Involvement of action-related brain regions in nicotine addiction

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Yalachkov Y, Naumer MJ. Involvement of action-related brain regions in nicotine addiction. J Neurophysiol 106: 1–3, 2011. First published April 27, 2011; doi:10.1152/jn.00195.2011.—The study of Wagner et al. (J Neurosci 31: 894–898, 2011) reveals the neural correlates of spontaneously activated action representations in smokers when subjects watch movie characters smoke. We stress the importance of differentiating how these representations are activated: while the anterior intraparietal sulcus and inferior frontal gyrus are part of the mirror neuron system of smokers, the middle frontal gyrus, premotor cortex, and superior parietal lobule represent the smoking-related tool use skills and action knowledge activated by smoking paraphernalia.

action observation network; action representations; smoking

UNDERSTANDING HOW MOTIVATION, memory, and executive control processes interact with drug-associated cues to trigger a relapse into drug-seeking behavior is of prime importance for the development of effective treatments for drug addiction. Correspondingly, the majority of the neuroimaging literature on drug cue reactivity has focused on subcortical and prefrontal correlates of reward, learning, and executive functions in addiction.

However, basic neuroscience research has shown that further cognitive and neural processes can influence the link between an environmental cue and a behavioral response (Boy et al. 2010a,b; Grezes and Decety 2002; Lewis 2006; Nachev et al. 2008; Summer and Husain 2008). In particular, manipulable objects activate action-related brain regions such as the premotor and parietal cortices, reflecting the engagement of automatized motor schemata and action knowledge. Furthermore, observing others’ actions recruits parietal and lateral frontal cortices, which are activated also when individuals plan, imitate, or execute the same actions, thus demonstrating that the action representations can be accessed via different ways. Given that addicted people are frequently exposed to drug use paraphernalia and to other users engaging in drug-taking behavior, the precise and detailed investigation of the relevance of action-related brain regions for drug cue reactivity is essential.

A recent study by Wagner et al. offers an interesting perspective on this issue (Wagner et al. 2011). Since smoking comprises a manual action component and many smokers engage in smoking in an automatized manner (Tiffany 1990), they hypothesized that brain regions such as the anterior intraparietal sulcus (aIPS) and the inferior frontal gyrus (IFG), which are responsible for the planning, initiating, and imitating of manual actions, would be recruited to a greater extent in smokers than in nonsmokers when subjects watch movie characters smoke. The authors measured the blood-oxygen-level-dependent (BOLD) signal in smokers’ and nonsmokers’ brains by employing functional magnetic resonance imaging (fMRI) while the participants watched movies containing both smoking and neutral scenes. The subjects were told that the authors were interested in the neural correlates of watching movies. Thus, subjects did not have any particular expectations of viewing smoking-related stimuli.

When contrasting smoking-related vs. control scenes across all participants, several brain regions were revealed. Functionally, these regions can be divided into two groups: the first consisted of the dorsal anterior cingulate cortex (dACC), orbitofrontal cortex (OFC), and dorsolateral prefrontal cortex (DLPFC), brain regions known for their role in important components of addiction: reward, craving, and executive functions. The second group comprised the aIPS, left IFG, and premotor cortex (PMC), which store and process action representations. Further region-of-interest (ROI) analysis showed that smokers exhibited higher smoking cue reactivity than nonsmokers in the left aIPS and IFG as well as in the dACC, OFC, and bilateral DLPFC. Finally, correlations between neural cue reactivity in smokers and post-scan ratings of cue-induced cigarette craving were found for the dACC only.

The reported results are in line with the current addiction literature, demonstrating that smoking-related stimuli elicit higher activation in smokers than in nonsmokers in dACC, OFC, and DLPFC, reflecting cue processing by the cortical motivation and executive control systems. Furthermore, Wagner et al. (2011) showed that observing smoking people activates the aIPS and IFG regions more strongly in smokers than in nonsmokers. The authors interpret their findings as an indication for an engagement of the action observation network (AON; consisting of aIPS and IFG) in addiction. Since the AON is known to be recruited when observing, planning, or simulating an action, it can be assumed that smokers simulate internally the action of smoking when viewing movies containing smoking scenes. This motor resonance would reduce the threshold for executing the actual action and thus enhance the probability for relapse in abstinent smokers. These experimental results have important implications not only for theoretical models of addiction but also for the practical implementation of neuroscientific findings in the treatment of drug dependence. While most of the research has concentrated on the brain mechanisms of reward, learning, and behavioral control, it is now high time to consider the involvement of action-related processes in addiction and relapse. The neural cue reactivity of action planning brain regions offers another target for developing a reliable biomarker of addiction. Moreover, the relevance of the action observation network for cue

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reactivity in nicotine dependence has crucial consequences for the daily routine of a smoker trying to quit: this person would have an increased risk for relapse even when watching movies containing smoking scenes. This is not a trivial issue, since movies and television are of ubiquitous presence in our lives.

According to the authors, only few neuroimaging studies of smoking cue reactivity have reported an activation of action-associated cortices. They attribute this to the common use of static cues (e.g., photographs of smoking paraphernalia) instead of dynamic movies. Indeed, there are much fewer reports of cue reactivity in action-related brain regions than neuroimaging studies reporting activations in the striatum or in prefrontal regions. However, this might also be attributable to the popular ROI-based analysis of neuroimaging data, where the scope of the analyzed brain regions is often limited to brain structures such as the striatum and the prefrontal cortex, which have been studied extensively in animal research and have proven relevant for addiction. On the other hand, several studies using a whole brain analysis approach have demonstrated how sensorimotor brain networks contribute to addiction (for a review, see Yalachkov et al. 2010). Although some of these studies employed static stimuli (e.g., smoking-related pictures), they still revealed activations in frontal and parietal action-related cortices (e.g., Janes et al. 2010; Smolka et al. 2006; Yalachkov et al. 2009). This finding has been further corroborated by correlations found between cue reactivity in these brain regions and the individual severity of nicotine dependence, automatized behavioral responses towards smoking cues, and the subjects’ ability to maintain tobacco abstinence during a smoking cessation attempt. These observations converge with the results of Wagner et al. (2011) by demonstrating the activation of action representations in the addicted brain. However, there is evidence that these neural representations can be accessed via multiple ways. Wagner et al. postulated that observing other people smoke activates the IFG and aIPS, which are part of the AON. The AON is closely related to the mirror neuron system and assumes that the visual perception of an action elicits an internal simulation of the same action (Cattaneo and Rizzolatti 2009). Thus, smoking-associated action representations are automatically activated while observing interactions between an agent and an object (e.g., seeing how a person lights a cigarette). An alternative explanation might be based on the fact that frontal and parietal regions are part of a brain network responsible for the processing of tool use knowledge and object manipulation skills (Lewis 2006). Pictures of manipulable objects without an agent acting upon them have been shown to activate the IFG, middle frontal gyrus (MFG), PMC, and superior parietal lobule (SPL). The coordinated interaction of these sensorimotor brain regions is necessary for the skillful use of a tool. This cortical network can be activated without any agent acting upon an object stimulus, and the respective motor representations are triggered solely by tool affordances, i.e., the properties of a tool that are relevant for its use. This has an important implication for cue reactivity in addiction, since object affordances automatically potentiate motor actions associated with the use of a tool. Indeed, it has been demonstrated that for smokers, static pictures depicting smoking paraphernalia without people acting upon them induce automatized behavioral responses towards the smoking cues. Interestingly, the magnitude of this effect was correlated with the neural cue reactivity in action-related brain regions elicited by pictures showing people smoking (Yalachkov et al. 2009).

The study by Wagner et al. (2011) makes an important contribution to the understanding of how sensorimotor brain regions are involved in addiction. Based on the new findings of Wagner et al. and the existing literature (Yalachkov et al. 2009, 2010), it is evident that smoking cues can activate corresponding action representations in the addicted brain. Apparently, this can happen via two complementary pathways. The first one involves observing an agent acting upon the respective drug paraphernalia and is facilitated by internal simulation and the AON (Fig. 1). The second one is based on drug-related object affordances, which reliably trigger the automated action schemata associated with the use of the respective paraphernalia (Fig. 1).
The present study might have benefited from the additional application of a whole brain ANOVA allowing to test for a potential interaction between the two factors “group” (smokers vs. nonsmokers) and “movie” (smoking-related vs. neutral). One might speculate that such a complementary analysis strategy might have revealed further sensorimotor brain regions involved in the neural cue reactivity in smokers watching smoking movies. Furthermore, when testing for correlations between fMRI activations and post-scan craving, smokers’ craving ratings were correlated with parameter estimates extracted from ROIs, which were defined on the basis of the data of both smokers and nonsmokers. Defining the ROIs solely based on the data of the smokers might have facilitated the detection of significant correlations in other brain regions.

The study of Wagner et al. contributes substantially to the understanding of sensorimotor aspects of addiction, an issue of markedly growing interest in the neuroscientific community. By demonstrating neural cue reactivity in brain regions such as the aIPS and IFG, which are commonly involved in action representations, the authors replicate and extend previous findings. Future research which carefully tests the exact role of action simulation and object affordances in smoking cue reactivity will further deepen our understanding of nicotine addiction and its underlying perceptual and action mechanisms.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

REFERENCES


