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Review article

# Proactive inhibition: An element of inhibitory control in eating disorders

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ABSTRACT

The aetiology of eating disorders (EDs) is unclear, but many hypotheses implicate alterations in behavioural control. Specifically and because of its relevance to symptomatology, there has been much interest in inhibitory control, i.e., the ability to inhibit inappropriate/unwanted behaviours. This has been studied in relation to reactive motor inhibition (withholding a response in reaction to a signal), reward-based inhibition (e.g., temporal discounting paradigms) and to reversal learning (e.g., set shifting tasks assessing cognitive flexibility and compulsivity). However, there has been less explicit exploration of *proactive* inhibitory control, i.e., a preparatory form of inhibitory control where responses are pre-emptively suppressed to improve performance either in terms of a dynamic strategy (e.g., post-error slowing) or as a more general suppression in the context of uncertainty (e.g., when the appropriateness of a response is less certain). This review considers proactive inhibition within the context of broader conceptual considerations of inhibitory control in EDs, discusses the existing behavioural and neural evidence, and concludes that this is a construct worthy of further exploration.



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## 1. Introduction

Eating disorders (EDs) are serious psychiatric disorders characterised by extreme dietary practices and pathological concerns over weight and shape (American Psychiatric Association, 2013). However, the mechanisms underlying the development and maintenance of EDs remain unclear (Kaye et al., 2015; Wu et al., 2013b). Investigations into the aetiology of EDs have predominantly employed experimental and neurobiological approaches that explore behavioural, cognitive and affective concepts, and the way in which these all interact. These include behavioural control, reward sensitivity, cognitive flexibility and anxiety.

Altered behavioural control and experience thereof is relevant to a number of core behavioural symptoms of EDs. For example, chronic food restriction may be associated with attempts to establish control, or with a loss of control over the ability to regulate food consumption. The experience of a loss of control is part of the definition of a binge eating episode (American Psychiatric

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Association, 2013). Individuals may engage in food restriction or purging behaviours such as self-induced vomiting or laxative use, to compensate for potential weight gain or the effects of overeating: as such, they reflect an attempt to re-establish control over weight/eating. However, purging episodes can also be experienced as being uncontrollable, with uncontrollable binge eating and purging being an indicator for potential hospital admission (Golden et al., 2015). In addition, EDs are highly comorbid with a number of psychiatric symptoms/disorders that are characterised by altered behavioural control, including suicidal behaviour (Franko and Keel, 2006), attention deficit hyperactivity disorder (Biederman et al., 2007; Nazar et al., 2008) and obsessive compulsive disorder (Blinder et al., 2006; Kaye et al., 2004). The odds of a comorbid impulse control disorder are considerably highest for BN, which is also associated with compulsive buying, shoplifting and substance abuse (e.g., Fernández-Aranda et al., 2008; Hudson et al., 2007; Mole et al., 2015; Nazar et al., 2008). In contrast, AN is not thought to be associated with substance use disorders (Calero-Elvira et al., 2009; Gadalla and Piran, 2007), and may even be a protective factor against substance use disorders (Brooks, 2016; Kaye et al., 2013).

On the basis of the above and other studies, spectrum models of EDs have been suggested (Brooks, 2016; Brooks et al., 2012). In these, anorexia nervosa (AN) restrictive subtype (AN-R) lies at the over-controlling (inhibitory) extreme, followed by AN binge-purge subtype (AN-BP) and bulimia nervosa (BN). Binge eating disorder (BED) is placed at the impulsive extremity (in terms of appetite control). Evidence, however, suggests patients with BN are more impulsive than patients with BED in other domains, e.g., in relation to self-harm and substance misuse (Hudson et al., 2007; Wu et al., 2013b). While it is unlikely that EDs can be described using a neurocognitive model including a single domain (inhibitory control), such a model provides a useful starting point for assessing the interactions between neurocognition and other behavioural, cognitive and biological factors that may explain certain phenomenological variations within the population. For example, such a model can generate hypotheses on how the cognitive processes underlying behavioural control interact with biological and motivational systems to influence pathological behaviours (such as chronic food restriction or binge eating).

There is much interest in behavioural and cognitive inhibitory control and how they may contribute to ED psychopathology. Behaviourally, these have been studied mainly in relation to reward-based inhibition (such as in temporal discounting paradigms), cognitive flexibility (such as in set shifting tasks), or reactive inhibition (i.e., withholding a response in the context of a stop signal, as in the stop signal task or go/no-go task). It seems likely that the relative contribution of different aspects of inhibitory control varies across EDs, in a similar way to established impulse-control disorders. For example, while reactive inhibition appears to be affected to a comparable degree in OCD, ADHD and schizophrenia, there is a smaller deficit in substance use disorders and Tourette's syndrome suggesting deficient reactive response inhibition may be less central to these latter disorders (Lipszyc and Schachar, 2010). In a similar way, different types of inhibitory control may contribute to the different EDs. For example, with respect to temporal discounting (i.e., the capacity to delay reward or gratification), individuals with AN show a greater ability to delay gratification than healthy individuals (Steinglass et al., 2012), whereas the opposite has been reported in people with BED (Davis et al., 2010; Manwaring et al., 2011; Mole et al., 2015) and BN (Kekic et al., 2016). In contrast, poorer reactive response inhibition in the stop signal task has been reported across the eating disorders (e.g., Galimberti et al., 2012; Svaldi et al., 2014; Wu et al., 2013a), although the findings are not consistent (Bartholdy et al., 2016). Thus, while there may be more disorder-specific aspects to temporal discounting in EDs, reactive inhibition may be affected in a similar way across disorders.

## 2. Proactive inhibition

To date, in EDs there has been less explicit exploration of proactive (preparatory) approaches, i.e., processes that pre-emptively suppress or gate motor responses or response tendencies ('braking') (Criaud et al., 2012). Individuals use proactive inhibition on a daily basis, acting more cautiously or reservedly when the required outcome is unknown. For example, individuals will drive more slowly in areas where children are likely to be playing, in case a child runs into the street. Studies of EDs have indirectly explored one framework of proactive inhibition, namely strategic proactive adjustment of behaviour to improve performance (e.g., post-error slowing). While such strategic proactive inhibition is present in a number of commonly employed neuropsychological tasks, this is a complicated manifestation of proactive inhibition that may interact with or depend on a number of additional task components, including signal detection, attention, and determination of response relevance. Proactive inhibition is more simply manifested as an automatic or general suppression of responses in the context of uncertainty or aversion (i.e., rather than as a dynamic strategy), assessed using simple reaction time paradigms involving spatially-uninformative cues. This simple manifestation of proactive inhibition is relatively underexplored in EDs. In this review, we discuss the potential relevance of proactive inhibition in relation to ED symptomatology, to the neural basis of EDs, and with reference to broader conceptual considerations of inhibitory control in EDs.

## 3. Evidence of altered proactive inhibition in eating disorders

One aspect of proactive inhibition relates to the strategic adjustment of response preparation to changing environmental demands (Aron, 2011; Verbruggen and Logan, 2009; Zandbelt et al., 2013; Zandbelt and Vink, 2010). This is reflected by slower reaction times when manipulating the overall context of the response (Aron and Verbruggen, 2008). It can be assessed by dynamically adjusting the degree of uncertainty between trials in established neuropsychological tasks that assess executive function or inhibitory control. For example, differences in response time when a response is uncertain compared to when it is a certainty can be considered an index of the cost of preparing a response (Chikazoe et al., 2009). This can be explored using a modified stop signal task that compares reaction time on 'pure' or go-only blocks (where stop signals are either absent or ignored) to 'mixed' blocks of go and stop trials (Boulinguez et al., 2009; Chikazoe et al., 2009; Verbruggen and Logan, 2009; Verbruggen et al., 2014b). It can also be investigated by altering the proportion of incongruent to congruent trials on a Stroop task, thereby manipulating the expectancy of a particular outcome and reducing the amount of response competition (Yücel et al., 2012). Strategic proactive inhibition can also be assessed using modified versions of the go/no-go or stop signal tasks, e.g., (a) altering the probability of stop trials (Verbruggen and Logan, 2009; Zandbelt et al., 2011), (b) varying the number of go trials between stop trials (Vink et al., 2005) or (c) using conditional stop trials that are dependent on a specific response (e.g., only stop when the stop signal appears on the left side of the screen) (e.g., Aron and Verbruggen, 2008; Zandbelt et al., 2011).

While this has not yet been *explicitly* studied in EDs, a number of neuropsychological paradigms, such as those described above, involve manipulations of uncertainty that elicit functions that resemble proactive inhibitory control. For example, post-error slowing demonstrates strategic proactive adjustment of cognitive