PERGAMON

Neuropsychologia 41 (2003) 1863–1867

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

# Neural correlates of thought suppression

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Received 12 December 2002; received in revised form 27 March 2003; accepted 5 August 2003

**Abstract**

The present report used functional magnetic resonance imaging (fMRI) to examine the neural correlates of thought suppression. Subjects were imaged while alternately (i) attempting to suppress a particular thought, (ii) attempting to suppress all thoughts, or (iii) thinking freely about any thought. Suppression of a particular thought, when compared to the free-thought control condition, revealed greater activation in the anterior cingulate. When the task of suppressing all conscious thoughts was compared to free-thought, a more distributed network of brain regions, including the anterior cingulate and the insula, was activated. These findings are consistent with previous research on cognitive control and may provide potential insights into psychological disorders involving recurring, intrusive thoughts.


*Keywords:* Cognitive control; Anterior cingulate; Insula

## 1. Introduction

A fundamental human capacity is the ability to regulate and control our thoughts and behaviors. Neural substrates of cognitive control have been investigated using a variety of methods that require suppression of actions (Bush et al., 1998; Casey et al., 1997; Garavan, Ross, & Stein, 1999; Gondo, Shimonaka, Senda, Mishina, & Toyama, 2000; Kawashima et al., 1996; Kiehl, Smith, Hare, & Liddle, 2000; Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000; MacDonald, Cohen, Stenger, & Carter, 2000). The procedures used in these studies require participants to inhibit behavior, such as refraining from making a button press in a go/no-go task (e.g. Gondo et al., 2000; Kawashima et al., 1996; Kiehl et al., 2000; Konishi, Nakajima, Uchida, Sekihara, & Miyashita, 1998; Liddle, Kiehl, & Smith, 2001) or inhibiting reading while naming the color in which a word is written (i.e. the Stoop task) (Bush et al., 1998; Leung et al., 2000). Less attention, however, has focused on the brain regions that are involved in the regulation of mental contents, such as when people are instructed to control their thoughts or memories (Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001; Wegner & Wenzlaff, 1996). Although regulating the contents of consciousness requires substantial cognitive effort (Wenzlaff & Wegner, 2000), thought control does not require the suppression of an overt motoric or verbal response. Thus, it is unclear whether similar neural mechanisms are involved in this variant of cognitive control. Noting this ambiguity, the present study investigates the neural mechanisms that underlie directed thought suppression.

Mental control is required for people to function effectively in their daily lives. Successfully controlling our thoughts is difficult; unwanted worries intrude and thoughts frequently wander when they should be focused on the task or goal at hand (Wenzlaff & Wegner, 2000). These intrusive thoughts often arise automatically, without any conscious effort to call them forth. Difficulties with mental control and inhibition are core symptoms in various clinical disorders (Purdon, 1999), such as post-traumatic stress disorder (PTSD) (e.g. Davies & Clark, 1998; Steil & Ehlers, 2000), attention-deficit hyperactivity disorder (ADHD) (e.g. Caplan, Guthrie, Tang, Nuechterlein, & Asarnow, 2001), obsessive–compulsive disorder (OCD) (e.g. Purdon, 2001; Tolin, Abramowitz, Hamlin, Foa, & Synodi, 2002), and depression (Beck, Rush, Shaw, & Emery, 1979; Greenberger & Padesky, 1995; Reynolds & Wells, 1999). Each of these disorders has been linked to deficits in the ability to regulate or suppress unwanted thoughts. The combined evidence from these several patient groups also raises the possibility that cognitive control over thoughts and actions may share common underlying neural mechanisms. Thus, understanding the neural basis of mental control over everyday thoughts in healthy individuals may provide insights into the cognitive processes associated with these various psychological disorders.

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0028-3932/$ – see front matter 
doi:10.1016/j.neuropsychologia.2003.08.001

Cognitive control of thoughts and actions may involve similar component processes and therefore recruit common brain regions. Action inhibition typically involves activation of the anterior cingulate (Braver, Barch, Gray, Molfese, & Snyder, 2001; Liddle et al., 2001; MacDonald et al., 2000) and the prefrontal cortex (Casey et al., 1997; Dove, Pollman, Schubert, Wiggins, & von Cramon, 2000; Logan & Cowan, 1984; Miller, 2000). The anterior cingulate is active across a variety of tasks that require inhibition of prepotent responses, such as the Stroop task (Peterson et al., 1999) and the go/no-go task (Casey et al., 1997; Kiehl et al., 2000; Liddle et al., 2001). Additionally, research has shown that there is diminished anterior cingulate activity in patients with PTSD when they are responding to emotional words, suggesting that this structure may play a key role in the ability to suppress intrusive thoughts (Shin et al., 2001). Recent studies have also implicated the insula in aspects of cognitive control (Bunge, Klingberg, Torkel, Jacobson, & Gabrieli, 2000; Dove et al., 2000; Garavan et al., 1999; Rubia et al., 2001). Garavan et al., using event-related fMRI, showed right insula activation during a task that required inhibition of prepotent motor responses to target letters (Garavan et al., 1999). Similarly, Dove et al. reported insula activity during task switching (Dove et al., 2000). Thus, the accumulated evidence to date suggests that the insula may be an important brain region in the network that subserves cognitive control.

Extending work of this kind, the present research used fMRI to identify the neural substrates of intentional thought suppression. Specifically, subjects were imaged during three task conditions: (1) trying to suppress a specific, unwanted thought; (2) trying to suppress all conscious thought; and (3) thinking freely about anything.

## 2. Method

### 2.1. Participants

Twelve subjects (six males, mean age = 19.7 years) participated in the study in exchange for class credit or US$ 10. All subjects were right-handed, reported no significant abnormal neurological history and had normal or corrected-to-normal visual acuity. Informed written consent for all participants was obtained prior to the experiment in accordance with the guidelines established by the Committee for the Protection of Human Subjects at Dartmouth College.

### 2.2. Materials

A block design was used with alternating epochs during which subjects viewed cue words presented in the center of the screen, indicating the task they were required to perform during the epoch. Visual stimuli were generated using a Dell computer running Cedrus Superlab Pro Version 2.10 software. Stimuli were projected to subjects with an Epson (model ELP-7000) LCD projector onto a screen positioned at the head end of the bore. Subjects viewed the screen through a mirror. Cushions were used to minimize head movement.

### 2.3. Procedure

Subjects were informed that the study examined the brain mechanisms involved in thinking. Prior to scanning, all subjects were asked to produce a personally relevant thought that was currently salient to them (e.g. “study for an exam” or “a phone call with a distant girlfriend”). This thought was used as the target that subjects were later required to suppress. They were then placed in the scanner. Subjects viewed one of three different instructional cues: “suppress” (specific thought suppression task), “clear” (clear mind task), or “fixate,” (free-thought task). In the SUPPRESS task, subjects were directed to suppress the particular thought they had generated prior to scanning. In the CLEAR task, subjects were directed to clear their minds of all thoughts and to think of nothing at all. The FREE-THOUGHT task served as a control condition in which subjects were permitted to think about anything. Across four functional runs (counterbalanced across participants), subjects alternated between two of the task conditions. Within a functional run, there were eight alternating 30 s epochs. In two of the functional runs, subjects alternated between the SUPPRESS and FREE-THOUGHT tasks. In the remaining two runs they alternated between the CLEAR and FREE-THOUGHT tasks. Cue words to indicate task instruction remained on the screen for the entire 30 s epoch.

It is important to note that no behavioral measure was collected during the functional runs. An important aspect of the current paradigm was to assess similarities and differences between the cognitive control of thought and behavior. In order to dissociate these two processes, no overt behavioral response was collected (e.g. pushing a button to index thought intrusions) as such a requirement contaminates thought suppression with response generation. Moreover, the current experiment was not concerned with failures of cognitive control per se, but rather the ongoing process of mental regulation. Post-experimental debriefing indicated that subjects found both the SUPPRESS and CLEAR tasks to be difficult, and all participants reported the occurrence of intrusive thoughts during the tasks.

### 2.4. Image acquisition

Imaging was performed on a 1.5 T whole body scanner (General Electric Medical Systems Signa, Milwaukee, Wisconsin) with a standard head coil. Anatomical images were acquired using a high resolution 3-D spoiled gradient recovery sequence (SPGR; 124 sagittal slices, TE = 6 ms, TR = 25 ms, flip angle = 25°, voxel size = 1 mm × 1 mm × 1.2 mm). Functional images were collected in runs using a gradient spin-echo echo-planar sequence sensitive to blood oxygen level-dependent (BOLD) contrast (T2*)