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A cross-sectional examination of age and physical activity on performance and event-related brain potentials in a task switching paradigm

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Abstract

Younger and older physically active and sedentary adults participated in a task switching paradigm in which they performed a task repeatedly or switched between two different tasks, while measures of response speed, response accuracy, P3 amplitude, and P3 latency were recorded. Overall, response times were faster and midline P3 amplitudes were larger for the active than for the sedentary participants. P3 latencies discriminated between active and sedentary individuals on trials in which multiple task sets were maintained in memory and task switches occurred unpredictably but not in blocks of trials in which a single task was repeatedly performed. Results are discussed in terms of the specificity and generality of physical activity effects on cognition.

Keywords: Exercise; Executive control; P3; ERP; Aging; Fitness

Over the past several decades there has been an increasing interest in the influence of physical activity and in particular aerobic exercise, on human cognition. Early studies of this relationship often examined the influence of physical activity differences, for both younger and older adults, on the performance of simple and choice reaction time (RT) tasks. For example, Spirduso and Clifford (1978) found that older physically active adults were significantly faster on a variety of different RT and movement time tasks than older sedentary adults. These initial observations were confirmed in numerous subsequent studies of cross-sectional physical activity differences on the performance and cognition of older adults (see Etnier et al., 1997 for a review). The literature that has examined whether younger adults show similar physical activity benefits on the performance of cognitive tasks has been more equivocal (Lupinacci et al., 1993; Rikli and Busch, 1986), perhaps as a result of the generally moderate to high activity levels of younger adults in the cohorts that have been studied.

The relatively strong relationship between physical activity and cognition, particularly with older adults, has not always been observed with randomized clinical trials in which an aerobic training group is compared to a non-aerobic control group. However, a number of intervention studies have reported improvements in particular aspects of cognition with physical activity training (see Colcombe and Kramer, 2003 for a review of this literature). Interpretation of the results from these studies is complicated by differences in the length, intensity, and type of training regimens, the age, health, and beginning and ending cardiovascular fitness levels of the study participants, the methods used for the assessment of cardiorespiratory fitness, and the tasks used to index perceptual, cognitive, and motor function improvements.

Given the relatively small sample of individuals who have participated in each of these studies, Colcombe and Kramer (2003) performed a meta-analysis on the randomized clinical studies of physical activity effects on cognition in an effort to determine whether (a) a reliable physical activity effect could be discerned with the additional power that is gained when aggregating data across studies and (b) if so, which factors moderate the effects of physical activity on cognition. Several interesting and potentially important results were obtained. First, a clear and significant effect of aerobic exercise training was found. Second, aerobic exercise training had both general and selective effects on cognitive function. Although physical activity effects were observed across a wide variety of tasks and cognitive processes, the effects were largest for those tasks

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that involved executive control processes (i.e., planning, scheduling, working memory, interference control, task coordination). Executive control processes have been found to decline substantially as a function of aging (West, 1996) as have the brain regions that support them (Raz, 2000). Therefore, the results of the meta-analysis suggest that even processes that are quite susceptible to age-related changes appear to be amenable to intervention.

Research employing event-related brain potentials (ERPs) has further established that physical activity may be beneficial to cognitive function in older adults (Dustman et al., 1990; Hillman et al., 2004, 2002). Habitual participation in aerobic forms of exercise has been associated with decreased differences in the neuroelectric profile between older and younger individuals, indicating that it may protect against cognitive aging. In particular, the P3 component of the ERP has been especially useful in understanding the relationship between physical activity and aging, since differences in the amplitude and latency have been observed that are indicative of the attentional resources allocated in the updating of working memory, and the speed of cognitive processing, respectively. Findings suggest that exercise participation may play a role in maintaining efficiency of cognitive performance with advanced age by increasing P3 amplitude and decreasing P3 latency (Hillman et al., 2002, 2004).

In the present study, we further examined the relationship between physical activity and cognition by asking physically active and sedentary younger and older adults to perform a task switching paradigm. This paradigm has been used to study selective aspects of executive control (e.g., Rogers and Monsell, 1995) and entails comparisons between three different conditions (repeated task trials in task-homogenous blocks, switch trials in task-heterogeneous blocks, and non-switch or repeated task trials in task-heterogeneous blocks). Comparisons among these conditions enable us to distinguish separate executive control components and to determine interactions among them. In task-homogenous blocks, participants perform the same task on every trial, while in task-heterogeneous blocks two (or more) tasks are intermixed. Task-heterogeneous blocks consist of two types of trials: switch trials, in which the task is different than the one in the preceding trial, and non-switch trials, in which the task is the same as the task in the preceding trial.

The difference between performance on switch trials and non-switch trials within task-heterogeneous blocks has been termed *local switch costs* (Meiran, 1996). Local switch costs reflect the effectiveness of executive control processes responsible for the activation of the currently relevant task set and the deactivation of the task set that was relevant on the previous trial. Another aspect of task switching is *global switch costs*, and is defined as the difference in performance between task-heterogeneous blocks and task-homogenous blocks. Global switch costs reflect the efficiency of maintaining multiple task sets in working memory as well as the selection of the task to be performed next (Kray and Lindenberger, 2000).

Many studies have shown age effects in local switch costs to be rather small or absent when age effects in general slowing are taken into account (e.g., Kray and Lindenberger, 2000; Mayr, 2001; but see De Jong, 2001; Kray et al., 2002). However, studies of task switching have often found age effects to be much more robust and pronounced in global switch costs (Kray and Lindenberger, 2000; Mayr, 2001). Importantly, older adults' performance deficits in global switch costs remain reliable after controlling for age effects in general slowing.

In the present study we tested several hypotheses within the context of a task switching paradigm in which the task to be performed next was cued upon the presentation of the stimulus and the order of tasks (in the heterogeneous trial blocks) was random and unpredictable. First, we examined the hypothesis that physical activity would positively influence task switching performance for both younger and older adults. As discussed above, previous research has been equivocal with respect to whether physical activity effects are equivalent for younger and older adults or larger for older adults—although a recent meta-analysis (Etnier et al., 1997) suggests age-equivalence. Given that the task we employed has shown strong aerobic fitness effects for older adults in a previous study (Kramer et al., 1999), we hypothesize that it will be sufficiently sensitive to detect physical activity effects for both younger and older adults in the present study. Second, we hypothesize that physical activity will have a larger effect on trials in the task-heterogeneous or switching blocks than in the task-homogenous (repeated task) blocks. We suggest that this will be the case because performance in the task-heterogeneous blocks requires more extensive executive control processes, the very processes that appear to be most sensitive to physical activity effects (Colcombe and Kramer, 2003; Kramer et al., 1999).

Third, we hypothesize that the event-related brain potential (ERP) measures, and specifically the amplitude and latency of the P3 component, will be more sensitive to physical activity effects than measures of performance (see Hillman et al., 2004). We believe that this will be the case because components of the ERP are selectively sensitive to processes that intervene between the encoding of the task-relevant stimuli and the production of a response. As a result of this characteristic we expect that the P3 measures will enable us to more precisely gauge the effects of physical activity than the performance measures. In the present study we utilize measures of P3 amplitude and latency to examine the nature and specificity of physical activity effects on important components of processing—that is, the speed of processing and the updating of memory representations during the performance of switch and non-switch trials.

1. Method

1.1. Participants

Sixty-six participants (34 male) were recruited based on age and physical activity history and placed into one of four gender-balanced groups: older physically active, older sedentary, younger physically active, and younger sedentary. Table 1 lists participants' demographic information and physical