Aging, physical activity, and cognitive processing: an examination of P300

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Abstract

Physical activity appears to attenuate the decline of cognitive function typically observed in older men and women. The P300 component of the event-related potential (ERP) is particularly affected by aging and allows for basic neurobiological assessment of cognitive function. Three aspects of the P300 component (i.e. latency, amplitude, and area under the curve (AUC)), elicited by an oddball task, were derived to assess cognitive function in young and older participants (N = 73) who were further classified as high- and low-active. The low-active elderly participants exhibited larger AUC values than those observed in all other groups which were undifferentiated. That is, the high-active elderly and the young participants exhibited smaller AUC values than the low-active older group. In conclusion, higher levels of physical activity in the elderly may be associated with a reduction in the neural resources allocated in response to simple cognitive challenge. This interpretation is consistent with the concept of psychomotor efficiency proposed by Hatfield and Hillman [The psychophysiology of sport: a mechanistic understanding of the psychology of superior performance. In: Singer RN, Hausenblas HA, Janelle CM, editors. Handbook of sport psychology. 2nd ed. New York: Wiley; 2001, p. 362–88].

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1. Introduction

In addition to numerous health benefits, frequent engagement in physical activity appears to moderate the decline of cognitive function typically associated with aging [7]. Employing both longitudinal and cross-sectional designs, a number of investigators have provided evidence of ameliorative effects of exercise and fitness for a range of cognitive functions including crystallized and fluid intelligence [8,9]. Decision making [34], and effortful memory [5,9]. Although the results of exercise interventions have been mixed, the evidence is more compelling for cross-sectional studies that allow for decades of exercise-related neurocognitive adaptations to accrue [13]. However, the temporal advantage of cross-sectional comparisons is limited by the possibility that competing explanations may account for the outcomes credited to the physical training stimulus. For example, the observed group differences in cognitive function could also be explained by differences in peripher-
A benefit of a P300 component elicited by an oddball task without a button press response is that it reflects minimal motor processing (see [10,41] for theoretical discussion) and thus more directly reflects cognitive function.

Although the P300 component offers advantages in the assessment of exercise and cognitive function in the elderly, surprisingly few such studies have been conducted using this measure [2,12,19]. Typically, two aspects of this component have been examined: latency, which has been related to classification speed and amplitude, which is proportional to the amount of attentional resources devoted to a task [28]. With age, latency consistently increases and amplitude usually decreases and becomes more evenly distributed over the scalp, however, the relationship of amplitude with age is not as consistent as that noted for latency [11,25,28]. In regard to the influence of physical activity, Dustman et al. [14] conducted a 6-month exercise intervention study with older men and women and failed to observe any change in P300 (see [12]). However, with employment of a cross-sectional extreme-groups comparison, Dustman et al. [12] examined young and elderly men who were further divided into groups of high- and low-fit participants based on assessment of aerobic capacity. The authors found P300 latency to be longer for the low-fit elderly group than for the other three groups while no such difference was found between the high-fit older men and the two younger groups. The examination of the P300 was somewhat constrained as amplitude measures were not reported and latency was derived from averaging those for the central and parietal midline sites as opposed to separate midline maximums as is typically reported in the literature. Further, the older men in the study averaged only 55 years of age, an age group that may be limited (i.e. relatively young) in providing a generalized model of aging, physical fitness, and cognitive function for men and women who are well beyond this age range. In a similar study, Hillman et al. [19] examined electrocortical potentials in young and elderly high- and low-fit participants performing a cognitive motor decision-making task. Employing a non-standard P300 protocol, the authors failed to replicate the P300 latency results reported by Dustman et al. [12] for midline sites (Fz, Cz, Pz). They did find an interaction of age and aerobic fitness for the lateral electrode sites (F3, F4, C3, C4, P3, P4). Even though the directionality of the means was similar to the previous finding [12], post hoc examination of the means revealed differences only between the young and older groups. Additionally, no effects for aerobic capacity were revealed for P300 amplitude at the midline or lateral sites. Finally, in a preliminary report, Bashore [2] demonstrated non-significant trends for shorter P300 latencies and higher amplitudes in high-fit than for low-fit elderly. Taken together, these studies lack the evidence needed to support the claim that a lifestyle including routine physical exercise attenuates the decline of cognitive function in the elderly as reflected by the P300 but suggest that such an effect may exist. A similar lack of convergent findings was observed in studies of younger exercise participants. A study of high- (mean age 30.0 years) and low-exercise participants (34.7 years) revealed that P300 amplitude was higher for high-versus low-exercise adherents [29]. However, in a study of cyclists, no differences between high-fit (mean age 21.2 years) and low-fit (22.9 years) participants were observed for P300 amplitude or latency [26]. In all, the effect of physical exercise on the age-related changes in P300 remains to be determined.

The inability of the P300 to consistently reflect the modulatory effects of physical fitness on the age-related declines in cognitive function may be, in part, due to the variable classification of the participants. While the existing P300 literature has classified participants solely on the basis of aerobic capacity, the effects of physical fitness on age-related changes in cognition have been established on the basis of both aerobic capacity and physical activity history. These criteria may lead to different classifications based on factors such as genetic differences [35] (e.g. participants may have a high aerobic capacity but little to no physical activity history). Furthermore, it is reasonable to assume that the P300 may be differentially affected by the cardiovascular adaptations associated with aerobic capacity (i.e. VO2max) versus the neural adaptations associated with long-term musculoskeletal activity. As such, the examination of physical activity history may yield a more robust P300 finding than that reported in the previous literature if beneficial effects of exercise on cognitive function are related to the physical activity. A second opportunity to enhance the detection of activity-related differences in P300 would be provided by a more comprehensive examination of the morphology of the component. Some investigators have employed area measures of P300 (i.e. area under the curve, AUC) [15,21,45] that capture a different aspect of the structure of the time series in an attempt to assess neuropsychological function. The AUC measure reflects not only the amplitude at the P300 peak, but also reflects the shape of the waveform in general. The use of this measure in addition to the P300 latency and amplitude provides additional information about the timing of the processes underlying the component. However, such an index has yet to be employed in studies of exercise and cognitive function in the elderly.

Because previous research has suggested that physical fitness may modulate the effect of aging on cognitive function [8,9,34,40], in the present study, we examined young and elderly men and women who were characterized by high and low physical activity histories using the P300 ERP as an index of cognitive function. Higher physical activity levels were expected to modulate the aging effect; that is, the high-active relative to the low-active elderly group was expected to be more similar in amplitude, AUC, and latency to the young groups. No observable differences were expected between the young high- and low-active groups due to the limited effect of aging on these participants and the mixed findings reported in the literature.
2. Method

2.1. Participants

The participants were 21 high-active (11 males) and 16 low-active (7 males) young volunteers, and 18 high-active (8 males) and 18 low-active (7 males) elderly volunteers. The young participants were recruited from the varsity track team and students enrolled in classes at a large university located in the eastern United States. The elderly subjects were recruited at senior athletic events and from senior community centers and civic groups as well as from a pool of older students enrolled at the same university from which the young participants were recruited. Participants were selected from a pool of potential volunteers following a screening that involved a modified version of a physical activity questionnaire employed in a national fitness survey and a health history questionnaire. Participants were screened to exclude a history of neurological, cardiovascular, and other major diseases, as well as the use of medications affecting both the CNS and the cardiovascular system. None of the participants presented visual disorders other than refractory errors, and all participants had either normal visual acuity or corrected vision with glasses. All participants were characterized by a stable pattern of physical activity engagement over the 5 years preceding the study. The highly active group was characterized by regular involvement in physical activities that were of a sufficiently high intensity and duration to produce a cardiovascular training effect (e.g., swimming, biking, and running). The low-active group was characterized by irregular involvement confined to low-intensity exercise (i.e., activities related to daily living such as gardening and property maintenance).

In order to quantify the characterization of the groups the average daily exercise kilocaloric expenditure (ADEKE) was calculated for high-intensity physical activity based on reported activity for the previous year. The participants listed up to four of the most frequent activities in which they had engaged over the past year and specified the number of hours per day, days per week, weeks per month, and months per year spent in each activity. Energy expenditure was calculated as the product of the time spent in each activity and the kilocaloric cost obtained from a compendium of physical activities [1]. All energy expenditures were adjusted for body weight and summed across the activities. Estimates of ADEKE were calculated only for physical activities of sufficient intensity and duration to produce an aerobic training effect. Participant characteristics are presented in Table 1. Mean comparisons are reported in the Section 3.

2.2. Procedures

Participants in this study were tested individually. After arriving at the laboratory each participant was informed of the requirements of the experiment, and they provided written consent on a form approved by the institutional review board. They then completed the health history and physical activity history questionnaires. On a day prior to EEG testing, the young participants completed a graded VO₂max test on a treadmill (Quinton Treadmill System, model 18–60, Quinton Instrument Company, Seattle, WA) to determine aerobic capacity. Due to the increased risk of performing a VO₂max test and the difficulty in determining a reliable assessment, the elderly groups were tested using a submaximal treadmill protocol [42]. All participants were tested after abstaining from food for 2–3 h and from exercise participation earlier in the day. Throughout both maximal and submaximal tests, the electrocardiogram (ECG) was monitored via pre-gelled, disposable electrodes attached to the subject in a CM5 configuration. Both tests began with a warm-up period during which the participant walked on the treadmill for 2 min at a level grade and a speed of 3 mph. For the maximal exercise test, after the warm-up the treadmill speed was then increased until the participant reached 75% of age-predicted maximal heart rate and remained constant thereafter. Participants then continued exercising for 4 min, after which the treadmill grade was increased to 4%. At the end of each subsequent minute the grade was increased by 2% until the participant reached voluntary exhaustion. For the maximal test only, expired gases were analyzed with a calibrated Beckman Metabolic Measurement Cart (Beckman Instruments, Inc., Fullerton, CA) to obtain 30-s averages of minute volume and fractional gas concentrations of oxygen and carbon dioxide. The assessment of VO₂max was deemed valid if the following three criteria were met: (1)

Table 1

<table>
<thead>
<tr>
<th></th>
<th>High-active</th>
<th>High-active</th>
<th>Low-active</th>
<th>Low-active</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>young (n = 21)</td>
<td>elderly (n = 18)</td>
<td>young (n = 16)</td>
<td>elderly (n = 18)</td>
</tr>
<tr>
<td>ADEKE</td>
<td>972 (99.7)</td>
<td>473 (52.7)</td>
<td>5 (3.4)</td>
<td>39 (25.5)</td>
</tr>
<tr>
<td>VO₂max (ml kg⁻¹ min⁻¹)</td>
<td>57.1 (1.3)</td>
<td>41.1 (2.0)</td>
<td>32.7 (1.9)</td>
<td>27 (1.7)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.3 (0.9)</td>
<td>66.1 (0.8)</td>
<td>23.1 (0.8)</td>
<td>68.9 (0.8)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>15.5 (1.5)</td>
<td>16.6 (0.6)</td>
<td>15.8 (0.4)</td>
<td>14.8 (0.7)</td>
</tr>
</tbody>
</table>

ADEKE: average daily exercise kilocaloric expenditure.

¹ Age by activity interaction, P < 0.001.
² VO₂max taken for young participants and submaximal estimates for elderly participants (see text).
³ Fitness and age main effects, P < 0.05 and <0.001, respectively.
heart rate equaled the age-predicted maximum ± 10 bpm, (2) the increase in oxygen consumption was less than 150 ml with an increase in workload, and (3) the respiratory quotient exceeded 1.10. All young participants met these criteria. For the young participants, the VO2max reported was the highest 30-s value obtained (see Table 1). For the sub-maximal treadmill tests, after the warm-up the treadmill grade was then increased by 2.5% every 2 min until the test was terminated at 85% of age-predicted maximal heart rate. Using the linear relationship between HR and oxygen uptake, maximal aerobic power was estimated by extrapolating actual HR responses to a predicted maximum [20].

The maximal and submaximal tests qualitatively support the ADEKE classification scheme, however, direct comparison between these tests would be inappropriate.

On a separate day, the participant was fitted with an electrode cap (Electro-Cap International, Inc., Eaton, OH) and was led into a sound-attenuated chamber (Industrial Acoustic Company, Inc., Bronx, NY) where testing occurred. During the experiment the participant was seated in a comfortable chair in front of a computer workstation and the chamber was darkened. The sole light source in the chamber was the computer display. The visual stimuli were presented on a computer monitor that was positioned at eye level 1 m from the nasion of the participant. An oddball procedure was used; two stimuli (X or O) were sequentially presented in the center of the computer monitor. The stimuli were white on a black background and were 3 cm high, subtending a visual angle of less than 2°. The stimuli appeared for 0.25 s and the inter-stimulus interval ranged from 2–2.5 s (2.28 s average). The participants were instructed to count the number of Os that appeared. Virtually every participant’s count was exactly accurate. A total of 120 stimuli appeared of which 24 were Os. Participants were instructed to fixate their gaze on a small blue cross in the center of the monitor in the interval between stimuli and to minimize blinking.

Electroencephalographic (EEG) and electro-oculographic (EOG) recordings were sampled continuously during each 1-min stimulus period. EEG activity was measured from tin electrodes positioned at sites Fz, Cz, Pz, C3, C4, T3, T4, O1, and O2 of the International 10–20 System which were referenced to linked ears while FPz served as the ground. Vertical and horizontal EOG signals were obtained with Grass gold electrodes (1 cm) attached to the skin above and to the right of the outer canthus of the right eye. All electrode impedances were below 5 kΩ. The EEG and EOG signals were amplified 50,000 times, bandpass filtered from 0.1 to 100 Hz by a Grass Model 12A Neurodata Acquisition system, and sampled at 256 Hz via a 12-bit analog-to-digital converter, which was controlled by NeuroScan software.

### 2.3. Data reduction

EEG data were edited and analyzed off-line to obtain P300 AUC, amplitudes, and latencies. The AUC measure is related to amplitude but is useful in that it also captures sharpness of the P300 peak. For each condition, the data were low-pass filtered at 30 Hz (12 dB rolloff). These EEG data were partitioned into 120 800-ms epochs, each one consisting of 100 ms of pre-stimulus data and 700 ms of post-stimulus data. Epochs were then examined for evidence of eye artifact and, when appropriate, an algorithm [33] was applied to remove the influence of eye movements. The post-stimulus EEG data were then baseline corrected using the pre-stimulus data. Baseline-corrected epochs that exhibited excursions with amplitudes higher than ±100 V were rejected; on average 20.5 sweeps were accepted. The filtered baseline-corrected data were then ensemble averaged for each of the sites for the X stimulus. As can be seen in Fig. 1, the ensemble averages yield apparent background high frequency activity in the elderly participants. We believe this activity to be an artifact of the increased jitter associated with increased latency variation within these groups. The P300 peak was quantified from each average waveform as the time and amplitude of the highest positive wave between 300 and 600 ms after the stimulus presentation. Fig. 2 illustrates an amplitude by latency scattergram. The P300 peak was quantified from each average waveform as the time and amplitude of the highest positive wave between 300 and 600 ms after the stimulus presentation. Fig. 2 illustrates an amplitude by latency scattergram. The P300 peak was quantified from each average waveform as the time and amplitude of the highest positive wave between 300 and 600 ms after the stimulus presentation. Fig. 2 illustrates an amplitude by latency scattergram.

For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23]. For each participant, the normalization entailed computing the percentage amplitude of the Pz values for each group when site effects were observed [23].
Fig. 1. Ensemble averages of event related potentials. The event related potentials (plotted positive polarity upward) are shown over the midline sites (Fz, Cz, Pz) for low-active (left) and high-active (right) participants. Vertical bars indicate stimulus onset. As these are grand mean averages, they are a somewhat distorted form of the individual waveforms especially in the elderly who had a larger latency variance as can be seen in Fig. 2. Distortions due to latency jitter may include reduced amplitude and increased apparent high frequency activity.

Fig. 2. Amplitude by latency scattergram as a function of age (young, elderly) and activity level (high, low).
3. Results

3.1. Participant characteristics

Mean participant characteristics and associated standard deviations for the young and elderly within each activity group are presented in Table 1. Importantly, these results demonstrate that the high- and low-active level groups differed on ADEKE. More specifically, the analyses revealed a significant interaction for ADEKE scores, $F(1, 69) = 21.1$, $P < 0.001$. Post hoc analysis revealed the ADEKE for the young high-active group was significantly greater than that for the other three groups and that the ADEKE for the elderly high-active group was significantly greater than that for the two low-active groups, which did not differ. The activity group and age main effects were significant for ADEKE, $F(1, 69) = 146.1$, $P < 0.001$, and $F(1, 69) = 16.1$, $P < 0.001$, respectively, but were superseded by the interaction. No significant differences were observed for education.

3.2. P300 measures

Ensemble averages of the ERPs for each of the four groups are illustrated in Fig. 1. The analysis of P300 latencies revealed a significant main effect for age, $F(1, 69) = 15.8$, $P < 0.001$, and site, $F(8, 552) = 3.6$, $\epsilon = 0.702$, $P < 0.005$. The age effect revealed that the elderly group (42.5 ± 6.3 years) had longer latencies than the young group (38.4 ± 5) by site. There was a trend for longer latencies progressing from rostral to caudal sites. Post hoc examination of the means specifically revealed that latencies at occipital sites were shorter than at temporal sites (see Table 2). However, no differences were detected by an ANOVA performed solely on the midline sites.

The analysis of P300 AUC revealed a significant Activity Group × Age interaction, $F(1, 69) = 4.2$, $P < 0.05$. This interaction was consistent with the hypotheses. No differences were observed between the elderly high-active group, the young high-active group, and the young low-active group. However, the elderly low-active group exhibited greater AUC than all three other groups. This pattern of activity was observed across each of the nine electrode sites. Means and standard errors for this effect are presented in Fig. 3. The analysis of P300 AUC also revealed a significant main effects for site, $F(8, 552) = 3.7$, $\epsilon = 0.445$, $P < 0.01$, age, $F(1, 69) = 30.9$, $P < 0.001$, and activity group $F(1, 69) = 6.0$, $P < 0.02$. The site main effect revealed the AUC at Fr was greater than at temporal and occipital sites. No other differences were observed between sites (see Table 2) and no differences were detected by an ANOVA performed solely on the midline sites. As is illustrated in Fig. 3, the age and activity group main effects were superseded by the interaction.

The analysis of P300 amplitude revealed a significant Activity Group × Age × Site interaction, $F(8, 552) = 4.8$, $\epsilon = 0.579$, $P < 0.001$. This complex interaction is illustrated in Fig. 4. At Fr, the activity group by age interaction was consistent with the predictions as no differences were observed between the elderly high-active and the young groups while the elderly low-active group had a higher amplitude than the young group. At Fz, C3, C4, O1, and O2, fitness had differential effects for age group. In general, at these sites young high-active participants showed higher amplitude than young low-active participants, while this pattern was reversed in elderly participants (i.e. the high-active group had lower amplitudes than the low-active group). Amplitudes at T3 and T4 were not differentiated between groups and showed reduced P300 amplitude relative to the other sites, a finding that is consistent with that of previous studies. Across sites, post hoc analysis revealed greater homogeneity of amplitude within the elderly high-active group relative to the other three groups. This effect appears to arise from the lower amplitudes in the midline and central sites in the elderly high active group.

To simplify this analysis and relate the data to the classical P300 literature, an Activity Group × Age × Site ANOVA was performed on just the midline sites. This analysis also revealed an Activity Group × Age × Site interaction, $F(2, 138) = 3.1$, $P < 0.05$, that was explained by two patterns of activity at different sites (see Fig. 4). First, at Cz and Pz, P300 amplitude increased with fitness level for the young participants but decreased with fitness level for the elderly participants. Second, at Fr, P300 amplitude increased with fitness level for both age groups, however, the increase was larger for the young participants than for the elderly participants. The analysis of P300 amplitude at the midline sites also revealed a significant interactions for Activity Group × Age, $F(1, 69) = 7.2$, $P < 0.01$, Age × Site, $F(1, 19, 138) = 12.9$, $P < 0.001$ and Site × Activity Group, $F(1, 19, 138) = 3.4$, $P < 0.05$, and a main effect for Site, $F(1, 19, 138) = 56.0$, $P < 0.001$. However, as these effects are all superseded by the three-way interaction and a third $2 \times 2 \times 3$ ANOVA was performed on normalized data, post hoc analysis were not reported for these lower order effects.

Table 2

<table>
<thead>
<tr>
<th>Site</th>
<th>Fr</th>
<th>Cz</th>
<th>Pz</th>
<th>O1</th>
<th>O2</th>
<th>C3</th>
<th>C4</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency (ms)</td>
<td>410 (8)</td>
<td>409 (6)</td>
<td>399 (7)</td>
<td>387 (7)</td>
<td>388 (8)</td>
<td>406 (8)</td>
<td>408 (7)</td>
<td>418 (8)</td>
<td>415 (8)</td>
</tr>
<tr>
<td>AUC (μV²·ms⁻¹)</td>
<td>6.9 (0.5)</td>
<td>6.5 (0.5)</td>
<td>6.3 (0.5)</td>
<td>6.0 (0.4)</td>
<td>5.9 (0.5)</td>
<td>6.5 (0.5)</td>
<td>6.4 (0.5)</td>
<td>6.1 (0.5)</td>
<td>6.1 (0.5)</td>
</tr>
</tbody>
</table>

* Site main effect, $P = 0.005$.
* Site main effect, $P < 0.01$. 
Fig. 3. Mean AUC as a function of age (young, elderly) and activity level (high, low). The low active elderly participants had significantly greater AUC than the other three groups.

Fig. 4. Mean amplitude as a function of age (young, elderly), activity level (high, low), and site (Fz, Cz, O1, O2, C3, C4, T3, T4).
Although these amplitude findings are, in part, consistent with those related to fitness in younger persons [29] and aging and midline topography [16], they are inconsistent with those of other studies that include young and/or elderly participants [2,19,26]. In fact, the P300 amplitudes of the older participants are in the opposite direction to those reported by Bashore [2]. As such, it appears that amplitude is not reliably related to physical activity history or its interaction with age.

P300 latency has been demonstrated to robustly reflect aging [28], a result also revealed in the current study. However, similar to amplitude, the effects of physical activity history on latency are mixed [12,19]. Although Dustman et al. [12] reported an interaction between aging and fitness level for averaged midline sites, neither Hillman et al. [19] nor the present study report a physical activity history by aging interaction at midline sites. Although Hillman et al. [19] did report effects of physical activity history at lateral sites, these effects were not replicated in the present study. Interestingly, Dustman et al. [14] conducted a 6-month exercise intervention study with older men and women that resulted in several improvements in sensory and cognitive function but failed to produce any change in terms of EEG and ERP measures. Because of the lack of significant findings they did not report the recording of the electrocortical measures [12]. Although they discussed the possibility that the time period of the intervention may have been too brief in that study to produce such basic neural changes [12] it appears equally plausible that P300 latency may be insensitive for the detection of such change. Thus, in a manner similar to amplitude, P300 latency does not appear to reliably reflect differences in physical activity history or any modulation of physical activity on cognitive function with aging.

One possible reason for different findings between studies may be due to the variable definition of fitness employed in the present study. For example, an explanation for why Dustman et al. [12] found latency effects while Hillman et al. [19] and the present study did not may arise from the categorization of the participant groups. In previous studies, participants were categorized for VO2max [12,14,19] whereas they were classified by the amount of vigorous physical activity in the present study. Although the two indices are correlated, genetic differences play a large role in determining the particulars of that relationship [15]. As such, given individuals potentially may be classified as high in VO2max while being classified as low amount of physical activity or vice versa. The present results are consistent with the interpretation that AUC reflects the effects of physical activity participation on cognitive aging.

The broad implication is that a lifestyle incorporating physical activity may enhance or limit the degradation of cognitive function over time. The AUC results of the present study, which suggest that the high-active elderly group was more similar to the younger controls than the low-active elderly group, support previous patterns of results reported for reaction time [34] and coding performance [40]. Interestingly, the hypothesized interaction of age and fitness was revealed in the present study for AUC but not the P300 amplitude associated with physical activity history that differentiated for each age group and electrode site. However, when these patterns of activity where normalized for the midline sites, greater equipotentiality was observed in the elderly, yet effects of physical activity history were not revealed. Although these amplitude findings are, in part, consistent with the interpretation that AUC reflects the effects of physical activity participation on cognitive aging.

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amplitude or latency measures. Potential insight regarding this phenomenon may be provided by an examination of the shape of the waveforms; wider P300 peaks were observed for the elderly groups than the younger groups (see Fig. 1) as was reflected in AUC measure. Methodologically, the AUC captures the general morphological structure of the time series enabling the opportunity to detect differences between the responses of different individuals that may have gone undetected in amplitude and latency analyses. On a functional level AUC may proportionally reflect the extent of neural processing. For example, P300 amplitude generated in response to a stimulus embedded in a tracking task has been demonstrated to increase with increased task difficulty [43]. These and related findings suggest that within the primary task the amplitude of the P300 may increase as more neural processing is required. The AUC measure reflects the amplitude over time and thus may index the amount of neural processing over a span of time. Extending this interpretation to the AUC results, the low-fit elderly performed more processing to complete the same task than the other three groups of participants. This interpretation fits within the conceptual framework of efficiency [18], a primary characterization of the physiological adaptations that accrue from physical activity involvement [27,36,44]. For example, Montani and deVries [27] described the relative efficiency of motor unit recruitment in trained skeletal muscle such that the integrated EMG activity recorded from stronger muscle is reduced relative to that observed in the untrained state during similar work, termed the efficiency of electroactivity of muscle (EEA). Further, increased efficiency, expressed as the ratio between work and effort, has been proposed to be a primary characteristic of the nervous system after training and is also expressed in the biomechanical quality of movement [36]. Hatfield and Hillman [18] extended this well-established concept to the central nervous system and the psychological domain. That is, these authors proposed that a given amount of work accomplished with fewer neural resources is indicative of greater psychological efficiency. In the present results, the lesser AUC while producing equal cognitive work of the high-active elderly muscle may modulate the decline of neuro-cognitive function in older men and women in a manner that is characterized as more efficient. Our results suggest that the P300 AUC measure may be a clearer index of this modulation than traditional P300 amplitude and latency measures, which have yielded mixed results in the previous and present studies. The clarity may derive from the fact that the AUC indexes the general shape of the P300 waveform, a component that may reflect the amount of cognitive processing over time and the relationship between frequent physical exercise and aging. While the present study shows the promise of the AUC to reveal the influence of physical activity, the use of this measure in conjunction with tasks that are highly sensitive to the aging process (i.e., tests of executive function; [24]) may realize its potential.

In conclusion, lifestyles incorporating increased physical activity may modulate the decline of neuro-cognitive function in older men and women in a manner that is characterized as more efficient. Our results suggest that the P300 AUC measure may be a clearer index of this modulation than traditional P300 amplitude and latency measures, which have yielded mixed results in the previous and present studies. The clarity may derive from the fact that the AUC indexes the general shape of the P300 waveform, a component that may reflect the amount of cognitive processing over time and the relationship between frequent physical exercise and aging. While the present study shows the promise of the AUC to reveal the influence of physical activity, the use of this measure in conjunction with tasks that are highly sensitive to the aging process (i.e., tests of executive function; [24]) may realize its potential.

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References


