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Coping food craving with neurofeedback. Evaluation of the usefulness of alpha/theta training in a non-clinical sample

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ABSTRACT

The aim of the present study was to explore the usefulness of the alpha/theta (A/T) training in reducing Food Craving (FC) in a non-clinical sample. The modifications of electroencephalographic (EEG) power spectra associated with A/T training was also investigated. Fifty subjects were enrolled in the study and randomly assigned to receive ten sessions of A/T training [neurofeedback group (NFG) = 25], or to act as controls [waiting list group (WLG) = 25]. All participants were administered the Food Cravings Questionnaire-Trait, the Eating Disorder Examination Questionnaire and the Symptom Checklist-90-Revised. In the post training assessment, compared to the WLG, the NFG showed a significant reduction of intentions and plans to consume food ($F_{1;\ 49} = 4.90$; $p = .033$; $d = 0.626$) and of craving as a physiological state ($F_{1;\ 49} = 8.09$; $p = .007$; $d = 803$). In NFG, changes in FC persisted after 4 months follow-up. Furthermore, A/T training was associated with significant a increase of resting EEG alpha power in several brain areas involved in FC (e.g., insula) and food cue reactivity (e.g., parahippocampal gyrus, inferior and superior temporal gyrus). Taken together, our results showed that ten sessions of A/T training are associated with a decrease of self-reported FC in a non-clinical sample. These findings suggest that this brain-directed intervention may be useful in the treatment of dysfunctional eating behaviors characterized by FC.

1. Introduction

The construct of craving is considered a key feature in Substance-related and Addictive Disorders (Sinha, 2013; Tiffany and Wray, 2012), functionally related to the maintenance of addictive behaviors (Everitt, 1997) as well as to relapse rates (Oslin et al., 2009). Craving has been defined as a strong motivational state characterized by "*intense desires typically relating to the anticipation of consuming pleasure-producing substances or engaging in hedonic behaviors*" (Potenza and Grilo, 2014, p. 1).

In the last decades several studies suggested that craving for food may also be clinically relevant for the understanding and treatment of obesity and eating disorders (EDs) (Potenza and Grilo, 2014). Food Craving (FC) has been defined as an intense desire to consume a particular food, which is extremely difficult to resist (Weingarten and Elston, 1990, 1991; White et al., 2002), and it is characterized by several crucial features such as the lack of control over eating (Meule et al., 2012a). FC is widespread detected in general population (Gendall et al., 1997a; Lafay et al., 2001; Pelchat, 1997) as well as in patients with EDs (Gendall et al., 1997b; Moreno et al., 2009; Ng and Davis, 2013). A recent meta-analysis (Boswell and Kober, 2016) on 3292 individuals showed that the experience of craving significantly contributes to dysfunctional eating behaviors and weight gain. Furthermore, FC appears to be a risk factor in precipitating binge eating episodes both in healthy subjects (Cepeda-Benito et al., 2000a, 2000b) and in patients with EDs (van der Ster Wallin et al., 1994; Waters et al., 2001), and it may also discriminate between successful and unsuccessful dieters (Meule et al., 2012b).

In overweight and obese patients, FC is associated with future high-caloric food intake (Martin et al., 2008) and may discriminate between patients with and without binge eating (Innamorati et al., 2015). FC severity is also positively related to both body mass index (BMI) (Delahanty et al., 2002; Franken and Muris, 2005; Meule et al., 2014a; White et al., 2002) and drop-out from weight lost programs (Meule et al., 2012b; Meule et al., 2011; Sitton, 1991). Finally, under a neurobiological point of view, several studies observed parallels between brain regions involved in FC and drug craving (e.g., anterior cingulate cortex and prefrontal cortex) (for a review see Frascella et al., 2010).

Given the crucial role of FC in obesity and EDs as well as the neurobiological overlapping with drug craving, several treatments have been implemented in order to reduce this crucial symptom. Previous studies reported that both pharmacological (for a review see Billes and

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Greenway, 2011; Billes et al., 2014) and psychotherapeutic treatments (Abiles et al., 2013; Alberts et al., 2010; Hill et al., 2011) may reduce FC in obese and EDs patients. Furthermore, a recent meta-analysis showed that non-invasive neuro-stimulation techniques, such as repetitive trans-cranial magnetic stimulation and transcranial direct current stimulation (tDCS), were effective in decreasing craving levels for substances as well as for high palatable food (Jansen et al., 2013).

Although these treatments are generally well tolerated, it has been recently suggested (Bartholdy et al., 2013) that the combination of cognitive therapy and neuromodulation elements, using feedback-based treatment (i.e. biofeedback and neurofeedback), may be effective in reducing EDs psychopathology, including FC. Furthermore, whereas other neuro-stimulation technique (i.e., tDCS) may be associated with several mild and transient adverse effects (Brunoni et al., 2011), it has been reported that electroencephalographic neurofeedback (EEG-NF) is not related to side effects (Lansbergen et al., 2011). Finally, EEG-NF seems to be an easy and affordable technique for general practices and clinicians (Sherlin et al., 2011; Thatcher, 2014).

As concerns the effectiveness of feedback-based treatment in EDs few studies are available. Meule et al. (2012a, 2012b) reported preliminary evidence for the effectiveness of heart rate variability biofeedback in decreasing FC in individuals with strong craving for food. Lackner et al. (2016) showed that in anorexic women EEG-NF (i.e., alpha frequency training) was associated with an improvement in eating behavior traits (e.g., dieting), emotion regulation as well as with significant modifications in resting EEG parameters. Furthermore, Schmidt and Martin (2015, 2016) reported that in non-clinical individuals with overeating, ten sessions of beta training NF are associated with a decrease of overeating episodes. Authors also detected a significant reduction in FC severity from pre-treatment to 3 months follow-up (Schmidt and Martin, 2015, 2016). Finally, Ihssen et al. (2016), in a functional Magnetic Resonance Imaging (fMRI)-based NF study, showed that fMRI feedback may reduce brain areas activation (i.e., insula and amygdala) during exposure to palatable food pictures.

Regarding NF training in Substance-related and Addictive Disorders, alpha/theta (A/T) training has been the most widely studied (Trudeau, 2005). This training was originally employed to facilitate autosuggestion in hypnagogic states in order to improve standard therapy approaches in substance abuse treatment programs and appears the most suitable in alcoholism (Trudeau, 2005). The goal of this training is to raise posterior theta (4.5–7.5 Hz) over alpha (8–12.5 Hz) amplitude with eyes closed without falling asleep. Typically, on eye closure the EEG displays high amplitude rhythmic alpha activity associated with shallow relaxation. Progressive increase of theta activity is associated with a deeper relaxation (Gruzelier, 2014). This would enhance well-being and the ability to better tolerate stress, during anxiety situation associated with addiction (i.e., withdrawal symptoms, craving) (Dehghani-Arani et al., 2013; Peniston and Kulkosky, 1989; Scott et al., 2005). Several studies showed the effectiveness of A/T NF training in decreasing substances craving (for a review see Sokhadze et al., 2008). Furthermore, previous reports have also shown similar EEG abnormalities between substance craving (for a review see Parvaz et al., 2011) and FC (Imperatori et al., 2015; Meule et al., 2013).

To the best of our knowledge, no studies have investigated the potential role of A/T training in FC. Therefore, the main aim of the present study was to explore the usefulness of the A/T training in reducing FC in a non-clinical population. Furthermore, according to suggestions by Schmidt and Martin (2015), we also investigated the modifications of EEG power spectra associated with A/T training.

2. Materials and methods

2.1. Participants

Participants were recruited at the European University of Rome through advertisements posted in the university. In the post, we briefly explained the NF procedure, and we stated that it consisted essentially in a relaxation technique. In order to avoid the participants' awareness of the experimental hypotheses, we did not reveal to the participants any hypotheses regarding the possible benefits of A/T training on FC. Study participants contributed voluntarily and anonymously after providing informed consent, and were free to drop out of the study at any moment. They did not receive payment or any other compensation (i.e., academic credit).

The enrollment lasted from November 2015 to May 2016. Inclusion criteria were: normal- or over-weight (BMI = 18.50–29.99 kg/m^2); age between 18 and 40 years, both genders. Exclusion criteria were: obesity (BMI ≥ 30 kg/m^2); underweight (BMI ≤ 18.49 kg/m^2); history of medical, psychiatric (including eating disorders) and/or neurologic diseases; head trauma; assumption of central nervous system active drugs in the two weeks prior to assessment (pre and post assessment); nutritional treatment (e.g., dietary restrictions) at the moment of assessment (pre and post assessment). A checklist with dichotomous items was used to assess inclusion criteria and exclusion criteria.

Sixty-two respondents were assessed for eligibility. Fifty individuals fulfilling the inclusion criteria were enrolled in the present study (fourteen men and thirty-six women, mean age: 22.90 ± 2.68 years, mean BMI 21.93 ± 3.41). After receiving information about the aims of the study all subjects provided written consent to participate in the study, which was performed according to the Helsinki declaration standards and was approved by the ethics review board of the European University.

Altogether, four subjects were lost to follow-up. Details on participant flow, are reported in the Consolidated Standards of Reporting Trials (CONSORT) diagram (Fig. 1).

2.2. Study design and procedures

2.2.1. Pre-treatment phase (T0)

After giving written informed consent, all participants were administered the Food Cravings Questionnaire-Trait (FCQ-T; Cepeda-Benito et al., 2000a, 2000b), the Eating Disorder Examination Questionnaire (EDE-Q; Fairburn and Beglin, 1994) and the Symptom Checklist-90-Revised (SCL-90-R; Derogatis, 1977). All participants also completed a checklist assessing socio-demographic (e.g., age, educational attainment) and clinical data (e.g., height and weight, tobacco and alcohol use in the last six months). After the assessment, all participants underwent a resting state (RS) EEG recording.

2.2.2. Neurofeedback training

According with a randomized, controlled study design, participants were randomly assigned to receive neurofeedback training [neurofeedback group (NFG) = 25], or to act as controls [waiting list group (WLG) = 25], with the constraint that the groups would be matched regarding sex.

2.2.3. Post-treatment phase (T1)

At the end of NF, all participants (i.e., NFG and WLG) were asked to complete the FCQ-T, the EDE-Q and the SCL-90-R again, and to perform another RS EEG recording.

2.2.4. Follow-up session (T2)

Participants were finally administered the FCQ-Trait 4 months after the last training session.

2.3. Questionnaires

The FCQ-T (Cepeda-Benito et al., 2000a, 2000b) is a 39-item questionnaire on 6-point Likert scale (from 1 = *never* to 6 = *always*) assessing FC severity. It is composed by nine dimensions detected through factor analysis (Cepeda-Benito et al., 2003; Cepeda-Benito et al., 2000a, 2000b; Franken and Muris, 2005; Moreno et al., 2008): (1)