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Research report

Subtypes of trait impulsivity differentially correlate with neural responses to food choices

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HIGHLIGHTS

- Twenty females performed an fMRI food choice task.
- Delay discounting correlates with number of high energy food choices.
- Impulsivity correlates with food choice-related brain activation in striatum.

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ABSTRACT

Impulsivity is a personality trait that is linked to unhealthy eating and overweight. A few studies assessed how impulsivity relates to neural responses to anticipating and tasting food, but it is unknown how impulsivity relates to neural responses during food choice. Although impulsivity is a multi-faceted construct, it is unknown whether impulsivity subtypes have different underlying neural mechanisms. We investigated how impulsivity correlates with brain responses during food choice and in how far different impulsivity subtypes modulate brain responses during food choice differently. Twenty weight-concerned females performed an fMRI task in which they indicated for high and low energy snacks whether or not they wanted to eat them. Impulsivity subtypes were measured by the monetary delay discounting task and the Barratt Impulsiveness Scale (total BIS-11 and subscales). Only temporal subtypes of impulsivity, namely delay discounting and the BIS-11 non-planning subscale, modulated responses to food choice; both measures correlated positively with striatum activation during high versus low energy choices. However, only delay discounting predicted high energy choices, whereas BIS-11 non-planning independently related to a striatum region that reflects subjective stimulus value. To conclude, the brain mechanisms underlying subtypes of impulsivity have a common ground but differ in specific aspects of food-related decision-making. The findings advance our understanding of the neural correlates of different impulsivity subtypes in the food domain.

1. Introduction

In the current Western environment, palatable high energy foods are omnipresent and this is thought to be an important contributor to unhealthy eating and the epidemic of overweight [1]. However, not every individual is equally susceptible to the presence of these immediately rewarding foods: there are large individual differences in personality that relate to the ability to regulate food choices [2,3]. A personality trait that has been repeatedly linked to unhealthy food choices and overweight/obesity is impulsivity [2,4–7]. Impulsivity is a complex and multifaceted construct, comprising of impaired behavioral inhibition, increased reward sensitivity, acting without thinking, and favoring immediate rewards over long-term goals [8–10]. Accordingly, a wide range of measures are employed to measure subtypes of impulsive behavior, including questionnaires that rely on an individuals' self-perception of behavior, and computer-based behavioral tasks that measure overt behavior related to impulsivity [9].

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The link between impulsivity and BMI has been shown in many studies, in many different populations, and with a wide range of impulsivity measures (for reviews, see [2,11]). On average obese individuals are more impulsive than normal weight individuals [12–14]. In line with this, several studies have reported positive correlations between impulsivity and BMI [15,16]. Furthermore, Sutin et al. [17] found that their top 10% most impulsive participants weighed on average 11 kg more than the bottom 10%. Moreover, Ryden et al. [18], who investigated a group of obese individuals, showed that more severely obese men were more impulsive than less severely obese men.

Also, in normal weight individuals, impulsivity is related to eating behavior. More impulsive individuals have a higher preference for high energy foods [19] and eat more in experimental settings [5,20,21]. Furthermore, high impulsivity is related to increased snacking [22] and non-obese individuals (BMI < 30) high in impulsivity have higher total energy intake in an experimental setting [23]. A large longitudinal study showed that high impulsivity scores are related to weight gain [17]. Furthermore, they found that individuals higher in impulsivity had more weight fluctuations, an effect that remained significant when controlling for baseline BMI.

An explanation for this link between impulsivity, overeating and excess weight is that more impulsive individuals are more tempted by immediately rewarding foods, which are generally higher in sugar and fat than bland foods. Also it has been proposed that impulsive individuals have more difficulty in sticking to longer term goals and controlling their direct impulses. Lastly, it has been proposed that highly impulsive individuals might be less good at planning meals, which might promote snack food consumption [11].

Despite the robust link between impulsivity and unhealthy eating behavior, only a few neuroimaging studies have analyzed how impulsivity and its subtypes modulate brain responses to foods [24–27]. To our knowledge, only one single study investigated how individual differences in impulsivity modulate neural responses to food cues [25]. In this study, higher impulsivity was related to increased activation in the anterior cingulate cortex and amygdala during anticipation of a pleasant taste and increased activation in the caudate during taste receipt. For reward sensitivity it has been shown that individuals high on this construct have stronger activation in reward areas like the medial orbitofrontal cortex (OFC), ventral striatum, amygdala and ventral tegmental area (VTA) in response to images of pleasant foods [24], although null-findings have also emerged [26,27].

There appear to be at least two gaps in our knowledge of the neural mechanisms underlying impulsivity in the food domain. First, it is unknown how impulsivity modulates neural responses during the behavior that actually initiates intake, i.e., during food choice. Earlier studies used taste stimuli or food image paradigms which measure responses related to anticipation and consumption [24–27]. Food choice constitutes more than anticipation alone: for many individuals, for example those who have the long-term goal to eat healthy or to lose weight, food choices require a trade-off between the immediate reward of eating a palatable food and their longer term health or dieting goal [28]. The outcome of this trade-off, that is, which food is chosen, is influenced by impulsivity [29]. Since eating behavior is ultimately determined by a series of food choices, it is crucial to know how impulsivity impacts on the underlying neural mechanisms of food choice.

The second knowledge gap concerns the multifaceted nature of impulsivity. The term impulsivity is regarded as an umbrella term for different subtypes and personality facets that relate to impulsive behavior. There are several theoretical models that explain impulsive behavior, which all have their own set of self-report and/or behavioral measurements. For example, Gray's biopsychological theory of personality led to the development of the BIS/BAS scales [30], the Five Factor model of personality led to the development of the UPPS [31], and Eysenk's personality theory [32] led to the development of the I7 (for reviews see [2,11,33]). Though the different models of impulsivity emphasize different aspects, researchers generally agree that there are three subtypes that have their approximate equivalent in the majority of the operationalizations of impulsivity [2,11,34]. The first broad subtype refers to the responsivity/sensitivity to reward, and the behavioral preference of short term gains over long term ones, which is sometimes denoted temporal impulsivity [11,35]. This subtype is measured by delay gratification paradigms (Metcalfe & Mischel, 1991, Psychol. Rev.) [83], delay discounting tasks [36] and several self-reports (non-planning subscale of the BIS-11 [37], Lack of premeditation subscale of the UPPS [31] and the BAS-scales of the BIS/BAS [30]. The second subtype refers to insufficient response inhibition, i.e., responding immediately without thinking. This subtype is operationalized by behavioral tasks (e.g., Stop signal task [38]) and self-report scales (e.g., Motor impulsivity subscale of the BIS-11 [37], Urgency subscale of UPPS [31], functional and dysfunctional impulsivity subscales of Dickman Impulsivity Inventory [39]). The third subtype refers to the inability to concentrate (Attentional impulsivity subscale of BIS-11 [37], Lack of perseverance subscale of UPPS [31]). In addition to these three, there are several subtypes which are less often noted as independent factors, like the tendency to pursue novel exciting activities (Sensation-seeking subscale of UPPS [31], BAS fun-seeking subscale of BIS/BAS scales [30]). In the behavioral field, several attempts have been made to confirm these independent subtypes by performing factor analyses on multiple impulsivity constructs [9,35,40]. Despite differences in exact mapping and labeling of impulsivity subtypes, there is general consensus that impulsivity is not a unitary construct, and represents multiple independent subtypes [9,35,40]. However, neuroimaging studies linking impulsivity with food-induced brain responses typically acquire a single measure and denote it as 'impulsivity', disregarding the wide array of processes and subtypes contributing to impulsive behavior [24–27]. Also, only self-report measures of impulsivity have been employed in the study of food-induced brain responses.

Although several single subtypes of impulsivity and self-report as well as behavioral measures of impulsivity have been linked to unhealthy eating and overweight [2,11], it has been suggested that these different subtypes tap into different underlying (neural) processes [9,40–42]. Temporal impulsivity and sensitivity to reward are thought to relate to a ventral striatal related circuit [24,34] while insufficient response inhibition has been linked to prefrontal structures like the dorsolateral prefrontal cortex [43,44]. Furthermore, it has been shown that behavioral and self-reported measures of impulsivity often do not correlate [9,35]. Therefore, it has been suggested that they may have different underlying (neural) mechanisms [9,35]. To date, it has not been tested how different impulsivity subtypes modulate the neural processes underlying food choice.

The present study intended to fill these gaps. The first aim was to determine how impulsivity modulates neural responses during food choice. The second aim was to investigate whether differ-

Table 1
Means and standard deviations ($n = 20$) of the scores on the delay discounting task and the BIS-11.

	Mean	Standard deviation
Delay discounting score	0.011	0.016
BIS-11 total score	57.35	6.64
BIS-11 motor subscale[a]	1.84	0.28
BIS-11 attentional subscale[a]	1.96	0.24
BIS-11 non-planning subscale[a]	1.95	0.32

[a] Score divided by the number of questions in the subscale.