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ORIGINAL ARTICLE

A Large-Scale Reanalysis of Childhood Fitness and Inhibitory Control

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Abstract

The aim of this study was to reanalyze several datasets to investigate the relation of childhood aerobic fitness on cognition via a number of task performance outcomes and the P3 event-related brain potential component during a modified flanker task, which modulates inhibitory control demands. In a sample of 702 preadolescent children (ages 8–11; 342 females), demographic measures of age, sex, IQ, socioeconomic status, and pubertal status were considered along with aerobic fitness (i.e., VO_2peak%). Correlational analyses were conducted to determine the influence of the demographic variables and aerobic fitness on inhibitory control outcomes of response accuracy, reaction time (RT), response variability, interference control, cognitive strategies, P3 amplitude, and P3 latency. Subsequent hierarchical regression analyses were performed with significant demographic factors in the first step and aerobic fitness in the final step. Results indicated that after accounting for significant demographic variables specific to each dependent outcome, aerobic fitness was positively related to response accuracy, with no such relations observed for response speed (RT) for congruent and incongruent conditions of the flanker task. However, greater aerobic fitness was associated with less RT variability and lower accuracy interference. In terms of cognitive strategies, greater fitness was also associated with better discrimination accuracy as well as faster and better quality of information uptake. Across a 15-site region of interest around the topographic maximum, findings indicated that aerobic fitness was positively associated with larger P3 amplitude during incongruent trials. No such relation was observed for P3 latency. Relying on a large aggregated dataset, we demonstrated that aerobic fitness may be particularly beneficial to the allocation of attentional resources, as indexed by P3 amplitude as well as response accuracy and intraindividual variability. These findings, while generalized across inhibitory control demands, were especially related to trials that required greater amounts of inhibition. Thus, aerobic fitness may benefit brain and behavioral outcomes during childhood and has public health implications for the role of childhood physical activity on aspects of cognition that underlie scholastic performance and lifelong effective functioning.

Keywords Aerobic fitness · Inhibition · Event related potentials

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Introduction

Children's fitness has rapidly declined over the last 20 years, at an estimated rate of almost 2%/year in the USA (Tomkinson et al. 2003). In children, higher aerobic fitness is inversely related to cardiovascular risk factors, metabolic risk factors, and measures of low-grade inflammatory markers (Ortega et al. 2008; Lang et al. 2017). Of particular relevance, higher fitness during childhood is also associated with advantageous structural and functional brain development (Khan and Hillman 2014), with additional benefits observed for cognitive function, with greater benefits observed for aspects of cognitive control. Cognitive control refers to goal-directed behavior involved in perception, memory, and action (Cohen et al. 1992; Chajczyk and Kahneman 1981). This particular aspect of cognition follows a protracted developmental course relative to other cognitive functions (Lamm et al. 2006; Zelazo and Müller 2002) and appears especially responsive to aerobic fitness. Cognitive control is mediated by a neural network comprised of the prefrontal cortex, the anterior cingulate cortex (ACC), and the basal ganglia (Miller and Cohen 2001; Koechlin et al. 2003; Durston et al. 2002; Casey et al. 1997; Bunge and Crone 2009; Ridderinkhof et al. 2004; Rueda et al. 2005). Core cognitive control processes involved include working memory, cognitive flexibility, and inhibition (Diamond 2006; Meyer and Kieras 1997; Norman and Shallice 1986). Inhibition, the focus of this study, refers to the ability to suppress task irrelevant information in the environment, and withhold a prepotent or impulsive response (Miyake et al. 2000). Improvements in inhibition continue through childhood and are evidenced by both inhibiting undesirable responses as well as executing correct responses (Luna 2009; McAuley and White 2011).

Inhibition can be measured in the laboratory using a variety of tasks. In particular, modifications of the Eriksen flanker task (Eriksen and Eriksen 1974) have commonly been employed for this purpose, as perceptual interference can be modulated to regulate inhibitory control. Flanker tasks require attentional inhibition, or the ability to attend to certain features of the stimulus environment while ignoring others (Posner and DiGirolamo 1998; Theeuwes 2010). Specifically, individuals are required to distinguish a centrally presented, target stimulus from interference-producing, lateral flanking stimuli. Interference can be created by manipulating the congruency of the target and flanking stimuli, such that in the congruent condition, the target and flanking stimuli engender the same response mapping, whereas in the incongruent condition, the target and flanking stimuli elicit alternative behavioral responses. Since target and flanking stimuli activate opposing action schemas, responses to incongruent trials are slower and less accurate than congruent trials (Eriksen and Schultz 1979). Furthermore, incongruent trials require greater amounts of inhibitory control since target and flanking stimuli activate multiple action schemas (Spencer and Coles 1999). Previous research from our laboratory has indicated that higher fit children outperform their lower fit peers on this task, with the largest differences in performance observed in the most difficult task conditions (Pontifex et al. 2011; Voss et al. 2011).

Response Variability Outcomes

In addition to the more typical outcomes describing mean tendency (i.e., average RT and response accuracy), multiple measures of individual variability have been reported in the literature (Moore et al. 2014; Wu et al. 2011a; MacDonald et al. 2006; Williams et al. 2005). Intraindividual variability, or within-person fluctuations in behavioral performance, is a useful tool for differentiating performance during tasks requiring variable amounts of interference control. Measures of variability provide a complementary index of both cognitive maturation (Williams et al. 2005) and neurological health (MacDonald et al. 2006). Greater variability in mean RT has been observed in children relative to young adults (Williams et al. 2005; McAuley et al. 2006a) and in children with attention-deficit and hyperactivity disorder (Kofler et al. 2013). Further evidence suggests that in typically developing children, aerobic fitness may benefit behavioral stability in the absence of differences in mean RT (Wu et al. 2011a; Moore et al. 2013), especially on more cognitively demanding tasks (Moore et al. 2013). In these studies, lower fit children showed more variable performance relative to their higher fit peers, as indicated by greater standard deviation (SD) of RT despite a lack of group differences in mean RT (Wu et al. 2011a; Moore et al. 2013).

To more accurately characterize the RT distribution during task performance, a growing number of reports have utilized the ex-Gaussian function (McAuley et al. 2006a; Moore et al. 2013; West et al. 2002), which more accurately describes the positively skewed distribution of performance latencies during cognitive tasks (Whelan 2008). The ex-Gaussian distribution represents the convolution of an exponential and Gaussian (normal) distribution. Parametrically, it can be characterized by three variables: mu (μ) and sigma (σ), which respectively describe the mean and SD of the normal component, and tau (τ), which represents the mean and SD of the exponentially distributed tail of a positively skewed distribution (Ratcliff 1979). However, mu and sigma of the ex-Gaussian distribution are not synonymous with the mean and SD of the Gaussian distribution. Specifically, the ex-Gaussian parameter μ = mean + tau, and σ = SD + tau. As scores become more normally distributed (i.e., as tau diminishes), μ and σ converge with the mean and SD, until tau reaches zero and the scores are normally distributed (Ratcliff 1979).

Differences in RT variability may therefore result from two distinct processes: the variability of the dominant, Gaussian

component of the RT distribution (σ) or the exponential component of the distribution (τ). Developmental changes in RT variability could be better described by decreasing variability of the dominant RT component (σ; McAuley et al. 2006a), while increased positive skew better characterizes increased performance variability in older adults (McAuley et al. 2006a; West et al. 2002). In confirmation, Moore et al. (2013) showed that fitness-related differences in variability of RT in typically developing children resulted from increased sigma, but not tau.

Cognitive Strategy Outcomes

The performance differences between children of different fitness levels may reflect the use of different cognitive control strategies (Kao et al. 2017). One means of examining these differences is through a conditional accuracy function (CAF), which calculates the average accuracy for multiple RT ranges (i.e., bins). CAF measures the rate of increase in discrimination accuracy as a function of RT. This measurement allows for a better understanding of the rate at which perceptual information is gained, as discrimination processing time is increased (Lappin and Disch 1972). CAF is also a useful tool for measuring the temporal dynamic of selective suppression (Ridderinkhof 2002; Wylie et al. 2010) and attentional transition (Heitz and Engle 2007); thus, CAF has been used to investigate cognitive processing during interference tasks such as the flanker task (Heitz and Engle 2007; Coles et al. 1985; Gratton et al. 1988, 1992; Wylie et al. 2009). CAF analyses of flanker tasks generally reveal lower accuracy for bins of faster responses, and particularly for the more challenging incongruent trials, which engender greater interference.

Response Strategy

An additional approach to understanding fitness-related differences in cognitive strategy involves a signal detection theory method known as diffusion modeling (Ratcliff 1979). This computational model goes beyond typical independent mean tendency analyses (accuracy and mean RT) and instead integrates these behavioral measures to investigate contributing latent variables that are thought to represent underlying cognitive processes. This model combines accuracy and RT information on a per trial basis into various underlying cognitive processes: drift rate, boundary separation, and nondecision time. Specifically, drift rate refers to the speed and quality of stimulus information uptake (i.e., a higher drift rate would indicate better performance), boundary separation indicates response conservativeness or speed-accuracy trade-off and therefore represents response strategy (a larger boundary separation indicates greater response conservativeness), and nondecision time reflects the time spent in all nondecision processing (i.e., time spent during encoding, memory access, and response execution) (Ratcliff 1978; Wagenmakers et al. 2007). Previous research has demonstrated that children have reduced uptake of quality information (Ratcliff et al. 2012) compared to young adults. In contrast, older adults exhibit more response conservativeness (Ratcliff et al. 2004) compared to young adults. However, to our knowledge, no studies have examined the role of aerobic fitness on these underlying cognitive processes in children.

Event-Related Potentials

Beyond behavioral outcomes of cognitive control, brain activity underlying cognitive processes can be measured using event-related brain potentials (ERPs). ERPs refer to neuroelectric activity resulting from, or preparing for, a stimulus or response, and they offer excellent temporal resolution relative to other neuroimaging tools (e.g., fMRI). This affords for the ability to parse the stimulus-response relationship into its constituent elements to better understand the specific aspects of the cognitive processing stream that may differ due to an exposure. ERPs are a valuable tool for understanding the neural underpinnings of cognition, and although many ERP components exist, this study will focus on the P3, which is a positive-going component occurring approximately 300–800 ms after stimulus onset (Herrmann and Knight 2001).

The P3 is an index of cognitive processes including inhibition and working memory and is typically maximal over the parietal region of the scalp (Polich 2007). P3 amplitude is related to the allocation of attentional resources (Polich 1987; Polich and Heine 1996), and its latency reflects the speed in which classification and evaluation of a stimulus occurs (Duncan-Johnson 1981; Verleger 1997). Greater amplitude is thought to reflect an increase in the allocation of attentional resources (Wickens et al. 1983; Polich 2007), and shorter latency is believed to reflect faster cognitive processing speed and thus superior cognitive performance (Polich and Herbst 2000). The P3 has been shown to be mediated by neocortical generators in the prefrontal cortex, temporoparietal junction, and primary auditory cortex, among others (Friedman 2003). Prior research has found a beneficial relationship between aerobic fitness and neurocognitive function in both cross-sectional studies of children bifurcated according to fitness (Pontifex et al. 2011) and randomized controlled trials that exposed participants to a 9-month physical activity intervention (Hillman et al. 2014). In these two studies, higher fit children or those that were exposed to the fitness intervention demonstrated a larger P3 amplitude and shorter P3 latency compared to their lower fit peers or those that did not participate in the physical activity intervention. These findings suggest that greater amounts of fitness benefit the allocation of attentional resources and cognitive processing

speed during tasks requiring variable amounts of inhibitory control.

Current Study

As such, more research is needed to better understand the relationship between aerobic fitness and neurocognitive development during childhood. While some research indicates a more generalized relationship between aerobic fitness and performance on tasks of inhibitory control (Moore et al. 2014), other research suggests a more specific relationship between fitness and particular aspects of inhibition (Pontifex et al. 2011; Voss et al. 2011). Thus, the present study sought to provide a more in-depth characterization of the relationship between aerobic fitness and inhibitory control using a variety of task performance outcomes as well as the P3-ERP component during modified versions of a flanker task in a large dataset of children, who represented the entire range of aerobic fitness. The present study further sought to better understand the nuances of these fitness-related differences on response variability, cognitive control strategies, and response strategies employed by children by examining more detailed measures of accuracy (types of errors, CAF) RT (variability, IIV), and diffusion modeling. The inclusion of these measures affords the opportunity to better understand the general and selective effects of aerobic fitness on inhibitory control. We predicted that aerobic fitness would be related to traditional measures of central tendency as well as to measures of performance consistency and cognitive strategy. Furthermore, we predicted that the observed fitness-related differences would be disproportionately larger for task conditions requiring greater amounts of inhibitory control (i.e., incongruent trials), rather than a more generalized relationship across conditions (i.e., congruent and incongruent trials) of the inhibition task.

Methods

Participants

The current study considered data from all studies conducted on preadolescent children in the Neurocognitive Kinesiology Laboratory at the University of Illinois Urbana-Champaign during the years 2004 through 2017. Studies were only included if they had behavioral and electroencephalographic (EEG) data from a flanker task, and aerobic fitness (i.e., VO_2peak) measures, which yielded $N = 782$ participants across 7 studies. Across these 7 studies, exclusionary criteria included a medical diagnosis of attention-deficit disorder, currently taking medications for neurological disorders, or specialized education due to educational or attentional disorders. In the case of intervention or repeated measures studies, only the baseline (i.e., pretest) data were incorporated into the current analysis. After examination of the dataset, 6 children were missing VO_2max data, 6 children did not complete the flanker task, 20 children were not affixed to an EEG during the flanker task, 5 children were removed as they fell outside the age range (≥ 7 and < 12 years old), 8 children were removed as they had pubertal status scores indicating that they were beyond the prepubertal stage (≥ 3 Tanner score), and 36 children were removed because they had low flanker task performance (congruent accuracy $< 55\%$), suggesting they did not adequately understand the task. Accordingly, the final sample size was $N = 702$ children.

Demographic information for the sample can be found in Table 1. Demographic variables included age, sex, pubertal status, and socioeconomic status (SES). Pubertal status was assessed to ensure prepubescence of participants (Tanner score ≤ 3; Taylor et al. 2001). For SES, a trichotomous index was calculated, which included parents' highest level of education, number of parents working full time, and whether participants were enrolled in free or reduced price mean program at school (Birnbaum et al. 2002). Three different IQ tests were administered across the 7 studies: the Kaufman Brief Intelligence Test (Kaufman and Kaufman 1990), the Kaufman Brief Intelligence Test Second Edition (Kaufman and Kaufman 2004), and Woodcock–Johnson III of Brief Intellectual Ability (Woodcock et al. 2001). While each test was standardized on the same scale (mean = 100 ± 15), a centered Z-score was calculated and used as the standard measure of IQ across studies so that comparisons could be made across different IQ tests. Missing demographic variables for particular participants were imputed via mean replacement: SES ($n = 2$) and pubertal timing ($n = 5$). Analyses conducted with and without these participants were equivalent.

Cardiorespiratory Fitness Measurement

VO_2peak was assessed as the criterion measure of cardiorespiratory fitness (Winsley et al. 2006), such that participants' oxygen consumption and delivery rate were measured using an indirect calorimetry system (ParvoMedics True Max 2400). Participants walked/ran at a constant speed with incremental grade inclines of 2.5% every 2 min until volitional fatigue. Participants wore a heart rate (HR) monitor during the test to determine maximal heart rate. Ratings of perceived exertion (RPE) were assessed every 2 min using the children's OMNI Scale (Utter et al. 2002). Relative peak oxygen consumption was expressed in milliliter per kilogram per minute and was based upon maximal effort as evidenced by (1) a plateau in oxygen uptake corresponding to an increase of less than 2 ml/kg/min despite an increase in exercise workload, (2) a peak HR ≥ 185 beats-per-minute (American College of Sports Medicine 2014), (3) respiratory exchange ratio (RER ≥ 1.0 (Bar-Or 1983), and/or (4) RPE ≥ 8 (Utter et al. 2002).

Table 1 Participant demographics

	N (#female)	Age	Pubertal timing	SES	*Z*-scored IQ	Average VO_2peak%
Overall	702 (342)	9.2 ± 0.8	1.40 ± 0.44	2.08 ± 0.82	0.01 ± 0.98	33.10 ± 30.36
Study 1	7 (2)	9.6 ± 0.5	1.36 ± 0.38	2.00 ± 0.00	0.41 ± 0.65	9.29 ± 7.50
Study 2	55 (27)	10.0 ± 0.6	1.43 ± 0.46	2.68 ± 0.64	0.07 ± 0.94	43.85 ± 37.75
Study 3	204 (97)	8.8 ± 0.6	1.69 ± 0.47	1.93 ± 0.87	− 0.13 ± 1.05	19.45 ± 21.25
Study 4	88 (36)	9.9 ± 0.6	1.41 ± 0.45	2.16 ± 0.74	0.04 ± 0.91	44.58 ± 31.87
Study 5	90 (39)	10.1 ± 0.6	1.32 ± 0.39	2.54 ± 0.64	0.05 ± 0.94	36.84 ± 31.61
Study 6	240 (131)	8.7 ± 0.5	1.34 ± 0.42	1.87 ± 0.77	0.07 ± 0.97	36.90 ± 30.33
Study 7	18 (10)	9.6 ± 0.4	1.36 ± 0.48	2.06 ± 0.64	0.26 ± 1.14	38.83 ± 29.34

VO_2peak percentile (VO_2peak%) was then determined based on the individual's age, sex, and relative score from normative data (Shvartz and Reibold 1990).

Modified Flanker Task

Participants completed a modified version of the Eriksen flanker task (Eriksen and Eriksen 1974) to assess inhibitory control. Congruent and incongruent trials require participants to respond based on the direction of the centrally presented target stimuli (i.e., fish or arrows). Congruent trials consisted of an array of five stimuli facing the same direction (e.g., >>>>>, <<<<<), while incongruent trials consisted of the four flanking stimuli facing the opposite direction of the target (middle) stimuli (e.g., >><>>, <<><<). After receiving task instructions, participants were afforded the opportunity to ask questions and practice the task prior to the start of testing. During practice trials, the experimenter observed the participant to ensure they understood the task and responded correctly. Stimuli were presented focally on a blue (for fish) or black (for arrows) background of a computer screen that was placed 1 m away using Neuroscan Stim software (Compumedics, Charlotte, NC) (see Fig. 1 for the fish and arrow stimuli). Participants were instructed to respond using a response pad as quickly and accurately as possible with a thumb press on the side corresponding to the directionality of the central target stimuli amid either congruent or incongruent flanking stimuli. Congruency and directionality of the target stimuli were equiprobable. Task parameters (stimuli type, target duration, interstimulus interval, etc.) varied across studies and can be found in Table 2. Total task time duration was ~ 7 min.

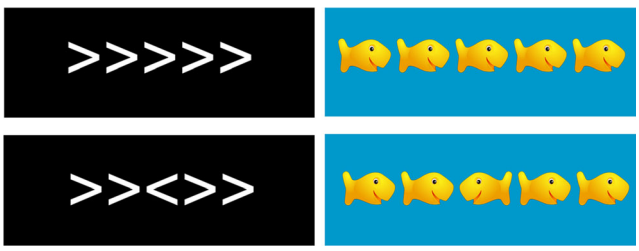

Fig. 1 Fish and arrow stimuli

There were numerous variables of interest for the flanker task, which were calculated for both congruent and incongruent trials when relevant. Accuracy was calculated as the percentage of correct responses. Mean RT was calculated for correct responses as the time in milliseconds (ms) from stimulus onset until response execution. Accuracy interference was calculated as congruent accuracy minus incongruent accuracy, with lower scores reflecting less interference and thus better performance. Mean RT interference was calculated as incongruent mean RT minus congruent mean RT, with smaller interference scores reflecting less interference and thus better performance. Types of errors (commission and omission) were divided by total number of trials. Error runs indicate the number of times that 2 or more sequential errors were made. Standard deviation of reaction time (SDRT) was calculated based on the reaction time dispersion from the mean. Coefficient of variation in reaction time (CVRT) was calculated as SDRT divided by the individual's mean RT. This measure allows for comparison of intraindividual variability across different groups of individuals.

Ex-Gaussian Analyses

Variables of interest included mu (μ) and sigma (σ), which respectively describe the mean and standard deviation of the normal component, and tau (τ), which represents the mean and SD of the exponentially distributed tail of a positively skewed distribution. As the RTs in our sample were positively skewed for both congruent (skewness 0.54 ± 0.09) and incongruent (skewness 0.51 ± 0.09) trials, ex-Gaussian parameters (μ, σ, τ) were fit to each individual's RTs using MATLAB software developed by Lacouture and Cousineau (2008). The procedure utilized a maximum likelihood algorithm to fit normal and exponential components to the RT distributions.

Table 2 Study parameters

	Stimulus type	Total trials	Stimulus presentation duration	ITI duration
Study 1	Arrow	200	125	1100, 1300, 1500
Study 2	Fish	200	200	1700
Study 3	Arrow	200	200	1700
Study 4	Fish	312	200	1500, 1600, 1700
Study 5	Fish	168	250	1600, 1800, 2000
Study 6	Fish	216	200	1550, 1750, 1950
Study 7	Arrows	216	175	1500, 1700, 1900

Conditional Accuracy Function

CAF was obtained by creating five bins for each participant, whereby the average accuracy and latency of response trials within specific percentile ranges of individual RT distribution were computed—bin 1: 20th percentile and below, bin 2: 20th percentile–40th percentile, bin 3: 40th percentile–60th percentile, bin 4: 60th percentile–80th percentile, and bin 5: 80th percentile and above.

Diffusion Modeling

Accuracy, correct response RT, and correct response RT variance were utilized in the calculation of the EZ-diffusion model (see Wagenmakers et al. 2007 for methods). This model allows for the calculation of drift rate, boundary separation, and nondecision time.

Neuroelectric Assessment

EEG activity was measured from 64 electrode sites arranged using the international 10–10 system with a Neuroscan Quik-cap (Compumedics, Charlotte, NC). During collection, data were referenced to a midline electrode placed at the midpoint between Cz and CPz, with AFz serving as the ground electrode. Interelectrode impedance remained at < 10 kΩ during data collection. Additional electrodes were placed above and below the left orbit and the outer left and right canthi to monitor electrooculogram activity with bipolar recording. Continuous data were digitized at a sampling rate of 500 Hz, amplified 500 times with a direct current to 70 Hz filter, and a 60-Hz notch filter using a Neuroscan Synamps2 Amplifier (Neuro, Inc. Charlotte, NC, USA). Offline EEG processing was conducted in MATLAB EEGLab (Delorme and Makeig 2004) and ERPLab (Lopez-Calderon and Luck 2010; Lopez-Calderon and Luck 2014) and included eye blink correction using an independent component analysis (ICA). ICA components that met or exceeded a 0.35 correlation with measured vertical EOG channel were considered to be correlated with eye blinks and thus removed from the data. The data were then re-referenced to average mastoids. Stimulus-locked epochs from −200 to 1200 ms relative to stimulus onset were created and baseline corrected using −200 to 0 ms prestimulus interval. The data were filtered using a zero-phase shift low pass filter at 30 Hz. Artifact detection involved a moving window peak-to-peak threshold of artifact rejection. This function computed the peak-to-peak amplitude within a series of windows for each epoch; it then found the largest peak-to-peak amplitude from these windows for a given epoch of data, compared this to the threshold values, and marked the trial for rejection if the largest value exceeded the ± 100 μV threshold. Averaged ERP waveforms were created for the correct trials. Waveforms were averaged across congruency. The stimulus-locked ERP component, P3, was defined as the largest positive peak within 300 and 600 ms latency window relative to response onset. Peak-interval amplitude and peak latency were the variables of interest for each component. Peak-interval amplitude is computed by taking the average voltage over a specified measurement window (50 ms interval surrounding the peak). Peak amplitude was defined as the time point corresponding to the maximum peak amplitude (CPz; 15.30 ± 0.33 μV). ERP data were averaged over an (ROI) around the topographic maxima of the P3 component (see Fig. 2). For the P3, the ROI consisted of an average of Cz, C1, C2, C3, C4, CPz, CP1, CP2, CP3, CP4, Pz, P1, P2, P3, and P4 electrodes. From this ROI, the average amplitude and latency were calculated.

Statistical Analysis

Initial Pearson product–moment correlations were conducted between dependent variables from the flanker task (behavioral and ERP), all demographic variables (e.g., age, sex, pubertal status, SES, IQ), and aerobic fitness (VO_2peak%). To account for variability across the studies, each of the studies was recoded into dummy variables, where a study of interest was coded as 1 and all other studies except for FITKids2 (which served as a reference) as 0. This process was repeated for each study (except for FITKids2). FITKids2 was chosen as

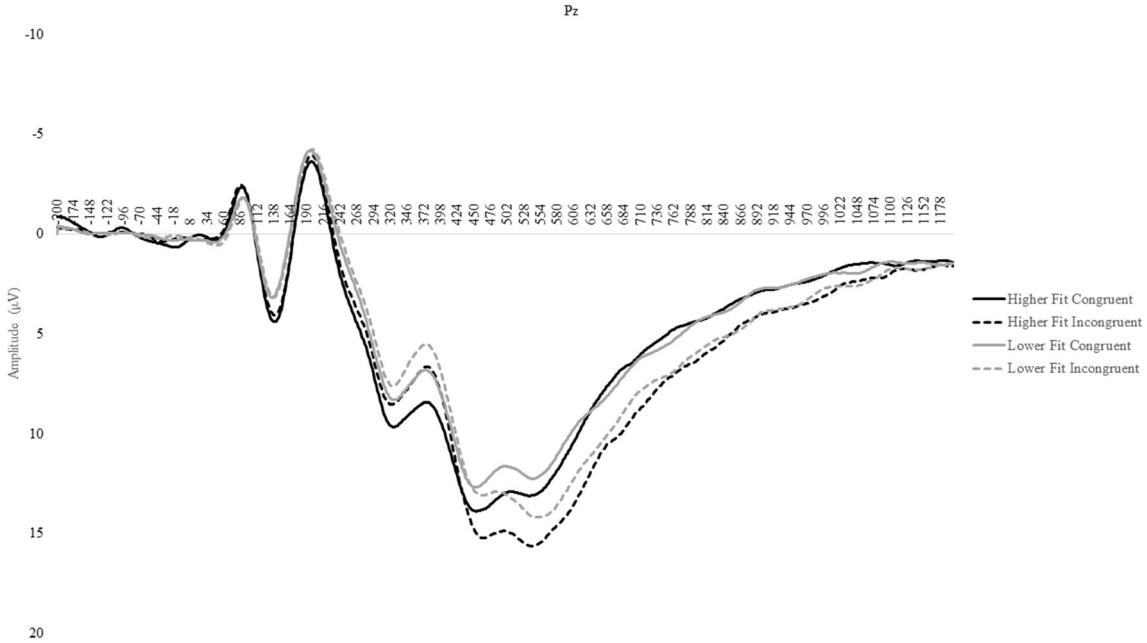

Fig. 2 Grand-averaged congruent and incongruent waveforms of the stimulus-locked ERP at Pz, the topographic maximum for the sample. For graphical representation, a median split was performed based on aerobic fitness

a reference category because it had the largest sample and the youngest age participants within the sample. Consequently, the reported values are in reference to this study (i.e., how much a study denoted by a dummy variable differed from FITKids2 on a variable of interest).

Next, separate multiple hierarchical linear regression analyses were conducted for each dependent measure. Any demographic factors found that significantly correlated during the initial Pearson correlations with the dependent measure were included in step 1. To account for differences between studies, study-related dummy variables were entered into step 2. To determine the unique contribution of fitness, VO_2peak% was entered into step 3. In order to assess the relative selectivity of the VO_2peak% relationship with incongruent trials (which required greater inhibitory control), secondary analyses were conducted when incongruent performance was significant, with the inclusion of congruent performance entered in step 3.

Results

Correlations between flanker variables, demographics, and aerobic fitness are presented in Table 2. In general, age, SES, IQ, and VO_2peak% were most frequently correlated with flanker performance variables, such that older children, children of higher SES, and children with higher aerobic fitness exhibited superior flanker performance (see Table 3 and Fig. 3). For a description of specific steps in each hierarchical regression, see the Supplemental Information.

P3-ERP

Higher VO_2peak% was associated with greater incongruent P3 amplitude ($\beta = 0.08$, $t(692) = 2.2$, $p = 0.03$, $f^2 = 0.01$), after controlling for the variance associated with descriptive variables, and differences between studies. This relationship remained significant in secondary regression analyses controlling for congruent P3 amplitude ($\beta = 0.01$, $t(691) = 2.61$, $p = 0.01$, $f^2 = 0.003$). However, no relationships were observed between VO_2peak% and either congruent P3 amplitude, congruent P3 latency, or incongruent P3 latency ($|\beta$'s$| \leq 0.06$, $t(690) \leq 1.65$, $p \geq 0.1$, $f^2 \leq 0.003$), after controlling for the variance associated with descriptive variables and differences between studies (see Fig. 4, Tables 4 and 5).

Central Tendency

Reaction Time and Response Accuracy

For both congruent and incongruent trials, higher VO_2peak% was associated with greater response accuracy (β's ≥ 0.08, $t(691) \geq 2.3$, $p \leq 0.02$, $f^2 = 0.01$), after controlling for the variance associated with descriptive variables and differences between studies. The relationship between incongruent accuracy and higher VO_2peak% was significant in secondary regression analyses controlling for congruent accuracy ($\beta = 0.02$,

Table 3 Correlation table between aerobic fitness and flanker performance

	Age	Sex	Pubertal timing	SES	IQ	VO_2%
ERPs						
Congruent						
P3 amplitude from 15 site ROI	0.16**	−0.06	−0.06	0.10**	0.04	0.14**
P3 latency from 15 site ROI	−0.33**	−0.04	−0.02	−0.12**	−0.10**	−0.11**
Incongruent						
P3 amplitude from 15 site ROI	0.15**	−0.03	−0.02	0.12**	0.06	0.17**
P3 latency from 15 site ROI	−0.37**	−0.01	−0.04	−0.09*	−0.05	0.00
Measures of central tendency						
Congruent						
Mean RT	−0.20**	−0.05	0.03	−0.07	−0.11**	0.02
Accuracy	0.40**	0.00	0.00	0.17**	0.12**	0.16**
Incongruent						
Mean RT	−0.16**	−0.07	0.01	−0.07	−.02*	0.05
Accuracy	0.35**	−0.03	−0.02	0.14**	0.12**	0.17**
Mean RT interference	0.07	−0.05	−0.03	0.00	0.04	0.09*
Accuracy interference	−0.02	0.05	0.03	0.00	−0.04	−0.06
Total commission errors	−0.30**	0.02	−0.03	−0.13**	−0.07	−0.13**
Commission error runs	−0.28**	0.05	−0.04	−0.11**	−0.06	−0.08*
Total omission errors	−0.31**	−0.01	−0.03	−0.17**	−0.09*	−0.12**
Omission error runs	−0.22**	0.00	−0.01	−0.11**	−0.08*	−0.11**
Measures of variability						
Congruent						
SDRT	−0.33**	−0.08*	0.04	−0.15**	−0.17**	−0.11**
CVRT	−0.31**	−0.06	0.04	−0.14**	−0.14**	−0.16**
Mu	−0.09*	−0.01	−0.01	−0.01	−0.03	0.11**
Sigma	−0.27**	−0.03	−0.06	−0.08*	−0.07	0.01
Tau	−0.21**	−0.08*	0.06	−0.10**	−0.14**	−0.14**
Incongruent						
SDRT	−0.35**	−0.11**	0.01	−0.16**	−0.20**	−0.12**
CVRT	−0.33**	−0.07*	0.00	−0.15**	−0.18**	−0.18**
Mu	−0.06	0.00	0.01	0.01	0.00	0.11**
Sigma	−0.26**	−0.08*	−0.01	−0.06	−.08*	−0.05
Tau	−0.17**	−0.11**	0.00	−0.12**	−0.15**	−0.11**
Cognitive strategy outcomes						
Congruent						
RT						
Bin 1	0.06	−0.01	0.04	0.02	−0.01	0.12**
Bin 2	−0.06	−0.04	0.02	−0.02	−0.04	0.09*
Bin 3	−0.14**	−0.05	0.02	−0.05	−0.07	0.06
Bin 4	−0.20**	−0.06	0.03	−0.07	−0.11**	0.01
Bin 5	−0.23**	−0.06	0.02	−0.11**	−0.13**	−0.03
Accuracy						
Bin 1	0.34**	−0.00	0.04	0.08*	0.09*	0.15**
Bin 2	0.29**	−0.00	0.02	0.12**	0.08*	0.12**
Bin 3	0.28**	−0.04	0.02	0.08*	0.04	0.12**
Bin 4	0.20**	0.04	−0.01	0.13**	0.09*	0.05
Bin 5	0.06	0.01	0.06	0.08*	0.04	−0.00
Incongruent						
RT						

Table 3 (continued)

	Age	Sex	Pubertal timing	SES	IQ	VO_2%
Bin 1	0.11**	0.00	0.03	0.03	0.03	0.14**
Bin 2	0.00	−0.04	0.01	−0.02	−0.01	0.12**
Bin 3	−0.09*	−0.06	0.01	−0.04	−0.05	0.08*
Bin 4	−0.17**	−0.08*	0.02	−0.06	−0.10**	0.03
Bin 5	−0.21**	−0.09*	0.01	−0.11**	−0.14**	−0.01
Accuracy						
Bin 1	0.19**	−0.04	0.02	0.02	0.04	0.03
Bin 2	0.28**	−0.06	0.03	0.08*	0.09*	0.17**
Bin 3	0.20**	−0.04	0.00	0.08*	0.06	0.11**
Bin 4	0.16**	−0.01	−0.04	0.04	0.09*	0.13**
Bin 5	0.07	−0.04	−0.03	0.06	0.09*	0.03
Measures of strategy						
Congruent						
Drift rate	0.45**	0.04	−0.01	0.20**	0.15**	0.19**
Boundary separation	0.03	−0.05	0.06	0.01	−0.04	0.06
Nondecision time	−0.06	−0.00	0.00	0.00	−0.02	0.09*
Incongruent						
Drift rate	0.41**	0.02	−0.01	0.18**	0.16**	0.19**
Boundary separation	−0.15**	−0.11**	−0.01	−0.08*	−0.12**	−0.02
Nondecision time	0.04	0.01	0.01	0.03	0.05	0.14**

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

$t(690) = 2.2$, $p = 0.03$, $f^2 = 0.002$). However, no association was observed between VO_2peak% and mean RT for either congruent or incongruent trials (β's ≤ 0.02, $t(692) \leq 0.4$, $p \geq 0.68$, $f^2 \leq 0.00$), after controlling for the variance associated with descriptive variables and differences between studies (see Tables 4 and 5).

Interference Scores

Higher VO_2peak% was associated with lower accuracy interference ($\beta = -0.08$, $t(694) = 2.2$, $p = 0.03$, $f^2 = 0.01$), after controlling for the variance associated with differences between studies. No association was observed between VO_2peak% and mean RT interference ($\beta = 0.02$, $t(694) = 0.5$, $p = 0.61$, $f^2 < 0.001$), after controlling for the variance associated with differences between studies (see Table 4).

Errors and Error Runs

Higher VO_2peak% was associated with fewer commission errors and commission error runs (β's ≤ -0.09, $t(692) \geq 2.4$, $p \leq 0.019$, $f^2 = 0.01$), after controlling for the variance associated with descriptive variables and differences between studies. No associations were observed between VO_2peak% and either omission errors or omission error runs (β's ≥ -0.05, $t(691) \leq 1.2$, $p \geq 0.219$, $f^2 < 0.01$), after controlling for the variance associated with descriptive variables and differences between studies (see Table 4).

Response Variability

Standard Deviation and Coefficient of Variation of Reaction Time

Across both congruent and incongruent trials, higher VO_2peak% was associated with decreased variability of reaction time as indexed by associations with SDRT and CVRT (β's ≤ -0.1, $t(690) \geq 2.9$, $p \leq 0.004$, $f^2 \geq 0.01$), after controlling for the variance associated with descriptive variables and differences between studies (see Table 4). The relationship between incongruent SDRT and CVRT and higher VO_2peak% was not significant in secondary regression analyses controlling for congruent SDRT and CVRT (β's ≤ 0.04, $t(689) \leq -0.93$, $p \geq 0.35$, $f^2 \leq 0.00$) (see Table 5).

Mu, Sigma, and Tau of Reaction Time

A selective association was observed for congruent mu, such that higher VO_2peak% was associated with longer mean reaction time only for congruent trials ($\beta = 0.09$, $t(688) = 2.24$, $p = 0.025$, $f^2 = 0.01$), after controlling for

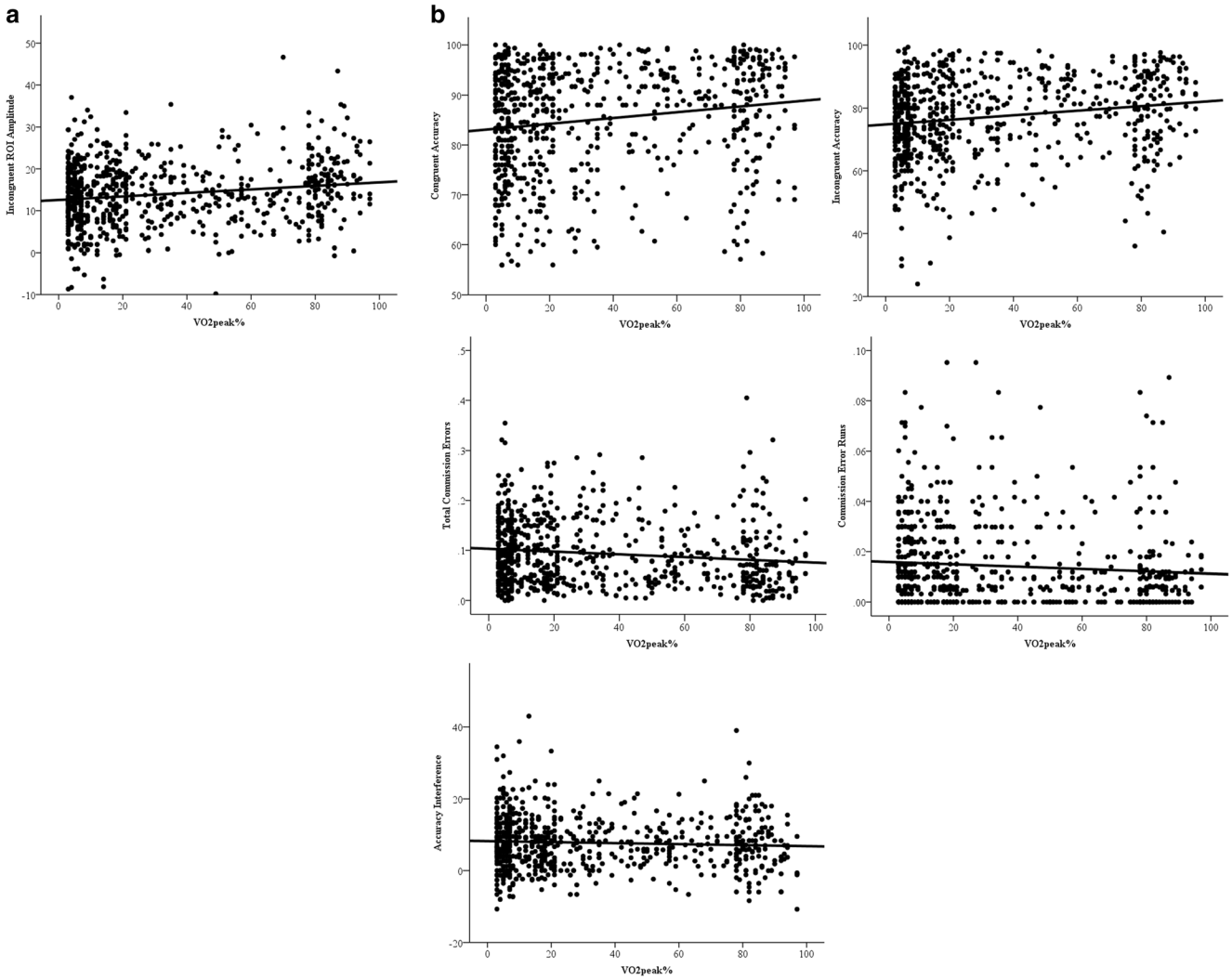

Fig. 3 Scatterplots for the significant associations between aerobic fitness and **a** P3 amplitude ROI, **b** measures of central tendency, **c** measures of variability, and **d** cognitive strategy

the variance associated with descriptive variables and differences between studies. No such relationship was observed for incongruent trials ($\beta = 0.06$, $t(691) = 1.6$, $p = 0.12$, $f^2 = .003$). Similarly, VO_2peak% did not account for additional variance in sigma for either congruent or incongruent trials (β's ≤ -0.02, $t(686$ and $687) \leq 1.7$, $p \geq 0.09$, $f^2 \leq .004$), after controlling for the variance associated with descriptive variables and differences between studies. However, higher VO_2peak% was related to decreased positive skew of the RT distribution for both congruent and incongruent trials (β's ≤ -0.10, $t(684$ and $688) \geq 2.4$, $p \leq 0.015$, $f^2 \geq 0.01$), after controlling for the variance associated with age, sex, SES, IQ, and differences between studies (see Table 4). The relationship between incongruent tau and higher VO2peak% was not significant in secondary regression analyses controlling for congruent tau ($\beta = -0.02$, $t(688) = -0.69$, $p = 0.49$, $f^2 = 0.00$) (see Table 5).

Cognitive Strategy Outcomes

Conditional Accuracy Function Mean RT

Across both congruent and incongruent trials, higher VO_2peak% was associated with slower RT for only the fastest reaction time bin (bin 1; β's ≥ 0.08, $t(694) \geq 2.2$, $p \leq 0.029$, $f^2 = 0.01$), with no such associations observed for slower reaction times characterized within later bins (bins 2–5; β's ≤ 0.06, $t(694) \leq 1.6$, $p \geq 0.111$, $f^2 < 0.01$). These associations were observed after controlling for the variance associated with descriptive variables and differences between studies (see Table 4). The relationship between incongruent bin 1 RT and higher VO_2peak% was not significant in secondary regression analyses controlling for congruent bin 1 RT ($\beta = -0.01$, $t(692) = 0.38$, $p = 0.71$, $f^2 = 0.00$) (see Table 5).

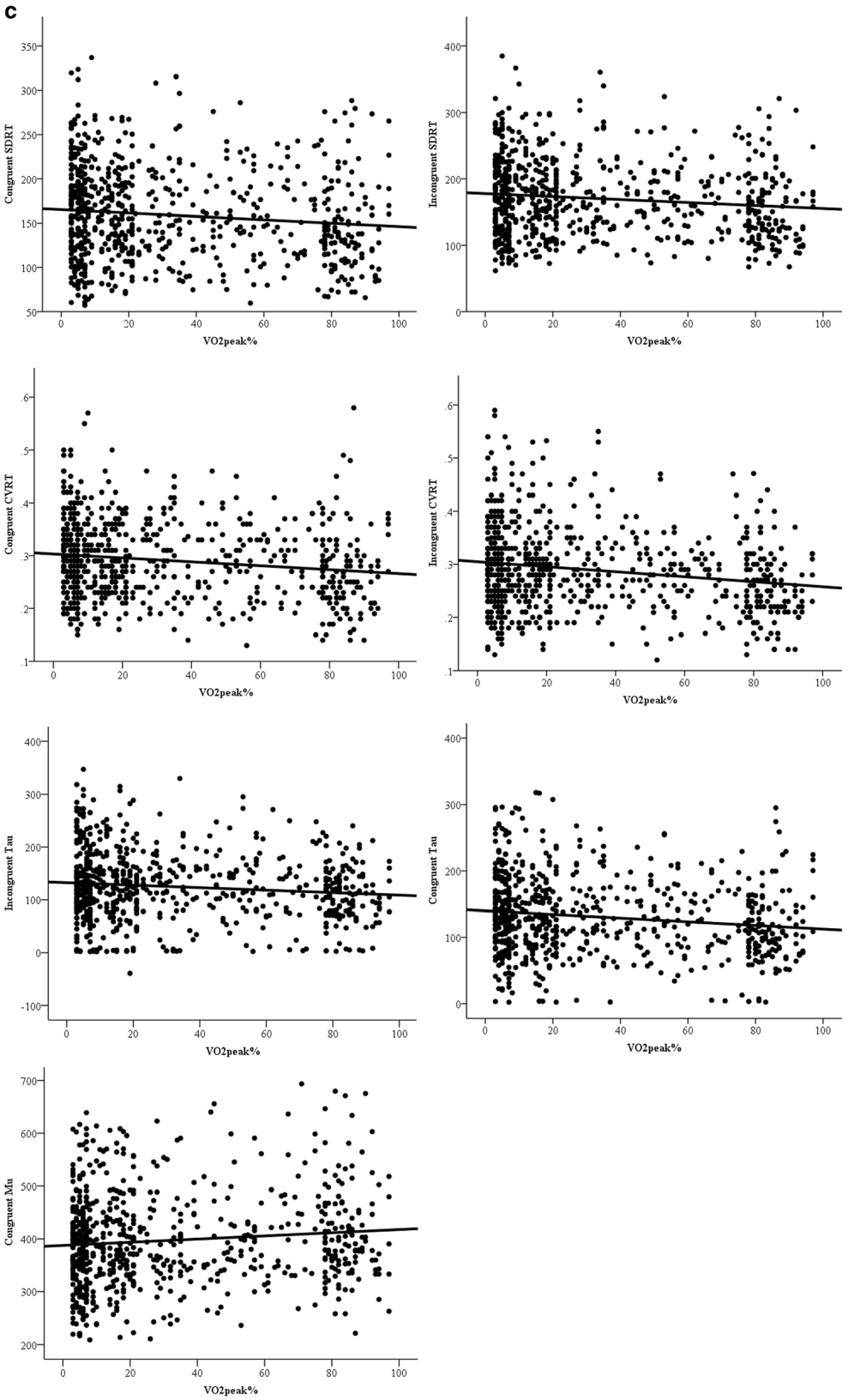

Fig. 3 (continued)

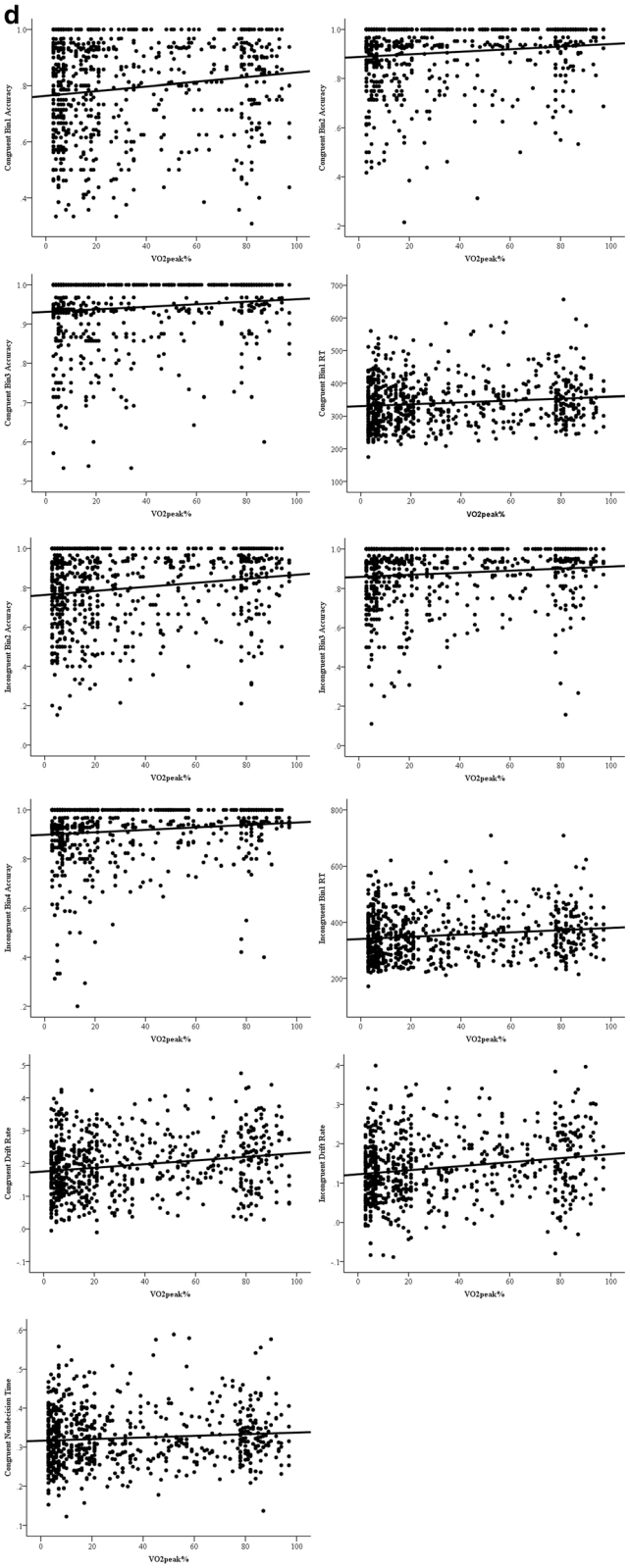

Fig. 3 (continued)

Conditional Accuracy Function Response Accuracy

For congruent trials, higher VO_2peak% was associated with greater response accuracy for faster reaction times characterized within earlier bins (bins 1–3; β's ≥ 0.08, $t(691) \geq 2.2$, $p \leq 0.031$, $f^2 = 0.01$), with no such associations observed for slower reaction times characterized within later bins (bins 4–5; β's ≤ 0.03, $t(693) \leq 0.9$, $p \geq 0.389$, $f^2 < 0.01$). These associations were observed after controlling for the variance associated with descriptive variables and differences between studies. In contrast, for incongruent trials, higher VO_2peak% was associated with greater response accuracy only during moderate reaction times characterized within bins 2–4 (β's ≥ 0.09, $t(692) \geq 2.3$, $p \leq 0.019$, $f^2 \geq 0.01$), with no such associations observed for more extreme reaction times characterized within bins 1 and 5 (β's ≤ 0.05, $t(693) \leq 1.2$, $p \geq 0.233$, $f^2 < 0.01$). These associations were observed after controlling for the variance associated with descriptive variables and differences between studies (see Table 4). The relationship between incongruent accuracy in bins 2 and 4 and higher VO_2peak% was significant in secondary regression analyses controlling for congruent accuracy in bins 2 and 4 ($\beta = 0.09$, $t(690) = 2.92$, $p = 0.004$, $f^2 = 0.01$) (see Table 5).

Measures of Strategy

Drift Rate

For both congruent and incongruent trials, higher VO_2peak% was associated with increased drift rate (β's $= 0.12$, $t(688) \geq 3.4$, $p \leq 0.001$, $f^2 = 0.01$), after controlling for the variance associated with descriptive variables and differences between studies (see Table 4). The relationship between incongruent drift rate and higher VO_2peak% was not significant in secondary regression analyses controlling for congruent drift rate ($\beta = 0.03$, $t(687) = 1.46$, $p = 0.15$, $f^2 = 0.00$) (see Table 5).

Boundary Separation

No relationships were observed between VO_2peak% and boundary separation for either congruent or incongruent trials (β's ≥ -0.04, $t(688) \leq 1.0$, $p \geq 0.645$, $f^2 < 0.001$), after controlling for the variance associated with descriptive variables and differences between studies (see Table 4).

Nondecision Time

For both congruent and incongruent trials, higher VO_2peak% was associated with increased time spent in nondecision processing (β's $= 0.09$, $t(688) \geq 2.3$, $p \leq 0.023$, $f^2 = 0.01$), after controlling for the variance associated with differences

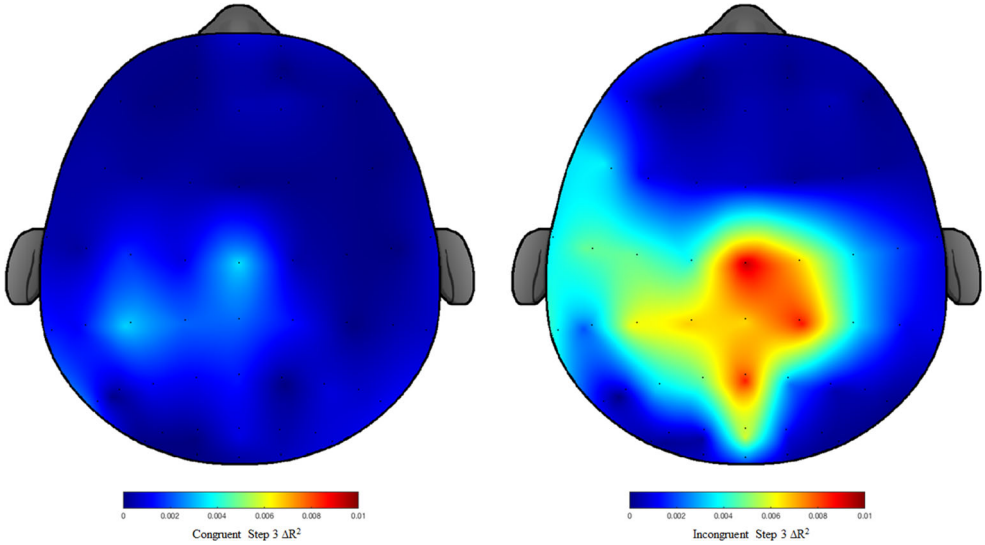

Fig. 4 Topographic maps of the P3-ERP for congruent and incongruent trials. The step 3 ΔR^2 is depicted in red in the topographic map

between studies (see Table 4). The relationship between incongruent nondecision time and higher VO_2peak% was not significant in secondary regression analyses controlling for congruent drift rate ($\beta = 0.02$, $t(690) = 0.85$, $p = 0.40$, $f^2 = 0.00$) (see Table 5).

Discussion

The current study compliments previous research within the field via examination of behavioral and neuroelectric outcomes in response to an inhibitory control task in over 700 preadolescent children from across the entire spectrum of aerobic fitness. These children came from several smaller, previously reported studies, in which we conducted reanalyses to (1) examine the main outcomes using a pooled sample to provide greater power for the statistical analyses, and (2) investigate a number of previously unreported behavioral moderators to further shed light on the relationship of aerobic fitness to cognitive outcomes during an inhibitory control task. The findings of these smaller studies were not always in agreement with one another, as some studies observed general associations between aerobic fitness and cognition (Wu et al. 2011a; Kao et al. 2017; Chaddock et al. 2010; Scudder et al. 2014), while other found selective effects of aerobic fitness on cognitive function (Pontifex et al. 2011; Voss et al. 2011; Moore et al. 2013). Such differences may have occurred due to sampling effects (sample size, sample demographics) and a focus limited to primarily measures of central tendency. Therefore, the merging of these studies affords a unique opportunity to examine these nuanced differences, as well as a comprehensive examination of behavioral and neuroelectric outcomes with adequate power.

Novel to this investigation was the large sample size as well as the multifaceted analyses involving neurophysiological and behavioral assessments to better understand the various components of task performance, generally categorized by central tendency, response variability, and cognitive strategies along with associated neuroelectric underpinnings. In general, higher fitness was associated with larger incongruent P3 amplitude, greater response accuracy, decreased RT variability, and enhanced cognitive strategies, a pattern indicating that higher fitness is associated with more optimal cognitive performance, as measured at the level of brain and behavior.

P3-ERP

The use of ERPs in this investigation allowed for a greater understanding of the relationship between aerobic fitness and cognition through the examination of a specific component, the P3 potential, which affords insight into some of the cognitive operations that occur following stimulus engagement (Polish 2003). The P3 reflects context updating, which refers to the allocation of attentional resources in the service of working memory to update the mental representation of the stimulus environment. The amplitude of the P3 is related to the allocation of attentional resources (Polich 1987; Polich and Heine 1996), such that increases in amplitude are thought to reflect an increase in the allocation of attentional resources (Polich 2007). In the current study, the P3 amplitude findings are in agreement with previous research (Pontifex et al. 2011), such that higher aerobic fitness was correlated with larger P3 amplitude irrespective of the congruent and incongruent trials, suggesting greater allocation of attentional resources toward task-related stimuli. After controlling for a number of demographic variables, such a pattern of results was maintained as task demands increased during incongruent trials requiring greater amounts of inhibition to mitigate perceptual interference associated with the flanking stimuli. Thus, the current

Table 4 Summary of the final step of the hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables and differences between studies

	B	SE *B*	Beta	*t*	*p*	ΔR^2
ERPs						
Congruent						
P3 amplitude from 15 site ROI	0.01	0.01	0.03	0.90	0.37	0.001
P3 latency from 15 site ROI	−0.16	0.10	−0.06	1.65	0.10	0.003
Incongruent						
P3 amplitude from 15 site ROI	0.02	0.01	0.08	2.23	0.03	0.01
P3 latency from 15 site ROI	0.05	0.09	0.02	0.57	0.57	0.00
Measures of central tendency						
Congruent						
Mean RT	0.03	0.13	0.01	0.26	0.79	0.00
Accuracy	0.02	0.01	0.08	2.32	0.02	0.01
Incongruent						
Mean RT	0.06	0.14	0.02	0.41	0.68	0.00
Accuracy	0.05	0.02	0.17	3.18	0.002	0.01
Overall						
Mean RT interference	0.03	0.05	0.02	0.51	0.61	0.00
Accuracy interference	−0.02	0.01	−0.08	2.16	0.03	0.01
Total commission errors	0.00	0.00	−0.12	3.11	0.002	0.01
Commission error runs	−0.00	0.00	−0.09	2.36	0.02	0.01
Total omission errors	0.00	0.00	−0.04	1.11	0.27	0.00
Omission error runs	0.00	0.00	−0.05	1.23	0.22	0.00
Measures of variability						
Congruent						
SDRT	−0.19	0.06	−0.11	3.06	0.002	0.01
CVRT	0.00	0.00	−0.15	4.13	0.00	0.02
Mu	0.26	0.11	0.09	2.24	0.03	0.01
Sigma	−0.02	0.04	−0.02	0.49	0.62	0.00
Tau	−0.29	0.07	−0.15	3.90	0.00	0.02
Incongruent						
SDRT	−0.20	0.07	−0.10	2.89	0.004	0.01
CVRT	0.00	0.00	−0.14	3.72	0.00	0.06
Mu	0.22	0.14	0.06	1.57	0.12	0.00
Sigma	−0.10	0.06	−0.07	1.72	0.09	0.00
Tau	−0.21	0.08	−0.10	2.44	0.02	0.01
Cognitive strategy outcomes						
Congruent						
RT						
Bin 1	0.21	0.09	0.09	2.24	0.02	0.01
Bin 2	0.18	0.12	0.06	1.58	0.12	0.00
Bin 3	0.09	0.13	0.03	0.72	0.47	0.00
Bin 4	0.01	0.15	0.00	0.05	0.96	0.00
Bin 5	−0.24	0.22	−0.04	−1.10	0.27	0.00
Accuracy						
Bin 1	0.00	0.00	0.10	2.61	0.01	0.01
Bin 2	0.00	0.00	0.08	2.17	0.03	0.01
Bin 3	0.00	0.00	0.09	2.39	0.02	0.01
Bin 4	0.00	0.00	0.01	0.25	0.81	0.00
Bin 5	0.00	0.00	0.03	0.86	0.39	0.00

Table 4 (continued)

	B	SE *B*	Beta	*t*	*p*	ΔR^2
Incongruent						
RT						
Bin 1	0.23	0.10	0.08	2.18	0.03	0.01
Bin 2	0.21	0.13	0.06	1.60	0.11	0.00
Bin 3	0.08	0.15	0.02	0.53	0.60	0.00
Bin 4	0.00	0.17	0.00	0.00	1.00	0.00
Bin 5	−0.20	0.24	−0.03	−0.82	0.41	0.00
Accuracy						
Bin 1	0.00	0.00	0.04	0.95	0.34	0.00
Bin 2	0.00	0.00	0.14	3.64	0.00	0.02
Bin 3	0.00	0.00	0.09	2.34	0.02	0.01
Bin 4	0.00	0.00	0.10	2.55	0.01	0.01
Bin 5	0.00	0.00	0.05	1.19	0.23	0.00
Measures of strategy						
Congruent						
Drift rate	0.00	0.00	0.12	3.40	0.001	0.01
Boundary separation	0.00	0.00	−0.02	0.46	0.64	0.00
Nondecision time	0.00	0.00	0.09	2.27	0.02	0.01
Incongruent						
Drift rate	0.00	0.00	0.12	3.57	0.00	0.01
Boundary separation	0.00	0.00	−0.04	1.00	0.32	0.00
Nondecision time	0.00	0.00	0.09	2.38	0.02	0.01

findings support those of prior studies (Pontifex et al. 2011; Moore et al. 2013) that were combined for this reanalysis, and indicated that greater aerobic fitness may reflect an enhanced ability to inhibit extraneous information during stimulus

Table 5 Summary of the final step of the hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables, differences between studies, and congruent performance

	B	SE *B*	Beta	*t*	*p*	ΔR^2
ERPs						
Incongruent						
P3 amplitude from 15 site ROI	0.01	0.01	0.06	2.61	0.01	0.00
Measures of central tendency						
Incongruent						
Accuracy	0.02	0.01	0.05	2.19	0.03	0.00
Measures of variability						
Incongruent						
SDRT	−0.04	0.05	−0.02	−0.93	0.35	0.00
CVRT	0.00	0.00	−0.04	−1.28	0.20	0.00
Mu	0.22	0.14	0.06	1.57	0.12	0.00
Sigma	−0.10	0.06	−0.07	1.72	0.09	0.00
Tau	−0.21	0.08	−0.10	2.44	0.02	0.01
Cognitive strategy outcomes						
Incongruent						
RT						
Bin 1	0.01	0.04	0.01	0.38	0.71	0.00
Accuracy						
Bin 2	0.00	0.00	0.09	2.92	0.00	0.01
Bin 3	0.00	0.00	0.05	1.33	0.18	0.00
Bin 4	0.00	0.00	0.09	2.57	0.01	0.01
Measures of strategy						
Incongruent						
Drift rate	0.00	0.00	0.03	1.46	0.19	0.00
Nondecision time	0.00	0.00	0.02	0.85	0.40	0.00

processing. Furthermore, these results confirm that the P3 potential, as a measure of brain function, may be particularly sensitive to differences in aerobic fitness, serving as a useful biomarker for understanding the role of aerobic fitness on brain health.

Alternatively, an association was not observed between aerobic fitness and P3 latency, a measure of cognitive processing speed, or the speed in which classification and evaluation of a stimulus occurs (Duncan-Johnson 1981; Verleger 1997). Shorter latency has been related to faster cognitive processing speed and thus superior cognitive performance (Polich and Herbst 2000). Unpredictably, unlike prior studies with smaller sample sizes (Pontifex et al. 2011), the present reanalysis utilizing a larger sample did not find significant associations between aerobic fitness and P3 latency, and thus, the large sample size and expanded measurement approach may represent a more "true" relationship between aerobic fitness and P3 latency. Alternatively, the increased variance introduced through the merging of multiple studies into larger database may have obscured the relationship of fitness and P3 latency. Regardless, this surprising finding does not confirm many of the earlier reports (Pontifex et al. 2011; Hillman et al. 2005) and suggests that there may be discrepancies in the association between aerobic fitness and context updating speed, as measured via P3 latency. These discrepancies may occur for a variety of reasons. Specifically, the present investigation included a larger age range of children compared to prior studies and examined association across the entire aerobic fitness range, rather than a comparison of extreme groupings of fitness levels. For example, in a study of children ages 7–10 years, no associations were observed between P3 latency and executive control functioning (Brydges et al. 2014). Furthermore, the different task parameters from the various studies may have also contributed to these discrepancies (Verleger 1997). Thus, this lack of a relationship is not entirely unexpected given the variability in age, sample characteristics, and P3 latency development (Dinteren et al. 2014).

Response Accuracy

The current findings revealed that both congruent and incongruent accuracy were positively associated with aerobic fitness after accounting for significant demographic variables. These findings replicate and extend previous findings indicating that lower amounts of fitness may relate to general impairments in performance on cognitive control tasks (Wu et al. 2011a; Kao et al. 2017; Chaddock et al. 2010; Scudder et al. 2014). In addition, a significant relationship was realized for aerobic fitness and flanker accuracy interference scores on task performance outcomes, wherein greater fitness was associated with lesser amounts of accuracy interference. Such a finding indicates that a decreased ability to inhibit irrelevant stimuli is associated with poorer aerobic fitness, or alternatively, that greater amounts of fitness are positively associated with greater inhibitory control. Prior research has revealed that younger children are less able to suppress irrelevant information and thus experience greater interference relative to older children (Ridderinkhof et al. 1997). Collectively, the association between increased fitness and decreased interference suggests more mature inhibitory control (Pontifex et al. 2011).

Interestingly, commission errors rather than omission errors were also negatively associated with aerobic fitness, such that increased fitness was related to fewer commission errors. This finding implies a failure to inhibit behavioral responses with poorer aerobic fitness. The relation of fitness to error commissions is interesting given that the flanker task requires complex rule sets whereby multiple action schemas are activated based on their agreement (or disagreement) with the target stimulus direction. Children must be able to exert effortful control in order to flexibly apply these rule sets. The negative relationship observed for aerobic fitness and commission error production suggests a disconnect in the overt behavioral responses to these stimuli. Collectively, the pattern of results observed herein suggests that increases in fitness are related to overall better cognitive performance and that greater aerobic fitness may be particularly beneficial when task demands are most challenging (Colcombe et al. 2003; Colcombe and Kramer 2003). These findings support prior findings in older adults suggesting both a general benefit of fitness to cognition as well as a selectively greater benefit to tasks or task components requiring greater amounts of cognitive control (Colcombe and Kramer 2003).

Reaction Time

Corroborating all prior studies incorporated in this reanalysis, fitness was not related to mean RT. Such findings do not stand alone, as most inhibition studies in children that compare differences among fitness grouping have demonstrated effects in response accuracy rather than response speed (Etnier et al. 2006; Van der Niet et al. 2014). To that end, Davidson et al. (2006) suggested that response accuracy may be a more meaningful outcome in children due to their inherent desire to respond as quickly as possible on cognitive tasks, without regard to errors of commission. Such a pattern of responding differs from that of older adults, who favor delaying their response speed in favor of response accuracy. In contrast, young children favor responding quickly at the expense of accuracy, highlighting the impulsive nature of children (Davidson et al. 2006). The present findings corroborate this pattern of responding, with no differences in response speed observed across fitness groups.

Variability

Interestingly, when RT measures were investigated using a number of different outcomes that have not typically been employed with datasets investigating the fitness-cognition relationship, a number of novel findings emerged, suggesting that mean tendency measures of response speed may not be sensitive to capture small fitness-related differences in behavior. Specifically, fitness was negatively associated with variability in RT, and this pattern was observed across the SDRT and CVRT, two different measures of response variability. These measures of variability are important because they have been used as behavioral markers of neurological health and function, whereby greater variability has been linked to neurodegenerative pathology and certain brain disorders. Elderly individuals, those with mild cognitive impairments, individuals with dementia, and children with ADHD exhibit increased variability related to impairments in attention and decreased cognitive control abilities (MacDonald et al. 2006). Thus, the findings that higher levels of aerobic fitness are related to decreased variability suggest a beneficial effect of fitness on neurological health and function.

SDRT refers to within-person fluctuations in behavioral performance, and in children, SDRT is increased relative to adolescents and adults (Williams et al. 2005, 2007; Li et al. 2004). The current findings suggest that the association between increased fitness and decreased SDRT may indicate a more mature performance pattern. These findings are in agreement with previous research in older adults whereby more active individuals demonstrated decreased SDRT compared to their inactive counterparts (Samson et al. 2008), as well as previous research in children that found a relation between higher aerobic fitness and decreased response variability across all conditions of a flanker task with selectively greater effects for those requiring greater amounts of cognitive control (Moore et al. 2013; Wu et al. 2011b). Furthermore, reductions in SDRT are related to white matter tract maturation and increased functional connectivity in children, suggesting a neural substrate for observed differences in variability of task performance (Tamnes et al. 2012). Taken together, these results suggest that greater fitness may relate to greater neural maturation during preadolescent development, including maturation of white matter integrity, which may result in greater cognitive efficiency.

Ex-Gaussian

In addition to variability in RT, ex-Gaussian analyses were also performed. Ex-Gaussian analyses involve describing the shape of the RT distributions and allow for a more accurate description of the distribution of performance latencies during cognitive tasks (Whelan 2008), and its distribution represents the convolution of an exponential and Gaussian (normal) distribution. Contrary to our hypothesis, fitness was not related to response variability in the Gaussian portion of the RT distribution, or sigma. This contrast to the findings related to interindividual variability is not surprising given that variability in reaction time is also influenced by an individual's effectiveness in response preparation and selection (Mostofsky and Simmonds 2008). However, fitness was negatively associated with congruent and incongruent tau, representing variability in the tail, or a negative shift of the distribution's leading edge. Tau is the mean and SD of the exponential function and reflects extremes in performance (McAuley et al. 2006b). This suggests a decrease in response variability with greater fitness, and hence, the effect on ex-Gaussian parameters appears to be influential and selective to this specific parameter. Increased tau indicates significantly longer RTs relative to an individual's mean RT. Thus, in the present investigation, increased aerobic fitness was associated with decreased RT variability within their given response distribution. Increased tau has also been interpreted as lapses in attention (Leth-Steensen et al. 2000). Our results suggest that higher aerobic fitness may specifically benefit the effectiveness of inhibitory control processes by facilitating sustained attentional effort. As such, our findings align with previous reports (Pontifex et al. 2011; Voss et al. 2011; Moore et al. 2013) of fitness-related benefits to attentional control, where higher fit children were better able to allocate attentional resources and to flexibly regulate attentional effort during inhibitory control task (Pontifex et al. 2011). As such, the effectiveness observed in the tau portion of the ex-Gaussian curve may reflect an enhanced ability to maintain sustained attentional effort.

Cognitive Strategy

In addition to investigating behavioral outcomes in isolation (e.g., RT, response accuracy), there are techniques which combine various outcomes to better understand underlying cognitive strategies (e.g., speed-accuracy tradeoffs). One technique that has been used to examine the influence of both RT and accuracy outcomes is CAF, which calculates the average accuracy for multiple RT ranges (i.e., bins). CAF measures, as a function of RT, the rate of increase in discrimination accuracy, allowing for a better understanding of the rate at which perceptual information is gained as processing time is increased (Lappin and Disch 1972). The use of CAF allows for the examination of accuracy based on individual RTs, which provides an enhanced understanding of the temporal course of attentional transition as well as the proficiency of selective suppression. In the present investigation, aerobic fitness was associated with beneficial cognitive strategies on the flanker task as indicated by CAF, wherein higher fitness was associated with greater accuracy during early and middle bins across congruency conditions (bins 1, 2, and 3 for congruent; bin

2, 3, and 4 for incongruent) but longer RT during first bin across congruency conditions. Decreased aerobic fitness thus appears to be associated with a speed-accuracy trade-off within the fastest bin, whereby lower fit children are responding faster but less accurately than higher fit children. This suggests that for very fast responses, decreased fitness is associated with a more impulsive response tendency. Taken together, this suggests differences in strategy as a function of fitness, such that higher fit children may more effectively regulate their actions during stimulus evaluation to respond more accurately, indicative of enhanced cognitive control strategies, and less impulsive response tendencies. These findings complement previous research examining fitness groupings of children, which showed that higher fit children had greater accuracy in earlier bins, when the time for discriminative processing was constrained (Kao et al. 2017). Given that the pattern of behavioral responses associated with greater aerobic fitness is more adult-like (Kao et al. 2017), the present findings again suggest that greater aerobic fitness may be associated with a more mature (i.e., "adult-like") cognitive strategy. Taken together, these results suggest that greater fitness may relate to better accuracy during constrained response times, indicative of more developed cognitive control abilities.

Other models for investigating cognitive strategies also exist. In this reanalysis, we investigated diffusion modeling, which allows for a better understanding of the specific aspects of the behavioral outcomes that are associated with aerobic fitness. Congruent and incongruent trial drift rates were both positively associated with aerobic fitness, suggesting that fitness is associated with faster and better quality of information uptake. Given that drift rate improves into adulthood (Ratcliff et al. 2012), the present findings suggest that higher fit children may display more "adult-like" patterns of information uptake.

It is worth noting that the effect sizes in the present analyses are relatively small. The more precise measurements afforded for by the large sample size as well as the expanded measurement approach result in small but significant effects. Collectively, these findings provide evidence that greater aerobic fitness during childhood is associated with larger P3 amplitude, greater response accuracy, less RT variability, and enhanced cognitive strategies during performance of an inhibitory control task that modulates perceptual interference. These beneficial findings align with developmental gains in inhibitory control, which mature throughout childhood as indicated by improvements on various cognitive control tasks with age (van den Wildenberg and van der Molen 2004). Thus, higher aerobic fitness may be a health factor which serves to broadly benefit inhibitory control during preadolescent development. Moreover, these results indicate that aerobic fitness may be associated with more effective inhibitory control capacity, allowing children to better perform tasks requiring variable amounts of inhibition within the stimulus environment.

Although continued work is necessary to delineate the exact mechanisms relating aerobic fitness and cognition, several viable mechanisms have been proposed across the human and nonhuman animal literatures. Specifically, aerobic fitness may be particularly beneficial during childhood as this is a time of significant cognitive and neural development (Caviness et al. 1996; Casey et al. 2005), wherein health behaviors may be especially effective in shaping brain structure and function. Based on animal models, exercise induces changes on a wide range of brain health markers: cell number, dendritic complexity, several growth factors (e.g., BDNF, VEGF), and synaptic plasticity (Farmer et al. 2004; Cotman et al. 2002; van Praag et al. 1999), and these changes result in a healthier brain. In addition, exercise-induced changes in BDNF, insulin-like growth factor (IGF1), and VEGF are implicated in angiogenesis, neurogenesis, cellular proliferation, and neural plasticity (van Praag et al. 1999; Russo-Neustadt et al. 2001; Vaynman et al. 2006), and these factors may also be related to the observed associations between fitness and cognition (Gomez-Pinilla and Hillman 2013; Cotman et al. 2007). In rodents, after a running wheel exercise protocol, capillary density in the cerebellum was increased (Black et al. 1990), and there was an increase in the number of new hippocampal cells (van Praag et al. 1999). These changes may underlie the fitness-related improvements in cognition.

In humans, the cerebral circulation hypothesis suggests aerobic fitness is related to enhanced oxygen transport to the brain (Chodzko-zajko and Moore 2016), resulting in better cognitive performance. In children, higher aerobic fitness is associated with larger volume of the dorsal striatum, a specific region within the basal ganglia that is involved in cognitive control (Chaddock et al. 2010). In older adults, exercise has been shown to increase the volume of microglia and astrocytes in several brain regions (Dan Ehninger 2003), and leads to growth of blood vessels in the hippocampus (van Praag et al. 2005), cortex (Ding et al. 2017), and cerebellum (Black et al. 1990). Importantly, these changes are associated with better cognitive performance, particularly on tests requiring greater amounts of cognitive control (Colcombe et al. 2004, 2006; Kramer et al. 1999). Despite these interesting mechanistic avenues, additional research is needed to better understand the mechanisms linking aerobic fitness and cognition in children. In summary, research suggests that exercise acts on the CNS to influence protein expression, neurogenesis, angiogenesis, synaptic plasticity, dendritic complexity, and glial cell integrity. In addition, aerobic fitness has been related to gray matter volume, increased white matter integrity, decreased neuroinflammation, and increased brain blood flow. This relates to improved cognitive abilities as well as real-world functioning (Esteban-Cornejo et al. 2017; Ortega et al. 2017; Voss et al. 2013).

Conclusion

Across the globe, children have become increasingly unfit and inactive, and in the USA, over 50% of 6–11-year olds do not meet the recommended 60 min/day of moderate to vigorous physical activity (Troiando et al. 2008). Such a trend is concerning because in children, lower fitness is associated with increased cardiovascular risk (Brage et al. 2004), as well as decreased brain health, which has implications for cognitive and scholastic performance (Pontifex et al. 2011; Voss et al. 2011; Moore et al. 2014; Kao et al. 2017; Chaddock et al. 2010; Wu et al. 2011b; Chaddock-Heyman et al. 2015). The results of this large-scale analysis indicate a beneficial relationship between aerobic fitness and cognitive control during a task that varied inhibition requirements. Further, such fitness-related differences were observed across a host of behavioral outcomes, which were bolstered by the neuroelectric findings. Accordingly, these findings add to a growing body of research indicating the beneficial relation of aerobic fitness on cognitive control, and more broadly on brain health, in school-aged children.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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Supplemental Information: Results

P3-ERP

Congruent Amplitude from 15-site ROI : The Step 1 regression analysis for congruent amplitude was significant, adjusted $R^2 = 0.03$, $F(2, 699) = 11.40$, $p \leq 0.001$. The addition of study in Step 2 was also significant, $\Delta R^2 = 0.16$, $F(8, 693) = 20.14$, $p \leq 0.001$, with study accounting for an incremental amount of variance in congruent amplitude beyond associated descriptive variables. Step 3 was also significant, $\Delta R^2 = 0.001$, $F(9, 692) = 17.99$, $p \leq 0.001$; however, the addition of VO_2peak% did not account for an incremental amount of variance in congruent amplitude beyond the first two steps of the model (see Figure 4 and Supplemental Table 1).

Incongruent Amplitude from 15-site ROI: The Step 1 regression analysis for incongruent amplitude was significant, adjusted $R^2 = 0.03$, $F(2, 699) = 11.23$, $p \leq 0.001$. The addition of study in Step 2 was also significant, $\Delta R^2 = 0.14$, $F(8, 693) = 17.27$, $p \leq 0.001$, with study accounting for an incremental amount of variance in incongruent amplitude beyond associated descriptive variables. Step 3 was also significant, $\Delta R^2 = 0.01$, $F(9, 692) = 16.00$, $p \leq 0.001$, with the addition of VO_2peak% accounting for an incremental amount of variance in incongruent amplitude beyond the first two steps of the model, demonstrating that higher VO_2peak% was associated with greater incongruent P3 amplitude (see Figure 4 and Supplemental Table 1).

Latency from 15 site ROI: Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent latency was significant, adjusted R^2*'s* ≥ 0.12, F*'s*$(3, 697) \geq 37.92$, p*'s* ≤ 0.001. The addition of study in Step 2 for both models was also significant, ΔR^2*'s* ≥ 0.02, $F(9, 691) = 12.98$, $p \leq 0.001$, with study accounting for an incremental amount of variance in congruent and incongruent latency beyond associated

descriptive variables. Step 3 for both models was also significant, ΔR^2's ≥ 0.003, F's$(10, 690) \geq 11.98$, p's ≤ 0.001, however, the addition of VO_2peak% did not account for an incremental amount of variance in congruent or incongruent latency beyond the earlier steps of the model (see Supplemental Table 1).

Central Tendency

Response Accuracy: Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent and incongruent accuracy was significant, adjusted R^2's ≥ 0.14, F's$(3, 698) \geq 38.60$, p's ≤ 0.001. The addition of study in Step 2 for both models was also significant, ΔR^2's ≥ 0.04, F's$(9, 692) \geq 18.32$, p's ≤ 0.001, with study accounting for an incremental amount of variance in accuracy beyond associated descriptive variables. Step 3 for both congruent and incongruent accuracy was also significant, ΔR^2's ≥ 0.01, F's$(10, 691) \geq 17.72$, p's ≤ 0.001, with VO_2peak% accounting for an incremental amount of variance in accuracy beyond the early steps in the model, indicating that higher VO_2peak% was associated with greater accuracy across task conditions (see Supplemental Table 2).

Accuracy Interference Scores: No demographic variables were significantly related to this outcome. Thus, the Step 1 regression analysis for accuracy interference accounted for study, adjusted $R^2 = 0.03$, $F(6, 695) = 4.49$, $p \leq 0.001$. Step 2 was also significant, $\Delta R^2 = 0.01$, $F(7, 694) = 4.53$, $p \leq 0.001$, with VO_2peak% accounting for an incremental amount of variance in accuracy interference beyond study, indicating that higher VO_2peak% was associated with lower accuracy interference (see Supplemental Table 2).

Reaction Time and Reaction Time Interference: Separate models for congruent trials, incongruent trials, and reaction time interference scores yielded similar results. Specifically, the Step 1 regression analysis for mean RT variables were significant, adjusted R^2's ≥ 0.03, F's$(2,$

699) ≥ 12.05, *p's* ≤ 0.001. The addition of study in Step 2 for all models was also significant, ΔR^2*'s* ≥ 0.10, *F's(*8, 693) ≥ 13.68, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in mean RT variables beyond associated descriptive variables. Step 3 for all models was also significant, ΔR^2*'s* ≥ 0.00, *F's(*9, 692) ≥ 12.17, *p's* ≤ 0.001, however, the addition of VO_2peak% did not account for an incremental amount of variance in any mean RT variables beyond associated descriptive variables or study (see Supplemental Table 2).

Commission Errors and Error Runs: Separate models for commission errors and commission error runs yielded similar results. Specifically, the Step 1 regression analysis for commission errors and commission error runs was significant, adjusted R^2*'s* ≥ 0.078, *F's*(2, 699) ≥ 29.76, *p's* < 0.001. The addition of study in Step 2 for both models was also significant, ΔR^2*'s* ≥ 0.039, *F's*(8, 693) ≥ 13.35, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in commission errors and commission errors runs beyond associated descriptive variables. Step 3 for both models was also significant, ΔR^2*'s* ≥ 0.01, *F's*(9, 692) ≥ 14.51, *p's* ≤ 0.001, revealing an association of higher VO_2peak% with fewer commission errors and commission error runs beyond the early steps in the model (see Supplemental Table 2).

Omission Errors and Error Runs: Separate models for omission errors and omission error runs yielded similar results. Specifically, the Step 1 regression analysis for the omission errors and omission error runs was significant, adjusted R^2*'s* ≥ 0.04, *F's*(2, 699) ≥ 16.16, *p's* ≤ 0.001. The addition of study in Step 2 for both models was also significant, ΔR^2*'s* ≥ 0.050, *F's*(8, 693) ≥ 9.03, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in the number of omission errors and omission error runs beyond associated descriptive variables. Step 3 for both models was significant, ΔR^2*'s* ≥ 0.00, *F's*(9, 692) ≥ 8.02, *p's* ≤ 0.001, however, the addition of

VO_2peak% did not account for an incremental amount of variance in omission errors or omission error runs beyond earlier steps (see Supplemental Table 2).

Response Variability

Standard Deviation of Reaction Time (SDRT): Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent and incongruent SDRT was significant, adjusted R^2*'s* ≥ 0.14, *F's(*4, 697) ≥ 29.84, *p's* ≤ 0.001. The addition of study in Step 2 for both models was significant, ΔR^2*'s* ≥ 0.04, *F's(*10, 691) ≥ 16.20, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in SDRT beyond associated descriptive variables. Step 3 for both models was also significant, ΔR^2*'s* $\geq$ 0.01, *F's(*11, 690) ≥ 15.76, *p's* $\leq$ 0.001, with VO_2peak% accounting for an incremental amount of variance in congruent and incongruent SDRT beyond the earlier steps in the model, and demonstrating that higher VO_2peak% was associated with decreased variability (see Supplemental Table 3).

Coefficient of Variation of Reaction Time (CVRT): Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent and incongruent CVRT was significant, adjusted R^2*'s* ≥ 0.12, *F's(*3, 698) ≥ 31.31, *p's* ≤ 0.001. The addition of study in Step 2 for both models was significant, ΔR^2*'s* ≥ 0.04, *F's(*9, 692) ≥ 15.01, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in CVRT beyond associated descriptive variables. Step 3 for both models was also significant, ΔR^2*'s* $\geq$ 0.02, *F's(*10, 691) ≥ 15.54, *p's* ≤ 0.001, with VO_2peak% accounting for an incremental amount of variance in congruent and incongruent CVRT beyond the earlier steps, indicating that higher VO_2peak% was associated with decreased variability in reaction time (see Supplemental Table 3).

Congruent mu: Step 1 of the regression analyses for congruent mu was significant, adjusted R^2=0.01, $F(1, 695) = 5.05$, $p = 0.02$. The addition of study in Step 2 was significant, ΔR^2=0.06, $F(7, 689) = 7.47$, $p \leq 0.001$, with study accounting for an incremental amount of variance in congruent CVRT mu associated descriptive variables. Step 3 was also significant, R^2=0.01, $F(8, 688) = 7.20$, $p \leq 0.001$, with VO_2peak% accounting for an incremental amount of variance in congruent mu beyond the earlier steps (see Supplemental Table 3).

Incongruent mu: No demographic covariates were significantly correlated with this outcome. Thus, the Step 1 regression analysis for incongruent mu accounted for study, adjusted R^2=0.09, $F(6, 692) = 11.89$, $p \leq 0.001$. Step 2 was also significant, ΔR^2=0.003, $F(7, 691) = 10.57$, $p < 0.001$, however, the addition of VO_2peak% did not account for an incremental amount of variance in incongruent mu beyond Step 1 (see Supplemental Table 3).

Sigma: Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent and incongruent sigma was significant, adjusted R^2*'s* ≥ 0.07, F*'s*$(2, 693) \geq 25.41$, p*'s* ≤ 0.001. The addition of study in Step 2 for both models was also significant ΔR^2*'s* ≥ 0.04, F*'s*$(8, 687) \geq 10.28$, p*'s* $\leq .001$, with study accounting for an incremental amount of variance in sigma beyond associated descriptive variables. Step 3 for both models was significant, ΔR^2*'s* ≥ 0.000, F*'s*$(9, 686) \geq 9.16$, p*'s* ≤ 0.001, however, the addition of VO_2peak% did not account for an incremental amount of variance in sigma beyond the earlier steps (see Supplemental Table 3).

Tau: Separate models for congruent and incongruent trials yielded similar results. Specifically, the Step 1 regression analysis for congruent and incongruent tau was significant, adjusted R^2*'s* ≥ 0.06, F*'s*$(4, 695) \geq 12.02$, p*'s* ≤ 0.001. The addition of study in Step 2 for both models was significant, ΔR^2*'s* ≥ 0.02, F*'s*$(10, 689) \geq 6.52$, p*'s* ≤ 0.001. Step 3 for both models

was also significant, ΔR^2's ≥ 0.01, F's$(11, 688) \geq 6.51$, p's ≤ 0.001, such that increased VO_2peak% was related to decreased positive skew of the RT distribution on congruent and incongruent trials (see Supplemental Table 3).

Cognitive Strategy Outcomes

Congruent accuracy in Bins 1, 2, and 3: Separate models for congruent accuracy in Bins 1, 2, and 3 yielded similar results, with a significant effect observed for Step 1 of the regression analysis, adjusted R^2's ≥ 0.08, F's$(3, 699) \geq 30.16$, p's ≤ 0.001. For Bins 1 and 2, the addition of study in Step 2 was significant, ΔR^2's ≥ 0.02, $F(9, 692) = 9.27$, $p < 0.001$, with study accounting for an incremental amount of variance in congruent accuracy at Bins 1 and 2 beyond associated descriptive variables. However, for Bin 3, the addition of study in Step 2 was not significant, $\Delta R^2 = 0.01$, $F(8, 693) = 8.10$, $p < 0.001$. Step 3 for Bins 1, 2, and 3 was significant, ΔR^2's ≥ 0.01, F's$(9, 692) \geq 7.88$, p's ≤ 0.001, revealing an association of higher VO_2peak% with greater congruent accuracy at Bin 1, 2, and 3 (see Supplemental Table 4).

Congruent accuracy in Bins 4 and 5: Separate models for congruent accuracy in Bins 4 and 5 yielded similar results, with a significant effect observed for Step 1 of the regression analysis, adjusted R^2's ≥ 0.01, $F(1, 700) = 4.30$, $p = 0.04$. For Bin 4, the addition of study in Step 2 was not significant, $\Delta R^2 = 0.012$, $F(9, 692) = 5.67$, $p < 0.001$. However, for Bin 5, the addition of study in Step 2 was significant, $\Delta R^2 = 0.03$, $F(7, 694) = 3.57$, $p = 0.001$, with study accounting for an incremental amount of variance in congruent accuracy in Bin 5 beyond associated descriptive variables. For both models, Step 3 was significant, ΔR^2's ≥ 0.000, F's$(10, 691) \geq 5.11$, p's ≤ 0.001, however, the addition of VO_2peak% did not account for an incremental amount of variance in congruent accuracy in Bins 4 and 5 beyond earlier steps in the model (see Supplemental Table 4).

Incongruent accuracy in Bin 1 and 5: Separate models for incongruent accuracy in Bins 1 and 5 yielded similar results. Specifically, the Step 1 regression analysis for incongruent accuracy in Bins 1 and 5 was significant, adjusted R^2*'s* ≥ 0.01, *F's*$(1, 700) \geq 6.28$, *p's* ≤ 0.01. For both models, the addition of study in Step 2 was also significant, ΔR^2*'s* ≥ 0.02, *F's*$(7, 694) \geq 3.04$, *p's* ≤ 0.004, with study accounting for an incremental amount of variance in incongruent accuracy at Bin 1 and Bin 5 beyond associated descriptive variables. Step 3 was also significant for both models, ΔR^2*'s* ≥ 0.002, *F's*$(8, 693) \geq 2.84$, *p's* ≤ 0.004, however, the addition of VO_2peak% did not account for an incremental amount of variance in incongruent accuracy beyond earlier steps in the model (see Supplemental Table 4).

Incongruent accuracy in Bins 2, 3, and 4: Separate models for incongruent accuracy in Bins 2, 3, and 4 yielded similar results. Specifically, the Step 1 regression analysis for incongruent accuracy in Bins 2-4 was significant, adjusted R^2*'s* ≥ 0.04, *F's*$(2, 699) \geq 12.90$, *p's* ≤ 0.001. For all models, the addition of study in Step 2 was also significant, ΔR^2*'s* ≥ 0.02, *F's*$(8, 693) \geq 5.21$, *p's* ≤ 0.001, with study accounting for an incremental amount of variance in incongruent accuracy at Bins 2-4 beyond associated descriptive variables. Step 3 was also significant, ΔR^2*'s* ≥ 0.01, *F's*$(9, 692) \geq 5.39$, *p's* ≤ 0.01, revealing an association of higher VO_2peak% with greater incongruent accuracy at Bin 2-4 (see Supplemental Table 4).

Congruent Reaction Time in Bin 1: Given that no descriptive variables were correlated with congruent reaction time at Bin 1, study was entered into Step 1, which was significant, adjusted $R^2 = 0.05$, F$(6, 695) = 6.30$, $p < 0.001$. The addition of VO_2peak% in Step 2 was also significant, $\Delta R^2 = 0.007$, $F(7, 694) = 6.15$, $p < 0.001$, revealing an association of higher VO_2peak% with longer congruent reaction time in Bin 1 (see Supplemental Table 4).

Incongruent Reaction Time in Bin 1: The Step 1 regression analysis for incongruent RT in Bin 1 was significant, adjusted $R^2 = 0.01$, $F(1, 700) = 8.90$, $p = 0.003$. The addition of study in Step 2 was also significant, $\Delta R^2 = 0.082$, $F(7, 694) = 10.41$, $p < 0.001$, with study accounting for an incremental amount of variance in incongruent RT in Bin 1 beyond associated descriptive variables. Step 3 was also significant, $\Delta R^2 = 0.006$, $F(8, 693) = 9.75$, $p < 0.001$, revealing an association of higher VO_2peak% with longer incongruent RT in Bin 1 (see Supplemental Table 4).

Reaction Time in Bin 2-5: Separate models for congruent and incongruent RT in Bins 2-5 yielded similar results. Specifically, for Bin 2, no descriptive variables were correlated with congruent or incongruent RT, thus study was entered into Step 1, which was significant, adjusted R^2*'s* $\geq$ 0.04, F*'s*$(6, 695) \geq 4.37$, p*'s* ≤ 0.001. For Bin 2, Step 2 was also significant, ΔR^2*'s* $\geq$ 0.003, F*'s*$(7, 694) \geq 4.11$, p*'s* ≤ 0.001, however the addition of VO_2peak% did not account for an incremental amount of variance in congruent or incongruent RT beyond step 1. For congruent and incongruent RT in Bins 3-5, the Step 1 regression analysis was significant, adjusted R^2*'s* $\geq$ 0.01, F*'s*$(1, 700) \geq 5.91$, p*'s* ≤ 0.02. For RT in Bins 3-5, the addition of study in Step 2 was also significant, ΔR^2*'s* ≥ 0.09, F*'s*$(7, 694) \geq 10.83$, p*'s* ≤ 0.001, with study accounting for an incremental amount of variance in congruent and incongruent RT beyond associated descriptive variables. Step 3 was also significant, ΔR^2*'s* ≥ 0.00, F*'s*$(8, 693) \geq 9.50$, p*'s* ≤ 0.011, however the addition of VO_2peak% did not account for an incremental amount of variance in congruent or incongruent RT (see Supplemental Table 4).

Drift Rate: Separate models for congruent and incongruent drift rate yielded similar results. Specifically, Step 1 in the regression analysis for congruent drift rate was significant, adjusted R^2*'s* ≥ 0.20, F*'s*$(3, 695) \geq 57.63$, p*'s* ≤ 0.001). For both models, Step 2 was also

significant, ΔR^2's ≥ 0.06, F's$(6, 689) \geq 9.80$, p's $\leq .001$), with the addition of study accounting for a significant amount of variance in congruent and incongruent drift rate, after adjusting for demographic variables. Step 3 was significant in both models, ΔR^2's ≥ 0.01, F's$(1, 688) \geq 12.77$, p's $\leq .001$, indicating that higher VO_2peak% was associated with increased drift rate in congruent and incongruent trials (see Supplemental Table 4).

Nondecision Time: Separate models for congruent and incongruent boundary separation yielded similar results. For both models, no demographic variables were significantly related to the outcomes and thus study was entered into Step 1, which was significant, adjusted R^2's ≥ 0.04, F's$(6, 698) \geq 4.64$, p's $\leq .001$). Step 2 was also significant, ΔR^2's $\geq = 0.01$, F's$(1, 691) \geq 5.16$, p's ≤ 0.02, demonstrating that higher VO_2peak% was associated with increased time spent in congruent and incongruent nondecision processing (see Supplemental Table 4).

Boundary Separation: Separate models for congruent and incongruent boundary separation yielded similar results. For congruent boundary separation, no demographic variables were significantly correlated with this outcome, thus study was entered into Step 1 and was significant, adjusted $R^2 = 0.09$, $F(6, 693) = 11.00$, $p < 0.001$). Step 2 was significant, $\Delta R^2 = 0$, $F(1, 691) = 0.21$, $p = 0.64$, however, VO_2peak% did not account for a significant amount of the variance in congruent boundary separation. For incongruent boundary separation, Step 1 in the regression analysis was significant, adjusted $R^2 = 0.05$, $F(4, 698) = 8.82$, $p < .001$). Step 2 was also significant, $\Delta R^2 = 0.09$, $F(6, 688) = 5.72$, $p < .001$), with study accounting for a significant amount of variance in boundary separation, after adjusting for demographic variables. Lastly, Step 3 was not significant, $\Delta R^2 = 0$, $F(1, 687) = 1.00$, $p = 0.32$), indicating that VO_2peak% did not account for a significant amount of the variance in incongruent boundary separation (see Supplemental Table 4).

Nondecision Time: Separate models for congruent and incongruent boundary separation yielded similar results. For both models, no demographic variables were significantly related to the outcomes and thus study was entered into Step 1, which was significant, adjusted R^2*'s* ≥ 0.04, *F's*$(6, 698) \geq 4.64$, *p's* $\leq .001$). Step 2 was also significant, ΔR^2*'s* $\geq = 0.01$, *F's*$(1, 691) \geq 5.16$, *p's* ≤ 0.02, demonstrating that higher VO_2peak% was associated with increased time spent in congruent and incongruent nondecision processing (see Supplemental Table 4).

Supplemental Table 1. P3-ERP hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables and differences between studies.

Congruent P3 Amplitude from 15 Site ROI

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.029**
Age	1.27	0.33	0.15	3.82**	
SES	0.64	0.34	0.07	1.90	
Step 2					0.16**
Study1	-3.79	2.53	-0.05	-1.50	
Study2	-0.72	0.63	-0.05	-1.15	
Study3	5.88	1.16	0.22	5.05**	
Study4	5.68	1.03	0.26	5.53**	
Study5	9.06	0.97	0.42	9.34**	
Study7	8.17	1.64	0.18	4.97**	
Step 3					0.001
VO_2%	0.01	0.01	0.03	0.90	

Incongruent P3 Amplitude from 15 Site ROI

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.03**
Age	1.20	0.35	0.13	3.42**	
SES	0.84	0.35	0.09	2.39*	
Step 2					0.14**
Study1	-5.62	2.69	-0.07	-2.09*	
Study2	-0.13	0.67	-0.01	-0.20	
Study3	6.47	1.24	0.23	5.23**	
Study4	5.17	1.09	0.23	4.74**	
Study5	8.83	1.03	0.39	8.56**	
Study7	8.52	1.75	0.18	4.88**	
Step 3					0.01*
VO_2%	0.02	0.01	0.08	2.23*	

Congruent P3 Latency from 15 Site ROI

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.12**
Age	-32.26	3.54	-0.33	-9.11**	
SES	-1.78	3.67	-0.02	-0.49	
IQ	-8.91	2.96	-0.11	-3.01**	
Step 2					0.021*
Study1	-45.83	28.89	-0.06	-1.59	
Study2	-10.36	7.17	-0.06	-1.45	
Study3	-27.63	13.29	-0.09	-2.08*	
Study4	-43.95	11.72	-0.18	-3.75**	
Study5	-33.53	11.08	-0.14	-3.03**	
Study7	-17.95	18.77	-0.04	-0.96	
Step 3					0.003
VO_2%	-0.16	0.10	-0.06	-1.65	

Incongruent P3 Latency from 15 Site ROI

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.14**
Age	-33.42	3.23	-0.37	-10.35**	
SES	-0.19	3.27	0.00	-0.06	
Step 2					0.02*
Study1	4.63	26.41	0.01	0.18	
Study2	-21.22	6.54	-0.13	-3.25**	
Study3	-12.79	12.16	-0.05	-1.05	
Study4	-34.44	10.72	-0.16	-3.21**	
Study5	-25.39	10.13	-0.11	-2.51*	
Study7	4.81	17.15	0.01	0.28	
Step 3					0.00
VO_2%	0.05	0.09	0.02	0.57	

Supplemental Table 2. Central Tendency hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables and differences between studies.

Congruent Accuracy

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.18**
Age	5.08	0.46	0.39	11.11*	
SES	0.70	0.47	0.05	1.48	
IQ	1.41	0.38	0.13	3.69*	
Step 2					0.04**
Study1	0.92	3.68	0.01	0.25	
Study2	-0.40	0.91	-0.02	-0.44	
Study3	-0.76	1.69	-0.02	-0.45	
Study4	4.17	1.49	0.13	2.79	
Study5	6.29	1.41	0.20	4.45	
Study7	2.81	2.39	0.04	1.18	
Step 3					0.01*
VO_2%	0.02	0.01	0.08	2.32	

Incongruent Accuracy

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.14**
Age	5.34	0.56	0.35	9.58**	
SES	0.52	0.58	0.03	0.90	
IQ	1.73	0.47	0.13	3.68**	
Step 2					0.05**
Study1	-5.24	4.49	-0.04	-1.17	
Study2	0.32	1.11	0.01	0.28	
Study3	-4.97	2.07	-0.10	-2.40*	
Study4	5.27	1.82	0.14	2.89**	
Study5	5.87	1.72	0.15	3.41**	
Study7	0.45	2.92	0.01	0.15	
Step 3					0.01**
VO_2%	0.05	0.02	0.17	3.18**	

Congruent Mean RT

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.05**
Age	-26.41	4.66	-0.21	-5.66**	
IQ	-12.34	3.92	-0.12	-3.15**	
Step 2					0.06**
Study1	-10.20	38.59	-0.01	-0.26	
Study2	-32.77	9.55	-0.14	-3.43**	
Study3	31.01	17.36	0.08	1.79	
Study4	24.42	15.35	0.08	1.59	
Study5	10.92	14.75	0.03	0.74	
Study7	105.82	25.06	0.16	4.22**	
Step 3					0.00
VO_2%	0.03	0.13	0.01	0.26	

Incongruent MeanRT

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.03**
Age	-23.01	5.25	-0.16	-4.39**	
IQ	-10.61	4.41	-0.09	-2.41*	
Step 2					0.10**
Study1	15.99	42.30	0.01	0.38	
Study2	-52.19	10.47	-0.20	-4.98**	
Study3	50.94	19.03	0.12	2.68**	
Study4	8.00	16.83	0.02	0.48	
Study5	16.10	16.17	0.05	1.00	
Study7	156.41	27.47	0.21	5.69**	
Step 3					0.00
VO_2%	0.06	0.14	0.02	0.41	

Accuracy Interference

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.03**
Study1	5.38	2.74	0.07	1.96*	
Study2	-0.94	0.68	-0.06	-1.38	

MeanRT Interference

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.14*
Study1	25.98	14.68	0.06	1.77	
Study2	-19.54	3.65	-0.22	-5.36**	

Study3	3.26	1.07	0.12	3.04**		Study3	19.46	5.72	0.13	3.40**	
Study4	-2.07	0.88	-0.10	-2.34*		Study4	-16.91	4.73	-0.14	-3.57**	
Study5	-0.44	0.89	-0.02	-0.50		Study5	4.75	4.77	0.04	1.00	
Study7	1.63	1.75	0.04	0.93		Study7	50.32	9.35	0.19	5.38**	
Step 3					0.01*	**Step 3**					0.00
VO_2%	-0.02	0.01	-0.08	-2.16*		VO_2%	0.03	0.05	0.02	0.51	

Commission Errors

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.09**
Age	-0.023	0.003	-0.286	-7.72**	
SES	-0.005	0.003	-0.065	-1.75	
Step 2					0.04**
Study1	-0.023	0.024	-0.035	-0.97	
Study2	-0.022	0.006	-0.153	-3.75**	
Study3	-0.033	0.011	-0.136	-3.03**	
Study4	-0.029	0.010	-0.148	-3.00**	
Study5	-0.040	0.009	-0.204	-4.42**	
Study7	0.012	0.015	0.030	0.80	
Step 3					0.01**
VO_2%	0.000	0.000	-0.117	-3.11**	

Commission Error Runs

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.08**
Age	-0.005	0.001	-0.26	-7.06**	
SES	-0.001	0.001	-0.05	-1.37	
Step 2					0.01*
Study1	-0.006	0.006	-0.037	-1.01	
Study2	-0.006	0.002	-0.172	-4.15**	
Study3	-0.005	0.003	-0.074	-1.6	
Study4	-0.009	0.003	-0.168	-3.36**	
Study5	-0.006	0.002	-0.120	-2.57**	
Study7	0.002	0.004	0.022	0.58	
Step 3					0.01*
VO_2%	-0.00	0.00	-0.09	-2.36*	

Omission Errors

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.11**
Age	-0.023	0.003	-0.29	-7.88**	
SES	-0.007	0.003	-0.086	-2.27*	
IQ	-0.006	0.002	-0.086	-2.34	
Step 2					0.07**
Study1	0.12	0.024	0.19	5.33**	
Study2	-0.011	0.006	-0.077	-1.95	
Study3	-0.038	0.011	-0.15	-3.51**	
Study4	-0.010	0.010	-0.050	-1.04	
Study5	-0.036	0.009	-0.18	-3.95**	
Study7	-0.018	0.015	-0.043	-1.19	
Step 3					0.001
VO_2%	0.00	0.000	-0.041	-1.105	

Omission Error Runs

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.06*
Age	-0.004	0.001	-0.22	-5.70**	
SES	-0.001	0.001	-0.047	-1.20	
IQ	-0.001	0.001	-0.076	-2.02**	
Step 2					0.06*
Study1	0.028	0.005	0.190	5.19**	
Study2	-0.001	0.001	-0.042	-1.02	
Study3	-0.001	0.002	-0.017	-0.37	
Study4	0.000	0.002	-0.006	-0.11	
Study5	-0.006	0.002	-0.136	-2.91**	
Study7	-0.002	0.003	-0.019	-0.51	
Step 3					0.002
VO_2%	0.00	0.000	-0.047	-1.23	

Supplemental Table 3. Response Variability hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables and differences between studies.

Congruent Standard Deviation of Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.14*
Age	-20.75	2.29	-0.33	-9.06**	
Sex	-5.45	3.66	-0.05	-1.49	
SES	-2.08	2.37	-0.03	-0.88	
IQ	-9.18	1.91	-0.17	-4.80**	
Step 2					0.04**
Study1	-53.76	18.41	-0.10	-2.92**	
Study2	-24.93	4.56	-0.22	-5.46**	
Study3	-13.38	8.46	-0.07	-1.58	
Study4	-12.72	7.47	-0.08	-1.70	
Study5	-11.10	7.07	-0.07	-1.57	
Study7	3.22	11.94	0.01	0.27	
Step 3					0.01**
VO_2%	-0.19	0.06	-0.11	-3.06**	

Incongruent Standard Deviation of Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.17**
Age	-23.60	2.45	-0.34	-9.63**	
Sex	-9.67	3.92	-0.08	-2.47	
SES	-2.58	2.54	-0.04	-1.02	
IQ	-11.94	2.05	-0.21	-5.82**	
Step 2					0.04**
Study1	-48.80	19.81	-0.09	-2.46**	
Study2	-19.42	4.91	-0.16	-3.95**	
Study3	-2.67	9.10	-0.01	-0.29	
Study4	-21.13	8.04	-0.12	-2.63**	
Study5	-10.74	7.61	-0.06	-1.41	
Study7	19.65	12.85	0.05	1.53	
Step 3					0.01**
VO_2%	-0.20	0.07	-0.10	-2.89**	

Congruent Coefficient of Variation of Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.12*
Age	-0.03	0.00	-0.31	-8.33**	
SES	0.00	0.00	-0.03	-0.89	
IQ	-0.01	0.00	-0.15	-3.97**	
Step 2					0.05**
Study1	-0.09	0.03	-0.13	-3.67**	
Study2	-0.03	0.01	-0.19	-4.63**	
Study3	-0.04	0.01	-0.16	-3.68**	
Study4	-0.04	0.01	-0.17	-3.55**	
Study5	-0.03	0.01	-0.12	-2.70**	
Study7	-0.04	0.02	-0.09	-2.38*	
Step 3					0.02**
VO_2%	0.00	0.00	-0.15	-4.13**	

Incongruent Coefficient of Variation of Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.15
Age	-0.03	0.00	-0.33	-9.02**	
Sex	-0.01	0.01	-0.05	-1.44	
SES	0.00	0.00	-0.03	-0.93	
IQ	-0.02	0.00	-0.19	-5.26**	
Step 2					0.03*
Study1	-0.09	0.03	-0.11	-3.23**	
Study2	-0.01	0.01	-0.05	-1.17	
Study3	-0.03	0.01	-0.10	-2.28*	
Study4	-0.04	0.01	-0.18	-3.75**	
Study5	-0.03	0.01	-0.12	-2.59**	
Study7	-0.03	0.02	-0.06	-1.76	
Step 3					0.06**
VO_2%	0.00	0.00	-0.14	-3.72**	

Congruent mu

Incongruent mu

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.01*
Age	-9.20	4.09	-0.08	-2.25*	
Step 2					0.06**
Study1	52.99	33.71	0.06	1.57	
Study2	-14.27	8.37	-0.07	-1.71	
Study3	38.21	15.33	0.11	2.49*	
Study4	29.59	13.43	0.11	2.20*	
Study5	11.48	12.95	0.04	0.89	
Study7	121.14	21.89	0.21	5.53**	
Step 3					0.01**
VO_2%	0.26	0.11	0.09	2.24*	

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.09**
Study1	82.92	40.22	0.08	2.06*	
Study2	-59.47	10.02	-0.25	-5.94**	
Study3	19.18	15.68	0.05	1.22	
Study4	-28.34	12.96	-0.09	-2.19	
Study5	-21.34	13.07	-0.06	-1.63	
Study7	91.13	26.33	0.13	3.46**	
Step 3					0.00
VO_2%	0.22	0.14	0.06	1.57	

Congruent Sigma

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.07**
Age	-11.24	1.61	-0.26	-6.98**	
SES	0.38	1.63	0.01	0.23	
Step 2					0.04**
Study1	5.49	13.03	0.02	0.42	
Study2	-7.41	3.24	-0.10	-2.29*	
Study3	7.85	6.00	0.06	1.31	
Study4	-3.21	5.29	-0.03	-0.61	
Study5	-5.32	5.00	-0.05	-1.06	
Study7	31.76	8.46	0.14	3.75**	
Step 3					0.00
VO_2%	-0.02	0.04	-0.02	-0.49	

Incongruent Sigma

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.08**
Age	-14.77	2.01	-0.27	-7.34**	
Sex	-7.08	3.33	-0.08	-2.12*	
IQ	-2.78	1.69	-0.06	-1.64	
Step 2					0.05**
Study1	11.60	16.63	0.03	0.70	
Study2	-21.20	4.14	-0.21	-5.12**	
Study3	-2.89	7.53	-0.02	-0.38	
Study4	-19.50	6.63	-0.14	-2.94**	
Study5	-17.68	6.38	-0.13	-2.77**	
Study7	14.89	10.79	0.05	1.38	
Step 3					0.00
VO_2%	-0.10	0.06	-0.07	-1.72	

Congruent Tau

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.07**
Age	-15.15	2.67	-0.22	-5.68**	
Sex	-7.88	4.26	-0.07	-1.85	
SES	-8.12	2.26	-0.14	-3.60**	
IQ	-3.22	2.76	-0.05	-1.17	
Step 2					0.03**
Study1	-70.57	21.49	-0.12	-3.28**	

Incongruent Tau

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.06**
Age	-11.93	3.01	-0.15	-3.96**	
Sex	-14.55	4.81	-0.11	-3.02**	
SES	-9.05	2.54	-0.14	-3.57**	
IQ	-4.51	3.11	-0.06	-1.45	
Step 2					0.02*
Study1	-89.24	24.52	-0.14	-3.64**	

Study2	-19.03	5.35	-0.15	-3.55**		Study2	2.86	6.10	0.02	0.47	
Study3	-26.86	10.01	-0.12	-2.68**		Study3	0.99	11.27	0.00	0.09	
Study4	-6.76	8.73	-0.04	-0.77		Study4	5.22	9.95	0.03	0.52	
Study5	-7.19	8.26	-0.04	-0.87		Study5	8.90	9.42	0.05	0.95	
Study7	-18.54	13.95	-0.05	-1.33		Study7	11.12	15.91	0.03	0.70	
Step 3					0.02**	**Step 3**					0.01*
VO_2%	-0.29	0.07	-0.15	-3.90**		VO_2%	-0.21	0.08	-0.10	-2.44*	

Supplemental Table 4. Cognitive Strategy hierarchical regression analysis for the relationship between VO_2peak% after controlling for the variance associated with descriptive variables and differences between studies.

Bin 1 Congruent Accuracy

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.13**
Age	0.07	0.01	0.36	9.78**	
SES	-0.01	0.01	-0.03	-0.79	
IQ	0.02	0.01	0.12	3.18**	
Step 2					0.03**
Study1	-0.02	0.06	-0.01	-0.32	
Study2	0.00	0.02	-0.01	-0.12	
Study3	-0.01	0.03	-0.02	-0.51	
Study4	0.09	0.02	0.18	3.70**	
Study5	0.07	0.02	0.14	3.00**	
Study7	0.00	0.04	0.00	0.05	
Step 3					0.01**
VO_2%	0.00	0.00	0.10	2.61**	

Bin 1 Incongruent Accuracy

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.04**
Age	0.04	0.01	0.19	5.01**	
Step 2					0.07**
Study1	-0.20	0.07	-0.11	-3.06**	
Study2	0.05	0.02	0.12	2.86**	
Study3	-0.06	0.03	-0.09	-1.92	
Study4	0.10	0.03	0.19	3.80**	
Study5	0.05	0.03	0.10	2.05*	
Study7	-0.06	0.04	-0.05	-1.33	
Step 3					0.00
VO_2%	0.00	0.00	0.04	0.95	

Bin 2 Congruent Accuracy

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.09**
Age	0.04	0.01	0.28	7.53**	
SES	0.01	0.01	0.03	0.89	
IQ	0.01	0.00	0.08	2.25*	
Step 2					0.02*
Study1	0.01	0.05	0.00	0.13	
Study2	0.01	0.01	0.03	0.74	
Study3	0.01	0.02	0.03	0.68	

Bin 2 Incongruent Accuracy

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.08**
Age	0.06	0.01	0.28	7.61**	
SES	0.00	0.01	-0.01	-0.17	
IQ	0.02	0.01	0.10	2.74**	
Step 2					0.03**
Study1	-0.03	0.07	-0.01	-0.37	
Study2	0.02	0.02	0.06	1.37	
Study3	0.02	0.03	0.04	0.77	

Study4	0.06	0.02	0.15	2.96**		Study4	0.12	0.03	0.21	4.19**	
Study5	0.05	0.02	0.12	2.57**		Study5	0.08	0.03	0.15	3.12**	
Study7	0.00	0.03	0.00	-0.10		Study7	0.07	0.04	0.06	1.58	
Step 3					0.01*	**Step 3**					0.02**
VO_2%	0.00	0.00	0.08	2.17*		VO_2%	0.00	0.00	0.14	3.64**	
	Bin 3 Congruent Accuracy						**Bin 3 Incongruent Accuracy**				
	B	SE B	Beta	t	*Adj R^2*		B	SE B	Beta	t	*Adj R^2*
Step 1					0.08	**Step 1**					0.04*
Age	0.03	0.00	0.28	7.40**		Age	0.04	0.01	0.20	5.14**	
SES	0.00	0.00	0.02	0.54		SES	0.01	0.01	0.03	0.89	
Step 2					0.01	**Step 2**					0.02*
Study1	0.04	0.03	0.05	1.30		Study1	0.06	0.06	0.04	1.01	
Study2	0.00	0.01	0.01	0.17		Study2	0.00	0.01	0.00	-0.11	
Study3	0.00	0.01	0.01	0.29		Study3	-0.03	0.03	-0.06	-1.21	
Study4	0.02	0.01	0.06	1.28		Study4	0.04	0.02	0.10	1.94	
Study5	0.02	0.01	0.07	1.55		Study5	0.03	0.02	0.07	1.56	
Study7	0.01	0.02	0.02	0.54		Study7	0.01	0.04	0.01	0.15	
Step 3					0.01*	**Step 3**					0.01*
VO_2%	0.00	0.00	0.09	2.39*		VO_2%	0.00	0.00	0.09	2.34*	
	Bin 4 Congruent Accuracy						**Bin 4 Incongruent Accuracy**				
	B	SE B	Beta	t	*Adj R^2*		B	SE B	Beta	t	*Adj R^2*
Step 1					0.05**	**Step 1**					0.03**
Age	0.01	0.00	0.19	4.90**		Age	0.02	0.01	0.17	4.46**	
SES	0.01	0.00	0.07	1.85		IQ	0.01	0.00	0.10	2.64**	
IQ	0.01	0.00	0.08	2.16*							
Step 2					0.02	**Step 2**					0.02*
Study1	0.03	0.02	0.05	1.25		Study1	0.03	0.04	0.03	0.78	
Study2	0.00	0.01	0.01	0.35		Study2	-0.02	0.01	-0.07	-1.69	
Study3	-0.02	0.01	-0.09	-1.96		Study3	-0.05	0.02	-0.11	-2.41*	
Study4	0.00	0.01	0.02	0.33		Study4	0.01	0.02	0.04	0.83	
Study5	0.01	0.01	0.05	1.08		Study5	0.01	0.02	0.02	0.35	
Study7	0.00	0.02	0.00	-0.05		Study7	0.00	0.03	0.01	0.15	
Step 3					0.00	**Step 3**					0.01*
VO_2%	0.00	0.00	0.01	0.25		VO_2%	0.00	0.00	0.10	2.55*	
	Bin 5 Congruent Accuracy						**Bin 5 Incongruent Accuracy**				
	B	SE B	Beta	t	*Adj R^2*		B	SE B	Beta	t	*Adj R^2*

Step 1					0.01*
SES	0.01	0.00	0.08	2.07*	
Step 2					0.03**
Study1	0.03	0.03	0.04	1.04	
Study2	0.02	0.01	0.14	3.20**	
Study3	0.01	0.01	0.02	0.43	
Study4	0.01	0.01	0.03	0.79	
Study5	-0.02	0.01	-0.07	-1.78	
Study7	0.00	0.02	0.01	0.23	
Step 3					0.00
VO_2%	0.00	0.00	0.03	0.86	

Bin 1 Congruent Reaction Time

Step 1					0.01*
IQ	0.01	0.00	0.09	2.51*	
Step 2					0.02*
Study1	-0.04	0.04	-0.04	-0.98	
Study2	0.02	0.01	0.07	1.59	
Study3	-0.02	0.02	-0.06	-1.56	
Study4	0.03	0.01	0.08	1.96	
Study5	-0.02	0.01	-0.05	-1.17	
Study7	0.00	0.03	0.00	0.05	
Step 3					0.00
VO_2%	0.00	0.00	0.05	1.19	

Bin 1 Incongruent Reaction Time

	B	SE B	Beta	t	*Adj* R^2
Step 1					
Step 2					0.04**
Study1	15.22	27.20	0.02	0.56	
Study2	-7.51	6.76	-0.05	-1.11	
Study3	17.66	10.60	0.07	1.67	
Study4	28.61	8.77	0.13	3.26**	
Study5	17.98	8.84	0.08	2.03*	
Study7	72.04	17.34	0.16	4.16**	
Step 3					0.01*
VO_2%	0.21	0.09	0.09	2.24*	

Bin 2 Congruent Reaction Time

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.01**
Age	11.26	3.78	0.11	2.98**	
Step 2					0.08*
Study1	22.28	30.82	0.03	0.72	
Study2	-17.60	7.62	-0.10	-2.31*	
Study3	44.37	13.86	0.14	3.20**	
Study4	47.70	12.26	0.19	3.89**	
Study5	42.92	11.78	0.17	3.64**	
Study7	106.73	20.01	0.20	5.33**	
Step 3					0.01*
VO_2%	0.23	0.10	0.08	2.18*	

Bin 2 Incongruent Reaction Time

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.03**
Study1	-9.25	34.11	-0.01	-0.27	
Study2	-20.64	8.47	-0.10	-2.44*	
Study3	5.14	13.30	0.02	0.39	
Study4	5.90	11.00	0.02	0.54	
Study5	-4.70	11.09	-0.02	-0.42	
Study7	82.20	21.74	0.14	3.78**	
Step 3					0.00
VO_2%	0.18	0.12	0.06	1.58	

Bin 3 Congruent Reaction Time

	B	SE B	Beta	t	*Adj* R^2
Step 1					0.7**
Study1	16.76	38.82	0.02	0.43	
Study2	-39.41	9.64	-0.17	-4.09**	
Study3	26.55	15.13	0.07	1.75	
Study4	1.39	12.51	0.00	0.11	
Study5	5.75	12.62	0.02	0.46	
Study7	121.02	24.74	0.18	4.89**	
Step 3					0.00
VO_2%	0.21	0.13	0.06	1.60	

Bin 3 Incongruent Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.02**
Age	-17.81	4.64	-0.14	-3.84**	
Step 2					0.05**
Study1	-8.49	38.51	-0.01	-0.22	
Study2	-24.82	9.53	-0.11	-2.60**	
Study3	35.34	17.32	0.09	2.04	
Study4	27.41	15.32	0.09	1.79	
Study5	14.12	14.72	0.05	0.96	
Study7	105.99	25.01	0.16	4.24**	
Step 3					0.00
VO_2%	0.09	0.13	0.03	0.72	

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.01*
Age	-12.87	5.29	-0.09	-2.438*	
Step 2					0.09**
Study1	31.57	43.02	0.03	0.73	
Study2	-45.09	10.64	-0.18	-4.24**	
Study3	57.06	19.35	0.13	2.95**	
Study4	15.26	17.11	0.04	0.89	
Study5	20.21	16.45	0.06	1.23	
Study7	145.24	27.93	0.20	5.20**	
Step 3					0.00
VO_2%	0.08	0.15	0.02	0.53	

Bin 4 Congruent Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.05**
Age	-30.35	5.39	-0.21	-5.63**	
IQ	-14.06	4.53	-0.11	-3.10**	
Step 2					0.05**
Study1	-16.97	44.66	-0.01	-0.38	
Study2	-37.30	11.06	-0.14	-3.37**	
Study3	40.34	20.09	0.09	2.01	
Study4	28.06	17.77	0.08	1.58	
Study5	11.59	17.07	0.03	0.68	
Study7	116.81	29.01	0.15	4.03**	
Step 3					0.00
VO_2%	0.01	0.15	0.00	0.05	

Bin 4 Incongruent Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.04**
Age	-27.80	6.02	-0.17	-4.62**	
Sex	-16.96	9.94	-0.06	-1.71	
IQ	-14.24	5.05	-0.10	-2.82**	
Step 2					0.08**
Study1	16.47	49.04	0.01	0.34	
Study2	-50.30	12.15	-0.17	-4.14**	
Study3	58.24	22.04	0.12	2.64**	
Study4	10.22	19.52	0.03	0.52	
Study5	16.64	18.77	0.04	0.89	
Study7	166.60	31.81	0.20	5.24**	
Step 3					0.00
VO_2%	0.00	0.17	0.00	0.00	

Bin 5 Congruent Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					0.07**
Age	-49.02	8.05	-0.23	-6.09**	
SES	-5.27	8.34	-0.02	-0.63	
IQ	-24.89	6.73	-0.14	-3.70**	
Step 2					0.06**
Study1	-97.74	64.42	-0.06	-1.52	

Bin 5 Incongruent Reaction Time

	B	SE B	Beta	t	*Adj R^2*
Step 1					*0.07***
Age	-47.37	8.74	-0.20	-5.42**	
Sex	-27.87	13.96	-0.07	-2.00*	
SES	-7.67	9.04	-0.03	-0.85	
IQ	-28.24	7.30	-0.15	-3.87**	
Step 2					0.07**
Study1	-58.06	69.20	-0.03	-0.84	

Study2	-73.44	15.97	-0.19	-4.60**		Study2	-75.01	17.16	-0.18	-4.37**	
Study3	13.50	29.62	0.02	0.46		Study3	58.78	31.79	0.08	1.85	
Study4	17.56	26.13	0.03	0.67		Study4	2.97	28.08	0.01	0.11	
Study5	35.88	24.70	0.07	1.45		Study5	52.22	26.57	0.09	1.976*	
Study7	110.62	41.85	0.10	2.64**		Study7	189.48	44.90	0.16	4.22**	
Step 3					0.00	**Step 3**					0.00
VO_2%	-0.24	0.22	-0.04	-1.10		VO_2%	-0.20	0.24	-0.03	-0.82	

Congruent Drift Rate

Incongruent Drift Rate

	B	SE B	Beta	t	*Adj R^2*		B	SE B	Beta	t	*Adj R^2*
Step 1					0.23**	**Step 1**					0.2**
Age	0.05	0.00	0.44	12.83**		Age	0.04	0.00	0.40	11.45**	
SES	0.01	0.00	0.06	1.65		SES	0.00	0.00	0.05	1.26	
IQ	0.01	0.00	0.15	4.42**		IQ	0.01	0.00	0.17	4.88**	
Step 2					0.03**	**Step 2**					0.06**
Study1	-0.02	0.03	-0.02	-0.65		Study1	-0.05	0.03	-0.06	-1.84	
Study2	0.01	0.01	0.07	1.73		Study2	0.01	0.01	0.05	1.25	
Study3	0.00	0.01	0.01	0.29		Study3	-0.03	0.01	-0.09	-2.173*	
Study4	0.04	0.01	0.15	3.38**		Study4	0.04	0.01	0.19	4.04**	
Study5	0.05	0.01	0.20	4.72**		Study5	0.04	0.01	0.17	3.97**	
Study7	0.02	0.02	0.03	0.79		Study7	0.00	0.02	-0.01	-0.24	
Step 3					0.01**	**Step 3**					0.01**
VO_2%	0.00	0.00	0.12	3.40**		VO_2%	0.00	0.00	0.12	3.57**	

Congruent Boundary Separation

Incongruent Boundary Separation

	B	SE B	Beta	t	*Adj R^2*		B	SE B	Beta	t	*Adj R^2*
Step 1						**Step 1**					0.04**
						Age	0.00	0.00	-0.15	-3.85**	
						Sex	0.00	0.00	-0.10	-2.59**	
						SES	0.00	0.00	-0.02	-0.45	
						IQ	0.00	0.00	-0.12	-3.10**	
Step 2					0.08**	**Step 2**					0.05**
Study1	-0.03	0.01	-0.13	-3.56**		Study1	-0.02	0.01	-0.13	-3.38**	
Study2	-0.01	0.00	-0.19	-4.51**		Study2	-0.01	0.00	-0.16	-3.75**	
Study3	-0.01	0.00	-0.12	-3.07**		Study3	0.00	0.00	-0.07	-1.51	
Study4	0.00	0.00	0.02	0.40		Study4	0.00	0.00	-0.02	-0.49	
Study5	0.01	0.00	0.11	2.74**		Study5	0.00	0.00	0.04	0.84	
Study7	0.01	0.00	0.06	1.56		Study7	0.00	0.00	0.04	1.09	

Step 3					0.00	**Step 3**					0.00
VO_2%	0.00	0.00	-0.02	-0.46		VO_2%	0.00	0.00	-0.04	-1.00	
	Congruent Nondecision Time						**Incongruent Nondecision Time**				
	B	SE B	Beta	t	*Adj* R^2		B	SE B	Beta	t	*Adj* R^2
Step 1					0.03**	**Step 1**					0.09
Study1	0.04	0.03	0.06	1.49		Study1	0.07	0.03	0.08	2.17**	
Study2	0.00	0.01	-0.02	-0.43		Study2	-0.03	0.01	-0.16	-3.75**	
Study3	0.02	0.01	0.06	1.47		Study3	0.03	0.01	0.08	2.076*	
Study4	0.01	0.01	0.04	1.10		Study4	0.01	0.01	0.04	0.97	
Study5	-0.01	0.01	-0.03	-0.83		Study5	0.01	0.01	0.03	0.69	
Study7	0.08	0.02	0.17	4.45**		Study7	0.12	0.02	0.21	5.695**	
Step 3					0.01*	**Step 3**					0.01*
VO_2%	0.00	0.00	0.09	2.27*		VO_2%	0.00	0.00	0.09	2.38*	