Neuroscience and Biobehavioral Reviews 36 (2012) 1107–1118

Contents lists available at SciVerse ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

Intentional inhibition in human action: The power of 'no'

Elisa Filevich[a,*,1], Simone Kühn[b,c,1], Patrick Haggard[a]

[a] Institute of Cognitive Neuroscience, University College London, London WC1N 3AR, UK
[b] Department of Experimental Psychology and Ghent Institute for Functional and Metabolic Imaging, Ghent University, Gent, Belgium
[c] Charité University Medicine, St. Hedwig-Krankenhaus, Clinic for Psychiatry and Psychotherapy, Große Hamburger Straße 5-11, 10115 Berlin, Germany

ARTICLE INFO

Article history:
Received 13 July 2011
Received in revised form 5 December 2011
Accepted 20 January 2012

Keywords:
Intention
Inhibition
Volition
Action
Cognitive control
Anarchic hand syndrome

ABSTRACT

The capacity to inhibit and withhold actions is a key feature of human cognition. Withholding action forms the basis of self-control, delayed gratification, social contracts, and trust in others. Most experimental studies of this function come from studying the processing of external stop signals. However, another important aspect of inhibition is 'will-power', i.e., intentional inhibitory control over one's own actions, in the absence of external countermanding signals. We review whether a concept of intentional inhibition is justified, and how it might differ from externally triggered inhibition. Further, we consider three types of neuroscientific evidence that can clarify the brain's mechanisms of inhibition: neuropsychology, neurostimulation and neuroimaging. Finally, we propose a model in which intentional inhibition, unlike externally triggered inhibition, is linked to representing longer range consequences of action decisions. We suggest that the human brain contains a 'neural brake' mechanism that blocks specific ongoing motor activity, and that this mechanism plays a key role in action decisions.

Contents

1. Introduction

1.1. What is intentional inhibition?

Most people recognise the experience of being about to commit an action, and suddenly holding back at the last possible moment. Often there is a distinct experience of cancelling the action as a result of a quite specific decision or process, and for an identifiable reason. Consider two examples. You are writing an to your boss,

* Corresponding author at: Institute of Cognitive Neuroscience, 17 Queen Square, London WC1N 3AR, UK. Tel.: +44 20 7679 1130; fax: +44 20 7813 2835.
E-mail address: e.filevich@ucl.ac.uk (E. Filevich).
[1] These authors made equal contribution to this work.

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doi:10.1016/j.neubiorev.2012.01.006

perhaps because you are upset or angry. You are just about to click the 'Send' button, when you seem to hear a voice in your head that says "do you really want to send that?", and you hold back. You are posting a letter, and are just about to release your grip on it and let it fall into the post box, when you suddenly get the feeling that you should check whether you put a stamp on the envelope. You tighten your grip and inspect the letter. In both these cases, one intentionally withholds an action whose preparation and path towards execution has already begun. Further, in both cases, there appear to be clear reasons for making the action, and also clear reasons for stopping it.

We will use the term 'intentional inhibition' to refer to this capacity to voluntarily suspend or inhibit an action. Intentional inhibition shares some features with other instances of inhibition in psychology, where participants are instructed to withhold responses when presented with particular stimuli, such as NoGo stimuli and stop signals. For example, there is a prepotent or otherwise salient motivation for action. Further, the preparatory processes that lead to action are already underway when inhibition occurs. However, intentional inhibition has other features that are not shared with other forms of inhibition. By definition, the process or signal that cancels or inhibits the action is not the result of any external signal or instruction, but is generated *internally* by the participant themselves. In this respect, intentional inhibition clearly differs from classic psychological paradigms where an external stop signal is used to trigger inhibition (Logan and Cowan, 1984), or NoGo tasks (Pfefferbaum et al., 1985; Eimer, 1993). Further, intentional inhibition prevents motor output, but clearly does not remove the reason for action. For example, stopping myself from sending the angry does not stop me wanting to express my anger. Finally, intentional inhibition seems linked to three quite specific experiences: an urge to act, a simultaneous experience of a distinct reason to resist the urge to act, and often a feeling of frustration at failure to achieve the desired action.

We suggest that intentional inhibition is a core process of the general capacity that psychologists have termed self-control (Baumeister et al., 2007). In particular, the capacity to withhold a prepotent action, and to adjust or cancel an action after its initial preparation, gives humans the capacity to act flexibly and strategically.

1.2. A factorial structure for action control

Studies of action control classical distinguish between an internally generated and an externally triggered route to action (Goldberg, 1985; Jahanshahi et al., 1995; Jenkins et al., 2000). An action may either be a direct and immediate result of an imperative stimulus, or may occur for reasons that seem unrelated to any obvious stimulus at all, but are instead strongly related to the internal states of the subject. In fact, a standard operational definition of voluntariness refers to actions that lack an immediate preceding stimulus (Passingham et al., 2009). Instead, intentional actions are assumed to follow from desires, goals and intentions of the subject.

These desires and intentions are, of course, generally related to the external environment, and could thus be seen as representations that mediate between the external world and the expression of behaviour. This mediation means that voluntary actions can be remote in time from many of the factors that we consider relevant to their causation, and can thus have 'freedom from immediacy' (Shadlen and Gold, 2004).

The distinction between these two routes is often based on the neuroanatomical distinction between a medial frontal system for internally generated action, centred on the pre-SMA, and a more lateral parietal-premotor system for externally triggered action.

The origin of the observed differences between internally generated and externally triggered actions remains controversial. Whilst some authors argue that internally generated actions depend on evaluation and monitoring of internal states (Passingham et al., 2009); others strongly reject this view, and suggest instead that internal generation is related to the evaluation of a complex environment (Nachev and Husain, 2010). More generally, the nature of voluntary action remains highly controversial, both in neuroscience and in philosophy (Haggard, 2008).

Although the source of the differences is controversial, empirical data point unequivocally to the fact that internally generated and externally triggered actions represent two extremes of a continuum. Here, we suggest that the same continuum may be found in inhibition of behaviour. Our assertion of similar continua for action and inhibition is largely independent of the conceptual issue of how this continuum is understood. Particularly, we believe that the internally generated vs. externally triggered distinction can be made just as clearly for inhibition as for action. If it is true that action can be either internally- or externally triggered, then in principle inhibition of actions could show a similar distinction. A person may withhold an action either because of an external stop signal, or because of an internal decision to do so. The decision to inhibit, like the decision to act, may depend on external stimuli, or on internal reasons and desires. For example, the current situation may make a particular action inappropriate or undesirable, even though it might be highly appropriate in other situations. Indeed, the brain processes balance between enabling instrumental action in some situations, and inhibiting it in others, are thought to underlie the flexible nature of social behaviour (Crockett et al., 2010). For now, it is important to point out that the internal/external dimension for inhibition is *orthogonal* to the internal/external dimension for action. That is, one can intentionally inhibit both actions that one decided oneself to make, or actions that are triggered by environmental signals or objects, as in anarchic hand syndrome (AHS). On this view, the cognitive control of action has a factorial structure, as illustrated in Table 1.

Interestingly, many people also recognise the experience of going ahead with action, while simultaneously acknowledging possible reasons for withholding it, and then later regretting having made the action. One common example is saying an unkind and gratuitous word to someone whom we should respect, and regretting the comment as soon as it is made. Such actions can produce unpleasant consequences, and have high personal and moral cost.

2. Methodological issues in studying intentional inhibition

Despite the importance of intentional inhibition as a cognitive control process, it has received relatively little attention in the psychological or neuroscientific literature. Indeed, one might ask whether we need a concept of intentional inhibition at all. So far, the evidence for intentional inhibition we have given above is only subjective experience, and this is a notoriously unreliable guide to cognitive processing (Nachev and Husain, 2010). Clearly, stronger evidence is required.

Classically, psychologists have postulated internal processes when and only when they are required to explain behaviour (Turing, 1950). This leads to three important methodological difficulties arising from the features of intentional inhibition outlined above. First, intentional inhibition produces no behavioural output. Since behaviour is our standard guide to internal processes, can we be justified in drawing *any* inferences about internal cognitive processes from the absence of behaviour? Moreover, *measurement* of intentional inhibition is problematic because there is no overt behaviour to measure. Behavioural experiments on intentional inhibition may do no more than elicit failures to inhibit. In contrast, neurophysiological and neuroimaging methods can be particularly valuable, since they identify brain processes associated with the