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Inhibiting uncertainty: Priming inhibition promotes reduction of uncertainty

Eyal Kalanthroff[a,b,c,d,*,1], Omer Linkovski[c,d,1], Avishai Henik[c,d], Michael G. Wheaton[a,b,e], Gideon E. Anholt[c]

[a] Department of Psychiatry, Columbia University Medical Center, New York, NY, United States
[b] Anxiety Disorders Clinic and the Center for OCD and Related Disorders, New York State Psychiatric Institute, New York, NY, United States
[c] Department of Psychology Ben-Gurion University of the Negev, Beer Sheva, Israel
[d] Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer Sheva, Israel
[e] Ferkauf Graduate School, Yeshiva University, Bronx, NY, United States

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ABSTRACT

Uncertainty affects performance in many cognitive tasks, including the visual-search task, and individual differences in the experience of uncertainty may contribute to several psychological disorders. Despite the importance of uncertainty, to date, no study has explained the basic mechanisms underlying individual differences in the experience of uncertainty. However, it has been suggested that inhibition, a cognitive mechanism aimed at suppressing unwanted thoughts or actions, may affect the development of uncertainty. In the current study, we investigated the relationship between inhibition and behavioral responses to uncertainty in the visual-search task. To accomplish this goal, forty six university students completed a novel combined visual-search and stop-signal task, in which we manipulated the degree to which the inhibitory control system was activated by varying the proportions of stop signals in separate blocks. We utilized target-absent trials in the visual-search task as a behavioral probe of responses to uncertainty. We found that activating higher levels of inhibitory control resulted in faster responses to target-absent visual-search trials, while not affecting target-present trials. These findings suggest that activation of inhibitory control may causally affect behavioral responses to uncertainty. Thus, individual differences in inhibitory control may influence the ability to rely on internal-ambiguous cues which are common in visual-search and other cognitive tasks. Clinical implications for obsessive-compulsive disorder (OCD) and other disorders involving deficient inhibitory control and difficulty with uncertainty are discussed.

1. Introduction

Increased uncertainty, a state of increased doubt, hesitancy or ambiguity, promotes checking behavior and commonly slows reaction times (RTs) on various tasks (Banca et al., 2014; Hodsoll and Humphreys, 2001; Najmi and Amir, 2010; Toffolo et al., 2013; Treisman and Gormican, 1988). For example, in the visual-search task performance is linked to uncertainty, as target-absent trials require responses based on internal criterion as there is no external target present (Toffolo et al., 2013). Moreover, it has been shown that increased uncertainty underlies several disorders such as panic disorder (Carleton et al., 2014), health anxiety (Fetzner et al., 2014), generalized anxiety disorder, and obsessive-compulsive disorder (OCD) (Aardema et al., 2009; Holaway et al., 2006). Furthermore, increased uncertainty may constitute a general risk factor in emotional disorders (Boswell et al., 2013). Specifically, difficulties with uncertainty has been suggested as a key factor that drives repeated-checking behaviors, a process underlying various psychopathologies (Dar, 2004; Van Uijen and Toffolo, 2015). For example, in OCD as well as in various anxiety disorders, uncertainty motivates repeated checking – a major symptom of these disorders. Therefore, reducing the experience of uncertainty, and its effects on behavior, is a key element in psychological treatment of these disorders (Belloch et al., 2011; Dugas et al., 2010). Despite the importance of uncertainty, to date, no study has examined the basic mechanisms underlying individual differences in proneness to uncertainty. However, it has been suggested that inhibition, a cognitive mechanism aimed at suppressing unwanted thoughts or actions (Logan, 1994; Logan et al., 1984), may affect the development of uncertainty (Linkovski et al., 2013, 2015). Thus, in the current study we used a novel task to investigate the influence

* Corresponding author at: Department of Psychiatry, Columbia University Medical Center, New York, NY, United States.
E-mail address: eyalkant@gmail.com (E. Kalanthroff).
[1] These researchers contributed equally to the current study.

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of inhibition on uncertainty.

In a recent study that investigated behavioral manifestations of uncertainty Toffolo et al. (2013) used a version of the visual-search task, in which participants were asked to decide whether a target stimulus was present or absent in an array of stimuli. In this task, which is commonly used to assess spatial attention, performance is also affected by a non-spatial aspect of attention—ambiguity and uncertainty. Target-absent trials involve a degree of ambiguity, as participants must decide that no target is present while also considering the possibility that they might have overlooked the target in their visual search. Thus, it is difficult to be completely confident about one's decision in these trials. Indeed, surveys of participants show significantly more uncertainty in target-absent than in target-present trials (Toffolo et al., 2014). An important distinction between target-absent and target-present trials is whether the decision is made based on an internal or external cue. On target-present trials, the target itself provides an external visual cue that allows participants to respond with a high degree of confidence (as the target remains on the screen until the response is made), high accuracy, and little uncertainty (Toffolo et al., 2013, 2014). In contrast, decisions about a target's absence involve internal ambiguous cues (an internal representation of the target that was not found). Previous work suggests that decisions based on internal-ambiguous cues induce uncertainty (e.g., Lazarov et al., 2012). In addition, target absent trials also map nicely onto some conceptualizations of OCD symptoms, in which doubts and uncertainty motivate symptoms. Toffolo et al. (2013) found that only in target-absent trials participants with elevated OCD symptoms (sub-clinical) searched longer and used more eye fixations compared to participants with low OCD tendencies (whereas these groups did not differ in target-present trials). The finding that individuals with difficulty tolerating uncertainty (i.e., participants with high OCD symptoms) take longer to respond to target-absent (but not to target-present) trials, along with participants' self-reports that they were less certain about their responses in the target-absent trials, strengthen the notion that target-absent trials induce uncertainty and highlights the usefulness of this cognitive task as a tool to study OCD symptoms. Although Toffolo et al.'s study found differences in responses to uncertainty between the two groups, its correlational design precludes conclusions about the origin of this difference. Because OCD patients are known to exhibit deficient inhibition (e.g., Chamberlain et al., 2006; De Wit, 2012; Penadés et al., 2007), results in that study may involve differences in the efficiency of inhibitory control systems between the two groups (Linkovski et al., 2013). In a recent study, efficient inhibition was suggested to prevent the development of uncertainty (Linkovski et al., 2013). This study replicated the paradoxical effect of repeated checking on uncertainty–the more one checks, the more uncertain one becomes (Boschen and Vuksanovic, 2007; Linkovski et al., in press; Van den Hout et al., 2008; Van den Hout and Kindt, 2003). However, effects of repeated-checking on uncertainty were moderated by inhibition levels such that participants with high levels of inhibitory control were unaffected by repeated checking (Linkovski et al., 2013).

To investigate the causal effects of inhibition on uncertainty we used a novel task that combined the visual-search task and the stop-signal task. The classic stop-signal task (Logan and Cowan, 1984) examines the ability to suppress an already initiated action that is no longer appropriate (for a review see Verbruggen and Logan (2008)). In the classic task, participants are asked to respond to a visual stimulus (go signal) with a motor response as fast as possible, knowing that in some trials an auditory stimulus (stop signal) will follow the visual go signal. Participants are instructed to inhibit their motor response when they hear the stop signal. Recently, Verbruggen et al. (2012) demonstrated that this task can be used to manipulate, rather than to measure, inhibition. Verbruggen and colleagues showed that integrating stop signals in a gambling task activates inhibitory control and reduces risky decision-making (see also: Verbruggen et al., 2013). Guerrieri et al. (2012) showed that the degree to which the inhibitory system is activated can be manipulated by changing the proportions of stop trials within the stop-signal task. These researchers found that the group that completed a block with higher proportion of stop trials had significantly lower caloric intake (i.e., were more inhibited in eating) during a subsequent taste test compared to participants in the "low proportion stop-signal" group.

In the current study we employed two blocks of a novel combined visual-search and stop-signal task that differed in the proportions (high vs. low) of stop trials. This task allowed us to manipulate the degree to which the inhibitory system is activated, with the aim of investigating its effects on the behavioral manifestation of uncertainty (i.e., visual-search target-absent trials). We predicted that in the high inhibitory demand condition (i.e., greater proportion of stop trials), participants would exhibit less uncertainty (i.e., faster response) compared with the low inhibitory demand condition. For target-absent trials, we predicted that (RTs) would be significantly shorter in the high inhibitory demand condition as compared to low inhibitory demand condition. For target-present trials, in which there is no ambiguity about the presence of a cue, we predicted no effect of inhibitory demand.

2. Method

2.1. Participants

Forty-nine participants (recruited via the university's online experiments system) participated for course credit or a small monetary reward. The study was approved by University's Institutional Research Board and all participants signed an informed consent form prior to participating in this study. All participants had normal or corrected-to-normal vision, had no self-reported history of attention deficit hyperactivity disorder (ADHD) or dyslexia, and all were naive as to the purpose of the experiment. In addition, in order to ensure participants' engagement, accuracy of 0.75 in the visual-search task was set as the threshold for inclusion. Three participants were excluded based on this criterion; thus the analyzed sample comprised 46 participants (29 females and 17 males; average age = 24.13 years, SD = 1.95).

2.2. Stimuli

The target line in the visual-search task was a 1.4 cm long green line, at a 45° incline. Non-target lines differed in either color (pink, gray) or orientation (vertical, 135° incline), so that all lines shared one feature with the target (i.e., orientation or color). The auditory stop signal was a brief tone (750 Hz, 85 dB, 50 ms; see Fig. 1)

2.3. Procedure

Participants completed the novel combined visual-search task with stop signals (see Fig. 1). On stop trials participants were instructed to inhibit their responses and wait for the following trial. The portion of the trials on which a stop signal appeared was manipulated to create high and low inhibitory demand conditions. In the high demand condition stop signals were presented on 30% of trials. In the low demand condition stop signals were presented on 10% of trials. Blocks of trials were administered, in a counter balanced order, to induce differential activation of the inhibitory system.

Prior to beginning the task, a target stimulus (a unique combination of color and angle) was introduced and participants were