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Food addiction is associated with impaired performance monitoring

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ABSTRACT

Currently, there is an ongoing debate about whether it is possible to be addicted to food. There are several indications pointing in this direction, but research is scarce. Up to this date it is not exactly known whether this "food addiction" shares common neurocognitive deficits observed in the more classical types of addictions such as substance use disorders (SUDs). One commonly observed finding in SUD patients is that there is an impaired cognitive control. One of the essential components of cognitive control is performance monitoring. In the present study it is studied whether persons with "food addiction" have impaired error monitoring. For this purpose the performance monitoring of persons meeting the criteria for "food addiction" (n = 34) according to the Yale Food Addiction Scale (YFAS) were compared with a control group (n = 34) while performing an Eriksen flanker task and EEG measurement. Both electrophysiological (ERN and Pe component) and behavioral measures were compared between the two groups. The present study indicates that the "food addicted" persons have reduced ERN and Pe waves. In addition, the "food addiction" group demonstrates a higher number of errors on the flanker task. In general, the results provide indications that persons with a "food addiction" display impaired performance monitoring. These findings provide an indication that food addiction, similar to other addictions, is characterized by impaired cognitive control.

1. Introduction

Recently, there is some debate whether food addiction can be considered as a real addiction (Smith & Robbins, 2013; Ziauddeen, Farooqi, & Fletcher, 2012). This debate falls within the broader discussion whether the excessive involvement in rewarding non-substance use behaviors such as gambling, gaming, and shopping can be regarded as an addiction (Billieux, Schimmenti, Khazaal, Maurage, & Heeren, 2015; Grant, Potenza, Weinstein, & Gorelick, 2010; Marks, 1990; Potenza, 2006). One important issue is whether these "new" addictions share common neurocognitive aspects that are usually associated with the "traditional" addictions, i.e., alcohol and drug addiction (Potenza, 2015). One of the hallmarks of addiction is a poor self-control over behavioral engagement (i.e., poor self-regulation). One commonly observed finding is that there is some kind of impaired cognitive control in patients diagnosed with a substance use disorder (SUD). An essential component of cognitive control is performance monitoring (Luna, Marek, Larsen, Tervo-Clemmens, & Chahal, 2015; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004). Performance monitoring, particularly the processing of errors, refers to the ability to monitor actions and their consequences, in order to adjust behavior to prevent future errors. Previous studies in several addictive behaviors (Franken, van Strien, Franzek, & van de Wetering, 2007; Hester, Simoes-Franklin, & Garavan, 2007; Luijten, van Meel, & Franken, 2011), including behavioral addictions (Littel et al., 2012) show impaired performance monitoring (see for a review Luijten et al., 2014).

Generally, performance monitoring is measured using behavioral measures, such as the number of errors on a flanker task, and physiological measures such as fMRI (e.g., Hester, Nestor, & Garavan, 2009) and EEG. For the present study we will now focus on EEG. The making of an error can clearly be observed in the EEG: An initial Error-Related Negativity (ERN) and a later P3-like Error-positivity (Pe) wave will emerge after committing an error. Several studies show that both components can be reliably measured (Olvet and Hajcak, 2009; Rietdijk, Franken, & Thurik, 2014). Although the exact nature of these two components is still debated, there are indications that the ERN wave represents the initial and preconscious brain response on the making of an error and that the Pe wave is associated with the conscious recognition of the error, and probably with the motivational significance attributed to this error (Overbeek, Nieuwenhuis, & Ridderinkhof, 2005). Several

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studies show that the ERN and/or Pe is reduced in cigarette smokers (Franken, van Strien, & Kuijpers, 2010; Luijten et al., 2011), and cocaine dependent patients (Franken et al., 2007; Marhe, van de Wetering, & Franken, 2013).

In order to contribute to this ongoing discussion we aimed to investigate whether persons who can be considered as having a food addiction have impaired performance monitoring. We used the Yale Food Addiction Scale (YFAS, Gearhardt, Corbin, & Brownell, 2009) to classify persons as having a food addiction. The YFAS is the most used self-report instrument to investigate food addiction. We realize that the debate whether this is a real addiction is still ongoing, for readability purposes, we will use the term "food addiction group" to indicate these persons.

2. Methods

2.1. Participants

All subjects were selected from a broader pool of 650 subjects who all filled out the YFAS (for a validation study, not reported in the present paper). Participants were selected by means of the YFAS questionnaire (see below), which was administered among students from the Erasmus University of Rotterdam between the ages of 18–40, in the context of a survey concerning eating (several eating questionnaires were assessed, data not shown), personality and health. Students had the option to indicate if they wanted to be approached for a follow-up study. Students received course credits for participating. Besides that, the questionnaire was spread amongst friends and family of the researchers and research assistants, and among students from other universities with the help of social media (Facebook). These participants received a financial compensation for participating. Persons meeting the criteria for food addiction were invited to participate in the present study. We defined persons with ≥3 symptoms as having a food addiction. This is in accordance with the guidelines of the YFAS (Gearhardt et al., 2009) and other studies in this area (Innamorati et al., 2015), including other EEG studies (Imperatori et al., 2015). In addition, control subjects were selected from this pool from the group that had none or one positive YFAS symptom. They were matched as much as possible with the food addiction group on age, gender and educational level. Participants were excluded if they had currently self-reported psychiatric or physical illness that could influence body weight, eating habits or the EEG-signal. We also excluded participants when they used medicine that could potentially influence eating habits, body weight or EEG activity or when they had a history of drug abuse. In total 68 subjects participated in the present study, 34 in each group. Mean age of the controls was 20.8 years (SD = 3.0) and mean age of the food addiction group was 19.9 (SD = 1.7). No differences between both groups were observed in terms of age, education, or gender (p's > 0.1). In addition, (BIS11, Patton, Stanford, & Barratt, 1995) no significant group differences (all *ps* > 0.08) were observed in impulsivity (BIS11; Patton et al., 1995). Importantly, also no differences between both groups in substance use variables (i.e., use of medication, smoking status, the use of other drugs, alcohol use frequency, alcohol use quantity) were observed (all *ps* > 0.3). As might be expected, persons in the food addiction group (M = 22.7; SD = 4.6) had a higher BMI than the controls (M = 20.7, SD = 1.6), although both were in the normal range on average.

For the EEG analyses 7 participants (3 controls and 4 food addicted persons) were excluded from the analyses because they had fewer than 8 artifact-free incorrect response EEG epochs (see Rietdijk et al., 2014). Consequently, the group for the EEG analyses consisted of 31 controls and 30 persons meeting the criteria for food addiction. The study was conducted in accordance with the Declaration of Helsinki and all procedures were carried out with the adequate understanding and written informed consent of the subjects. The ethics committee of the Institute of Psychology of the Erasmus University Rotterdam approved the study.

2.2. YFAS

The YFAS (Gearhardt et al., 2009) is a 25-item self-report questionnaire, which measures addiction-like intake of certain (high fat/high sugar) foods in the 12 months prior to completion of the questionnaire. Three items are primers for other items and not relevant for scoring. The other twenty-two items represent eight criteria, corresponding with DSM-IV criteria of substance dependence. Seven of these criteria reflect symptoms of food addiction (e.g. withdrawal, tolerance); one criterion concerns the clinical significance of these symptoms. Meule and Gearhardt (2014) give a detailed description of the YFAS symptoms, items and scoring. As mentioned above, in the present study, the number of symptoms (range 0–7) was used to assign participants to the food addiction group (≥3 symptoms) or the control group (≤1 symptom). Psychometric characteristics of the YFAS have been investigated in different languages and populations. The YFAS consistently has been found to possess adequate to good validity and reliability (for an overview, see Meule & Gearhardt, 2014).

2.3. Task and procedure

At arrival, subjects were instructed about the procedure and informed consent was obtained. Subsequently, participants were seated on a comfortable chair in a light and sound-attenuated room and electrodes were attached. Since the present study was part of a larger study, subjects then first performed a task that was not related to the present study (i.e., half of the subjects a taste task and half of the subjects a counting task; not reported in this study). After that the subjects had a small break in which they could read a magazine. After that they performed an Eriksen flanker task (Eriksen & Eriksen, 1974; see Franken et al., 2010), while ERPs were measured. The Eriksen flanker task was programmed in E-Prime 2.0 Professional, a suite of software applications for experiment generation, with the possibility to integrate behavioral data with EEG. (www.pstnet.com/eprime.cfm). Four different letter strings (SSHSS, SSSSS, HHSHH, HHHH) were presented on the computer screen and subjects were instructed to press a button with the right index finger of the central letter was an H and with the left if the central letter was an S. Response accuracy and response times from onset stimuli to button press on congruent (SSSSS, HHHHH; n = 200) and incongruent trials (SSHSS, HHSHH; n = 200) were recorded. Trials started with a 150 ms cue ($\hat{}$) where the central letter of the letter strings would appear. Letter strings were presented for 52 ms. Responses were followed 700 ms later by a feedback symbol (duration = 500 ms) about correctness of the response (+ or −). When no response was made within 700 ms, participants received a feedback stimulus informing them their answer was not fast enough.

2.4. Electroencephalographic (EEG) recording and signal processing

The EEG was recorded using Biosemi Active-Two amplifier system from 32 scalp sites (10–20 system) with Ag/AgCl electrodes (active electrodes) mounted in an elastic cap. Furthermore, six additional electrodes were attached to the left and right mastoids, two to the outer canthi of both eyes (HEOG), two to the infraorbital and supraorbital regions of the eye (VEOG). All signals were digitized with a sample rate of 512 Hz and 24-bit A/D conversion. Data were off-line re-referenced to a computed linked mastoids. Off-line, EEG activity was filtered with a bandpass of 0.15–30 Hz (phase