CMJ Cambridge Medicine Journal

# Real-time functional Magnetic Resonance Imaging Neurofeedback in the prevention of Food Craving and Binge Eating Episodes

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**Abstract**

Neurofeedback is a type of biofeedback in which the subject is given information about specific brain activity with the objective of obtaining self-regulation of brain processes in response to certain external stimuli. Food craving is a contributor to the obesity epidemic that appears to be associated with overstimulation in areas of the central nervous system. That makes it a candidate target for techniques which allow the subject to self control specific brain activity, like neurofeedback. There isn't many published data on the use of neurofeedback for eating disorders or food craving and our research didn't find any studies reporting the use of real time fMRI neurofeedback with that aim.

Here we review the literature on these matters and ponder on the possibility of success of that approach.

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## Contents

## 1. Neurofeedback

Neurofeedback (NF) is a type of biofeedback in which the individual is provided with information about specific brain activity related with a target behavior [1]. The main objective would be to make it a technique of self-regulation allowing the subject to avoid unwanted reactions to certain external stimuli. It works by having the subject on a brain monitoring device while a monitor displays a graphic representation that visually translates the activity in a target area. The subject is given access to the monitor and indications by the researcher on how to control it through meditation and mindfulness techniques (Figure 1).

Since its inception in the 1940's, [2] many forms of NF

have been tried. The ones more frequently mentioned in the literature are the traditional Electroencephalography (EEG)- neurofeedback, Magnetoencephalography (MEG)-neurofeedback, Functional Near-Infrared Spectroscopy (fNIRS)-neurofeedback and real time functional Magnetic Resonance Imaging (rt fMRI)-neurofeedback. Among all these, recent results with rt fMRI NF seem to hold the most promising possibilities in the road towards a self-regulating brain [1].

Clinical trials with mixed results have been published in regard to the use of NF techniques for attentional-deficit/hyperactivity disorder (ADHD), major depressive disorder (MDD), generalized anxiety disorder (GAD), alcohol and nicotine addiction and insomnia, among others [3].

The main challenge appears to be surpassing the efficiency of some drug therapies already available for these problems [4] and sometimes the inability to surpass the results of a "faux-NF" control group [5].

## 2. Food Craving/Binge Eating/Eating Disorders

Obesity is a public health problem that can't be overlooked. According to the World Health Organization [6] (WHO) its prevalence has more than doubled worldwide since 1980
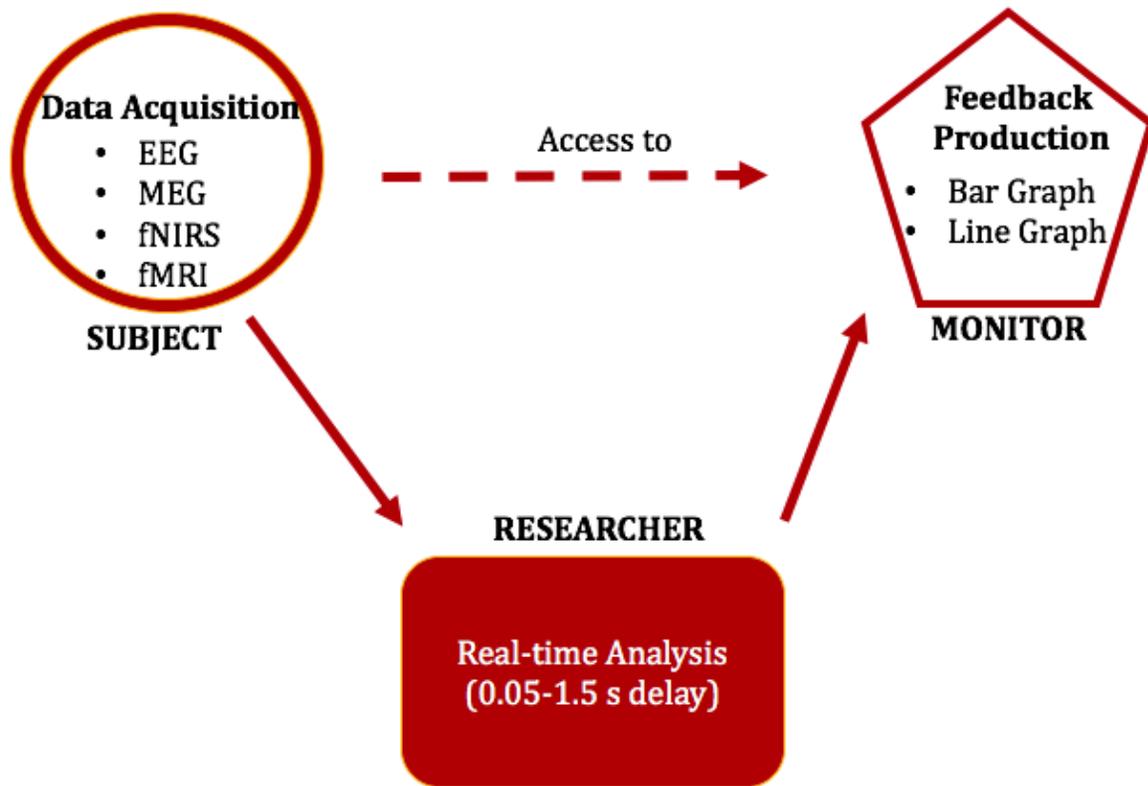
**Figure 1.** Schematic Representation of Neurofeedback Mechanisms (Adapted with permission [1]).

and, in 2014, 600 million adults were obese.

"Cue-induced craving" is a type of Food Craving (FC) that can be defined as an acute period of craving (a strong desire to eat) caused by environmental/external stimuli [7]. Its clinical importance relies mainly on the established associations between FC and weight gain [8], making it a probable contributor to the obesity epidemic.

In terms of neural correlates, different theories have been published linking FC with increased corticolimbic-striatal activation in response to cues, [9] other subcortical regions like the caudate, thalamus, and midbrain [10] or even regions related with other substance cravings: dorsal striatum, orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), amygdala, hippocampus, and insula [11]. It has been suggested that a network approach using connectivity-based feedback or multi-voxel pattern classification (MVPA) could be preferable [12] given the apparent highly distributed circuitry related with the matter.

Another widely accepted theory postulates that craving, either for drugs or food, is the result of the interaction between two independently run neural systems of "wanting" and "liking" [13]. The proponents of that 'Incentive-Sensitization Theory' suggest that after an initial period of the addiction when "liking" the effects of the drug/food dominate, the perpetuation of the effect is caused by the "wanting" and that should be the target of mechanisms trying to stop it.

The abolishment of Food Craving in different groups of individuals remains an elusive goal in the management of obesity even though in specific populations techniques like cognitive-behavioral therapy, mindfulness or transcranial direct current stimulation have been found to at least temporarily reduce craving and food consumption [14].

Integrating this information with the general description of neurofeedback presented above, an ideal system would be obtained by monitoring the brain activity of an obese patient while presenting the type of food that is usually craved for, giving the subject access to the main areas of activity recorded through some form of schematic representation and teaching the subject how to control it via the individual strategy considered more effective [15].

## 3. Current Studies with Neurofeedback for Eating Disorders

Given the already discussed similarities between FC and other types of drug cravings in the context of addiction, it has for long been suggested that NF could also be of help in the disruption of behaviors contributing to the development of eating disorders. There is, however, a relatively limited number of published studies of NF for FC or other eating disorders.

In 2016, Imperatori et al. [16] published the results of

alpha/tetha EEG-neurofeedback training to reduce FC in a non-clinical sample of about 50 subjects. They reported a decrease in intentions and plans to consume food and in craving as a physiological state, two components of FC. These results were stable after 4 months' follow-up after finishing NF training.

A group at the University of Wuppertal in Germany has also been publishing on this subject, with their last paper (Schmidt & Martin [17]) reporting the effects of a cue exposure EEG-NF protocol put to test in a sample of female subjects reporting regular occurrence of binge eating episodes (but excluding clinical eating disorders). That specific protocol was focused on reducing EEG high-frequency beta activity in response to cue induced stimuli. They report significant reductions in food craving and binge eating episodes in the NF group with reduced beta activity even though the study design didn't contain a sham neurofeedback group, which would have been the most accurate way of ruling out a placebo effect [1].

A different approach was recently taken by a group in the UK that for the first time tried an fMRI-NF approach to food visual cue reactivity [18]. The study used individually determined target areas (amygdala, basal ganglia, thalamus) on a quest to downregulate craving activation after 4 hours of fasting in healthy female subjects. The results showed a correlation between downregulation of the targeted areas and hunger reduction reported by the subjects and the authors conclude that fMRI-NF could be a potential avenue to alter craving in clinical samples.

## 4. rt-fMRI Neurofeedback: the next logical step?

No published studies (Figure 2) have yet analyzed the effectiveness of fMRI-NF on patients with eating disorders related to food craving. However, comparing the results of fMRI-NF and EEG-NF for other conditions there is reason to hope rt-fMRI NF could be a big step towards an effective, self-controlled treatment option for FC.

Promising results have been published regarding rt-fMRI NF for chronic pain, [19] cigarette cravings, [20] reduction of pain perception [21] and improvement of motor control in patients with Parkinson's disease [22].

Even though many of these seem to have incomplete study designs and sometimes lack the appropriate control, the fact that more and more research centers are acquiring fMRI machinery and developing the expertise necessary to take the most out of its data leads us to believe that fMRI-NF could emerge in many more double-blind, controlled, clinical sampled studies and regarding FC it seems the next logical step.

## 5. Call for studies and trials

Real time fMRI neurofeedback is still an expensive procedure that needs specific know-how in each of its components (neurofeedback, meditation and mindfulness, brain imaging, analytic software) and very cautious control conditions. We nonetheless challenge all the research groups with abilities and resources to pursue improvement in what is known on this promising technique that could undoubtedly change the lives of so many patients with so many different conditions and problems.

## Acknowledgments

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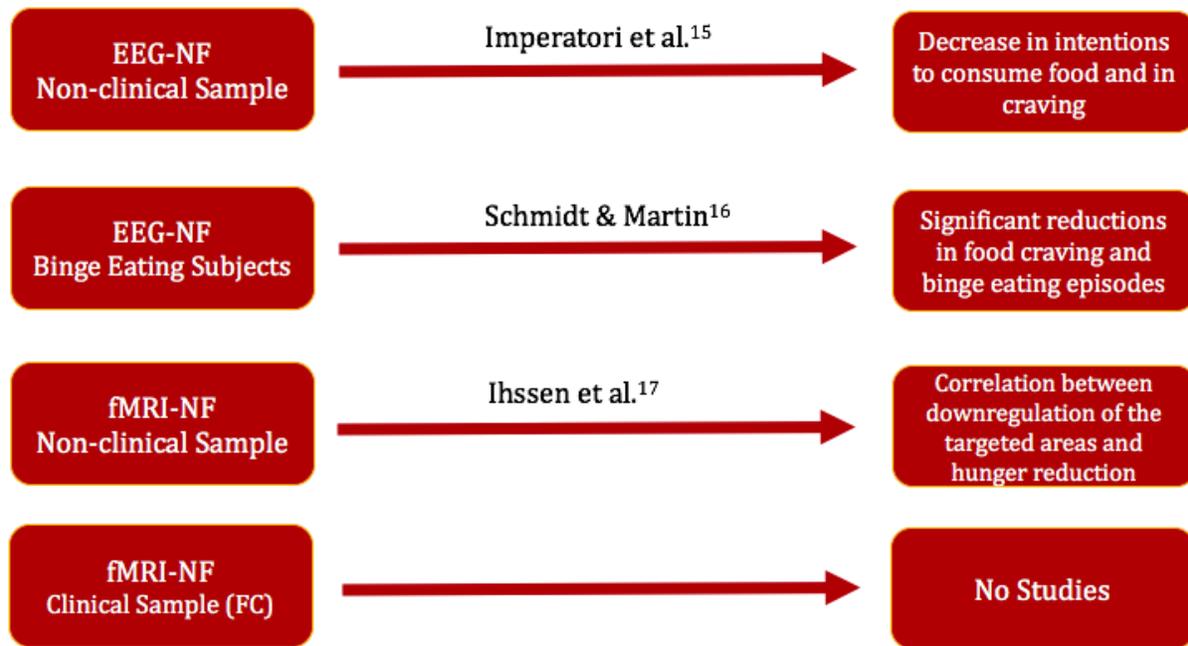
**Figure 2.** Published Studies on Neurofeedback for Eating Disorders.

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