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The developing brain in a multitasking world

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ABSTRACT

To understand the problem of multitasking, it is necessary to examine the brain's attention networks that underlie the ability to switch attention between stimuli and tasks and to maintain a single focus among distractors. In this paper we discuss the development of brain networks related to the functions of achieving the alert state, orienting to sensory events, and developing self-control. These brain networks are common to everyone, but their efficiency varies among individuals and reflects both genes and experience. Training can alter brain networks. We consider two forms of training: (1) practice in tasks that involve particular networks, and (2) changes in brain state through such practices as meditation that may influence many networks. Playing action video games and multitasking are themselves methods of training the brain that can lead to improved performance but also to overdependence on media activity. We consider both of these outcomes and ideas about how to resist overdependence on media. Overall, our paper seeks to inform the reader about what has been learned about attention that can influence multitasking over the course of development.

Introduction

A theme of this special issue set out by the guest editor is as follows:

"Fundamentally, the issue of multitasking in both experimental and everyday tasks is one of dividing and deploying attention resources effectively. . . . The basic questions that have fueled research

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for decades concern the processes and mechanisms that drive the deployment of attention, how they develop across childhood and the constraints under which they operate (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, 2015)."

In this paper we address these basic questions and discuss how the brain networks that underlie attention develop in infancy and childhood. A central theme of the paper is that attention training and brain state training procedures can improve the efficiency of the attention networks that are central to effective multitasking. We also examine individual differences in attention network efficiency, sensation seeking, and effortful control that might influence the frequency and efficiency of multitasking. Together, these findings allow us to better understand how brain plasticity can provide opportunities to improve multitasking ability but also has the potential for excessive use of the Internet and other media.

In the first section of the paper we review the brain's attention networks (i.e., alerting, orienting, and executive) as they relate to multitasking. In the second section we consider the development of these attention networks. During development, the connectivity of brain networks changes and these changes influence the control that individuals can exercise over their behavior. In the third section we discuss attention network plasticity and the effects of specific network training and practice (including the use of video games) on behavior. In the fourth section we discuss another aspect of plasticity; how the networks can be altered through the induction of different brain states and the consequences of this for their use and overuse. The fact that training can influence specific brain networks and brain states makes it plausible that exposure to new media and the constant need to switch between tasks and to deal with the interruptions inherent in multitasking could modify certain brain circuits. Finally, in the fifth section the attention training framework is used to explain how the brain might change with habitual multitasking and multimedia experience and how these effects might be moderated through techniques that can alter brain states (e.g., meditation) and improve self-regulation.

The brain's attention networks

Neuroimaging procedures have identified the brain networks that underlie attention and these have been discussed in detail in previous publications (Petersen & Posner, 2012; Posner, 2012). These specialized attention networks include *alerting*, defined as achieving and maintaining a state of high sensitivity to incoming stimuli; *orienting*, which is the selection of information from sensory input; and *executive attention* that involves mechanisms for monitoring and resolving conflict among thoughts, feelings and behavior. The function and processing efficiency of the three networks have been assessed with the Attention Network Test (ANT), a flanker-type task in which differences in reaction time (RT) between various test conditions are used to evaluate each network (Fan, McCandliss, Sommer, Raz, & Posner, 2002). The results of testing with the ANT and data from neuroimaging procedures across a wide age range indicate that the three networks engage separate brain mechanisms and are functionally independent, although there are some interactions among them in real life and in certain tasks (Fan et al., 2009).

It is important to note that the single tasks we perform consist of multiple components or operations and involve switching or resisting switching between brain areas. Neuroimaging has revealed that even the very simple task of shifting attention from one location to another activates a network of neural areas (Posner, 2012). In general, these networks consist of widely scattered nodes, often in both cortical and subcortical locations, that must be coordinated to carry out the task. For simple and highly practiced tasks, this switching does not involve any major effort. For more complex and effortful tasks, and particularly when multiple tasks are involved, the executive network is also needed. Below we discuss the role of the networks in multitasking, focusing particularly on the orienting and executive attention networks.

Orienting

Multitasking typically involves aligning ones attention with alternating sources of sensory input. These sources include computers, portable electronic devices, televisions, phones, radios, books,

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