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Selective attention and inhibitory deficits in ADHD: Does subtype or comorbidity modulate negative priming effects?

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Abstract

Selective attention has durable consequences for behavior and neural activation. Negative priming (NP) effects are assumed to reflect a critical inhibitory component of selective attention. The performance of adolescents with Attention Deficit/Hyperactivity Disorder (ADHD) was assessed across two conceptually based NP tasks within a selective attention procedure. Comorbidity (non-comorbid ADHD vs. comorbid ADHD) and subtype (ADHD combined vs. ADHD inattentive) were considered key issues. Results found NP effects to differ as a function of comorbidity but not subtype. Findings are discussed in light of functional neuroimaging evidence for neuronal enhancement for unattended stimuli relative to attended stimuli that strongly complements an inhibitory-based explanation for NP. Implications for the 'AD' in ADHD and contemporary process models of the disorder are considered.

Keywords: ADHD; Selective attention; Negative priming; Comorbidity; Subtype; ADHD-C; ADHD-I; Inhibition; Disinhibition

1. Introduction

A topic of continuing interest in cognitive neuroscience concerns how the human information processing system overcomes attentional competition generated by concurrent stimulus inputs (Serences & Yantis, 2007; Treisman, 2006). Attention is modulated by both goal-directed (top-down) and stimulus-driven (bottom-up) factors. In selective attention, the control or regulation of behavior is restricted to some subset of information relevant to a current goal. According to biased competition theory (Desimone & Duncan, 1995), top-down effects enhance processing for stimulus representations most relevant to current behavior while reducing or gating this process for unwanted competing stimuli representations. An alternative view suggests unwanted representations are not simply screened out, but implicitly registered and automatically subjected to active inhibition (Neumann & DeSchepper, 1992; Tipper, 2001).

These issues are critical to the valid development of current process models of Attention Deficit/Hyperactivity Disorder (ADHD) connecting frontal lobe control systems (Barkley, 1997) and subsidiary attentional signalling systems in the anterior regions of the cortex (Nigg & Casey, 2005; see also Casey & Durston, 2006) to difficulties with interference control. Inhibitory mechanisms are assumed to play an integral role in orchestrating performance in various domains, such as perception, selective attention, motor processes, working memory, and memory retrieval. Elucidating the precise forms of inhibition that operate in these multiple systems should further the development of theoretical and clinical knowledge of the specific attentional and cognitive deficits confronted by those with ADHD.

1.1. Disinhibition models of ADHD

Much of the literature on disinhibition in ADHD has focused on deficits in response inhibition and interference control as operationalized by the Stroop task (see Nigg, 2001, for a review). Stroop tasks typify a class of interfer-

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ence whereby the introduction of task-irrelevant stimulus dimensions slows response time. For instance, in Stroop interference tasks color naming times for color hues are impaired by the presence of a task-irrelevant incongruent color word (e.g., the word "red" printed in blue) relative to color naming times for neutral stimuli (e.g., the letters "iii" printed in blue). The Stroop effect is widely used as an index for inhibitory response or interference control in the study of psychopathology, with an increased effect often taken to indicate reduced capacity for inhibition. Debate continues, however, as to whether Stroop interference activates an inhibitory process to resolve conflict between competing stimulus dimensions or some other process such as the gating or screening of the irrelevant stimulus dimension (cf. Cohen, Dunbar, Barch, & Braver, 1997; Durgin, 2000, 2003; Schooler, Neumann, Caplan, & Roberts, 1997a, 1997b). Supplementing interference measures such as the Stroop task with the negative priming procedure may provide a more accurate assessment of the nature of interference resolution.

1.2. Negative priming and active inhibition

Evidence from behavioral priming studies suggests that unattended or ignored stimuli are implicitly registered and subjected to further processing, often producing a traceable "negative priming" (NP) effect (Tipper, 1985). Typically indexed over a series of sequential trials containing simultaneous target and distractor displays, NP refers to delayed or impaired responses to a target on a probe trial when that stimulus or close categorical relation was ignored as a distractor on the preceding prime trial (i.e., the ignored repetition [IR] condition). The NP effect is often gauged by subtracting the time taken to respond on trials in the unrelated (UR) condition, where probe target and prime distractor are unrelated, from the time taken to respond in IR trials.

NP was first documented in Dalrymple-Alford and Budyar's (1966) seminal study on the effect of Stroop stimuli sequencing on interference. This study found that naming the color hue of an incongruent color word stimulus on a Stroop task was further impaired if the current color had been employed as the distractor (i.e., the word stimulus) in the preceding trial relative to trials where current target and distractor stimuli were unrelated. Widely documented over a broad range of selective attention tasks (for reviews, see Fox, 1995; May, Kane, & Hasher, 1995), and operating at the level of semantic, perceptual, and auditory stimulus representations (Buchner & Mayr, 2004; Driver & Baylis, 1993; Tipper, 1985; Tipper & Driver, 1988), NP appears to reflect a general component of the selection process in situations with intensively clashing targets and concurrent distractors.

Inhibition-based accounts of NP hold that NP reflects an inhibitory component of selective attention and interference resolution (Houghton & Tipper, 1994; Neumann & DeSchepper, 1992; Strayer & Grison, 1999). These accounts incorporate activation–suppression models of attention in which the initial analysis of both unattended and attended items takes place in parallel prior to selection (e.g., Neill & Westberry, 1987; Neumann & DeSchepper, 1991; Tipper, 1985). For a response to be directed towards the target, an excitatory process operates to maintain or enhance the internal representation of the target, while an inhibitory process operates to suppress the distractor representation. Residual inhibition tied to the internal representation of an ignored distractor item is believed to produce the NP effect when that item is represented as a target. Applied to priming procedures, activation–suppression models predict a priming benefit or positive priming for recently attended stimuli and NP for recently unattended stimuli. Contemporary studies using behavioral and brain imaging techniques interpret NP as indicating that information in competition with current target information is subject to an involuntary form of neural inhibitory activity during target selection (e.g., Grison, Tipper, & Hewitt, 2005; Vuilleumier, Schwartz, Duhoux, Dolan, & Driver, 2005). While theoretical accounts of NP remain notoriously controversial (see Mayr & Buchner, 2007), the notion of an active inhibitory component in selective attention and interference resolution has become increasingly influential in the past two decades (see Tipper, 2001, for a review).

1.3. Neuronal enhancement as evidence for a functional inhibitory action on unattended stimuli

In the realm of cognitive neuroscience, priming paradigms continue to offer insight into the mechanisms that may underlie selective processing. A possible inhibitory locus for perceptual NP revealed during a recent fMRI study strongly complements an inhibitory-based explanation for NP (Vuilleumier et al., 2005). Vuilleumier et al. used a delayed repetition priming procedure during event-related fMRI to examine later neural traces for visual objects either attended or ignored during intial perceptual exposure in a selective attention task. At initial exposure, target and distracter objects in isoluminant colors were presented on screen as an overlapping visual display. Targets were selected by prespecified color via a manual key press. At later trial re-exposure, objects previously attended and unattended were presented in isolation for manual response. These authors found that while recently attended objects were associated with fMRI response decreases and behavioural positive priming effects, recently unattended objects were linked with fMRI response increases (neuronal enhancement). Vuilleumier et al. concluded that the neuronal enhancement effect observed for recently unattended objects on re-exposure trials would likely relate to the cost of overcoming inhibitory action triggered during initial exposure trials, an effect that would ultimately produce behavioral NP under typical IR conditions.

Identifying the precise psychological determinants and neural processes involved in NP seems critical to our understanding of the nature of the selective attention