate gyrus (see Table 9, Figure 28). For the fourth contrast (SEnoCig-NSEnoCig), we found activation in the cerebellum, precentral gyrus, inferior frontal gyrus, and middle frontal gyrus (see Table 9, Figure 29). For these two contrasts, some of these regions of activation are self-expansion related (reward, excitement, novelty etc.) and thus supports the idea that the self-expansion conditions were in fact more self-expanding. Particularly of note are the globus pallidus which has been associated with the pleasure of enjoying food (e.g., Berridge, Ho, Richard, & DiFelicieantonio, 2010; Cromwell & Berridge, 1993), and the inferior occipital gyrus, a region associated with monetary reward anticipation/risk-taking (Ernst et al., 2004). There were also activations in craving-related regions, particularly the precentral gyrus, inferior frontal gyrus, and middle frontal gyrus. However it is important to remember that we expected some overlap of craving-related regions for self-expansion since many of the regions that activate for cigarette cues are regions associated with attention, memory, and motivation, which we expect to be part of self-expansion. What is important to note from these contrasts is that above and beyond these overlap regions we are also seeing activations of regions associated with pleasure and reward/excitement.

Finally, for the fifth contrast (NSECig-SECig), we found activation in the anterior cingulate (see Table 9, Figure 30), which is a region associated with craving, supporting our hypothesis that there would be more craving in non self-expanding conditions with a cigarette cue as opposed to self-expanding conditions with a cigarette cue.

ROI analyses. We next ran ROI group analyses for our contrasts to investigate areas of a priori interest (see Tables 10 and 11). We used the Small Volume Correction (SVC) function in SPM8, creating 6-10mm spheres in Montreal Neurological Institute (MNI) space around our coordinates of interest and accepting clusters that were significant at $p < .05$ with FWE correction. We ran ROI analyses for several of our contrasts.

SECig-NSECig ROI analyses in reward regions (to test the effect of self-expansion). When we conducted ROI analyses for this contrast, we found significant activations in the VTA, putamen, caudate tail, caudate body (medial, postero-dorsal, and antero-dorsal), posterior cingulate/BA30/Retrosplenial cortex, and vermis of the cerebellum (see Table 12). These regions of reward/motivation activation suggest that the self-expanding manipulation was working. There were no significant reward region ROIs for the inverse contrast (NSECig-SECig).

SEnoCig-NSEnoCig ROI analyses in reward regions (to test the effect of self-expansion). When we conducted ROI analyses for this contrast, we found significant activations in VTA, caudate tail, caudate body (medial, postero-dorsal, and antero-dorsol), posterior cingulate/BA30/Retrosplenial cortex, orbitofrontal cortex, and vermis of the cerebellum (see Table 12). These regions of reward/motivation activation suggest that the self-expanding manipulation was working. There were no significant reward region ROIs for the inverse contrast (NSEnoCig-SEnoCig).

SECig-SEnoCig ROI analyses in craving regions (to test the effect of craving cues). When we conducted ROI analyses for this contrast, we found significant activations in the precuneus, striatum (internal capsule), posterior cingulate, thalamus, parietal cortex, and OFC (see Table 13), suggesting that the craving cues were working. There were no significant craving region ROIs for the inverse contrast (SEnoCig-SECig).

NSECig-NSEnoCig ROI analyses in craving regions (to test the effect of craving cues). When we conducted ROI analyses for this contrast, we found significant activation in the anterior cingulate, superior frontal gyrus, occipital cortex, cerebellum, striatum (internal capsule and NAcc), and fusiform gyrus (see Table 13), suggesting that the craving cues were working. There were no significant craving region ROIs for the inverse contrast (NSEnoCig-NSECig).

NSECig-SECig ROI analyses in craving regions (to test our craving difference hypothesis). When we conducted ROI analyses for this contrast, we found significant activation in the middle occipital gyrus and amygdala (see Table 13), confirming our hypothesis that the NSECig condition would yield more areas associated with craving than the SECig condition. There were no significant craving region ROIs for the inverse contrast (SECig-NSECig).

Group and correlational analyses. We ran a series of group and correlational whole-brain analyses in our main hypothesized contrast of interest (NSECig-SECig) to investigate potentially important differences based on some individual variables. For all group and correlational analyses, we accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels). We extracted eigenvariates for each participant and contrast at each region of significance to calculate effect sizes and create graphs.

First we conducted a paired sample t-test comparing men (10) and women (6) in our sample and found no significant sex differences. Next we conducted a 2-pair t-test comparing those participants whose partners were also smokers (8) to those whose partners were non-smokers (8) and found no significant differences. Next we conducted a correlational analysis of the number of cigarettes participants smoked per day and found no significant differences. There were also no significant differences in our contrast of interest based on addiction scores (Fagerstrom), relationship length, nor based on scores on the Self-Expansion Satisfaction Questionnaire (that measured how much the participant's need for self-expansion was being fulfilled). Because we were interested in the effect of excitement in the self-expansion with cigarette condition, we calculated two composite scores for each participant: a) the average self-reported excitement score for SECig minus the average self-reported excitement score for NSECig (this can be thought of as the excitement of self-expansion over and above the baseline game for our contrast) and b) the average self-reported excitement score for SECig minus the average self-reported pleasantness score for SECig (this can be thought of as the level of excitement above and beyond pleasantness for our self-expansion condition of interest). For the first composite score (SECig excitement minus NSECig excitement) we did not find any significant correlations. For the second composite score (SECig excitement minus SECig pleasantness) there was one significant positive correlation in our NSECig-SECig contrast in Brodmann Area 10 (part of the frontal cortex) at MNI coordinates -3, 44, -8, $p < .001$, $r = .80$ (see Figure 31). Finally we ran a correlational analysis with scores on the smoking conflict measure (how much smoking was a source of conflict in the relationship) and found several regions that were significantly negatively correlated with activation in our contrast (NSECig-SECig) including the cerebellum (see Table 14, Figure 32).

Discussion

Self report responses. We expected the self-expansion game to be more novel, challenging, and exciting than the non self-expanding game. We manipulated the novelty of the games (which visual stimuli were present) as well as the challenge of the games (how many targets there were and how long participants had to respond) with the expectation that these two manipulations would be enough to also increase excitement in the self-expansion games. This seemed to occur, as participants rated the self-expansion games significantly more exciting than the non self-expansion games. It is important to note however that the non self-expanding games was still rated as being pleasant and did not elicit significantly less positive mood or significantly more negative mood than the self-expanding games. Both versions were still pleasant games, with one simply being more self-expanding than the other.

Similar to Study 1 we found no significant differences across conditions for self-reported cigarette craving. Again since we asked people to assess cravings roughly every 30 seconds and gave participants only 4 options for assessing their craving (not at all, a little, somewhat and extremely), the combination of difficulty in assessing momentary cravings accurately and the low variance in self-reported craving (average ratings were between “a little” and “somewhat”) may have contributed to a lack of significant effects emerging.

fMRI data. As in Study 1, contrary to self-report, we did find craving differences across conditions when examining brain activations. For both whole-brain analyses and ROI analyses, we found activations in regions associated with craving when comparing conditions with cigarette stimuli to conditions without cigarette stimuli, supporting the effect of our cigarette cue. We also found activations in regions associated with reward when comparing self-expanding conditions to non self-expanding conditions, supporting the effect of our self-expanding two-player game. Of particular note is activation in the VTA for self-expanding conditions (compared to non self-expanding conditions), as VTA is a region very much associated with novelty (e.g., Bunzeck, & Düzel, 2006; Bunzeck et al., 2007; Wittman, Bunzeck, Dolan, & Düzel, 2007), a factor that we intentionally manipulated so that self-expanding conditions would be more novel than non self-expanding conditions.

We hypothesized a replacement effect such that we expected more activation in regions associated with craving in the NSECig condition compared to the SECig. We found support for our hypothesis both in our whole-brain analysis (with activation in the anterior cingulate) as well as our ROI analyses (with activation in the middle occipital gyrus and amygdala). These results support the idea that self-expansion can be a replacement for the reward of cigarettes, and that the mechanism behind this effect is craving attenuation. From our group and correlational analyses we also found that this effect was not significantly different by gender, whether the smoker's partner was also a smoker, the number of cigarettes smoked per day, self-reported addiction to cigarettes (Fagerstrom), relationship length, or the amount of self-expansion already present in participant's lives. Although the partner's smoking status was not influential on our effect, just as in Study 1, partner smoking conflict was important. Interestingly, unlike Study 1, partner smoking conflict was negatively correlated with our effect such that higher levels of conflict were associated with lower levels of the effect, therefore suggesting that increased conflict with the partner about smoking undermines the craving attenuation of self-expansion. It may be that as relationships become more long-term and move out of the early-stage intense phase, partners' preferences and conflict in the relationship do not exert as much influence on smokers' attention to and/or response to craving cues.

Finally we also found an interesting correlation with self-expansion excitement (specifically the excitement of the SECig condition over and above the pleasantness of that condition). This was a positive correlation in Brodmann Area 10, a region that is activated in cigarette cues of deprived smokers (Due et al., 2002; McClernon et al., 2005), suggesting that as the self-expansion condition increases in excitement over and above just pleasantness the craving attenuation effect also increases.

General Discussion

The two studies focused on the overlap between the reward experienced in self-expansion in the context of relationships and the reward experienced during nicotine addiction, with the idea that receiving self-expansion reward will undermine craving for cigarettes. Our studies supported the hypothesized rewarding effects of self-expansion, first in a previously tested paradigm of viewing pictures of a newly acquired romantic partner but also in a novel cooperative two-player game paradigm among long-term couples. Our studies also supported the hypothesized effects of craving induction via cigarette cues by showing brain activations in craving regions when these cues were present. Furthermore, our studies found that reward from self-expansion in the context of relationships undermined craving such that there was less activity in regions associated with cigarette-cue craving for self-expanding conditions compared to control conditions. These studies provide the first evidence that social self-expansion rewards can undermine craving for cigarettes in overnight abstinent smokers. The results of these studies could lead to an inexpensive, accessible and appealing tool to aid smokers in their cessation attempts, particularly if combined with drug therapy that can target negative effects of quitting such as withdrawal symptoms. It may also be extremely helpful in targeting a time-frame for quit-attempts, such that it may be easier to attempt to quit when there is a significant amount of self-expansion occurring. The replacement effect and the reduction in craving could also potentially apply to treating other addictions, and could perhaps benefit the treatment of polysubstance abusers.

However, before effective interventions can be developed, it is necessary to conduct future research in this area, particularly those focused on behavioral and longitudinal outcomes. While we saw consistent fMRI results in these studies, the self-reported cravings did not show our hypothesized effect. And although we believe this is mainly due to methodological issues involved in accurately assessing and reporting craving on a momentary basis, future studies that target self-reported cravings (utilizing a better measurement system) and/or actual voluntary cigarette abstinence is necessary to confirm that these suggestive fMRI findings can translate to behavior. Alternative biological assessments could also be used in future research to investigate this reduction in craving effect. Since craving is not something that is easily turned on and off, our fMRI methodology was not ideal for getting the most discrete patterns of effects. Other methods such as blood perfusion or PET might be better suited to pick up on the subtle differences that occur between conditions and yield stronger effects.

We did not directly investigate the possibility that part of the effect of self-expansion comes from distraction, as self-expanding conditions tend to be more engaging (e.g., the self-expanding game was more challenging, novel and exciting). We know from past research however (e.g., Younger et al., 2010) that self-expansion mitigates physical pain (which would be related to the discomfort associated with nicotine withdrawal) via reward regions, whereas distraction analgesia does not typically engage reward regions and instead elicits cortical activations. However, it is important that future studies on reward replacement directly test this in the context of nicotine cravings/withdrawal, and also test whether or not self-expansion and distraction can be used together to synergistically decrease discomfort/pain.

It will also be important for future studies to investigate potential mediators and moderators for this effect to better understand how interventions should be modeled. For example, since the replacement model relies on the idea that there is a ceiling effect for reward, individual differences need to be examined to determine what factors affect how much reward is necessary to successful help replace nicotine (or other substances). It is possible for example that those high on sensation seeking or less sensitive to rewards (e.g., fewer dopamine receptors or transmitters) would require more reward in order to have an effective outcome, whereas those extremely sensitive to reward might need less reward replacement (and perhaps more reward over this level might even be overwhelming and not helpful).

From the correlational analyses of both studies we also know that other important variables of note include level of smoking conflict and length of relationship. Interestingly, these variables were associated with the attenuation effect differently among early-stage intense romantic love participants (Study 1) than among long-term relationship participants (Study 2), suggesting that social context is in and of itself an important factor for the effectiveness of self-expansion. Specifically, although smoking conflict in the relationship helped the attenuation effect for early-stage smokers, the opposite was true for smokers in longer-term relationships. This may be due to the reward of the partner decreasing as relationships move from early-stage to later-stages (perhaps leading to participants spending more time noticing/thinking about the cigarette cue in later-stage relationship situations). It is also possible that these opposite results for Studies 1 and 2 emerged due to methodological differences rather than relationship differences among the partners. So for example, viewing images of your partner (or someone else) by yourself in the scanner might provide a qualitatively different self-expansion experience than actually participating in a self-expanding (or non self-expanding) game with your partner. This would be an interesting issue to investigate and test in a future study.

Interestingly, length of relationship was not significantly correlated with our effect in Study 2 (long-term relationships) but was significantly correlated with our effect in Study 1, such that longer relationship length was associated with more attenuation of craving. This seems to suggest that as relationships progress, the effect increases, but only up to a certain point. Recall that for Study 1 all participants were in a relationship no more than 3 years and that the average length was 14 months, whereas for Study 2 participants were in a relationship for no *less* than 2 years and with an average length of almost 4 years. This pattern of correlational results for relationship length seems to suggest that for relatively early-stage participants (who are still experiencing the self-expanding rewards of early-stage relationships), being in a more established relationship helps with the attenuation effect, whereas once you are already in a long-term established relationship, additional relationship time does not help with the effect.

For future studies on this topic, it is important to use longitudinal designs to determine the level of reward replacement that is appropriate throughout the quitting process. For example, nicotine-withdrawal is linked to significant elevations of brain reward thresholds for up to four days (Epping-Jordan, Watkins, Koob, & Markou, 1998), thus it may be necessary to establish higher levels of reward replacement during these first days of withdrawal (and/or to use nicotine-replacement therapy to help alleviate this withdrawal symptom) and then slowly lower the reward levels as brain reward thresholds return to normal.

Although much more research is necessary to better understand this replacement effect and to develop effective interventions for smoking cessation and perhaps cessation of other substances, these studies have provided the groundwork for a potentially fruitful area of research that can eventually lead to inexpensive, accessible, appealing and successful aids to help smokers quit. Finally, these studies have also provided us with a better understanding of self-expansion as well as the role it plays in relationships. While these studies focused on our hypothesized effects of self-expansion being able to replace for the reward from nicotine and thus help alleviate craving, this effect is potentially bidirectional and it is possible that the reward of nicotine could replace for self-expansion reward and that smokers may crave self-expansion less than non-smokers.

Future studies investigating this bidirectional possibility would be important not only to optimize self-expansion quitting interventions, but also to better understand the effect that nicotine (and other addictive substances) have on relationships and other forms of self-expansion. These studies are only the first in a potentially large field of research for scientists interested in relationships, self-expansion, addiction, and their neural correlates.

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Appendix A: Tables

Table1: Arousal and Valence ratings of stimuli for Study 1

	Arousal		Valence	
Stimuli Pair	*M*	*SD*	*M*	*SD*
Partner-CigHigh	4.31	0.74	4.66	0.48
Partner-CigMod	4.09	0.73	4.53	0.57
Partner-Pen	3.97	0.70	4.31	0.69
Friend-CigHigh	3.25	0.98	3.63	0.71
Friend-CigMod	3.25	0.62	3.59	0.67
Friend-Pen	2.94	0.95	3.50	0.62
Neutral-CigHigh	2.94	0.84	3.38	0.66
Neutral-CigMod	2.91	0.82	3.16	0.81
Neutral-Pen	2.53	0.88	2.97	0.90

Table 2: Average reported cigarette craving, partner craving and stress by stimuli pair while in the scanner for Study 1

	Cigarette Craving		Partner Craving		Stress	
Stimuli Pair	*M*	*SD*	*M*	*SD*	*M*	*SD*
Partner-CigHigh	2.55	1.02	3.42	0.78	2.13	0.97
Partner-CigMod	2.36	0.94	3.65	0.60	2.17	0.93
Partner-Pen	2.34	0.96	3.47	0.76	2.00	0.94
Friend-CigHigh	2.62	0.91	2.70	0.87	2.00	0.83
Friend-CigMod	2.55	0.78	2.83	0.84	2.00	0.86
Friend-Pen	2.24	0.74	2.89	0.80	1.87	0.93
Neutral-CigHigh	2.52	0.77	2.70	0.89	1.76	0.79
Neutral-CigMod	2.27	0.84	2.81	0.98	2.05	0.86
Neutral-Pen	2.42	0.89	3.00	0.88	1.98	0.95

Table 3: Regional activations and deactivations for contrasts in Study 1

	Talairach Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	# of voxels in cluster
Partner-cighigh vs Friend-cighigh				
Activations				
Left posterior cingulate	20	44	18	187
Right posterior cingulate	-17	38	12	62
Right posterior cingulate	-20	26	30	43
Left precentral gyrus	26	8	33	24
Partner-cighigh vs Neutral-cighigh				
Activations				
Right posterior cingulate and right caudate tail	-5	35	12	32
Deactivations				
Left cuneus	11	92	15	39
Partner-cigmod vs Friend-cigmod				
Deactivations				
Right precuneus	-2	65	24	25
Partner-cigmod vs Neutral-cigmod				
Deactivations				
Right insula and right postcentral gyrus	-59	29	21	96
Right precuneus	-2	65	27	57
Left insula	38	17	21	38
Partner-cigaveraged vs Neutral-cigaveraged				
Deactivations				
Left middle occipital gyrus	11	92	15	59
Right inferior parietal lobule and right angular gyrus	-50	62	42	45
Right postcentral gyrus and right insula	-62	23	21	44
Right precuneus	-2	65	30	32

We accepted $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

Table 4: Regional activations and deactivations for contrasts in Study 1 (FWE-corrected)

	Talairach Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	# of voxels in cluster
Partner-cighigh vs Friend-cighigh				
Activations				
White matter	-29	-47	15	128
White matter	23	-44	27	69
Partner-cighigh vs Neutral-cighigh				
Activations				
White matter	-17	-41	18	58
White matter	20	-41	21	49
Deactivations				
Left middle occipital gyrus/cuneus	-14	-89	15	64
Partner-cigmod vs Friend-cigmod				
Activations				
Right anterior cingulate/white matter	20	41	3	44
Partner-cigaveraged vs Neutral-cigaveraged				
Deactivations				
Left cuneus	-14	-89	12	60

Whole brain analyses. We accepted $p < 0.05$ (FWE-corrected) for the single peak voxel in a cluster with a minimum of 44 voxels (Cluster sizes were defined by a voxel-wise threshold of $p < 0.005$, uncorrected and Monte Carlo simulations of null hypothesis data using AlphaSim revealed cluster size cutoff of 44 voxels)

Table 5: Regional activations and deactivations for ROIs in Study 1

	Talairach Coordinates						
Brain region	peak *x*	peak *y*	peak *z*	central *x*	central *y*	central *z*	cluster size
Partner-CigAveraged vs. Partner-pen							
Activations							
Anterior cingulate cortex	-7	44	-4	-4	41	-2	46
Posterior cingulate cortex	-9	-55	16	-9	-50	20	226
Friend-CigAveraged vs. Friend-pen							
Activations							
Superior frontal cortex	-4	53	29	-7	52	26	68
Neutral-CigAveraged vs. Neutral-pen							
Activations							
Medial frontal	5	56	17	-6	49	17	479
Deactivations							
Precuneus	-28	-67	38	-31	-58	40	263

Cluster size refers to the number of voxels in the cluster

Table 6: Regional correlations of the BOLD signal for partner-cigaveraged vs. friend-cigaveraged contrast in Study 1

	Talairach Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	*r*-value
Partner Smoking conflict				
Activations				
Right cuneus	5	-80	33	-.69
Right precuneus	2	-35	48	-.61
	8	-74	45	-.69
Left precuneus	-8	-74	27	-.69
Right middle frontal gyrus	44	47	21	-.68
	50	17	36	-.53
Right lingual gyrus	17	-41	-1	-.61
Right insula	38	17	9	-.63
Right inferior parietal lobule	41	-53	57	-.47
Left cingulate gyrus	-5	-35	27	-.55
Left medial frontal gyrus	-20	44	-7	-.71

We accepted $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

Table 7: Regional correlations of the BOLD signal for partner-cigaveraged vs. neutral-cigaveraged contrast in Study 1

	Talairach Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	*r*-value
Partner Smoking conflict				
Activations				
Right middle frontal gyrus	29	50	-10	-.64
Length of relationship				
Activations				
Pons	11	-17	-31	-.72
Right superior temporal gyrus	44	-32	6	-.64
Right inferior frontal gyrus	50	5	24	-.36
Left precuneus	-20	-77	45	-.69
Left middle frontal gyrus	-41	35	18	-.59
CDS score				
Activations				
Left insula	-41	2	3	-.67
Right precentral gyrus	50	17	9	-.69

We accepted $p < 0.005$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

Table 8: Average reported cigarette craving, game pleasantness, game excitement, positive mood and negative mood by condition while in the scanner for Study 2

	Cigarette Craving *M(SD)*	Game Pleasantness *M(SD)*	Game Excitement *M(SD)*	Positive mood *M(SD)*	Negative mood *M(SD)*
Self-expansion with cigarette cue	2.49(1.18)	2.23(0.91)	2.34(0.97)	2.47(0.93)	1.81(0.97)
Self-expansion w/o cigarette cue	2.51(1.12)	2.32(0.94)	2.42(0.99)	2.52(0.94)	1.77(0.94)
No self-expansion with cigarette cue	2.62(1.02)	2.17(0.81)	2.06(0.88)	2.49(0.88)	1.69(0.92)
No self-expansion w/o cigarette cue	2.52(1.12)	2.05(0.84)	2.03(0.93)	2.47(0.93)	1.67(0.89)

Table 9: Regional activations of contrasts for Study 2

	MNI Coordinates							
	Left				Right			
Brain region	*x*	*y*	*z*	*p-value*	*x*	*y*	*z*	*p-value*
SECig-SEnoCig								
Putamen					27	-7	13	<.001
Precentral gyrus					39	-10	28	<.001
					45	-4	28	<.001
					54	-1	16	<.001
Postcentral gyrus					21	-34	64	<.001
Brodmann Area 6					18	-19	67	<.001
NSECig-NSEnoCig								
Cerebellum, uvula	-24	-82	-32	<.001				
Cerebellum, declive	-36	-76	-23	<.001				
	-45	-70	-26	<.001				
Fusiform gyrus					45	-67	-20	<.001
					39	-76	-20	<.001
SECig-NSECig								
Cerebellum, declive	0	-64	-23	<.001	0	-64	-23	<.001
Inferior occipital gyrus	-33	-76	-8	<.001				
Brodmann Area 9	-57	8	34	<.001				
Lateral globus pallidus					18	-4	-2	<.001
Thalamus					6	-10	1	<.001
Superior parietal lobule	-42	35	25	<.001				
	-24	-61	55	<.001				
Brodmann Area 6	-9	2	64	<.001				
Cingulate gyrus					15	14	37	<.001
SEnoCig-NSEnoCig								
Cerebellum, declive	0	-64	-20	<.001	15	-61	-17	<.001
Cerebellum, culmen	-24	-55	-23	<.001				
Precentral gyrus	-51	2	28	<.001				
	-33	-79	-5	<.001				
Inferior frontal gyrus					54	8	31	<.001
Middle frontal gyrus					42	50	-2	<.001
					33	50	1	<.001
NSECig-SECig								
Anterior cingulate	0	23	-8	<.001	0	23	-8	<.001

Whole brain analyses. We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

Table 10: Reward regions of interest (ROIs) based on Aron et al. 2005 and Xu et al. 2011 for Study 2

	MNI Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	Reference paper
Ventral Tegmental Area (VTA)	2	-12	-10	Xu et al., 2011
	2	-15	-9	Aron et al., 2005
Caudate tail	-32	-44	4	Xu et al., 2011
	32	-44	12	Xu et al., 2011
	-28	-40	10	Aron et al., 2005
	28	-40	10	Aron et al., 2005
Caudate body, medial	12	11	16	Aron et al., 2005
Caudate body, postero-dorsal	18	-20	23	Aron et al., 2005
Caudate body, antero-dorsal	14	-5	24	Aron et al., 2005
Posterior cingulate/BA30/ Retrosplenial cortex	30	-54	2	Aron et al., 2005
Orbitofrontal cortex, mid	38	28	-12	Xu et al., 2011
Cerebellum, vermis	4	-60	-24	Xu et al., 2011

MNI coordinates (x,y,z) used for the center of the small volume correction sphere (6-10mm sphere diameter), both left and right sides were searched.

Table 11: Predicted regions of activation for areas associated with craving for Study 2

Brain region	MNI Coordinates peak *x*	peak *y*	peak *z*	Reference papers
Insula	-36	12	2	Franklin et al., 2007; McBride et al., 2006*; Naqvi, Rudrauf, Damasio, & Bechara, 2007; Wang et al., 2007
Anterior cingulate	-16	-8	26	Brody et al., 2002; David et al., 2005; Lee et al., 2005; Lim et al., 2005; McBride et al., 2006*; McClernon et al, 2005; Wang et al., 2007; Wilson et al., 2005; Zubieta et al., 2005
Precuneus	0	-46	45	McClernon et al., 2009* ; Lee et al., 2005 ;
	-8	-58	35	McBride et al., 2006*
Superior frontal gyrus	-14	56	28	David et al., 2005*; Lee et al., 2005; McClernon et al., 2005; McClernon et al., 2009 ; Wilson et al., 2005
Occipital Cortex	14	-78	-17	David et al., 2005*; McClernon et al., 2009; Wang et al., 2007; Zubieta et al., 2005
Medial inferior occipital gyrus	-22	-60	6	McClernon et al., 2009*
Middle occipital gyrus	-30	-80	36	McClernon et al., 2009*
Superior occipital gyrus	-16	-86	40	McClernon et al., 2009*
Amygdala	-20	-3	-19	Franklin et al., 2007*; Wang et al., 2007
Cerebellum	-40	-68	-20	McClernon et al., 2009*
	10	-82	-20	McClernon et al., 2009* ; Zubieta et al., 2005
Striatum				
Internal capsule	-28	-26	14	McClernon et al., 2009*
Ventral striatum/ NAcc	8	14	-2	David et al., 2005* ; Franklin et al., 2007 ;
	-4	14	-2	Wang et al., 2007
Posterior cingulate	-6	-34	34	McBride et al., 2006; McClernon et al. 2009*; Wilson et al., 2005
Fusiform gyrus	23	-96	-12	David et al., 2005; Wilson et al., 2005*; Zubieta et al., 2005
Thalamus	-2	-6	6	Due et al., 2002; Franklin et al., 2007; McBride et al., 2006*; McClernon et al. 2009; Wang et al., 2007; Wilson et al., 2005
Parietal cortex	58	-56	24	McBride et al., 2006*; McClernon et al. 2009; Wilson et al., 2005; Zubieta et al., 2005
Orbitofrontal cortex	24	20	-21	David et al., 2005; Franklin et al., 2007*; Wang et al., 2007
Cuneus	23	-103	-14	Wilson et al., 2005*

*MNI coordinates (x,y,z) used for the center of the small volume correction sphere (6-10mm sphere diameter), both left and right sides were searched.

Table 12: Regional activations in reward areas for Study 2

	MNI Coordinates							
	Left				Right			
Brain region	*x*	*y*	*z*	*p-value*	*x*	*y*	*z*	*p-value*
SECig-NSECig								
VTA	-6	-16	-14	.03				
Caudate tail	-30	-34	7	.04	36	-46	-5	.003
	-27	-34	7	.01	24	-31	7	.014
Caudate body								
medial	-21	14	19	.037	21	14	19	.029
					21	8	19	.037
postero-dorsal	-21	-28	25	.009	21	-13	28	.039
					24	-22	28	.038
antero-dorsal	-21	2	22	.022	21	-4	31	.002
	-15	-1	31	.003	18	2	19	.02
Posterior cingulate/BA30/	-30	-61	-2	<.001	27	-54	-2	.014
Retrosplenial cortex					39	-58	-2	.001
Cerebellum, vermis	0	-64	-23	<.001	0	-64	-23	<.001
SEnoCig-NSEnoCig								
VTA	-6	-16	-2	.032	6	-13	-2	.027
	-9	-19	-2	.002	6	-13	1	.003
Caudate tail	-30	-34	4	.039	30	-34	10	.018
	-27	-31	7	<.001	27	-31	10	.001
Caudate body								
medial	-12	20	19	.007	21	14	19	.01
postero-dorsal	-21	-28	19	.001	24	-25	19	.013
antero-dorsal	-21	-7	19	.007	18	-1	28	.01
Posterior cingulate/BA30/ Retrosplenial cortex	-27	-64	-2	.007	39	-58	-2	.004
OFC, mid					36	29	-8	.037
Cerebellum, vermis	0	-64	-20	<.001	0	-64	-20	<.001

We used 6-10mm diameter spheres with a threshold of $p < .05$ for FWE correction. Both left and right sides were searched. MNI coordinates are for the highest intensity voxel in a cluster.

Table 13: Regional activations in craving areas for Study 2

	MNI Coordinates							
	Left				Right			
Brain region	*x*	*y*	*z*	*p-value*	*x*	*y*	*z*	*p-value*
SECig-SEnoCig								
Precuneus	-3	-61	34	.043	0	-46	61	.018
					3	-43	54	.019
Striatum (internal capsule)	-30	-25	10	.014				
Posterior cingulate	-3	-37	40	.033				
Thalamus, dorsomedial					3	-4	16	.047
Posterior parietal cortex	-57	-58	19	.041				
Posterior OFC	-30	14	-17	.03				
NSECig-NSEnoCig								
Striatum (internal capsule)	-27	-28	4	.04				
Ventral striatum	-6	17	11	.011	3	14	-2	.044
Superior frontal gyrus					9	53	25	.032
Cerebellum	-36	-76	-23	.003				
Anterior cingulate					18	-7	22	.007
Fusiform gyrus	-24	-88	-23	.042				
Occipital cortex					24	-79	-20	.042
NSECig-SECig								
Middle occipital gyrus	-39	-79	40	.04				
Amygdala	-18	-7	-26	.05				

We used 6-10mm diameter spheres with a threshold of $p < .05$ for FWE correction. Both left and right sides were searched. MNI coordinates are for the highest intensity voxel in a cluster.

Table 14: Regional correlations of the BOLD signal activations for non self-expansion with cigarette vs. self-expansion with cigarette (NSECig-SECig) contrast in Study 2

	MNI Coordinates			
Brain region	peak *x*	peak *y*	peak *z*	*r*-value
Partner Smoking conflict				
Cerebellum, tuber (left)	-48	-64	-35	-.90
Cerebellum, pyramis (left)	-18	-76	-44	-.89
Cerebellum, culmen (left)	-12	-61	-14	-.74
Cerebellum, declive (left)	-9	-79	-29	-.85
Cerebellar tonsil (left)	-39	-55	-47	-.86
Lingual gyrus (left)	-12	-82	-8	-.88
Brodmann Area 18 (left)	-9	-70	-8	-.85
Middle frontal gryus (right)	33	14	40	-.84

We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels).

Appendix B: Figures

Figure 1A: Moderate craving-inducing cigarette cue for Study 1

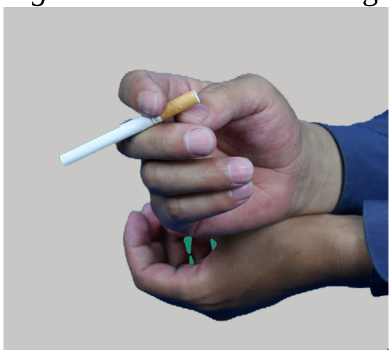


Figure 1B: High craving-inducing cigarette cue for Study 1

Figure 1C: Pen image (control) for Study 1

Figure 2A: Condition 1 (self-expanding with cigarette cue) for Study 2:

Figure 2B: Condition 2 (self-expanding without cigarette cue) for Study 2:

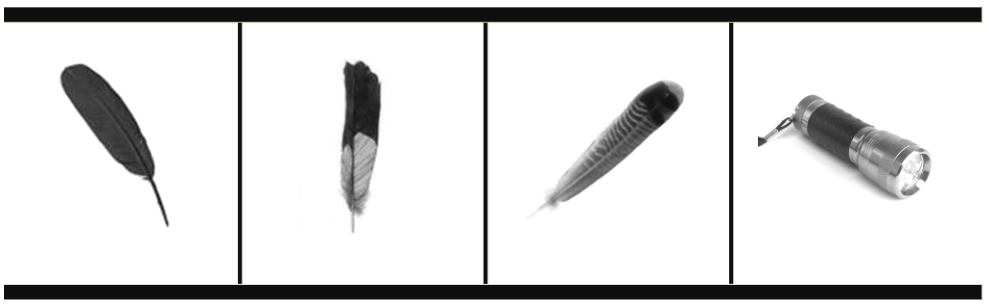


Figure 2C: Condition 3 (not self-expanding with cigarette cue) for Study 2:

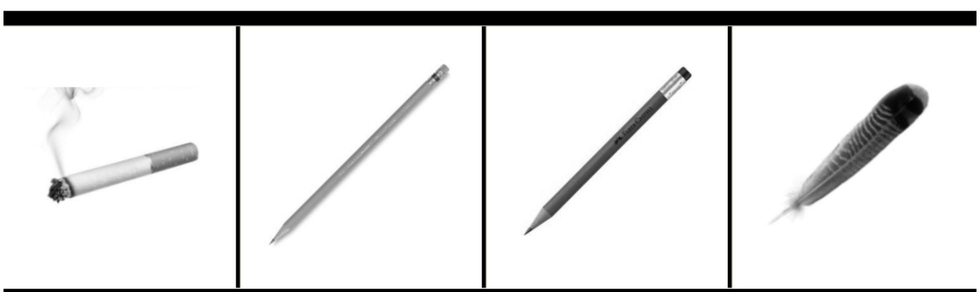


Figure 2D: Condition 4 (not self-expanding without cigarette cue) for Study 2:

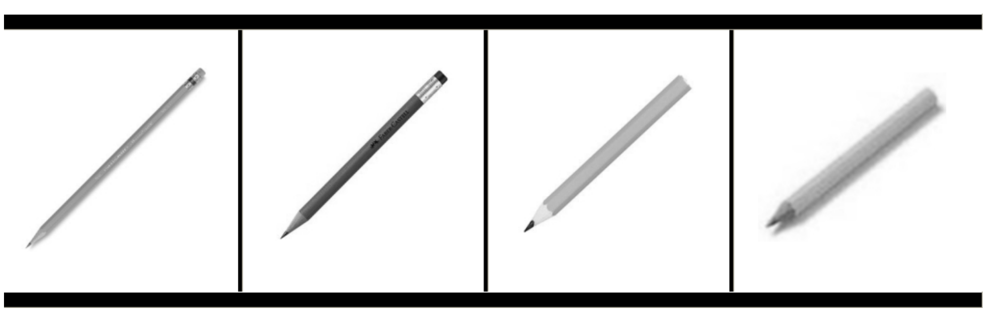


Figure 3: Average arousal of stimuli pairs for Study 1

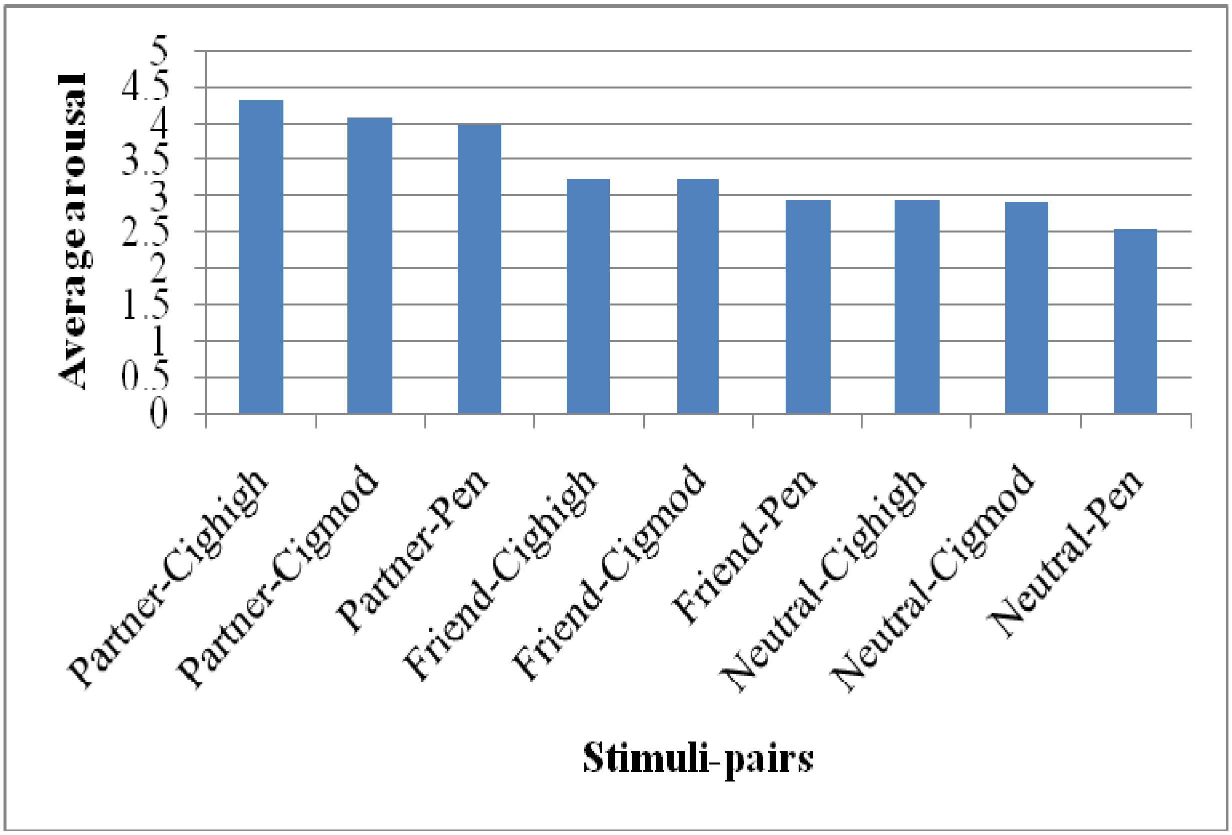


Figure 4: Average valence of stimuli pairs for Study 1

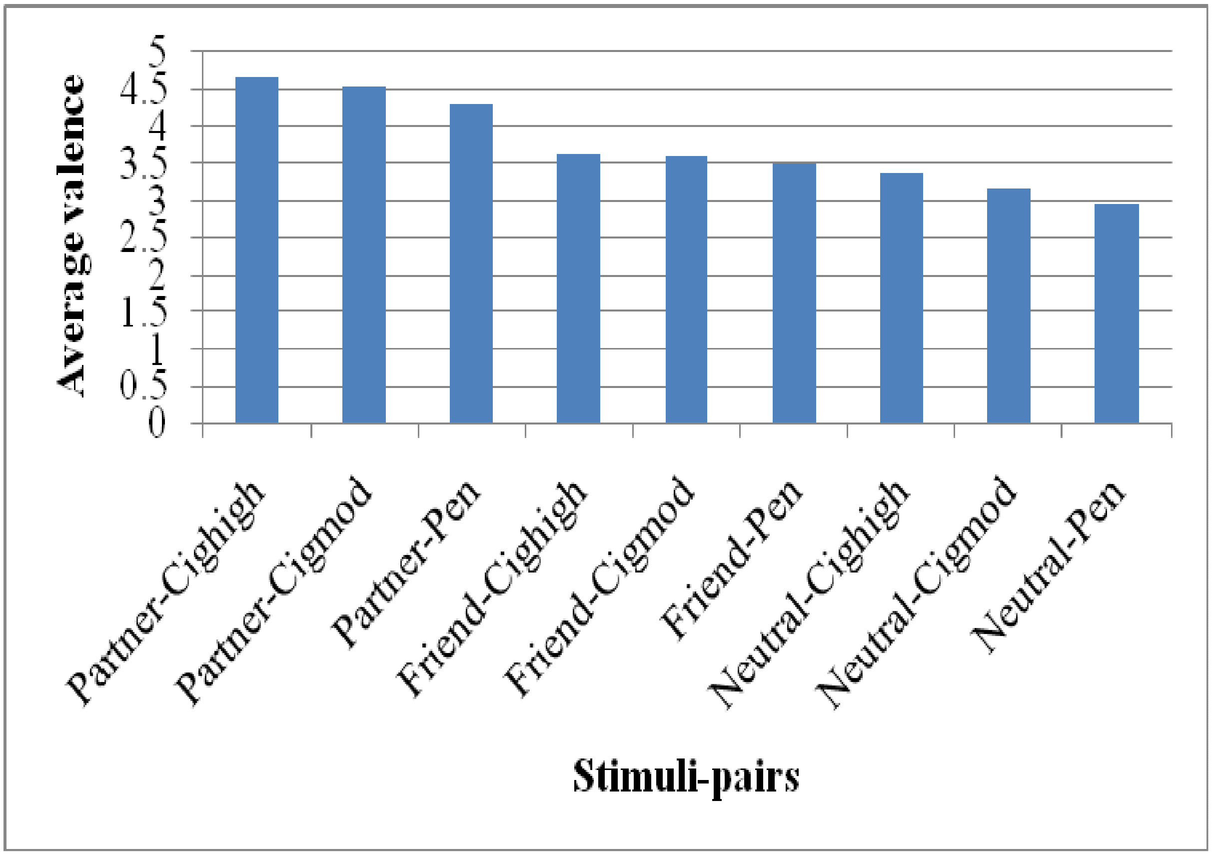


Figure 5: Average reported cigarette craving by stimuli pair while in the scanner for Study 1

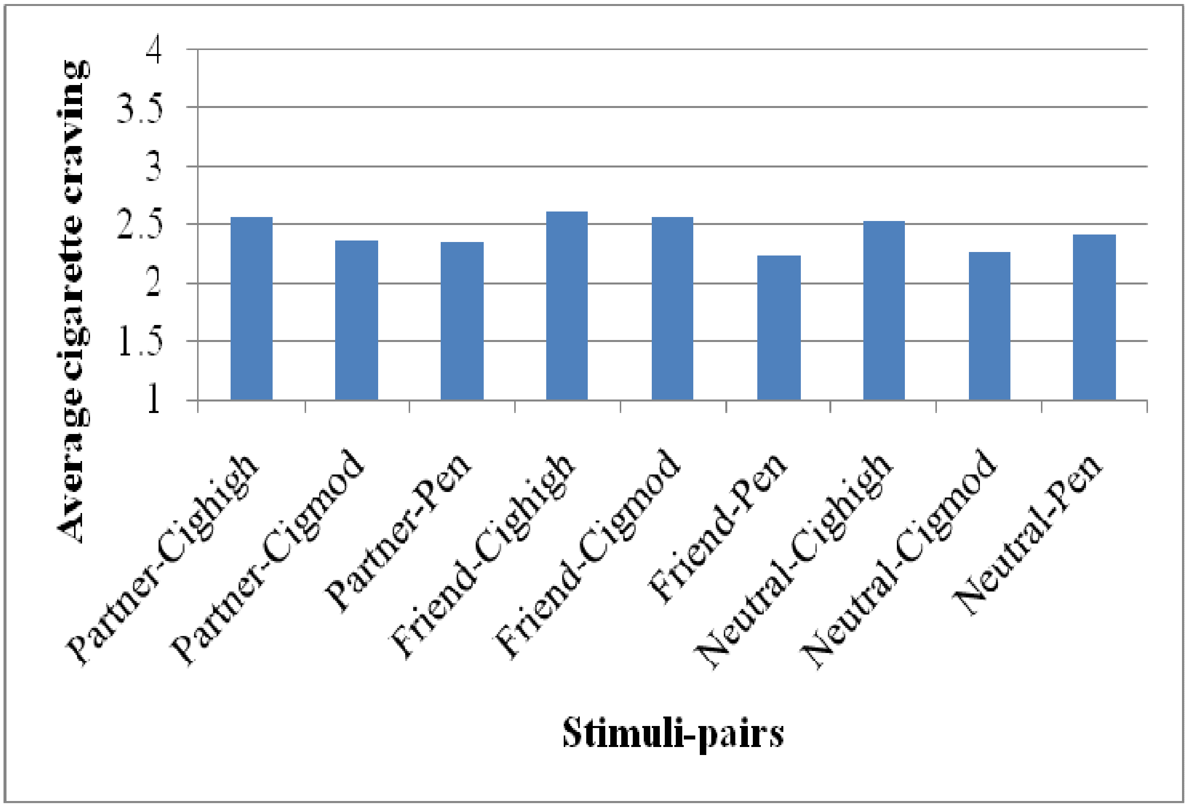


Figure 6: Average reported partner craving by stimuli pair while in the scanner for Study 1

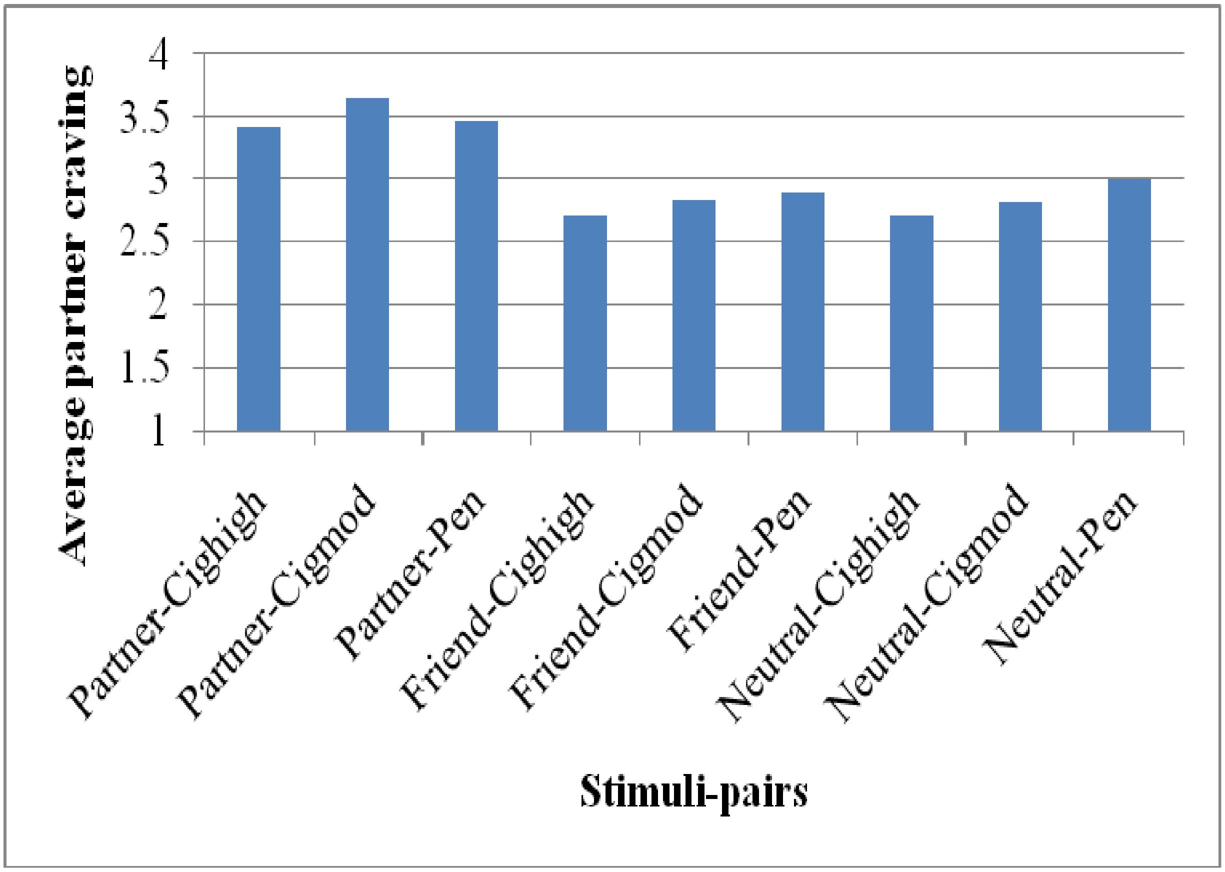


Figure 7: Average reported stress by stimuli pair while in the scanner for Study 1

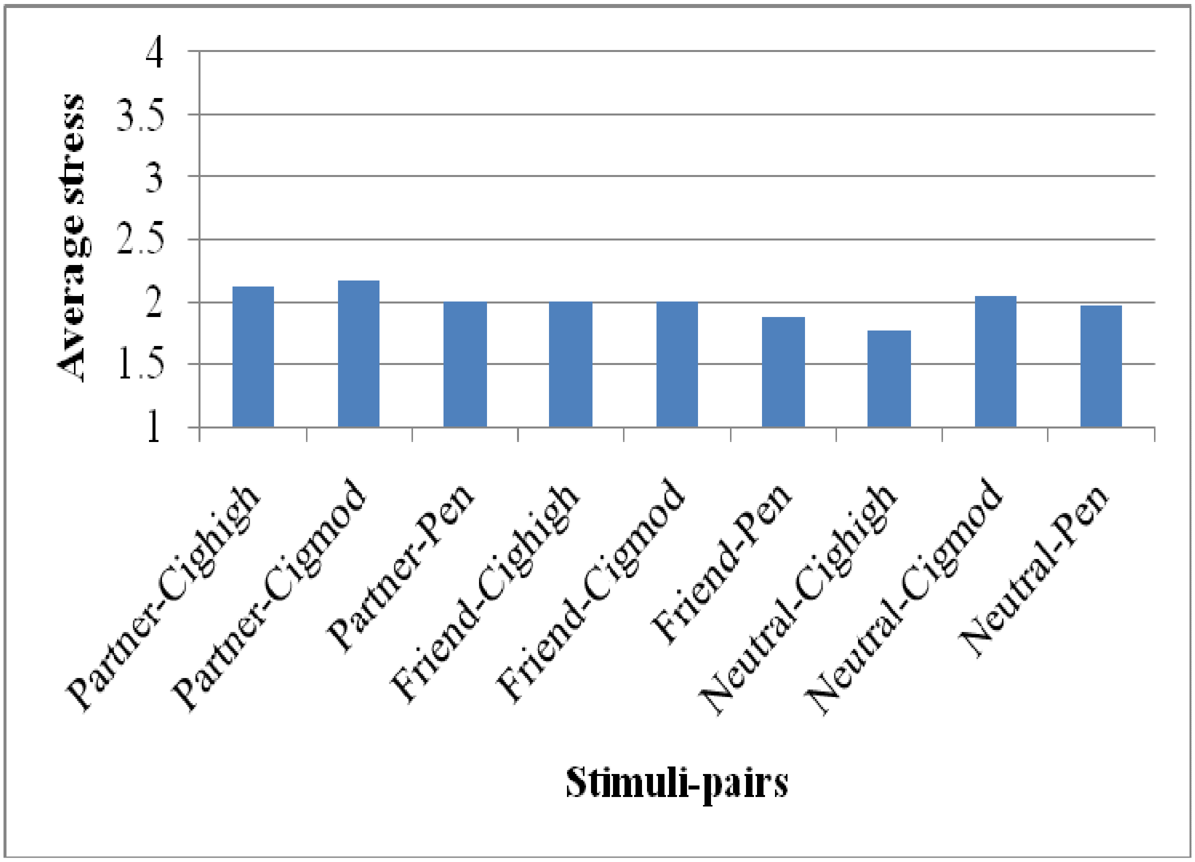


Figure 8: Average cigarette craving rating by condition while in the scanner for Study 2

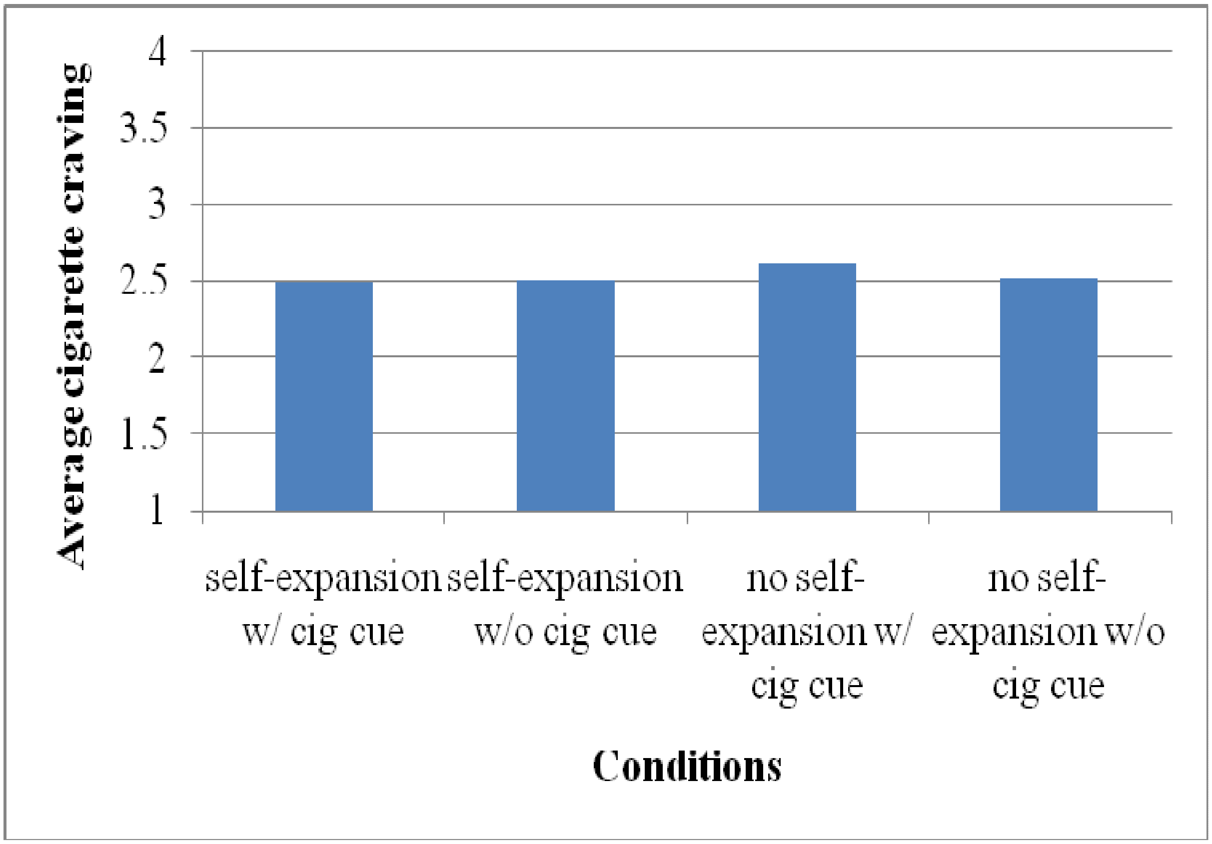


Figure 9: Average game pleasantness rating by condition while in the scanner for Study 2

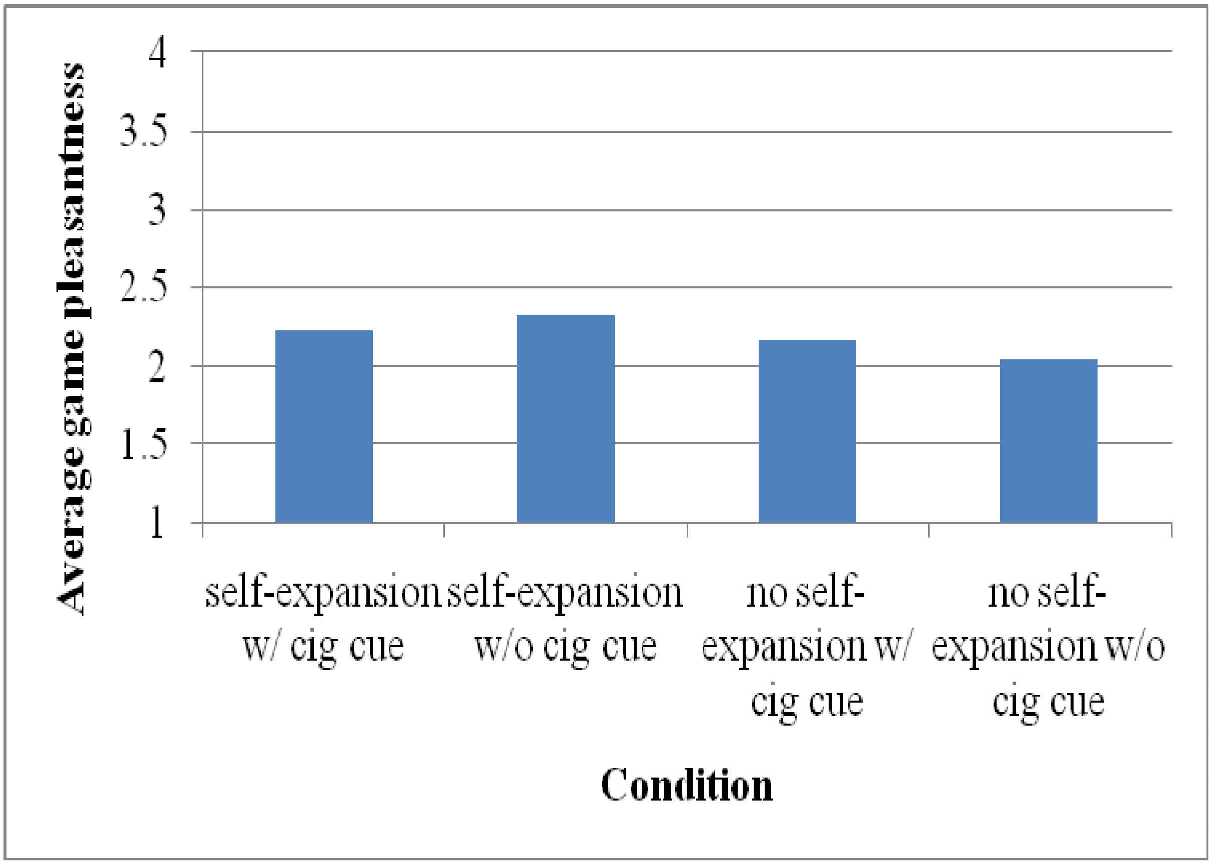


Figure 10: Average game excitement rating by condition while in the scanner for Study 2

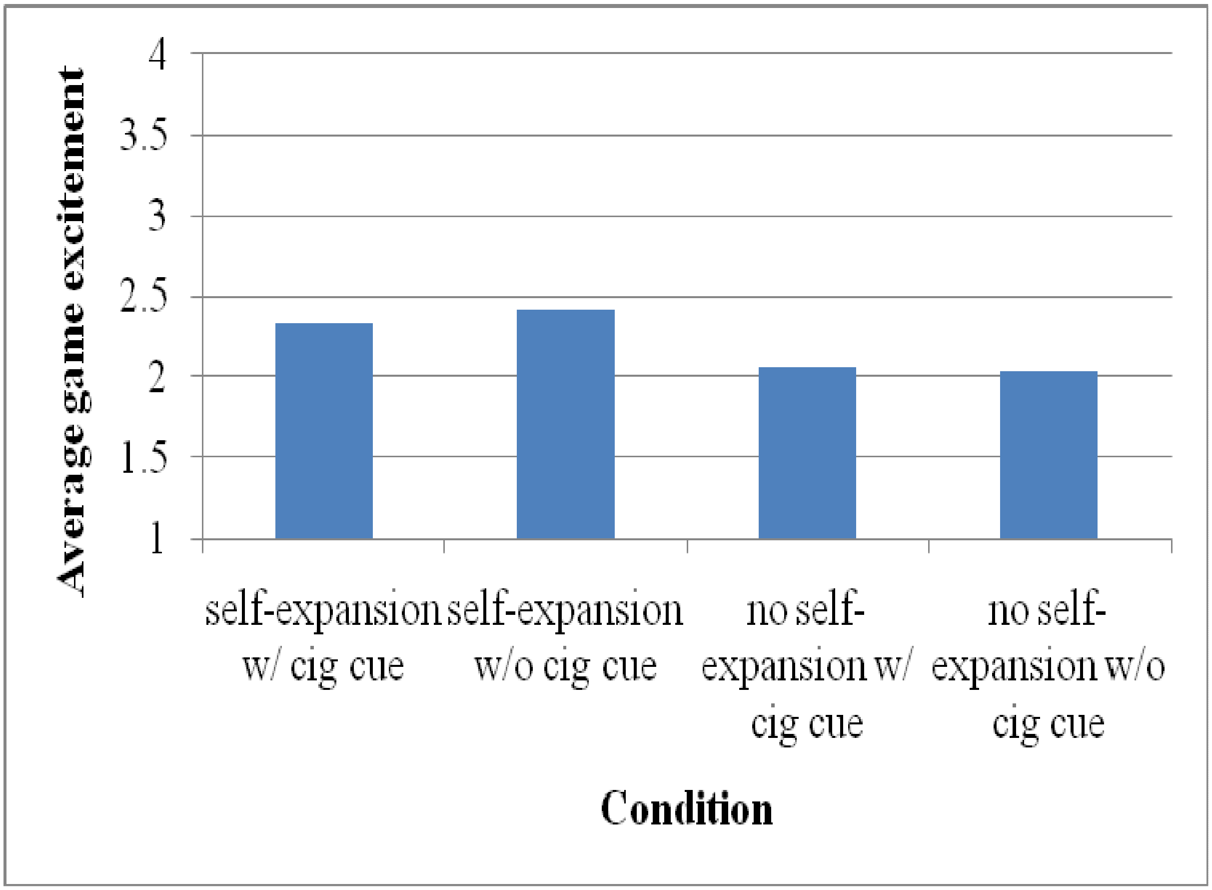


Figure 11: Average positive mood rating by condition while in the scanner for Study 2

Figure 12: Average negative mood rating by condition while in the scanner for Study 2

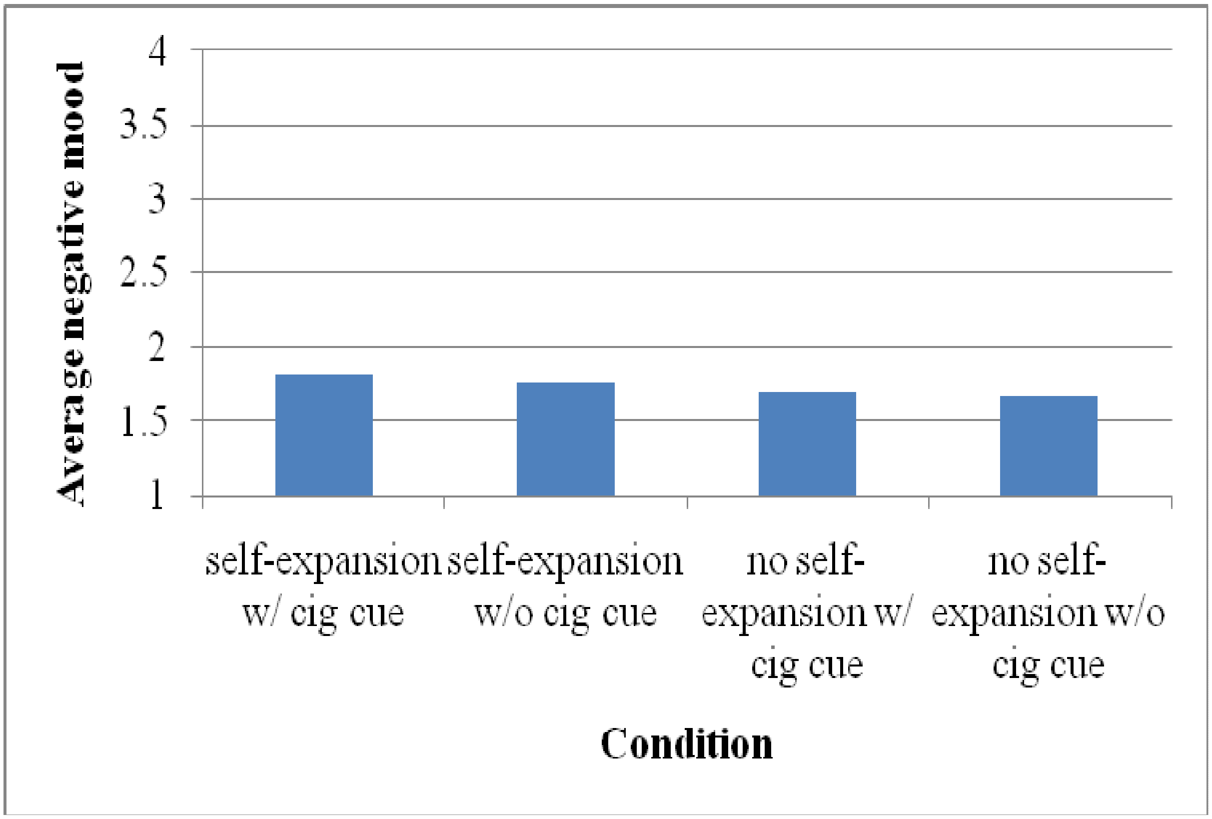
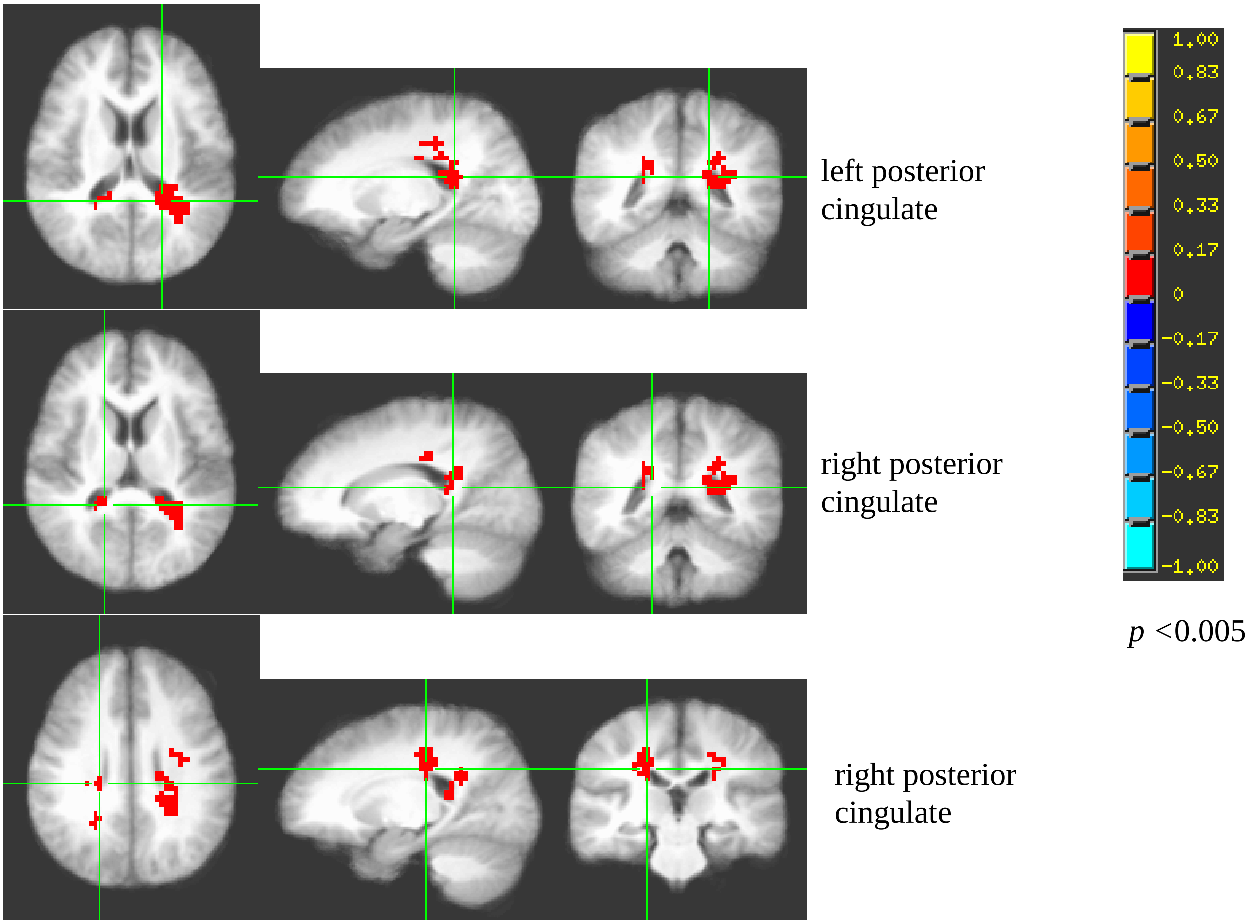
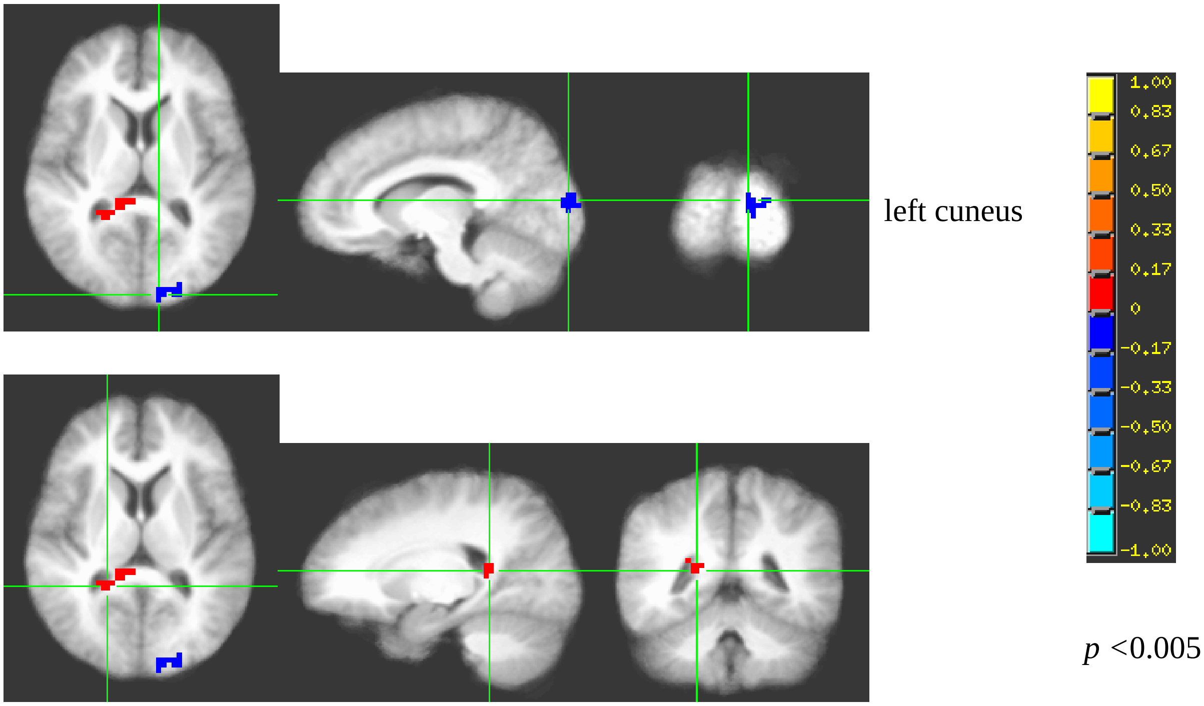


Figure 13: Regional activations specific to partner-cighigh compared to friend-cighigh in Study 1



We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels)

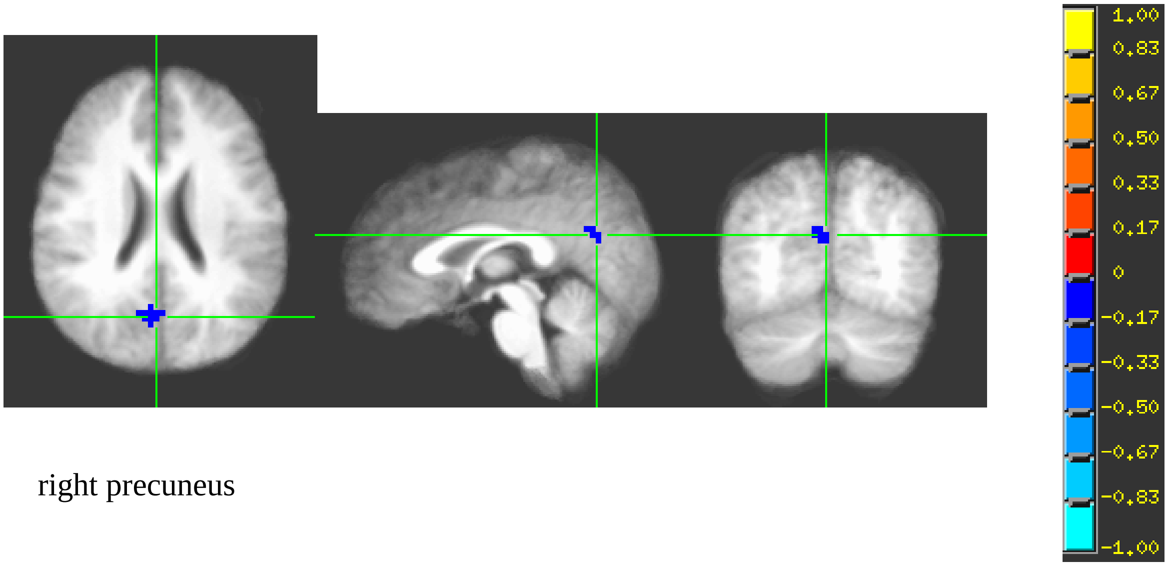
Figure 14: Regional activations and deactivations for partner-cighigh compared to neutral-cighigh in Study 1



right posterior cingulate and right caudate tail

We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels)

Figure 15: Regional deactivations for partner-cigmod compared to friend-cigmod in Study 1

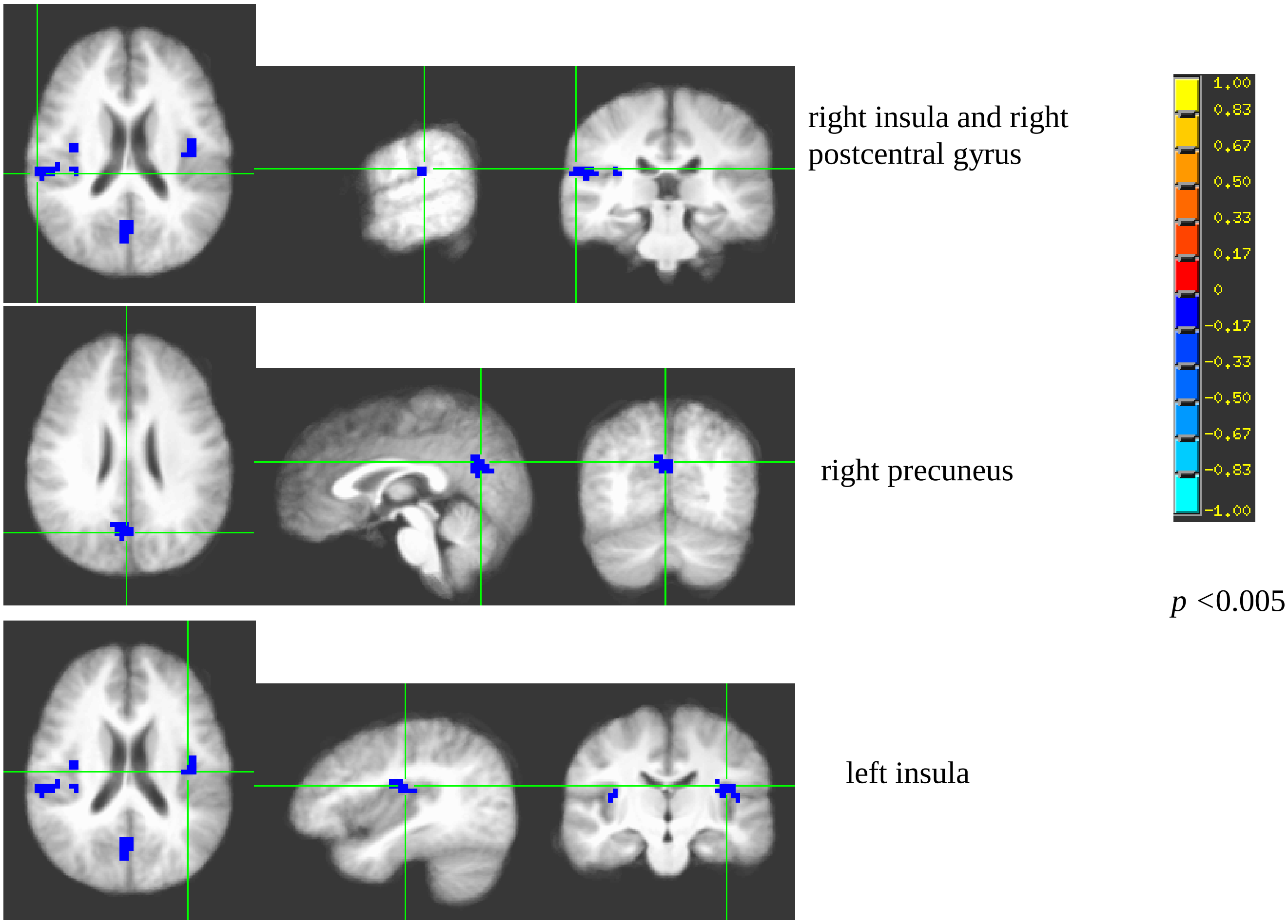


right precuneus

p <0.005

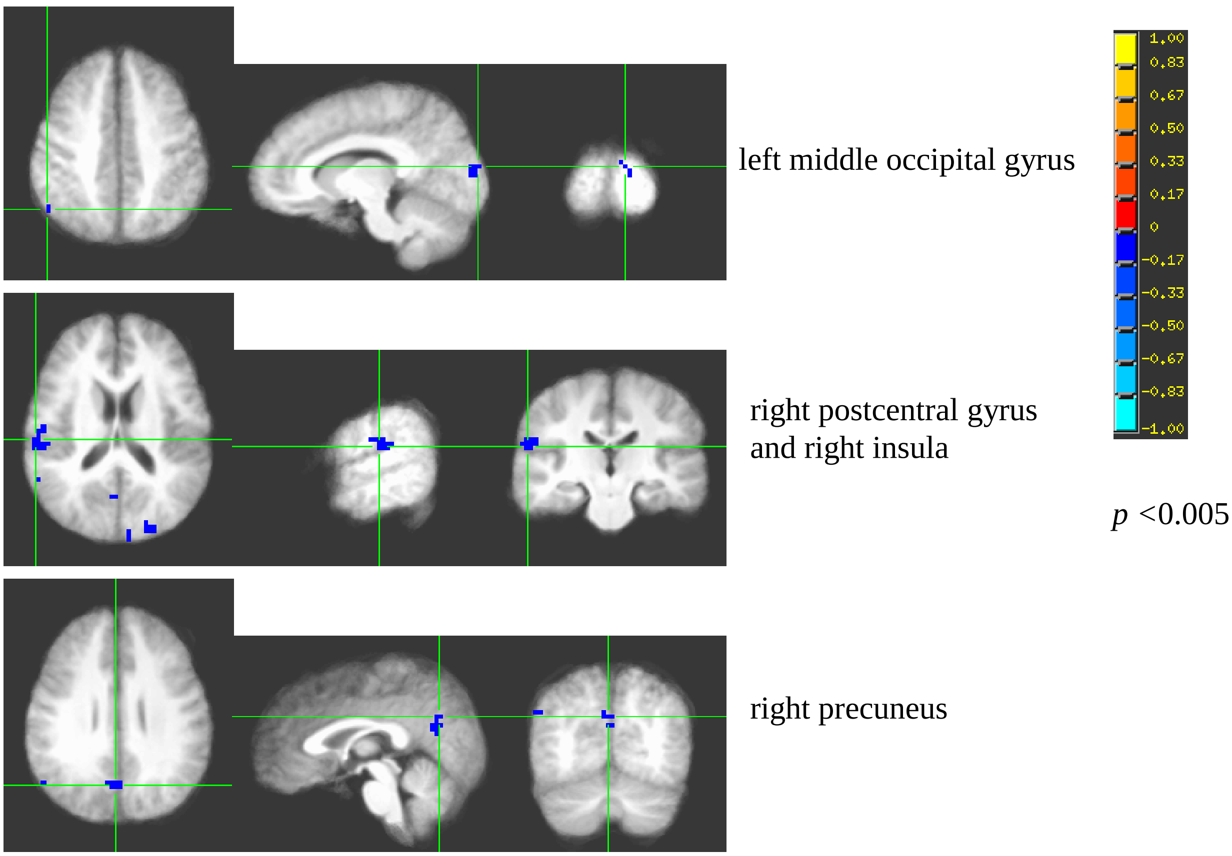
We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels)

Figure 16: Regional deactivations for partner-cigmod compared to neutral-cigmod in Study 1



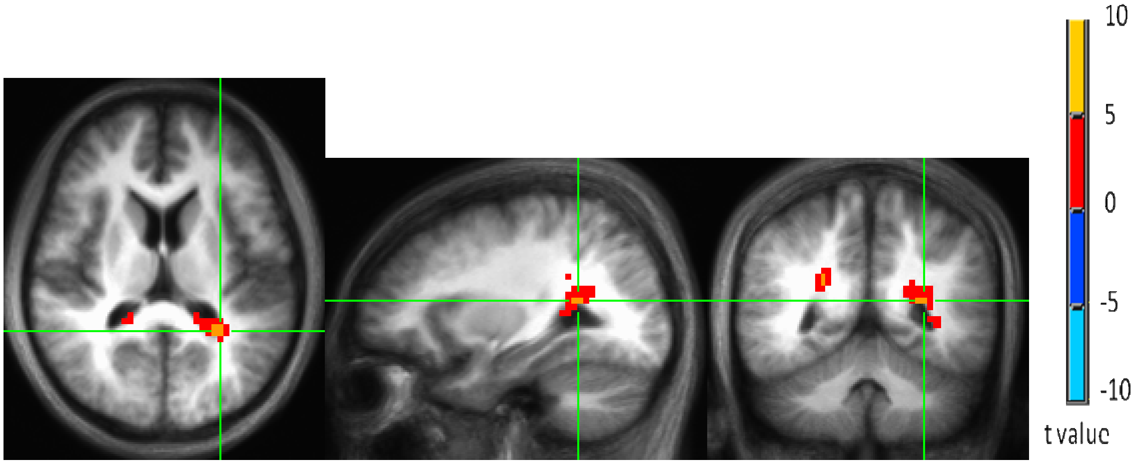
We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels)

Figure 17: Regional deactivations for partner-cigaveraged compared to neutral-cigaveraged in Study 1

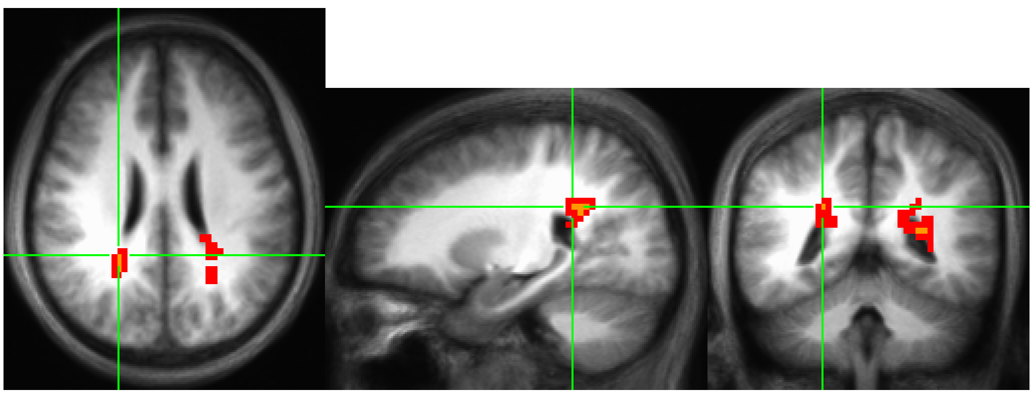


We accepted $p < 0.001$ (uncorrected) for the single peak voxel in a cluster (with a minimum of 20 voxels)

Figure 18: Regional activations specific to partner-cighigh compared to friend-cighigh in Study 1 (FWE-corrected).



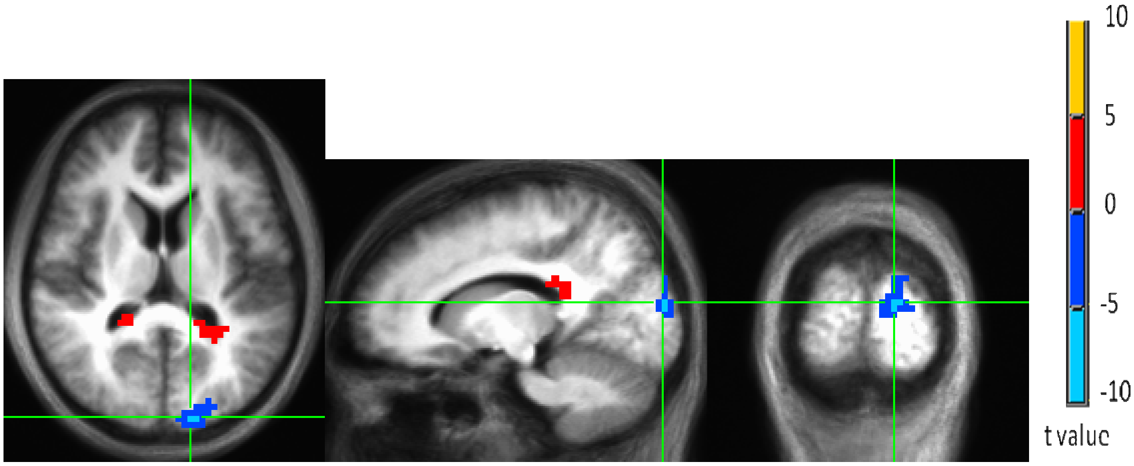
White matter



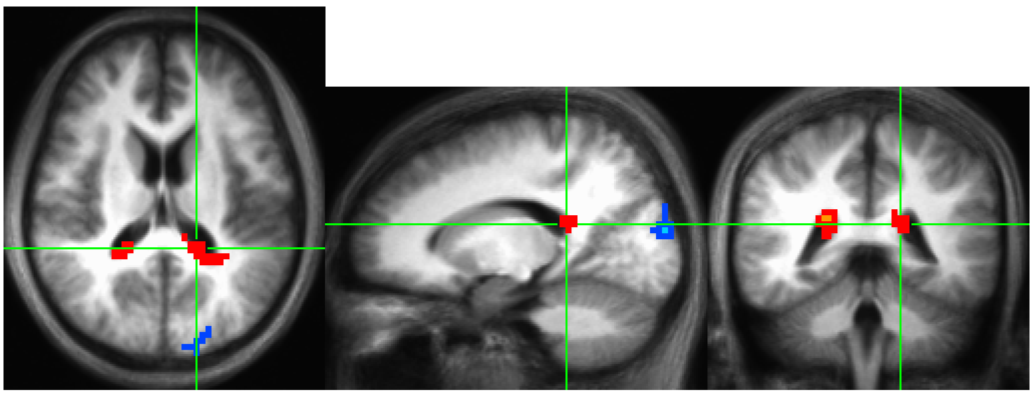
White matter

Clusters are p <.05 FWE-corrected with a minimum cluster-size of 44 voxels

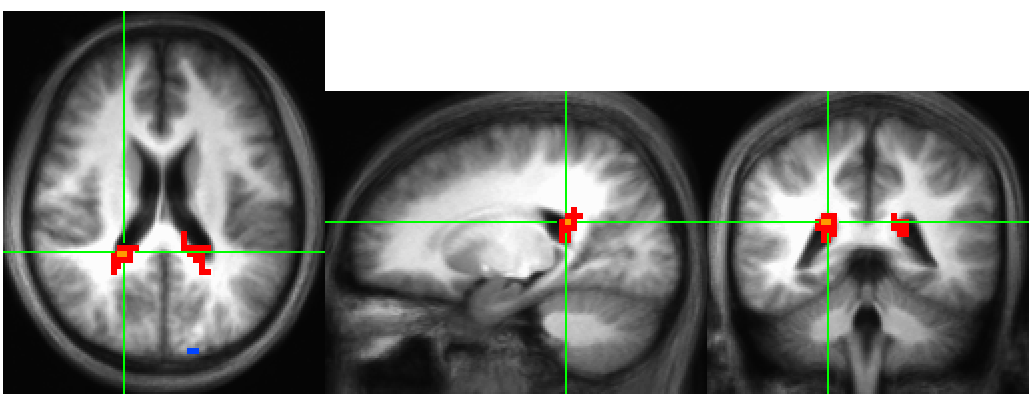
Figure 19: Regional activations and deactivations for partner-cighigh compared to neutral-cighigh in Study 1 (FWE-corrected)



Left middle occipital gyrus



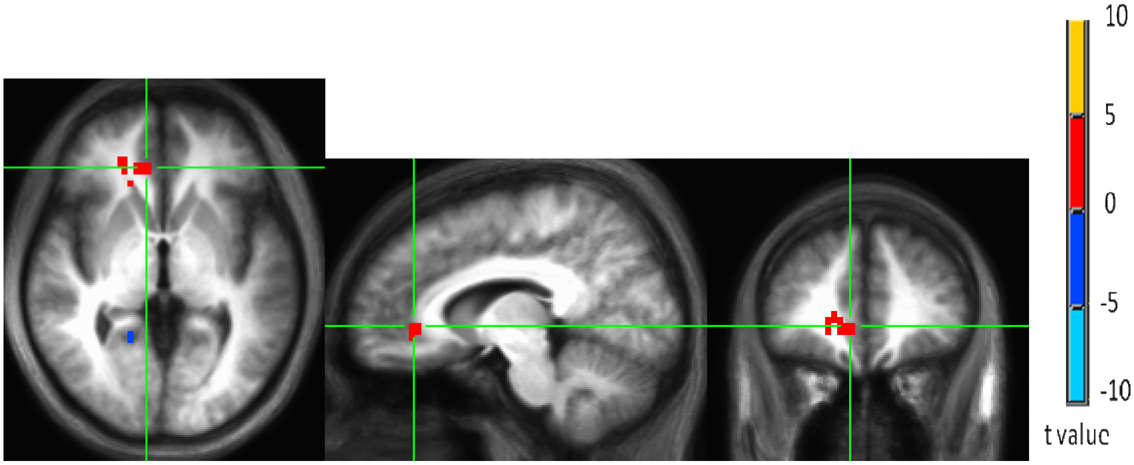
White matter



White matter

Clusters are p <.05 FWE-corrected with a minimum cluster-size of 44 voxels

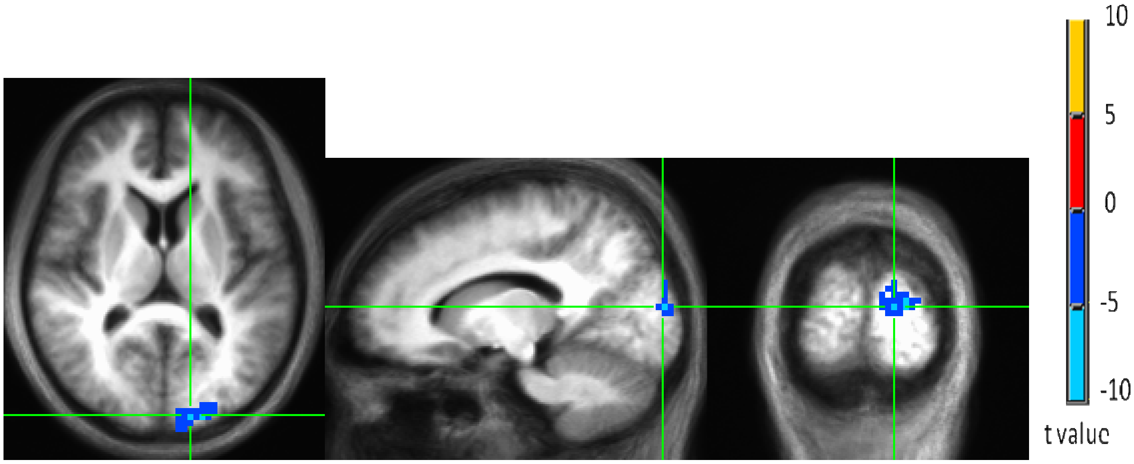
Figure 20: Regional deactivations for partner-cigmod compared to friend-cigmod in Study 1 (FWE-corrected)



Right anterior cingulate

Clusters are p <.05 FWE-corrected with a minimum cluster-size of 44 voxels

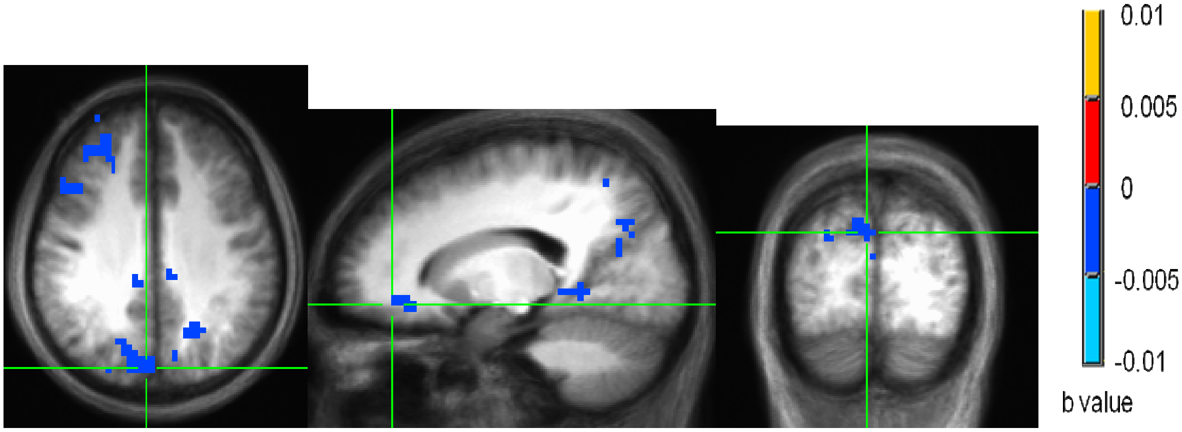
Figure 21: Regional deactivations for partner-cigaveraged compared to neutral-cigaveraged in Study 1 (FWE-corrected)



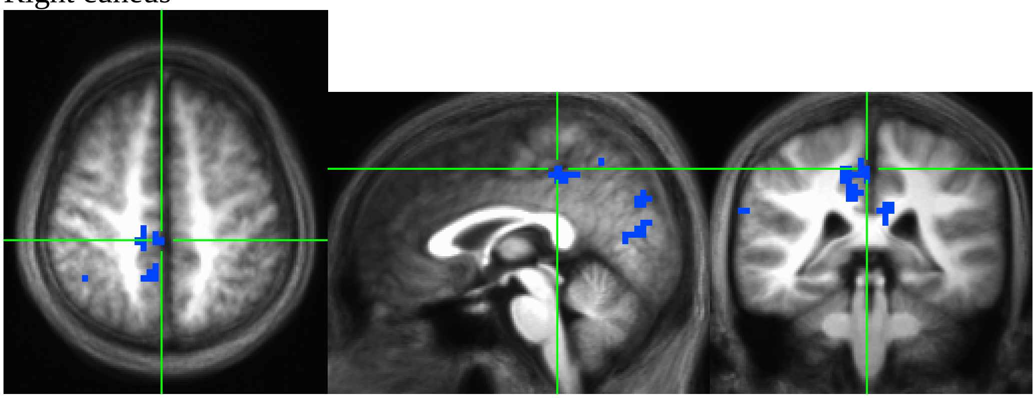
Left cuneus

Clusters are p <.05 FWE-corrected with a minimum cluster-size of 44 voxels

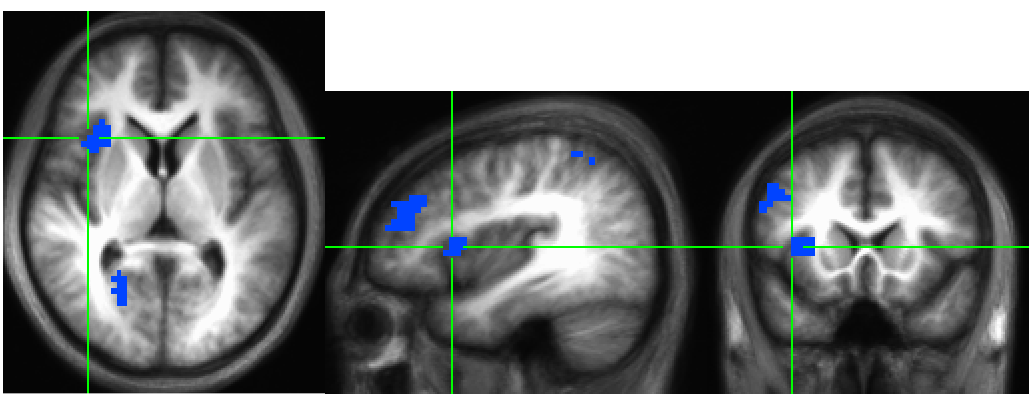
Figure 22: BOLD signal regional correlations of partner smoking conflict for partner-cigaveraged vs. friend-cigaveraged contrast in Study 1



Right cuneus



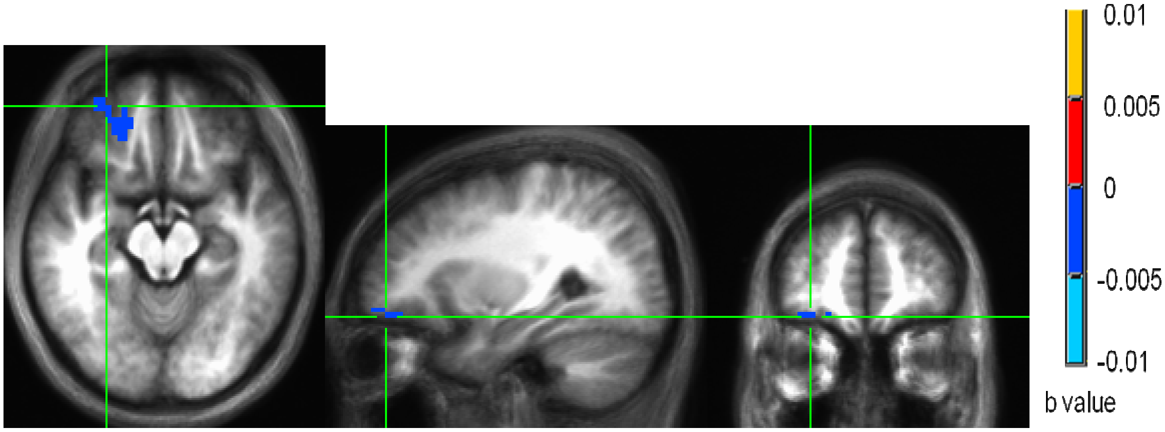
Right precuneus



Right insula

Correlations were p <.005 uncorrected with a minimum cluster of 20 voxels

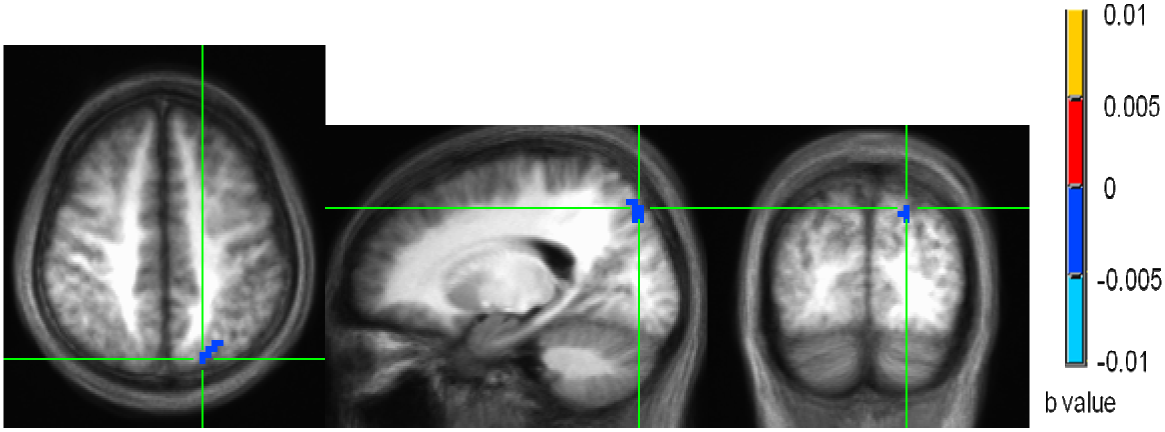
Figure 23: BOLD signal regional correlations of partner smoking conflict for partner-cigaveraged vs. neutral-cigaveraged contrast in Study 1



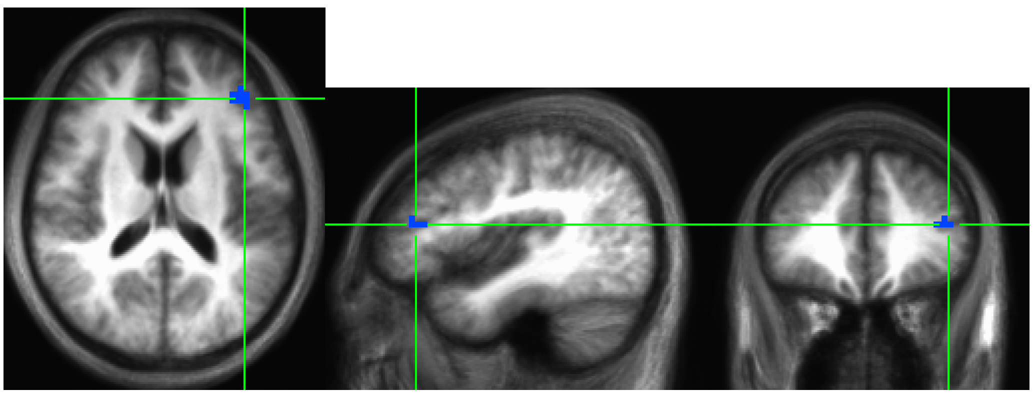
Right middle frontal gyrus

Correlations were p <.005 uncorrected with a minimum cluster of 20 voxels

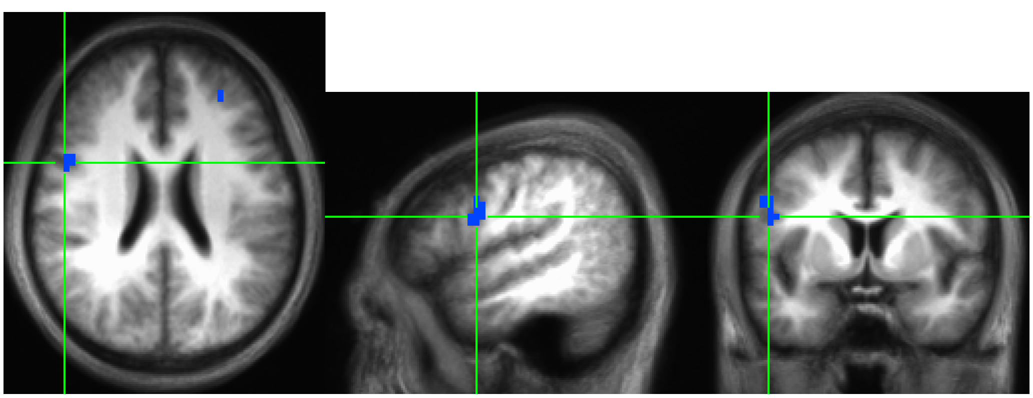
Figure 24: BOLD signal regional correlations of relationship length for partner-cigaveraged vs. neutral-cigaveraged contrast in Study 1



Left precuneus



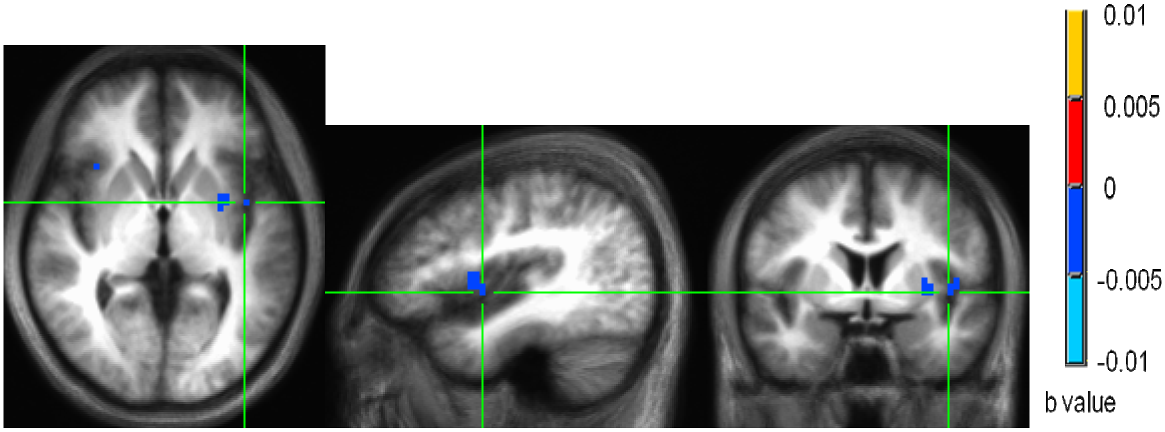
Left middle frontal gyrus



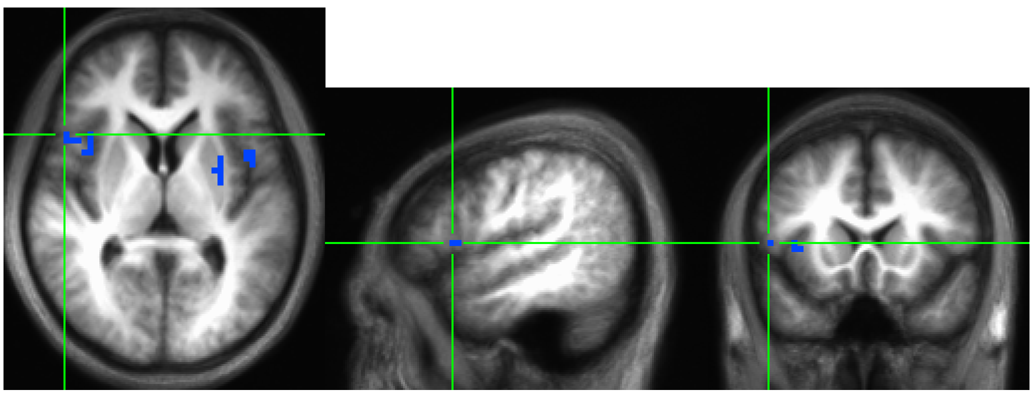
Right inferior frontal gyrus

Correlations were *p* <.005 uncorrected with a minimum cluster of 20 voxels

Figure 25: BOLD signal regional correlations of CDS score for partner-cigaveraged vs. neutral-cigaveraged contrast in Study 1



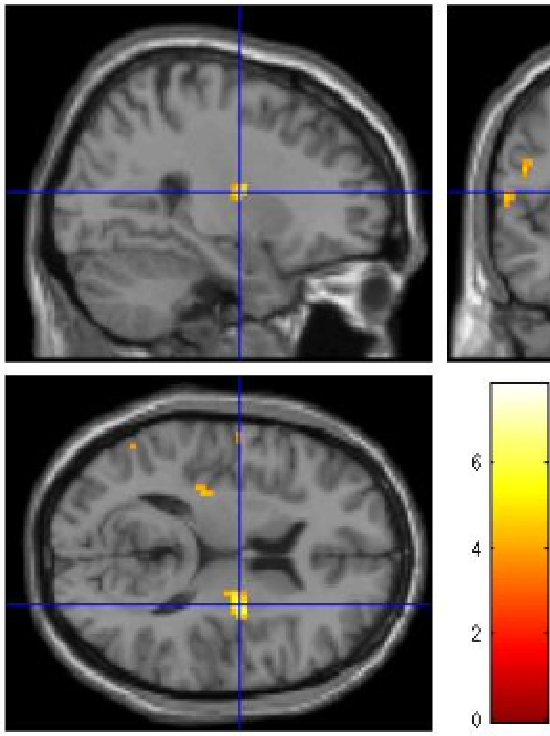
Left insula



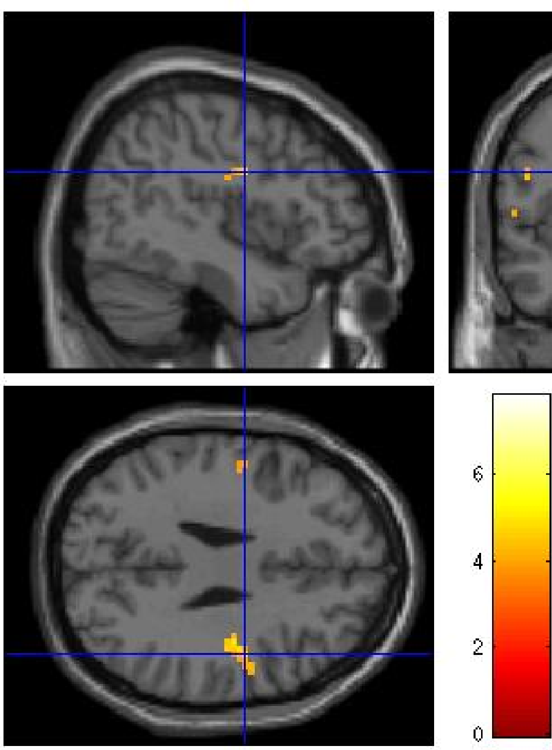
Right precentral gyrus

Correlations were p <.005 uncorrected with a minimum cluster of 20 voxels

Figure 26: Regional activations for SECig-SEnoCig in Study 2

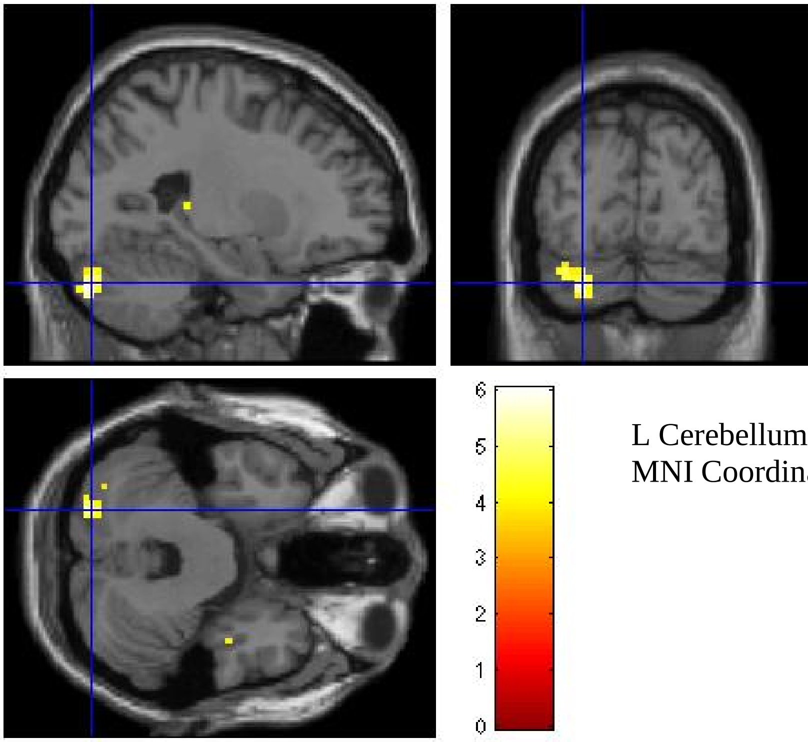


R Putamen
MNI Coordinates: 27,-7,13

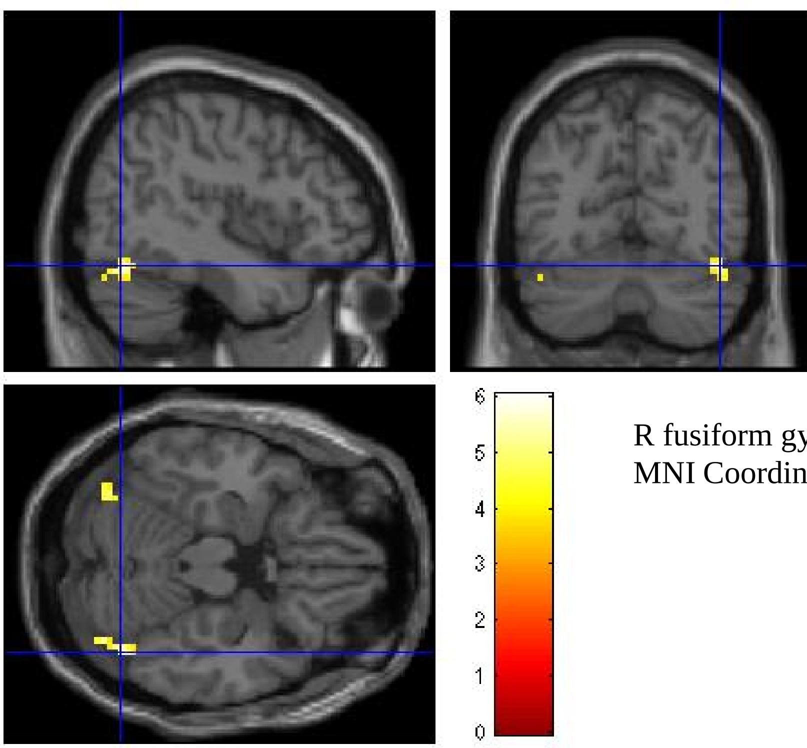


R Precentral gyrus
MNI Coordinates: 45, -4, 28

Figure 27: Regional activations for NSECig-NSEnoCig in Study 2

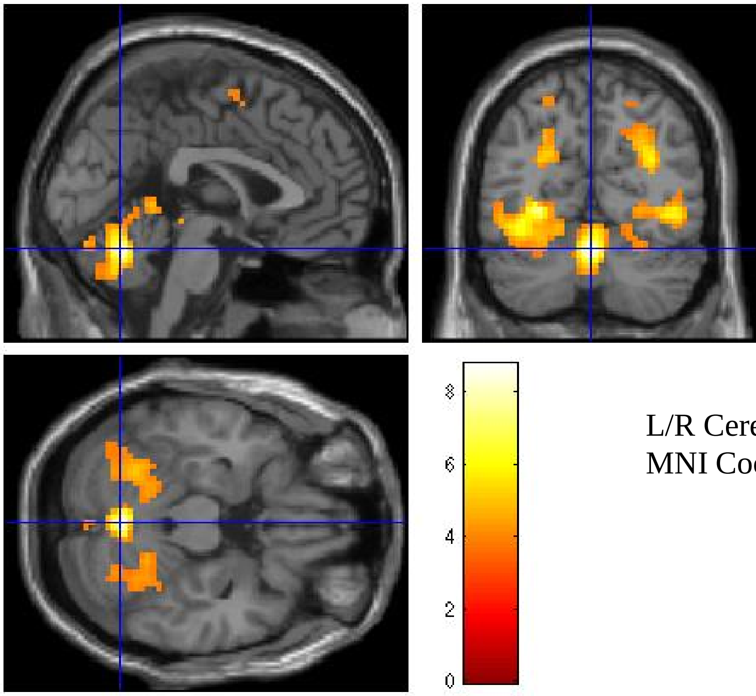


L Cerebellum (uvula)
MNI Coordinates: -24, -82, -32

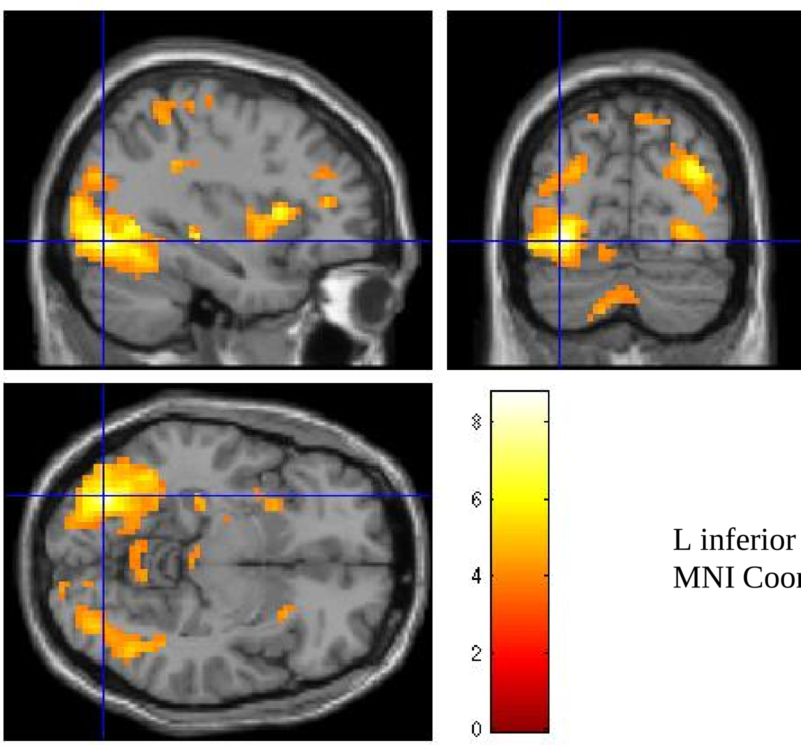


R fusiform gyrus
MNI Coordinates: 45, -67, -20

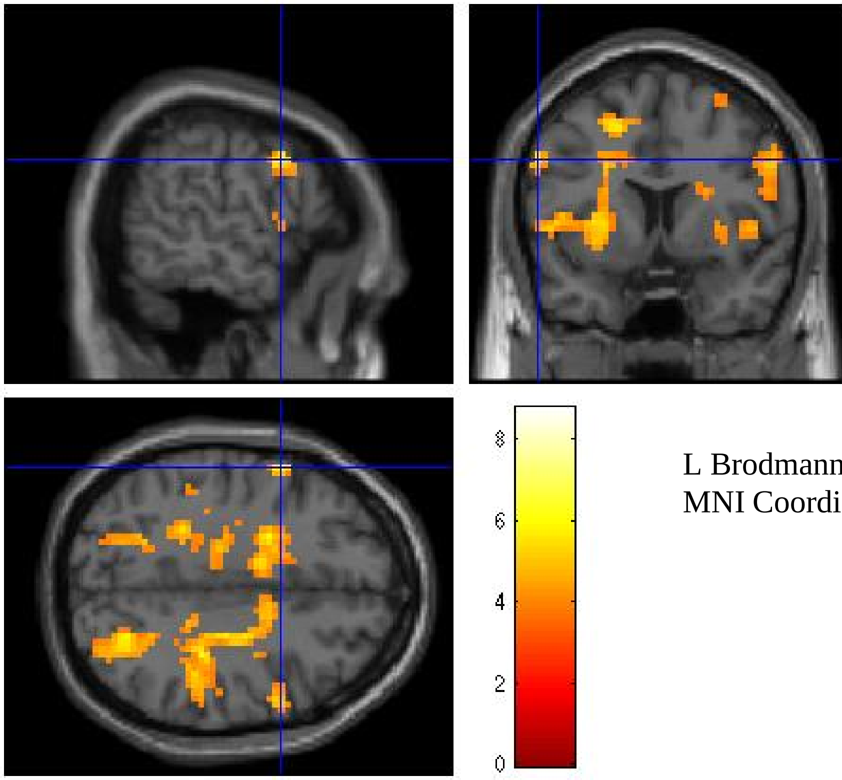
Figure 28: Regional activations for SECig-NSECig in Study 2



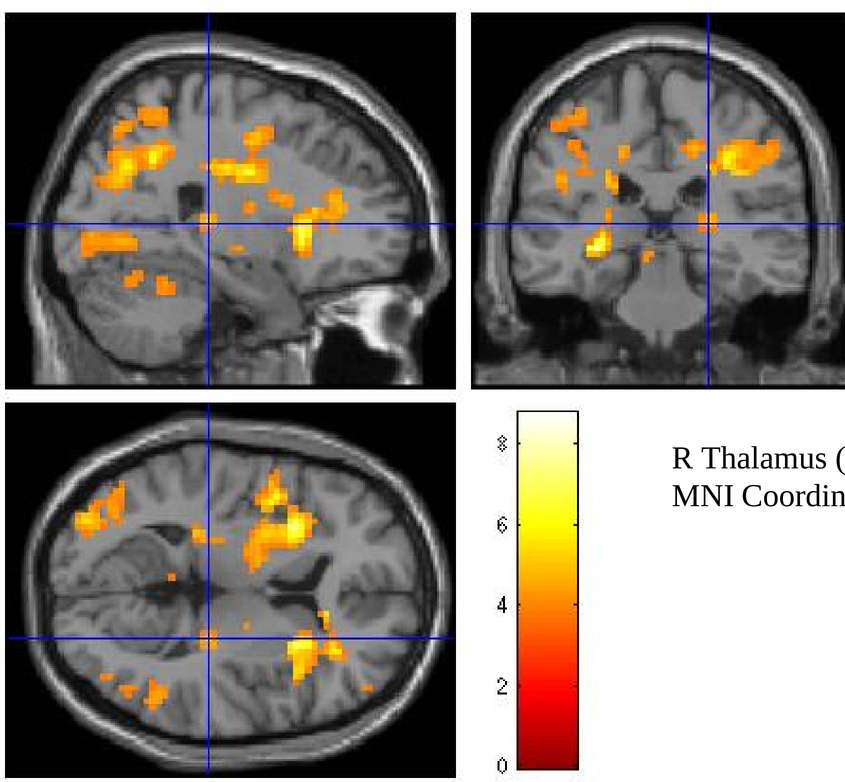
L/R Cerebellum (declive)
MNI Coordinates: 0, -64, -23



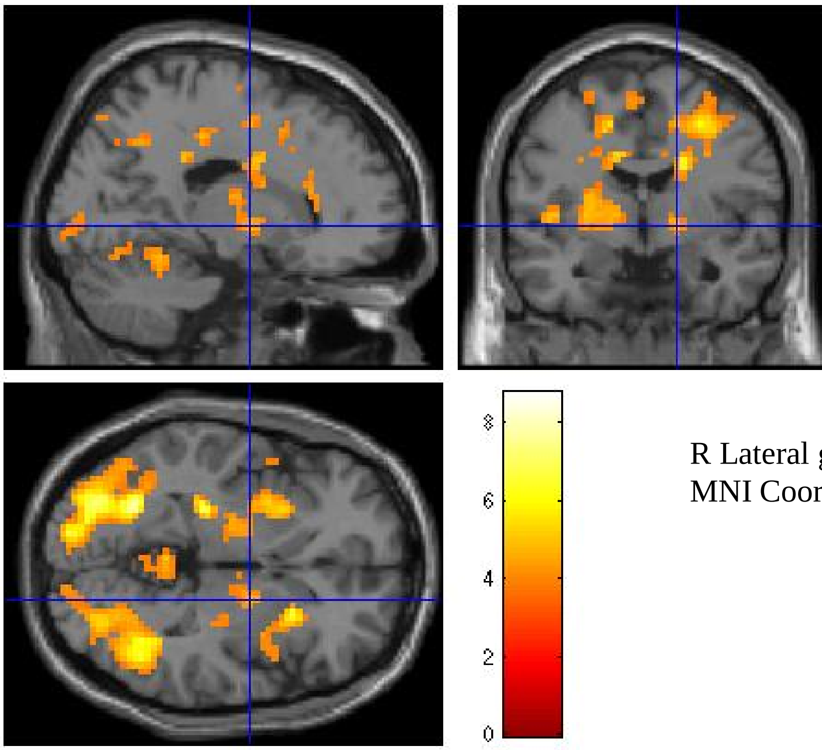
L inferior occipital gyrus
MNI Coordinates: -33, -76, -8



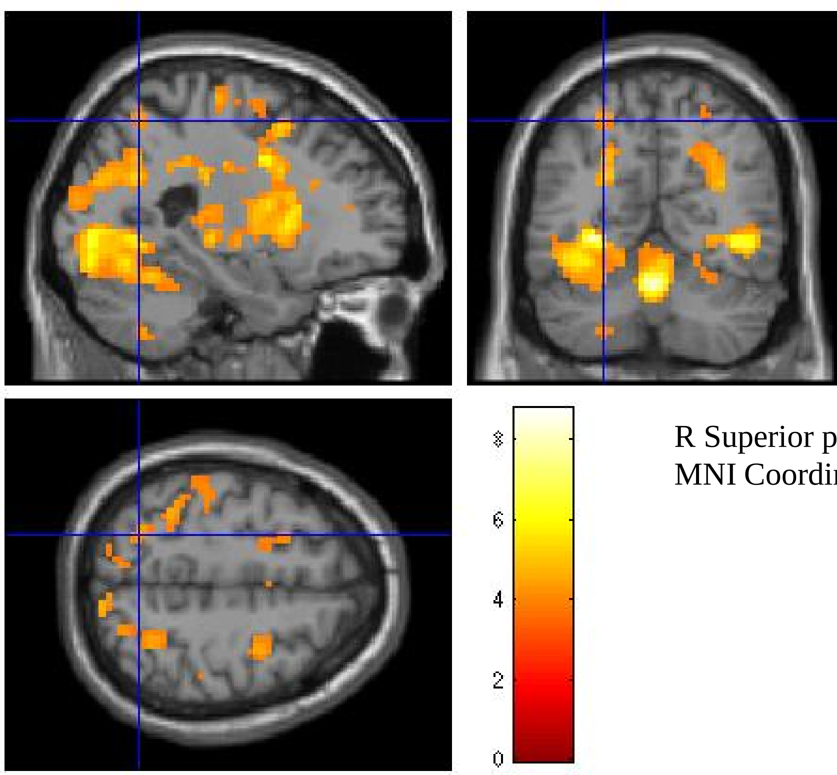
L Brodmann Area 9
MNI Coordinates: -58, 8, 34



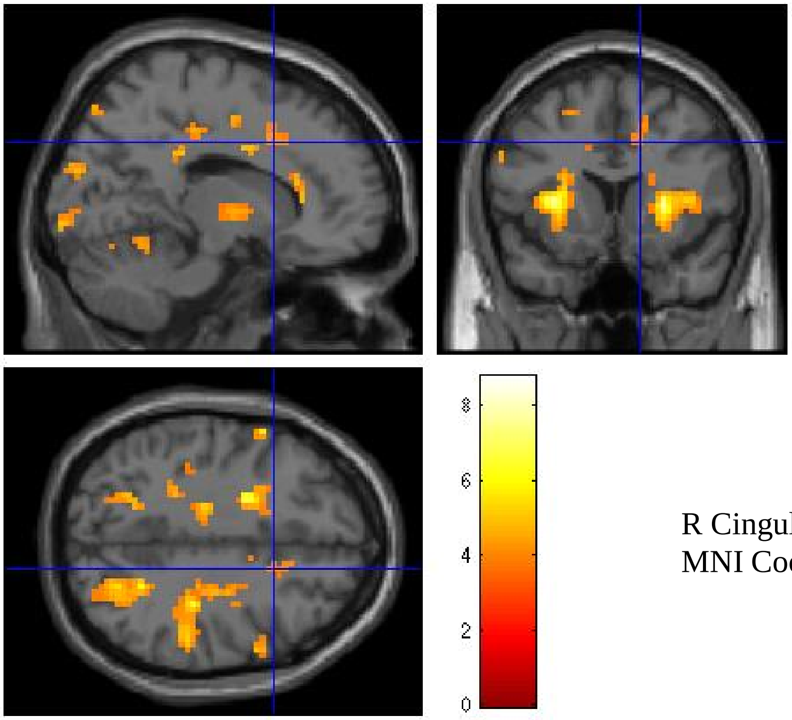
R Thalamus (pulvinar)
MNI Coordinates: 24, -28, 7



R Lateral globus pallidus
MNI Coordinates: 18, -4, -2

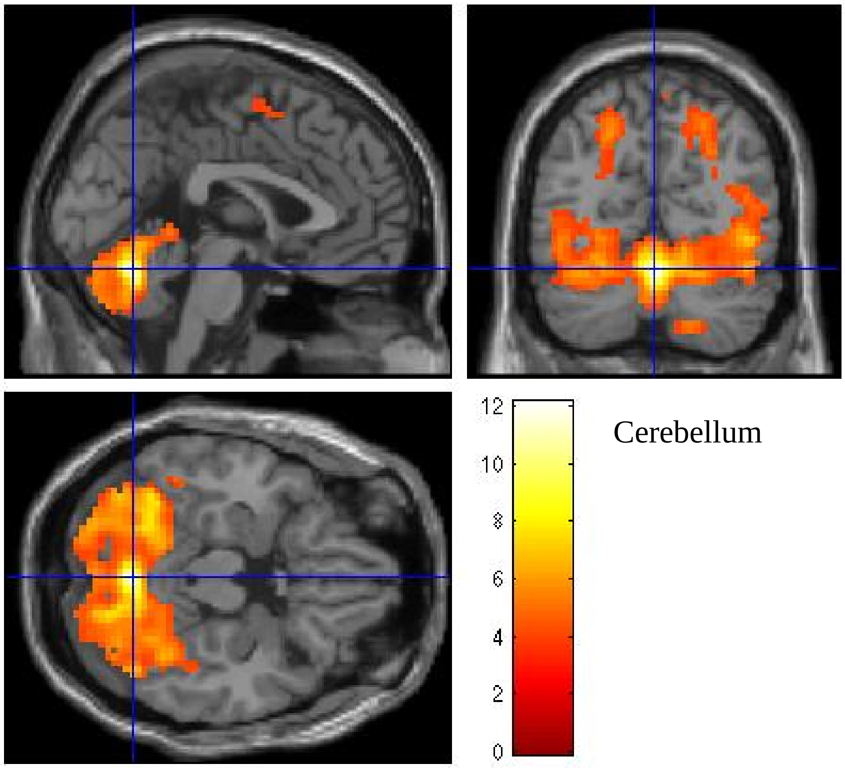


R Superior parietal lobule
MNI Coordinates: 24, -61, 55

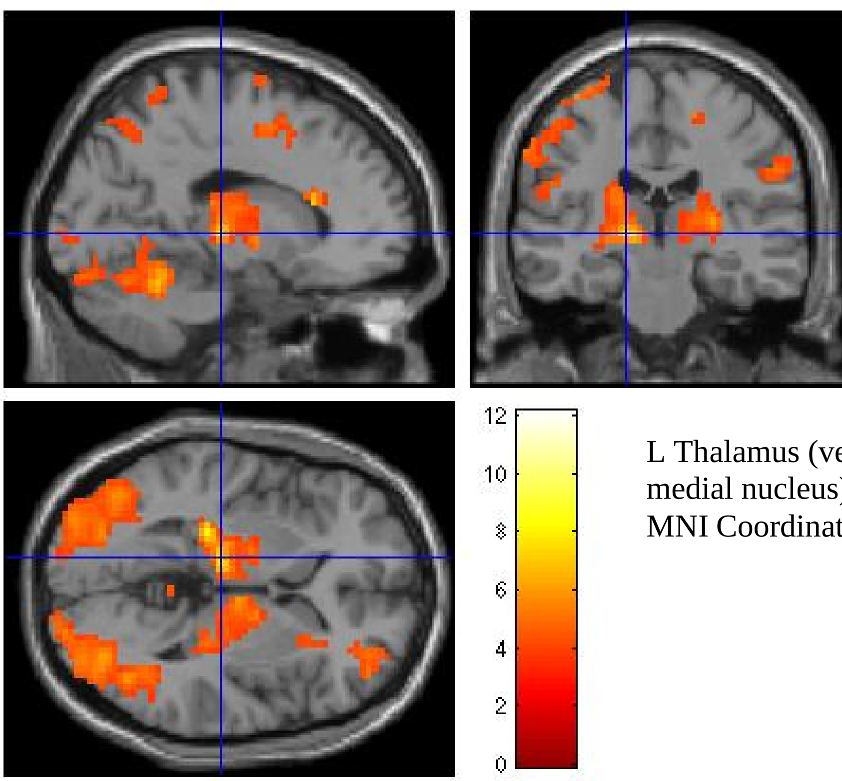


R Cingulate gyrus
MNI Coordinates: 15, 14, 37

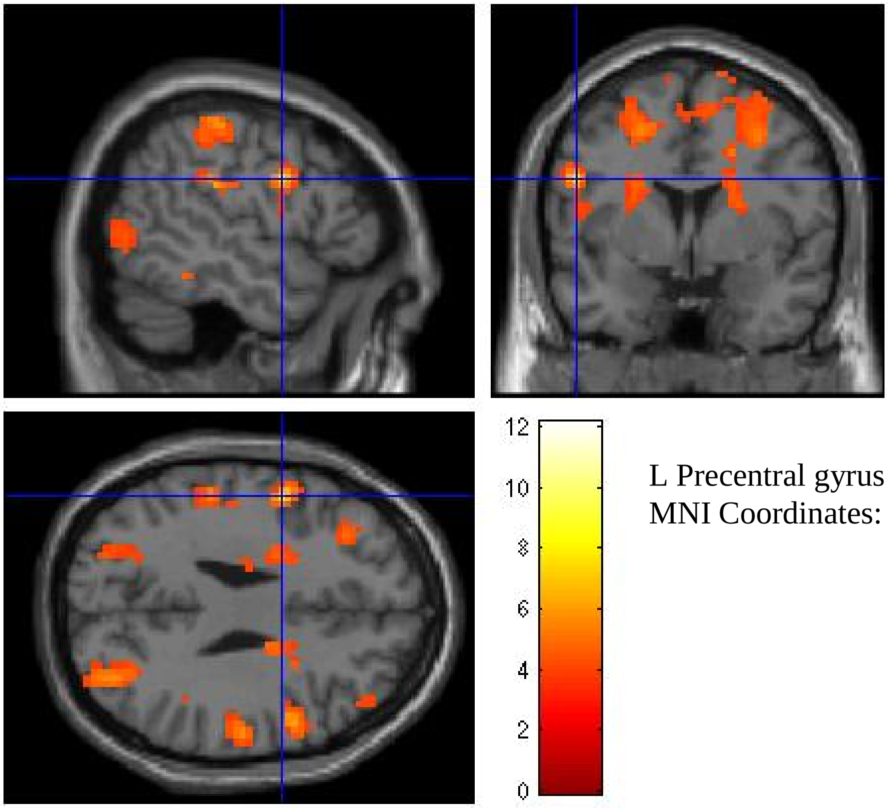
Figure 29: Regional activations for SEnoCig-NSEnoCig in Study 2



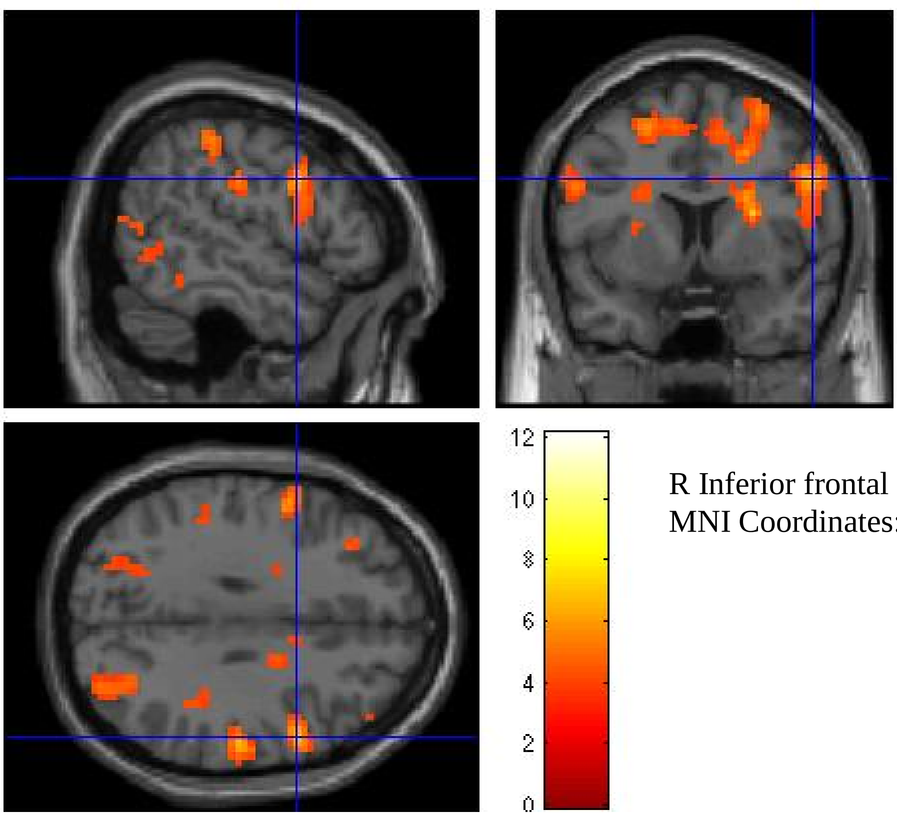
Cerebellum



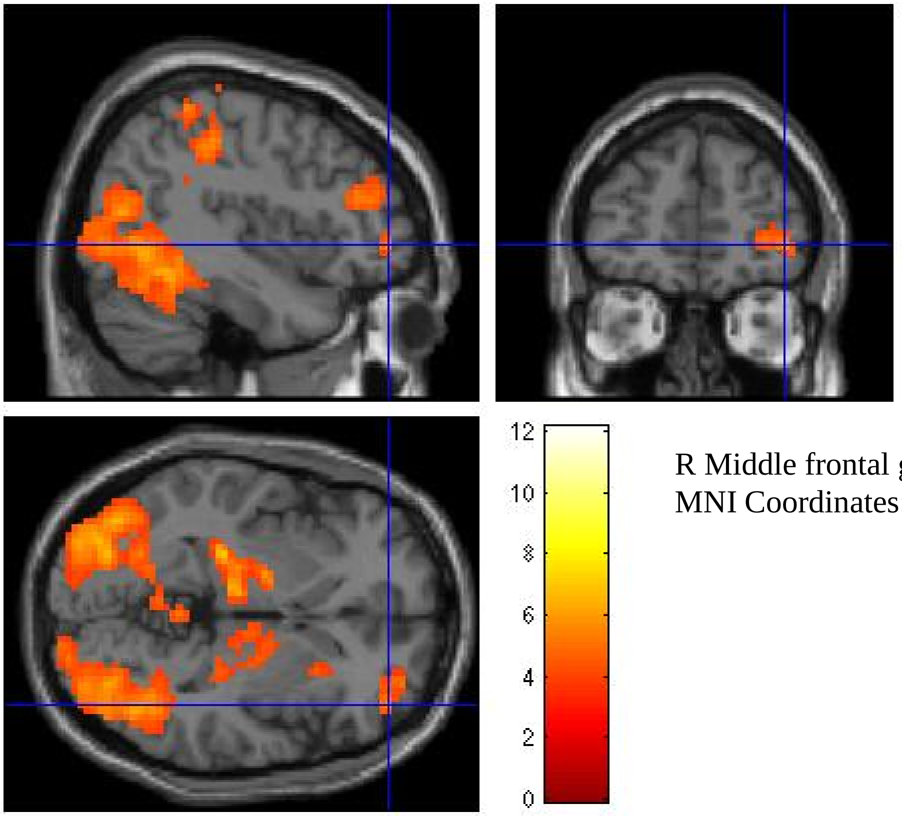
L Thalamus (ventral posterior medial nucleus)
MNI Coordinates: -15, -22, 1



L Precentral gyrus
MNI Coordinates: -51, 2, 28

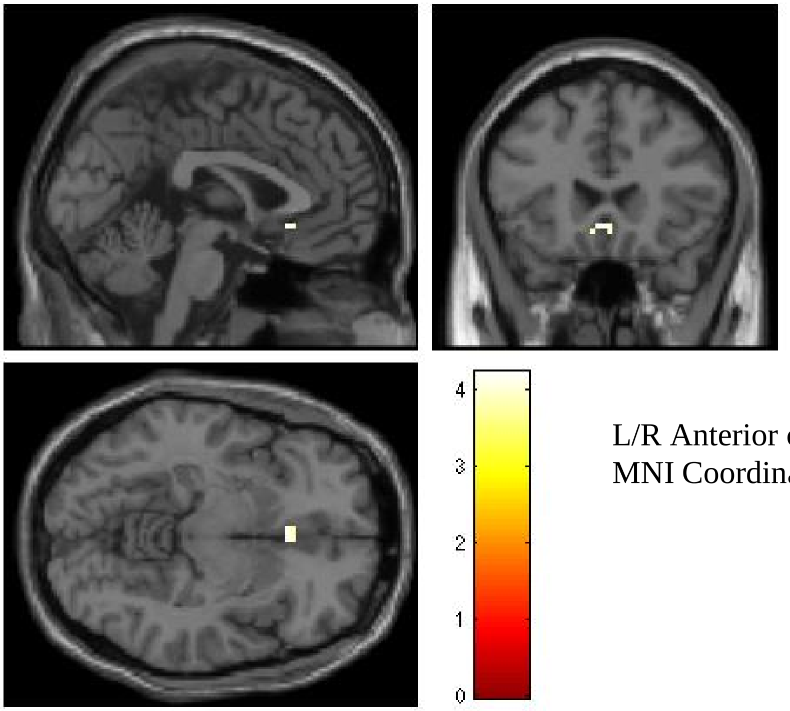


R Inferior frontal gyrus (BA6)
MNI Coordinates: 54, 8, 31



R Middle frontal gyrus
MNI Coordinates: 42, 50, -2

Figure 30: Regional activations for NSECig-SECig in Study 2



L/R Anterior cingulate
MNI Coordinates: 0, 23, -8

Figure 31: Correlation of BOLD activation in Brodmann Area 10 for SECig excitement minus SECig pleasantness variable (for NSECig-SECig contrast in Study 2).

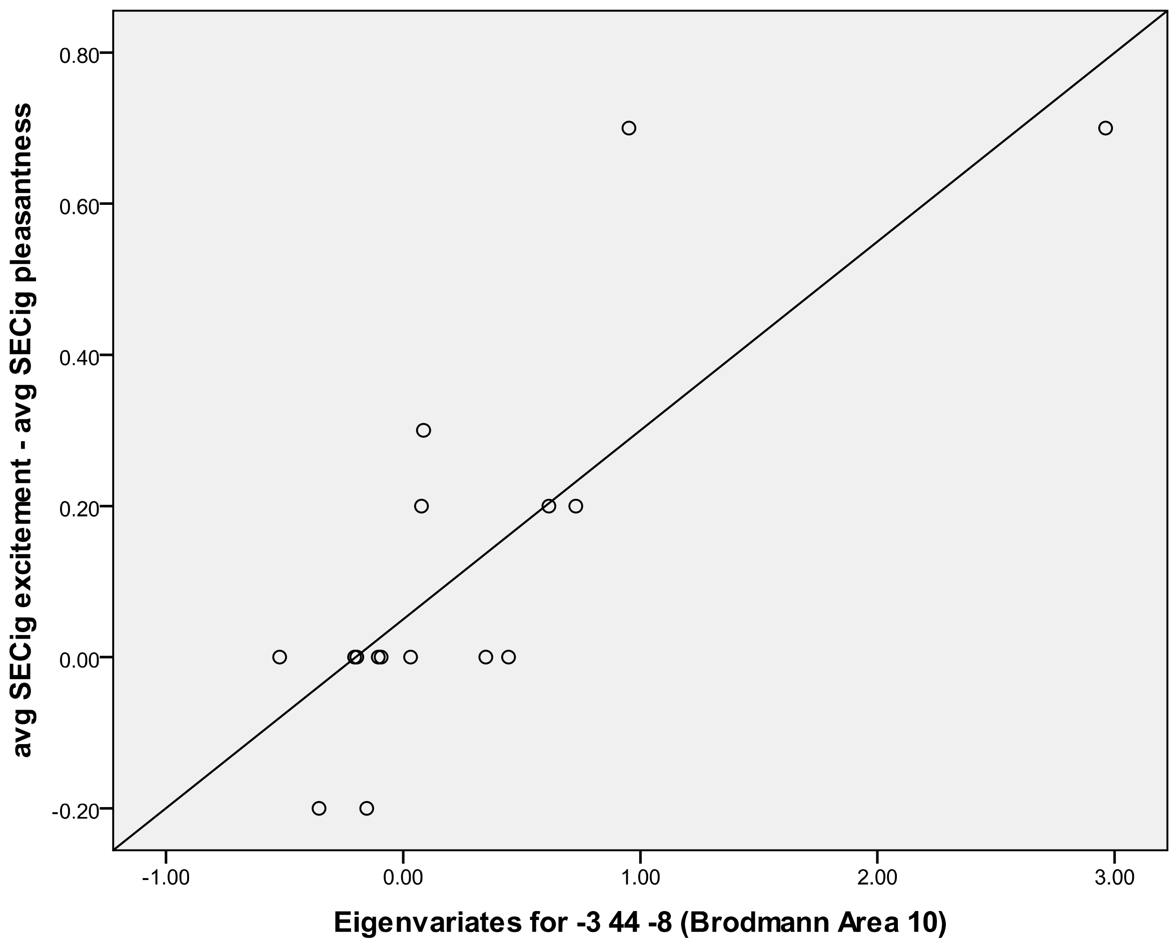


Figure 32: Correlations of BOLD activations in pyramis of the cerebellum and middle frontal gyrus for Smoking Conflict Measure (for NSECig-SECig contrast in Study 2)