

## Running Head: EXERCISE AND ANTICIPATION TIMING

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Effects of exercise intensity on anticipation timing performance during a cycling task at moderate and vigorous intensities in children aged 7-11 years.

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## Abstract

This study examined coincidence anticipation timing performance at moderate and fast stimulus speeds before, during, and after a 15 min cycling task. In a within-subject design, 24 children (18 males and 6 females) exercised on a cycle ergometer under two experimental conditions: exercise intensities of 50% (moderate) and 75% (vigorous) heart rate reserve. Coincidence anticipation timing was measured using the Bassin Anticipation Timer at stimulus speeds of 5 and 8 mph. A 2 (intensity) x 3 (time) repeated measures ANOVA was conducted to evaluate the effect of exercise intensity on coincidence anticipation performance before, during, and immediately after the cycling task. Results indicated that for absolute error there was no significant main effect for time ( $p = .633$ ) or experimental condition ( $p = .782$ ) at the 5 mph stimulus speed. However, there was a significant interaction effect between experimental condition and time ( $p = 0.026$ ) at the 5 mph stimulus speed. At the 8 mph stimulus speed, there was no significant main effect for time ( $p = .910$ ) or condition ( $p = .938$ ), or interaction effect between experimental condition and time ( $p = .591$ ). Cycling exercise at moderate intensity appears to influence anticipation timing performance during and immediately after exercise in children, but only when stimulus speeds are moderate in nature.

*Keywords:* Cognitive performance, aerobic exercise, paediatric populations, cycling performance

50 Effects of exercise intensity on anticipation timing performance during a cycling task at  
51 moderate and vigorous intensities in children aged 7-11 years.

52 Coincidence anticipation timing (CAT) is the capacity to anticipate the approach of a  
53 moving object at a specific mark in space and synchronise a movement response with that  
54 arrival (Fleury & Bard, 1985). It is imperative to a number of movements within sports  
55 performance, such as catching a ball or object, striking a moving object, and intercepting the  
56 actions of opposing players (Duncan, Smith, & Lyons, 2013). Consequently, CAT is essential  
57 in externally paced sports that demand uncertainty. CAT tasks require the precise completion  
58 of a number of stages, including a sensory phase, whereby, sensory information is employed  
59 to identify, correct, and guide motor actions (Goodgold-Evans, 1991); a sensory-motor  
60 integration phase in which the time and position of the approaching stimulus and the motor  
61 response are decided, and finally the execution or motor phase (Fleury & Bard, 1985).

62 Studies exploring the effects of exercise intensity on CAT performance have been  
63 ambiguous. Lyons, Al-Nakeeb, and Nevill (2008) examined the effects of moderate- and  
64 high-intensity (70% and 90% heart rate reserve; HRR) exercise on CAT performance in  
65 expert and novice Gaelic games players. Participants completed 20 CAT trials post exercise  
66 at moderate stimulus speeds (5 mph). A collection of analyses indicated that exercise  
67 intensity had no effect on CAT performance. However, moderate-intensity exercise did lead  
68 to improved CAT performance in the novice players only. Similar studies have also reported  
69 small or no effects of varying exercise intensities on CAT performance (Bard & Fleury,  
70 1978; Isaacs & Pohlman, 1991). Recently, however, Duncan et al. (2013) explored CAT  
71 performance during moderate- and high-intensity exercise. Participants completed 10 CAT  
72 trials at stimulus speeds of 3, 5, and 8 mph during an incremental running task. Results  
73 indicated that high-intensity exercise was associated with poorer CAT performances, with  
74 faster stimulus speeds associated with larger decrements in CAT performance. Given the

75 scarce number of studies that have explored the effects of different exercise intensities on  
76 coincidence anticipation performance, additional research is required to provide a more  
77 complete understanding of exercise intensity and CAT performance (Lyons et al., 2008).

78         A critical element underpinning the observed equivocal findings may be the timing of  
79 the performance task. In some studies (Al-Nakeeb & Lyons, 2007, Duncan et al., 2013, &  
80 Issacs & Pohlman, 1991), CAT performance and exercise were performed concurrently,  
81 whereas in others (Lyons et al., 2008) performance was assessed post-exercise. During  
82 exercise, a reduction in acetylcholine, potassium, adenosine triphosphate, phosphocreatine,  
83 and increases in muscle lactate will impede motor control; however, such biochemicals are  
84 rapidly replenished, and will quickly return to basal values (Davranche & Audiffren, 2004).  
85 As such, the timing of the CAT performance task may represent a pivotal element. Exploring  
86 performance during exercise once a steady state has been achieved has been recommended as  
87 a preferred method (Lyons et al., 2008). This suggestion is also congruent with broader  
88 research examining the effect of exercise on cognitive performance generally, where different  
89 effects are reported if cognitive performance is assessed during or immediately following  
90 exercise (Lambourne & Tomporowski, 2010).

91         Stimulus speed may also explain such discordant findings in the CAT literature.  
92 Although research has emphasised that stimulus speed should be a crucial consideration when  
93 exploring the effect of exercise on CAT performance (Fleury & Bard, 1985), some studies  
94 have utilised a single stimulus speed (Lyons et al., 2008). It has been shown that stimulus  
95 speed influences CAT performance (Duncan et al., 2013; Sanders, 2011); therefore, both the  
96 timing of performance task and stimulus speed requires careful consideration when  
97 conducting research of this nature.

98         Notably, the extant literature to date has only examined adult participants. This is  
99 despite the acquisition of CAT being critical to a number of perceptual-cognitive-motor tasks

100 during childhood such as catching and striking (Duncan et al., 2013). Coincidence  
101 anticipation skills also underpin the performance of some of the fundamental movement skills  
102 that are acquired in childhood and needed for participation in physical activity particularly  
103 those involving object control. Narrative and quantitative reviews have suggested that school  
104 age children may derive cognitive benefits from chronic physical activity participation as  
105 well as single, acute bouts of exercise (Hillman, Erickson, & Kramer, 2008; Sibley & Etnier,  
106 2003; Tomporowski, 2003). The data demonstrating acute effects of exercise on cognitive  
107 performance in adolescents is growing, and suggestive of a beneficial effect (Cooper, et al.,  
108 2016; Hillman, et al., 2008), yet data pertaining to the effect of exercise, and exercise  
109 intensity specifically on cognitive performance in children remain under examined. Research  
110 by Duncan and Johnson (2014) has reported that moderate but not vigorous intensity cycling  
111 improved reading, and that moderate and vigorous intensity cycling enhanced spelling  
112 performance but impaired arithmetic. They suggested that exercise selectively benefits  
113 cognition in children but further research was needed examining different tasks other than  
114 academic performance. To date, no study has examined the effect of an acute bout of exercise  
115 on CAT performance in children; thus, the extension of the findings within the adult  
116 populations to children is speculative. However, given the observed physical activity  
117 benefits, an acute exercise effect on CAT performance may be likely.

118         Although no research has explored the effect of exercise on CAT performance in  
119 children, some studies have used a prediction motion paradigm to investigate coincidence-  
120 timing, at rest, in children (e.g., Benguigui, Broderick, Baurès, & Amorim, 2008; Benguigui,  
121 Broderick, & Ripoll, 2004; Keshavarz, Landwehr, Baurès, Oberfeld, Hecht, & Benguigui,  
122 2010). Within this task, participants are presented with a moving object that is occluded  
123 before reaching the participant or a specified position. The participant is instructed to deliver  
124 a response (e.g., press a button) that will coincide momentarily with the moving objects



149           Following approval from a university ethics committee, parental informed consent  
150 and child consent, legal guardians completed a healthy history questionnaire, reporting that  
151 their child was free of neurological disease, cognitive impairment, attentional disorders, and  
152 physical disabilities. Children were not given any inducement to participate. Descriptive data  
153 for the sample are presented in Table 1.

#### 154 **Protocol**

155           The study used a repeated-measures design whereby participants undertook two visits  
156 to the laboratory. All visits occurred at the same time of day. In the first session, participants  
157 had their height (cm) and body mass (kg) assessed using a Stadiometre and weighing scales  
158 (Seca Instruments, Frankfurt, Germany) and were fitted with a heart rate monitor (Polar  
159 RS400, Polar Electro Oy, Kempele, Finland). Resting heart rate (HR) was recorded for 5  
160 minutes in a supine position. Recognising that the traditional 220-age equation to estimate  
161 HRmax overestimates exercise HR, HRmax was estimated using the Tanaka, Monahan, and  
162 Seals (2001) equation as this more effectively accounts for age related changes in HRmax  
163 and has been recommended for us by prior studies (Robergs & Landwehr, 2002). Exercise  
164 intensities of 50% (moderate) and 75% (vigorous) of maximal HRR (Karvonen & Vuorimaa,  
165 1988) were then calculated, and used in the subsequent experimental trials. In the present  
166 study, HRR values of 50% and 75% were employed as threshold values to denote moderate  
167 and vigorous physical activity, respectively. A HRR value of 50% compares to a brisk walk  
168 (Ridgers, Stratton, Clark, Fairclough, & Richardson, 2006), whereas a HRR value of 75%  
169 compares to a measure of vigorous physical activity, as this intensity may increase  
170 cardiorespiratory fitness in children (Praikh & Stratton, 2011). Both also represent  
171 recommended intensities of physical activity for health benefits in children (Ridgers et al.,  
172 2006).

173 Participants then completed two experimental conditions: moderate intensity and  
174 vigorous intensity exercise (one condition per day/visit). Conditions were counterbalanced  
175 and separated by at least 24 hours. The experimental sessions consisted of 15 minutes of  
176 aerobic exercise on a cycle ergometer (Corvial Pediatric, Lode B.V., Netherlands) at 50% and  
177 75% of maximal HRR for moderate and vigorous conditions, respectively. This duration was  
178 chosen as it ensures the exercise is at steady state. Also, meta regression analysis by  
179 Lambourne and Tomporowski (2010) suggested that exercise durations of less than 10  
180 minutes may result in negative effects on cognition due to dual task interference, common at  
181 the onset of exercise, which may not be truly representative of the effects of exercise on  
182 cognition. The 15-minute duration employed ensures that metabolic demands of exercise,  
183 which may influence cognitive performance, as suggested by Dietrich's (2003)  
184 hyperfrontality hypothesis are accounted for. Heart rate was monitored during all  
185 experimental trials. Cycling resistance was modified throughout to ensure that HRR remained  
186 at the correct intensity, as has been the case in similar studies (e.g., Duncan & Johnson,  
187 2014).

188 Participants completed measures of CAT immediately before, during: at 7 minutes 30  
189 seconds, and immediately following both experimental cycling tasks. Participants performed  
190 five trials on the CAT task at stimulus speeds of 5 and 8 mph. The rationale for the choice of  
191 stimulus speeds was based on prior work, which had determined a stimulus speed of 5 mph as  
192 'intermediate' (Duncan et al., 2013; Lyons et al., 2008). In order to explore the effect of  
193 varying stimulus speed, the stimulus speed of 8 mph was selected to represent a 'fast' speed,  
194 similar to previous work (Lobjois, Benguigui, & Bertsch, 2006). Presentation of stimulus  
195 speeds was counterbalanced.

196 The Basin Anticipation Timer (Model 35575, Lafayette, USA) was positioned  
197 vertically in front of the cycle ergometer. This enabled participants to complete the CAT trial



198 during the experimental cycling tasks (at 7 minutes 30 seconds) whilst cycling. Participants  
199 completed the CAT trials immediately before and after the experimental cycling tasks whilst  
200 stationary on the cycle ergometer. Prior to each experimental trial, each participant was  
201 familiarised with the Basin Anticipation timer and had five practice attempts at the stimulus  
202 speed used in the present study. Three sections of runway (2.24 m) were mounted onto the  
203 cycle ergometer. The sequentially lighted LED lamps, which were facing the participant,  
204 illuminated in a linear pattern with movement occurring from top to bottom, with light  
205 number 13 as the target. For each trial, scores were recorded in milliseconds (ms) and  
206 whether the response was early or late. The start and end speeds remained constant at 5 and 8  
207 miles h<sup>-1</sup> for all trials. To reduce the likelihood that the participant could internally time the  
208 trial, cue delay (visual warning system) was set as random on the timer with a minimum  
209 delay of one second and a maximum delay of 2 seconds (Duncan et al., 2013). For each trial,  
210 the signal was initiated by the experimenter. The participant was asked to press a trigger  
211 button, with their dominant hand, as close to the arrival time of the stimulus at the target  
212 location as possible. This is congruent with other research which has examined CAT during  
213 exercise (Duncan et al., 2013; Duncan et al., 2015).

214 Each participant's raw scores across each of the stimulus speeds were summarised  
215 into three error scores as a way of generating the dependent variables. This is consistent with  
216 previous recognised protocols using CAT (Duncan et al., 2013; Duncan et al., 2015; Isaacs &  
217 Pohlman, 1991; Lyons et al., 2008; Sanders, 2011). First, *constant error* represents the  
218 temporal interval (milliseconds) between the arrival of the visual stimulus and the end of the  
219 participant's motor response. It signifies the mean response of the participant and the  
220 direction of error (i.e., early or late). Second, *variable error* was the participant's standard  
221 deviation from their mean response, and symbolises the variability/inconsistency of responses  
222 (Lyons et al., 2008). However, as variable error signifies the standard deviation from the

223 mean, the data are positively skewed (all the values are positive). Therefore, the data set were  
224 log transformed as log-transforming data in this way has been shown to overcome skewness  
225 in previous work (Lyons et al., 2008). Third, *absolute error* was the value of each raw score  
226 discounting whether the response was early or late. Absolute error provides the best depiction  
227 of both the individual and combined effects of task characteristics as a whole (Sanders,  
228 2011), and therefore represents the most popular reported CAT outcome variable within the  
229 literature (Lyons et al., 2008; Sanders, 2011). Similar to variable error, the data for absolute  
230 error were skewed, therefore the data was log transformed akin to previous research (Lyons  
231 et al., 2008).

### 232 **Data Analysis**

233 To evaluate the effects of exercise intensity on CAT performance before, during, and  
234 immediately after the cycling task, a 2 (intensity) x 3 (time) repeated measures Analysis of  
235 Variance (ANOVA) was employed. Where significant differences were found, LSD post hoc  
236 pairwise comparisons were used to determine where the differences lay. Estimates of epsilon  
237 were used to test the assumption of sphericity. Epsilon estimate values were all close to 1,  
238 therefore, sphericity was not violated. The generalised eta squared statistic ( $\eta^2$ ), a measure  
239 of effect size, was reported to allow comparisons with other studies. In addition, the omega-  
240 squared ( $\omega^2$ ) statistic, a measure of effect size, was presented to provide an indication of the  
241 variance explained by the condition. The Statistical Package for Social Sciences (SPSS,  
242 Version 24, Chicago, IL, USA) was used for all analysis and statistical significance was set, a  
243 priori, at  $p = 0.05$ .

### 244 **Results**

245 Mean [95% CI] of constant error, variable error, and absolute error (secs) at stimulus  
246 speeds of 5 and 8 mph before, at 7 minutes 30 seconds during, and immediately after the  
247 cycling task at 50% and 75% HRR are presented in Table 2. Results revealed that for

248 constant error there was no significant main effect for time  $F(2,45) = 0.021, p = 0.979, \eta G^2 =$   
 249  $0.881, \omega^2 = 1.754$ ) or experimental condition ( $F(1,23) = 0.121, p = 0.731, \eta G^2 = 0.000, \omega^2 = -$   
 250  $0.001$ ), or interaction effect between experimental condition and time ( $F(2,46) = 1.100, p =$   
 251  $0.342, \eta G^2 = 0.003, \omega^2 = 0.002$ .) at the 5mph stimulus speed (Figure 1). At the 8 mph  
 252 stimulus speed, the results revealed that there was no significant main effect for time  $F(2,46)$   
 253  $= 1.081, p = 0.348, \eta G^2 = 0.005, \omega^2 = 0.003$ ) or experimental condition ( $F(1,23) = 1.372, p =$   
 254  $0.253, \eta G^2 = 0.005, \omega^2 = 0.002$ ), or interaction effect between experimental condition and  
 255 time ( $F(2,46) = 0.158, p = 0.854, \eta G^2 = 0.002, \omega^2 = -0.003$ ).

256 Results revealed that for variable error there was a significant main effect for time,  
 257 but the time main effect explained only a limited proportion of the variance  $F(2,46) = 4.021,$   
 258  $p = 0.025, \eta G^2 = 0.057, \omega^2 = 0.097$ ). The LSD post hoc pairwise comparison indicated that  
 259 variable error was significantly lower prior to exercise compared to during the cycling task at  
 260 the 5mph stimulus speed ( $p = 0.032$ ). However, there was no significant main effect for  
 261 experimental condition ( $F(1,23) = 0.616, p = 0.440, \eta G^2 = 0.008, \omega^2 = -0.005$ ), or interaction  
 262 effect between experimental condition and time ( $F(2,46) = 1.615, p = 0.210, \eta G^2 = 0.015, \omega^2$   
 263  $= 0.009$ ) at the 5mph stimulus speed (Figure 2). At the 8 mph stimulus speed, the results  
 264 revealed that there was no significant main effect for time  $F(2,46) = 1.717, p = 0.191, \eta G^2 =$   
 265  $0.043, \omega^2 = 0.060$ ) or experimental condition ( $F(1,23) = 0.554, p = 0.464, \eta G^2 = 0.011, \omega^2 = -$   
 266  $0.007$ ), or interaction effect between experimental condition and time ( $F(2,46) = 0.460, p =$   
 267  $0.634, \eta G^2 = 0.012, \omega^2 = -0.005$ ).

268 Results revealed that for absolute error there was no significant main effect for time  
 269 ( $F(2,46) = 0.461, p = 0.633, \eta G^2 = 0.003, \omega^2 = -0.001$ ) or experimental condition ( $F(1,23) =$   
 270  $0.079, p = 0.782, \eta G^2 = 0.001, \omega^2 = -0.009$ ) at the 5 mph stimulus speed. However, there was  
 271 a significant interaction effect between experimental condition and time, but only a limited  
 272 proportion of the variance was explained by the interaction effect ( $F(2,46) = 3.967, p =$

273 0.026,  $\eta G^2 = 0.030$ ,  $\omega^2 = 0.026$ ), at the 5 mph stimulus speed (Figure 3). The LSD post hoc  
274 pairwise comparison indicated that a higher absolute error during the cycling task at vigorous  
275 intensity exercise (75% HRR) compared to moderate intensity exercise (50% HRR) appeared  
276 to be driving the differences ( $p = 0.065$ ). At the 8 mph stimulus speed, the results revealed  
277 that there was no significant main effect for time  $F(2,46) = 0.094$ ,  $p = 0.910$ ,  $\eta G^2 = 0.001$ ,  $\omega^2$   
278  $= -0.010$ ) or experimental condition ( $F(1,23) = 0.006$ ,  $p = 0.938$ ,  $\eta G^2 = 0.000$ ,  $\omega^2 = -0.007$ ),  
279 or interaction effect between experimental condition and time ( $F(2,46) = 0.531$ ,  $p = 0.591$ ,  
280  $\eta G^2 = 0.005$ ,  $\omega^2 = 0.000$ ).

281 Three, 2 (intensity) x 2 (speed) x 3 (time) repeated measures ANOVA's were also  
282 conducted to investigate the effects of exercise intensity on CAT performance before, during,  
283 and immediately after the cycling task for constant error, variable error, and absolute error.  
284 However, no differences were evident (all  $p > 0.05$ ).

### 285 Discussion

286 This is the first study to examine the effect of exercise intensity on CAT performance  
287 in children. The results suggest that 15 minutes cycling based exercise does influence CAT  
288 performance in children aged 7-11 years. For absolute error, the speed of stimulus also  
289 appeared to influence CAT performance. At moderate intensity cycling exercise, CAT  
290 performance was improved during and immediately after exercise compared to rest.  
291 However, during vigorous intensity cycling exercise, CAT performance was reduced (i.e.,  
292 error scores were larger) during and immediately after exercise compared to rest. These  
293 findings were only found when the stimulus speed was moderate in nature (i.e., 5 mph).  
294 Furthermore, the results suggest that we failed to reject the null hypothesis, which indicates  
295 that no changes in CAT performance as a consequence of exercise intensity were observed  
296 when the stimulus speed was considered fast (i.e. 8 mph).

297           Given the paucity of research examining the effect of exercise intensity on  
298 anticipation timing in children it is difficult to draw direct comparisons to previously  
299 published work. However, the findings of the current work do align with prior studies using  
300 an adult population by Lyons et al. (2008), Duncan, et al. (2013) and Isaacs and Pohlman  
301 (1991). These aforementioned studies all documented improved CAT performance either  
302 during (Duncan et al., 2013) or following (Lyons et al., 2008; Isaacs and Pohlman, 1991)  
303 moderate intensity exercise. It has been suggested that exercise intensity that is moderate in  
304 nature may elicit optimal levels of CNS arousal (Chmura, Nazar, & Kaciuba-Uścilko, 1994;  
305 McMorris & Graydon, 2000) which, among other performance indicators, improves reaction  
306 time. Åstrand, Rodahl, Dahl, and Strømme. (2003) further add that moderate intensity  
307 exercise is beneficial to performance due to increased blood flow to the brain, warming up of  
308 the musculature, and increased speed of nerve transmission within the PNS. Such an  
309 explanation may apply in the current study as the 50% HRR condition may have led to an  
310 increase in general activation, which subsequently enhanced CAT performance. Conversely,  
311 it is possible that the increased dual demand of responding to the timing task and continuing  
312 to cycle during the vigorous intensity condition resulted in the children being unable to  
313 satisfactorily meet both demands with error scores being larger. In the current study the  
314 cycling cadence needed to be maintained at each intensity, thus, when intensity was higher  
315 (e.g., more difficult task demand), and resource availability cannot meet resource demands,  
316 performance on the second task may be likely to decline (Beurskens & Bock, 2012).

317 Although this has previously not been documented in children, in some ways this suggestion  
318 is not surprising. This is because an increase in dual task-costs occurs mainly in tasks  
319 requiring visual processing on information (as in the CAT task), and errors tend to be higher  
320 when task difficulty is greater when managing two tasks (as when cycling at vigorous  
321 intensity and attending to the CAT task; Menant, Sturnieks, Brodie, Smith, & Lord, 2014).

322 These suggestions are, however, speculative as assessment of CNS arousal or blood flow to  
323 the brain is difficult to assess in children during exercise.

324 The magnitude of differences (drawn from the inferential statistics), seen between  
325 exercise intensities in the present study also needs to be contextualised. The differences found  
326 in the present study are similar to those reported by Lyons et al. (2008) and Duncan et al.  
327 (2013) in adults. They are also commensurate with durations reported for timing of catching  
328 (or not catching) actions when stimuli are sighted (Savelsbergh & van der Kamp, 2000) and  
329 as such, the differences reported here may be considered as meaningful in the context of  
330 CAT.

331 Despite this, any differences in timing error were only evident when stimulus speed  
332 was 5 mph. When stimulus speed was 8 mph, there was no significant effect of exercise  
333 intensity on CAT timing performance. The rationale for the choice of stimulus speeds was  
334 based on prior work in adults which has determined a stimulus speed of 5 mph as  
335 ‘intermediate’ (Lyons et al., 2008; Duncan et al., 2013) and 8 mph as ‘fast’ (Lobjois et al.,  
336 2006). The optimal stimulus speed to assess coincidence anticipation timing is not known  
337 (Sanders, 2011) and it may be that the fast stimulus speed used in the current study was not  
338 sensitive enough for children to accurately respond too. Future work documenting ‘typical’  
339 anticipation timing stimulus speeds in children would therefore be welcome, and would  
340 provide a robust guide as to which stimulus speeds may be more sensitive when assessing  
341 CAT in paediatric populations.

342 It is also important to note that the exercise intensities selected in the current study of  
343 50% HRR and 75% HRR were chosen to reflect recognised thresholds for moderate and  
344 vigorous physical activity in children (Parikh & Stratton, 2011). These exercise intensities  
345 reflect thresholds related to health benefits in governmental guidelines for children’s physical

346 activity. As a consequence, the protocol employed in the current study sought to examine  
347 exercise intensities that were ecologically valid.

348         Moreover, the results suggest that for variable error, there was a greater variability in  
349 CAT responses during and immediately post the cycling task, compared to just before  
350 exercise, irrespective of intensity of exercise. It seems that the anticipation scores were  
351 somewhat ‘noisier’ especially during the cycling task. This may be due to an increase in dual-  
352 tasks costs, which arises when individuals are required to manage two branches of similar  
353 (e.g., visual) information (i.e., when cycling and attending to the CAT task in the present  
354 study), compared to when managing two tasks requiring different types of processing (e.g.,  
355 one visual and one auditory; Duncan et al., 2015; Menant et al., 2014). Furthermore, the  
356 increased physiological requirements of the 15-minute cycling task, coupled with the  
357 increased cognitive demands of the CAT task, may have led to decrements in CAT  
358 performance, as changes in pedal frequency would not be possible when cycling at a set  
359 intensity (Duncan et al., 2015).

360         Despite the findings presented here, this study is not without limitation. By assessing  
361 CAT during exercise, we sought to build on prior recommendations (Lyons et al., 2008) that  
362 CAT should be assessed during rather than post exercise. The current study also built on  
363 suggestions made by Lyons et al. (2008) that using different stimulus speeds is required to  
364 better understand the effect of exercise on CAT. However, when this approach is used, it is  
365 possible that divided attentional mechanisms, rather than exercise intensity alone, is  
366 responsible for decreased performance (Isaacs & Pohlman, 1991). The differences in CAT  
367 seen across exercise intensities and stimulus speeds in the present study may therefore be a  
368 result of divided attention, rather than simply the exercise intensity alone. However, the  
369 switch-press response (largely a sensory-based response with a very small motor component)  
370 was deliberately chosen so as to consider this point. It is also important to note that although

371 allocation of treatment was concealed to participants, and heart rate and other forms of  
372 feedback (e.g., cadence, speed) were removed from participants' sight, it is not possible to  
373 ensure complete blinding during such experimental trials. In addition, it is possible that  
374 important main effects were masked when adding the additional factor of speed in the three-  
375 way ANOVA; this is because the main effect would essentially look at combined effects from  
376 the pooled data.

377 Furthermore, research that has utilised a prediction motion paradigm to investigate  
378 coincidence-timing, at rest, in children have shown that errors in estimations increase with  
379 declining age (e.g., Benguigui et al., 2008; Benguigui et al., 2004). In our study, we grouped  
380 children ranging from 7-11 years old; therefore, the cognitive and motor development could  
381 have been significantly different (Benguigui et al., 2008). This could have potentially  
382 hindered important differences in the CAT performance of the oldest and youngest child.  
383 Future research should explore the effect of exercise intensity on CAT performance in  
384 different age groups of children (e.g., 7, 10, and 13 years old).

### 385 **Conclusion**

386 Given the lack of research that has examined CAT specifically, and cognitive  
387 performance more generally, during exercise at different intensities, we are aware that the  
388 data presented here is exploratory. However, the present study provides important novel  
389 findings that 15 minutes cycling based exercise at moderate intensity, appears to improve  
390 anticipation timing during and immediately after exercise in children, but only when stimulus  
391 speeds are moderate in nature.

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492 Table 1

493 *Mean [95% CI] and range of participants age, height, and body mass.*

	<i>Mean [95% CI]</i>	<i>Range</i>
Age (years)	9.00 [7.53, 9.01]	7.00 – 11.00
Height (m)	1.35 [1.30, 1.39]	1.21 – 1.45
Body Mass (kg)	30.70 [27.19, 34.21]	21.00 - 44.90

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513 Table 2

514 *Mean [95% CI] of constant error, variable error, and absolute error (secs) at stimulus speeds of 5 and 8 mph before, at 7 min 30 secs, and after*515 *15 min cycling at 50% HRR or 15 min cycling at 75% HRR.*

	50% HRR			75% HRR		
	Before	7 min 30 secs during	After	Before	7 min 30 secs during	After
	Constant error 5 mph (secs)	.07 [0.03, 0.10]	.05 [0.01, 0.09]	.06 [0.03, 0.09]	.06 [0.02, 0.09]	.07 [0.03, 0.11]
Constant error 8 mph (secs)	.05 [0.03, 0.08]	.06 [0.03, 0.09]	.07 [0.04, 0.09]	.06 [0.02, 0.10]	.07 [0.04, 0.11]	.07 [0.04, 0.10]
Variable error 5 mph (secs)	.07 [0.05, 0.09]	.09 [0.06, 0.11]	.07 [0.06, 0.09]	.06 [0.05, 0.08]	.11 [0.06, 0.15]	.08 [0.05, 0.12]
Variable error 8 mph (secs)	.08 [0.06, 0.10]	.08 [0.05, 0.11]	.07 [0.05, 0.08]	.08 [0.05, 0.10]	.11 [0.05, 0.17]	.07 [0.04, 0.09]
Absolute error 5 mph (secs)	.12 [0.08, 0.14]	.10 [0.07, 0.13]	.11 [0.08, 0.13]	.09 [0.07, 0.11]	.13 [0.09, 0.17]	.11 [0.07, 0.14]
Absolute error 8 mph (secs)	.09 [0.07, 0.11]	.13 [0.05, 0.20]	.09 [0.07, 0.10]	.09 [0.07, 0.12]	.10 [0.06, 0.13]	.12 [0.08, 0.15]

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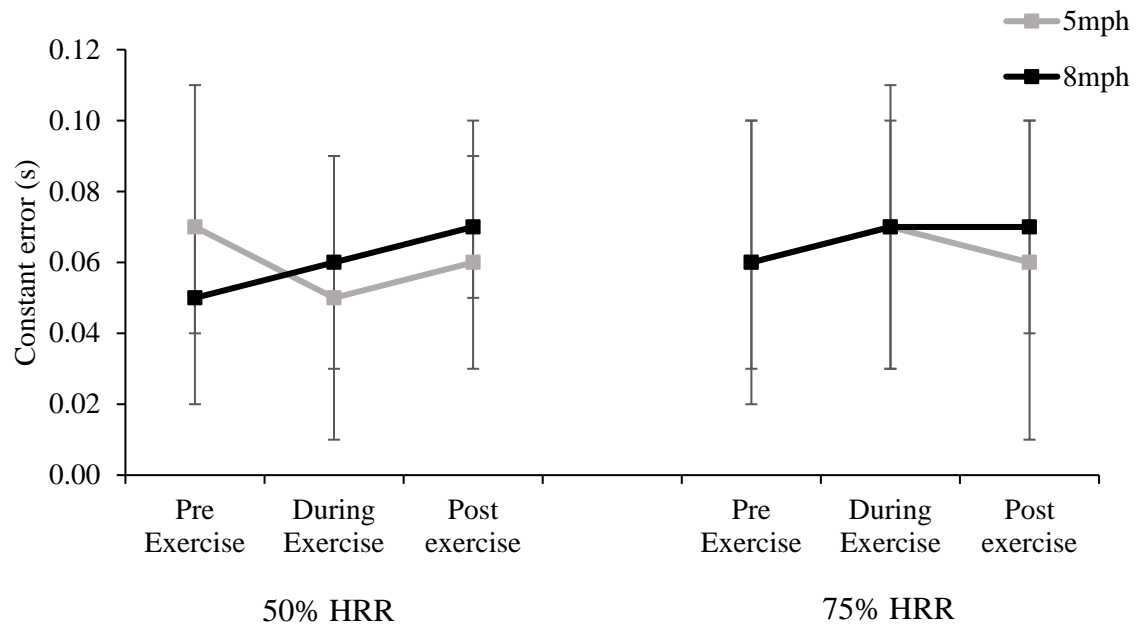


Figure 1: Mean of constant error (secs) at pre, during, and post exercise, at stimulus speeds of 5 and 8 mph in moderate (50% HRR) and vigorous (75% HRR) exercise intensity conditions. Error bars represent the 95% confidence interval.

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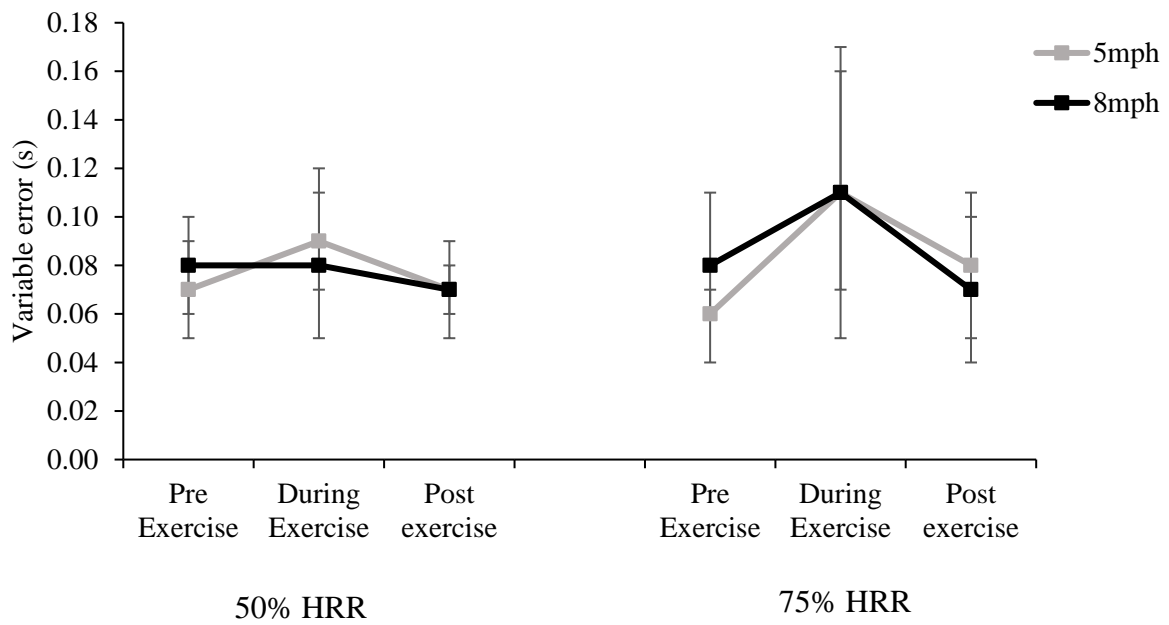


Figure 2: Mean of variable error (secs) at pre, during, and post exercise, at stimulus speeds of 5 and 8 mph in moderate (50% HRR) and vigorous (75% HRR) exercise intensity conditions. Error bars represent the 95% confidence interval.

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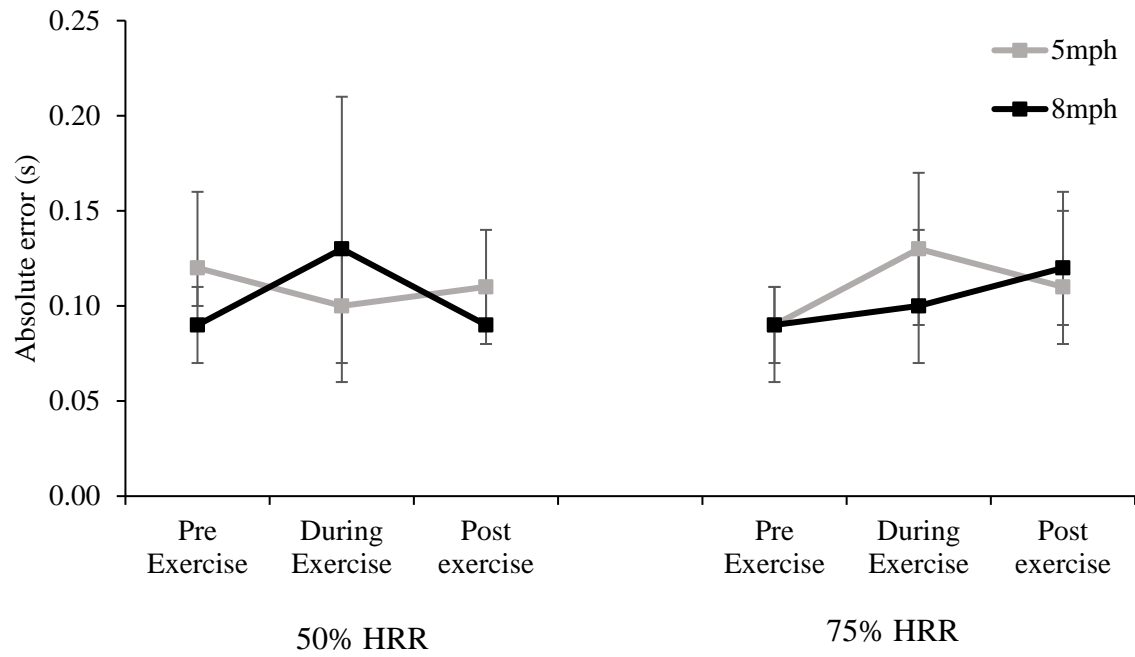


Figure 3: Mean of absolute error (secs) at pre, during, and post exercise, at stimulus speeds of 5 and 8 mph in moderate (50% HRR) and vigorous (75% HRR) exercise intensity conditions. Error bars represent the 95% confidence interval.