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Short communication

The association of physical activity to occipito-temporal processing during face recognition

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A B S T R A C T

Objectives: This study examined the association between physical activity level and primitive cognitive processing during a face recognition task in young adults, a topic that has received little attention.
Design: Cross-sectional.
Methods: The face recognition task required participants to respond to famous faces but not respond to unfamiliar faces. Task performance and several occipito-temporal event-related brain potentials reflecting the various stages of face processing, from perceptual encoding (N170) to recognition (N250 and face-N400), were assessed during the face recognition task.
Results: Although analyses revealed no significant group differences in behavioral performance measures, neuroelectric data showed different time courses of face recognition processes between groups. Active individuals exhibited larger N250 amplitude, reflecting an early stage of facial recognition, for famous relative to unfamiliar faces, whereas inactive individuals did not exhibit such a difference.
Conclusions: These findings are suggestive of a possible association between physical activity and relatively early, primitive cognitive processes.

Introduction

For more than a decade, neuroelectric studies using event-related brain potentials (ERPs), particularly focusing on the P3 component and error-related negativity (ERN), have indicated that physical activity and fitness are associated with cognitive functioning across a person's lifespan (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Hillman, Castelli, & Buck, 2005; Polich & Lardon, 1997; Pontifex, Hillman, & Polich, 2009; Themanson, Hillman, & Curtin, 2006). A majority of these studies have employed cognitive tasks requiring variable amounts of cognitive control (i.e., goal-directed cognitive operations underlying perception, memory, and action). This body of research indicates that the association between physical activity and cognitive function is disproportionately larger for tasks requiring extensive amounts of cognitive control, such as tasks involving inhibition, working memory, action monitoring, and cognitive flexibility (Hillman, Kamijo, & Pontifex, 2012). These ERP findings are in line with a functional magnetic resonance imaging (MRI) study (Colcombe et al., 2004) indicating that regular physical activity results in increased activation of the prefrontal cortex, which plays a key role in the effective regulation of cognitive control, and reduced anterior cingulate cortex activation, which reflects more efficient action monitoring. More recently, several studies have indicated that regular physical activity is also associated with hippocampal structure and function (Erickson et al., 2011).

Although there appears to be a consensus that physical activity is closely related to higher-order cognitive functions, it is important to clarify whether more primitive cognitive processes are also associated with physical activity level, in order to get a more complete picture of this association. Unfortunately, studies of such an association are scarce, with most previous research focusing on cognitive control and therefor examining the P3 ERP component or ERN. Accordingly, the present study aimed to clarify a potential association between physical activity level and primitive cognitive processes by focusing on face-related processing. Several occipito-temporal ERP components that reflect various stages of face processing, from perceptual encoding (i.e., N170) to recognition (i.e., N250, face-N400), can be elicited during a face recognition task. Specifically, given that the N170 is larger for faces than for non-face stimuli and is not sensitive to face familiarity, this component has

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been theorized to reflect a fairly early perceptual stage of face processing (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bentin & Deouell, 2000; Eimer, 2000). By contrast, the N250 and face-N400 are sensitive to face familiarity, with enhanced negative amplitudes for familiar compared to unfamiliar faces, suggesting that these components reflect stages of face recognition (Bentin & Deouell, 2000; Schweinberger, Pfutze, & Sommer, 1995).

Nonhuman animal models have suggested that voluntary wheel running increases nerve growth factors such as brain-derived neurotrophin factor (Neeper, Gomez-Pinilla, Choi, & Cotman, 1995), which may relate to increases in the number of synaptic connections and development of new neurons (van Praag, Christie, Sejnowski, & Gage, 1999). Additionally, human studies have indicated that aerobic fitness training increases plasma concentration of peripheral brain-derived neurotrophin factor (Zoladz et al., 2008). These changes may be associated with increases in brain volume. A structural MRI study (Colcombe et al., 2006) indicated that physical activity training increased tissue volume in the prefrontal and *temporal* cortices. This implies that physical activity is related not only to higher-order cognitive control as indexed by prefrontal cortex functioning but also to lower-order cognitive processes associated with the temporal cortex. It has been well established that the occipito-temporal cortex plays a crucial role in face processing (Kanwisher, McDermott, & Chun, 1997). The present study is designed to shed further light on a possible link between physical activity and face processing, as one example of an earlier and more primitive set of cognitive processes.

We used a face recognition task that required participants to respond to infrequently presented famous faces (i.e., presented at a 0.17 probability) and not respond to frequently presented unfamiliar faces (i.e., 0.83 probability). This task was intended to elicit the occipito-temporal ERP components described above. During this task (i.e., a hybrid face recognition/oddball task), a clear P3 component emerges following famous faces. The P3 is sensitive to the allocation of attentional resources during stimulus engagement (Polich, 2007), with larger P3 reflecting increased attention toward a stimulus. Previous ERP studies using an oddball task have indicated that higher-active/more-fit individuals exhibit larger P3 amplitude relative to their lower-active/less-fit peers (Hillman et al., 2005; Polich & Lardon, 1997; Pontifex et al., 2009), implying that higher-active/more-fit individuals may be able to recruit a greater amount of attentional resources to target rare stimuli.

Based on the findings of the structural MRI study referenced earlier (Colcombe et al., 2006), it is likely that physical activity is associated with occipito-temporal processing during face recognition. If this assumption is valid, it follows that face recognition processes as indexed by occipito-temporal ERPs would differ as a function of physical activity level. We further predicted that active individuals would exhibit larger P3 amplitude relative to inactive individuals.

Methods

Participants

Twenty physically active and 20 inactive students were recruited from the University of Tsukuba, Japan. All active group participants met the exercise recommendations of the American College of Sports Medicine (≥5 days/week of moderate intensity aerobic activities or ≥ 3 days/week of vigorous intensity aerobic activities) (American College of Sports Medicine, 2010), whereas no inactive group participants met these recommendations. Participants' physical activity levels were evaluated using the International Physical Activity Questionnaire long form (http://www.ipaq.ki.se/ipaq.htm). Reported physical activity level differed significantly between the groups, $t(38) = 7.0$, $p < .001$, $d = 2.2$. Table 1 provides participants' demographic and physical activity information. Participants provided written informed consent in accordance with the Institutional Human Research Committee (National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan).

Cognitive task

Prior to the face recognition task, each participant chose 30 famous faces with which they were familiar from a list of 60 famous faces (e.g., actors, athletes). The chosen 30 famous faces and 150 unfamiliar faces (i.e., unknown individuals) were used as stimuli. Each face appeared once within a single block of 180 randomly ordered trials. The face recognition task required participants to press a button with their right index finger, as quickly and accurately as possible, in response to the famous faces and to not respond to unfamiliar faces. Participants completed two trial blocks. Each face was presented for 200 ms, with a 1000 ms response window and a random stimulus onset asynchrony between 1000 and 2000 ms (mean = 1500 ms). All photographs were gray scale and presented from the shoulders up on a white background. Mean luminance of famous and unfamiliar face photographs was equivalent. Each photograph subtended horizontal and vertical visual angles of 6.2°.

ERP Recording

EEG activity was recorded from 19 electrode sites according to the International 10–20 system. Ongoing EEG activity was referenced to the left earlobe, with AFz serving as the ground electrode. Additional electrodes were placed above and below the right orbit and the outer left and right canthi to monitor electrooculogram activity with bipolar recording. Interelectrode impedances were kept below 5 kΩ. The time constant was set at 5 s with a high-cut filter of 300 Hz. Continuous data were digitized at a sampling rate of 1000 Hz. Trials with response errors were excluded from the analyses. Off-line processing of the ERP included: Re-referencing to average earlobes, creation of stimulus-locked epochs (−100–1000 ms relative to stimulus onset), baseline correction (−100 to 0 ms prestimulus period), band-pass filtering (0.1–30 Hz), and artifact rejection (epochs containing signals that exceeded ± 60 μV were rejected). In addition, independent components analysis, as implemented in EEGLab (Delorme & Makeig, 2004), was used to remove eye blink related components. Across groups, a mean of 39 and 147 trials were averaged for famous and unfamiliar faces, respectively.

Based on visual inspection of the grand average ERP waveforms (Fig. 1A), the N170 was defined as the mean amplitude within a 130–170 m latency window at T5 and T6 (Bentin et al., 1996). In addition, following Webb et al. (2010), mean amplitudes within a 50 ms window from 200 to 400 ms were calculated for the N250a (200–250 m), N250b (250–300 m), face-N400a (300–350 m), and face-N400b (350–400 m) at T5 and T6. The P3 was defined as the

Table 1
Mean (*SD*) values for participant characteristics.

Measure	Active		Inactive	
	Female	Male	Female	Male
Sample size (*n*)	10	10	9	11
Age (years)	19.9 (0.9)	20.9 (1.4)	22.4 (1.9)	22.2 (1.8)
BMI (kg/m^2)	20.7 (2.6)	21.5 (1.4)	20.7 (1.7)	21.3 (2.4)
IPAQ (kcal/week)	8473.3 (3479.0)	9985.4 (5739.7)	2056.7 (1363.3)	1404.9 (778.8)

Note: BMI = body mass index; IPAQ = International Physical Activity Questionnaire.