The Daily Mile™: Acute Effects on Children's Cognitive Function and Factors Affecting their Enjoyment

Abstract

The Daily Mile™ is a widely implemented school-based physical activity initiative. However, only two studies have explored the acute effects of participation in The Daily Mile on children's cognitive functioning, reporting conflicting findings. Moreover, enjoyment of exercise is a determining factor in children's motivation for, and adherence to, initiatives. However, factors affecting children's enjoyment of The Daily Mile are unknown. Therefore, this study examined the acute effects of The Daily Mile on cognition and explored children's enjoyment of participation in the initiative. Following familiarisation, 104 children (10.4±0.7 years) completed a Daily Mile and resting control trial in a randomised, counterbalanced order. Prior to, immediately following and 45 min following The Daily Mile and resting, children completed the Stroop test (inhibitory control), Sternberg paradigm (visual working memory) and Flanker task (inhibitory control and cognitive flexibility). Additionally, 87 children took part in focus groups to explore factors affecting enjoyment. Cognitive data were analysed using two-way (trial*time) and three-way (trial*time*sex; trial*time*fitness) repeated measures analysis of variance (ANOVA). Focus group data were analysed using qualitative content analysis. There were no statistically significant effects of The Daily Mile on cognition, compared to rest (all p>0.05). However, accuracy on the one-item level of Sternberg paradigm (p=0.073, η_p^2=0.028) and complex level of the Stroop test (p=0.057; η_p^2=0.031) tended to improve immediately following The Daily Mile, compared to resting; though this did not reach statistical significance. Children enjoyed participating in The Daily Mile, particularly due to its outdoor location, social context, and self-paced nature. However, some children found The Daily Mile boring due to its repetitive nature. Findings suggest that The Daily Mile does not significantly influence children's immediate or delayed (45 min) cognition. However, there was a tendency for improved accuracy in visual working memory and inhibitory control immediately following The Daily Mile. Moreover, the findings demonstrate that The Daily Mile promotes enjoyment, particularly through social relatedness and autonomy. However, future research could consider whether adding variety into the initiative may help to sustain engagement in the children experiencing boredom.

Keywords: cognitive function, enjoyment, exercise, physical activity, The Daily Mile

The Daily Mile™: Acute Effects on Children's Cognitive Function and Factors Affecting their Enjoyment

The Daily Mile™ is a school-based physical activity initiative that involves children completing ~1 mile (approximately 15–20 minutes) of outdoor, self-paced exercise each day, typically consisting of laps of the school playground. Since its development in 2012, it has gained popularity and is now implemented in more than 12,000 schools in 79 countries (The Daily Mile, 2020). The simple, inclusive and informal nature of The Daily Mile are thought to be key factors contributing to its popularity (Malden & Doi, 2019; Ryde et al., 2018). However, surprisingly little is known regarding the efficacy of The Daily Mile as a physical activity initiative (Fairhurst & Hotham, 2017). Whilst it has been suggested that The Daily Mile may be beneficial for children's health (Chesham et al., 2018), another commonly cited benefit of The Daily Mile is that it can enhance cognition. However, only two studies have explored the acute effects of participation in The Daily Mile on children's cognitive function, with contrasting findings. Specifically, Morris et al. (2019) demonstrated no effect of participation in The Daily Mile on executive function or Maths fluency, when compared to continued classroom activity. This study employed a between-subjects design however, and thus may have been confounded by inter-individual variability (e.g. due to differences in baseline cognition between the groups) (Williams et al., 2019). Additionally, Morris et al. (2019) utilised a relatively brief (30 s) and simple version of the Stroop test to assess executive function; whilst research suggests that more demanding cognitive tasks may be more sensitive to the beneficial effect of exercise (Pontifex et al., 2019). It is thus possible that the brief Stroop test lacked sufficient cognitive demand to demonstrate any enhancements to executive function that may result from participation in The Daily Mile.

In contrast to the findings of Morris et al. (2019), Booth et al. (2020) reported that participation in The Daily Mile led to greater improvements in inhibitory control and verbal working memory, compared to both near exhaustive exercise and seated rest. Additionally, compared to near exhaustive exercise, The Daily Mile led to greater improvements in visuospatial memory.

However, the research design involved remote data collection, meaning class teachers within each school administered the project. As noted by the authors, this approach to data collection may have impacted the order in which the physical activity and resting tasks were completed and the fidelity of, and adherence to, the tasks (Booth et al., 2020). Moreover, the three activities may have been administered at different times of day and the cognitive tests may have been administered at different times following each activity, with advice to teachers being only to conduct the tests within 20 minutes of each activity. Literature demonstrates that significantly larger cognitive effects are observed following exercise performed during the morning, when compared to exercise performed in the afternoon; and that exercise-induced effects to cognition are time sensitive, with enhancements to some domains presenting immediately and others after a delay (Chang et al., 2012). Therefore, a lack of control over experimental procedures may have influenced the results of the study.

The inconsistent findings of the limited studies in this area mean that policymakers and schools are currently implementing The Daily Mile without a full understanding of the acute effects on subsequent cognition in the classroom. Therefore, the primary aim of the research project is to examine the acute effects of participation in The Daily Mile on the cognitive domains of inhibitory control, cognitive flexibility and working memory. These executive functions are higher-order, self-regulatory cognitive processes (Carlson, 2005; Diamond, 2013). Consequently, executive functions are related to behaviour in the classroom (Riggs, Blair, & Greenberg, 2004), and academic achievement (McPherson et al., 2018). Furthermore, evidence suggests that executive functions are malleable (Diamond & Lee, 2011) and can be influenced by exercise (Drollette et al., 2012; Kamijo et al., 2011). Specifically, with regards to The Daily Mile, whilst Booth et al. (2020) reported improvements to inhibitory control and working memory from acute participation in The Daily Mile, Morris et al. (2019) reported no effects to inhibitory control, cognitive flexibility or working memory. Therefore, the effect of The Daily Mile on these executive functions requires further examination, in order to make inferences regarding the effect of participation on children's cognition and, subsequently, academic performance.

Another important consideration in the implementation of The Daily Mile is how young people perceive participation in the initiative. While qualitative research on The Daily Mile is increasing, studies thus far have focused on the factors which influence implementation of the initiative (e.g. flexible delivery, creating the right physical environment), and have primarily examined the perceptions of school staff (Malden & Doi, 2019; Ryde et al., 2018). No studies have investigated whether young people enjoy participating in The Daily Mile, or the factors influencing their enjoyment. Understanding children's level of enjoyment in a physical activity is essential, as their level of enjoyment will influence the effort they invest in the activity (Diamond, 2012). Moreover, fostering enjoyment in physical activity during the formative years facilitates long-term motivation for, and engagement in, physical activity (Cardinal et al., 2013; Nasuti & Rhodes, 2013), thus promoting health and well-being. Furthermore, enjoyment of physical activity has been shown to predict fitness improvements in children aged between 8 and 10 years (Elbe et al., 2017). It is thus vital that physical activity research evaluates children's enjoyment of interventions, as it will inevitably influence their effectiveness.

Therefore, the aim of the present study was two-fold: to examine the acute effects of participation in The Daily Mile on inhibitory control, cognitive flexibility and working memory, and to explore children's perceptions and enjoyment of participating in The Daily Mile through focus groups.

Methods

Participant characteristics:

A power calculation (G*Power version 3.1; Faul et al., 2007) with power = 0.95 and $\alpha = 0.05$, specified a minimum sample size of $n = 92$ would be satisfactory to detect a small ($d = 0.2$) effect size, typical of work in this area (Booth et al., 2020; Cooper et al., 2018). A total of 104 (56 male, 48 female) primary school children aged 9–11 years participated in the study. Eighty-seven (54 male, 33 female) of the 104 participants took part in focus groups, with 14 focus groups conducted in total. The 17 participants who failed to attend the focus groups were unable to participate due to school commitments (e.g. choir practice). Participant characteristics are displayed in Table 1.

Table 1.

Anthropometric Characteristics

	Overall (*n* = 104)	**Boys (*n* = 56)**	**Girls (*n* = 48)**	***p* value** [a]
Age (yrs)	10.4 ± 0.7	10.4 ± 0.7	10.4 ± 0.6	0.923
Height (cm)	143.3 ± 8.1	143.6 ± 7.6	142.9 ± 8.7	0.661
Body mass (kg)	36.1 ± 8.1	37.1 ± 8.7	34.9 ± 7.2	0.170
Body mass index (BMI; kg.m^2)	17.4 ± 2.6	17.8 ± 2.8	16.9 ± 2.1	0.084
BMI percentile	51.8 ± 28.0	58.7 ± 28.6	43.2 ± 25.0	0.005
BMI z-score	0.1 ± 1.1	0.3 ± 1.1	-0.2 ± 0.9	0.005
Maturity offset (yrs) [b]	-2.0 ± 0.8	-2.6 ± 0.5	-1.4 ± 0.7	2.967
Waist circumference (cm)	61.3 ± 7.1	61.8 ± 7.3	60.5 ± 6.7	0.423
Sum of skinfolds (mm)	54.2 ± 25.0	53.3 ± 27.7	55.5 ± 21.8	0.444
MSFT Distance (m)	760 ± 320	860 ± 380	660 ± 220	0.002

Note. [a] Comparison between boys and girls. [b] Calculated using the method of Moore et al. (2015).

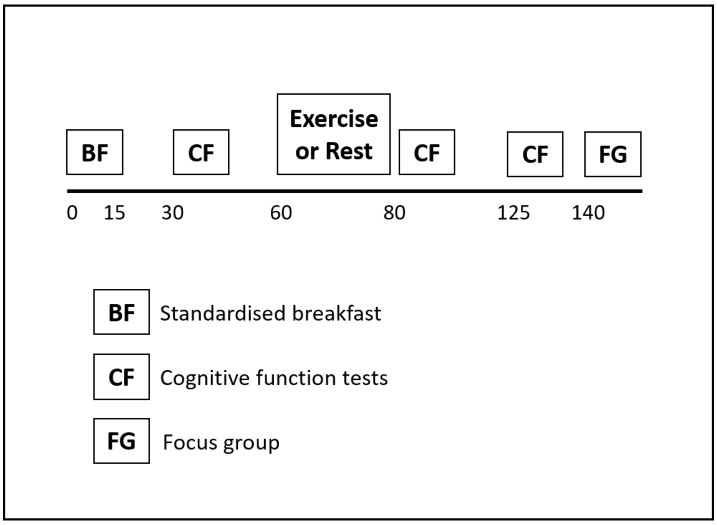
Study design:

Following approval from the institution's ethical advisory committee, primary schools in the East Midlands, UK were contacted via email and invited to participate. In total, ~100 primary schools were contacted and 8 primary schools agreed to participate in the study. In those schools who agreed to participate, children from years five and six (9–11 years old) were invited to participate in the study. The location of participating schools ranged from rural village to inner city, the schools varied in size (105–660 pupils) and distance from the University (5–25 km). Six schools were implementing The Daily Mile at the time of the study; the length of implementation at these schools ranged from 2–12 months. Two schools had never implemented the initiative. Headteacher consent was obtained, along with written informed consent from parents/guardians of participating children. Parents/guardians also completed a health screen questionnaire on behalf of the participant; this determined each child's eligibility for participation in the study by screening for any health conditions which may be negatively affected by participation (e.g. heart condition). Additionally, participants provided their written assent to be involved in the study.

The study employed a within-subject randomised crossover counterbalanced design. The study involved a familiarisation trial which took place 7 days prior to the first experimental trial. Participants then completed two experimental trials (exercise [The Daily Mile] and control [resting]), which were also separated by 7 days. During the familiarisation trial, the purpose and protocol of the study was explained to participants, with questions welcomed, and all participants had a practice of all study procedures (incl. battery of cognitive function tests and The Daily Mile). During familiarisation, participants also completed the Multi-Stage Fitness Test to provide a measurement of cardiorespiratory fitness and anthropometric measures (e.g. body mass, skinfolds) were taken. The focus group was performed upon completion of the exercise trial. Figure 1 presents the experimental protocol.

Figure 1:

Experimental Protocol



Pre-trial control:

Participants consumed a meal of their choice the evening before the first main experimental trial and were asked to replicate this meal prior to the subsequent trial. Participants fasted from 9 pm the evening before each trial until arrival at the school the following day. Water was allowed *ad libitum* during this time to maintain euhydration. Participants refrained from exercise and consumption of caffeine for 24 hr prior to each experimental trial. Parents/guardians were reminded of this information via telephone two days before each trial.

Shortly after arrival at school for each experimental trial, participants were provided with a standardised breakfast consisting of cornflakes, milk and toast; providing 1.5 g carbohydrate per kg body mass (Cooper et al., 2012). Dietary control was implemented due to the effect of breakfast on subsequent cognition (Cooper et al., 2011) and the potential for breakfast and exercise to interact to affect cognition (Cooper et al., 2015).

Exercise and rest protocol:

The exercise protocol consisted of The Daily Mile, which involved 20 minutes of self-paced activity completed outdoors (laps of the school playground or sports pitch), in groups of 5–16 participants (mean: 12 ± 3). Participants were encouraged by researchers to try their best but were able to choose their own pace (walk/jog/run/sprint) and whether to exercise alone or with peers. Participants wore normal school uniform with appropriate footwear. The exercise protocol was designed to replicate The Daily Mile, as it is currently implemented in schools. During the resting trial (and at all times during the exercise trial, with exception of the 20 min Daily Mile), participants sat in a classroom and conversed in a calm manner with their peers.

Measures:

Cognitive Function tests:

The battery of cognitive function tests consisted of a Stroop test, Sternberg paradigm and Flanker task (completed in that order). Participants completed these tests prior to, immediately following and 45 min following The Daily Mile and rest condition. The test battery lasted approximately 15 min and was administered via a laptop computer (Lenovo ThinkPad T450; Lenovo, Hong Kong). Prior to the completion of each test, instructions were presented on screen and were repeated verbally by an investigator. Participants were allowed an opportunity to ask questions. Each test (and test level) was then preceded by 3–6 practice stimuli (with feedback provided) to re-familiarise participants with the test and to negate any potential learning effects, the data for which were discarded. Once the tests started, no feedback was provided. Participants from each school completed the tests together in a classroom of 5–16 participants, in silence and seated separately to ensure no interaction during the tests occurred. Participants also wore sound cancelling headphones and lights were dimmed to minimise external disturbances. Participants were instructed to respond to each test as quickly and as accurately as possible. This testing procedure has been previously used successfully in a similar study population (Cooper et al., 2016; Williams et al., 2020). For all tests, the variables of interest were the response times of correct responses and the proportion of correct responses made. Detailed descriptions of the cognitive tests are provided elsewhere (Cooper et al., 2012; Williams et al., 2020), but in brief the tests were administered as follows:

Stroop test: The Stroop test measures the inhibitory control component of executive function and consists of two levels (simple and complex) (Stroop, 1935). During both levels, a test word appears in the centre of the screen, with a target and distractor word placed randomly on the left and right side. The target position was counterbalanced for the left and right side within each test level. On the simple level, all words are presented in white ink and participants must select (using the left or right arrow key) which word matches the central word. On the complex level, the words are presented in coloured ink and participants must select the word which represents the colour that the central word is displayed in, rather than the word itself (e.g. if 'blue' was written in red ink, the correct response would be red).

Sternberg paradigm: The Sternberg paradigm measures visual working memory and consists of three levels of ascending difficultly (Sternberg, 1969). At the start of each level, participants are assigned a target number or letters which they must remember. On the one-item level, the target was always the number ‘3’. On the three- and five-item levels the target was three and five randomly generated letters, respectively. During the test, a number or letter consecutively appears on screen and participants must select whether it is one of their assigned letters or number by pressing the right arrow key, or whether it is a distractor by pressing the left arrow key. The correct response was counterbalanced between the left and right arrow key for each level.

Flanker task: The Flanker task measures the inhibitory control and cognitive flexibility components of executive function and consists of two levels (congruent and incongruent) (Eriksen & Eriksen, 1974). During both levels, five arrows appear on screen. Participants must press the arrow key (left or right) which corresponds to the direction of the central target arrow. On the congruent level, all arrows point in the same direction (e.g. > > > > > or < < < < <), however on the incongruent level, the target arrow and the flanking arrows point in opposite directions (e.g. > > < > > or < < > < <). The Flanker task consisted of 60 stimuli, with an equal number of congruent and incongruent stimuli presented in a randomised order.

Focus groups:

Focus groups were utilised to explore children’s perceptions and enjoyment of participation in The Daily Mile within the study. Focus groups have previously been shown to be an effective method for gaining insight regarding the thoughts and perspectives of children (Gibson, 2007; Vaughn et al., 1996). A semi-structured guide, which included open-ended questions and prompts, enabled an exploration of children’s experience of The Daily Mile through appropriate language (see supplementary material 1) (Gibson, 2012; Greene & Hogan, 2005). To create a supportive and productive environment, the focus groups took place in a quiet classroom within the participants’ school and involved groups of between 5–8 children, grouped by age (Kennedy et al., 2001; Sparkes & Smith, 2013). Two lead moderators and two assistant moderators were involved in data collection, with one lead and one assistant moderator of mixed sex in each focus group, as deemed appropriate for focus groups with children (Morgan et al., 2002). To ensure consistency in approach between moderators, a manual was produced and followed. The duration of the focus groups varied according to group size and lasted between 12–27 min (18 ± 4 min). This time frame is deemed sufficient to gain in-depth responses to questions and appropriate for ensuring that children's concentration is maintained (Vaughn et al., 1996).

Data analysis

For cognitive function data, minimum (100 ms) and maximum (2000–4000 ms, depending on task complexity) cut-off points for response time data were applied in order to exclude unreasonably fast responses (i.e. anticipatory responses given before stimuli has been perceived) and slow (distracted) responses (Cooper et al., 2016, 2018; Draheim et al., 2016). Cognitive data were then analysed in Statistical Package for the Social Sciences (SPSS) (Version 24; SPSS Inc., Chicago, IL., USA) using a two-way (trial by time) repeated measures analysis of variance (ANOVA), with partial eta squared (η_p^2) effect sizes calculated and interpreted as per convention (small = 0.01, medium = 0.06, and large = 0.14). Subsequently, to examine the effect of sex and fitness on the exercise-cognition relationship, three-way (trial by time by sex, and trial by time by fitness) repeated measures ANOVAs were conducted, with sex and fitness as between-subject factors. Participants were assigned to high (top 50 % for each sex) and low (bottom 50% for each sex) fitness groups, based on distance covered in the Multi-Stage Fitness Test. Cognitive data are presented as mean ± standard error of the mean (SEM) and statistical significance was accepted as $p < 0.05$.

All focus groups were audio recorded and transcribed verbatim, with 115 pages of transcript produced in total. The transcripts for each focus group were checked against the recordings to ensure accuracy. During transcription, the data was deidentified by using codes for each participant. Data were analysed using qualitative content analysis, with an inductive and semantic approach employed (Vaismoradi et al., 2013, 2016, 2019). This involved a rigorous and recursive process of immersing oneself in the data and obtaining the sense of the data as a whole (preparation phase), interpreting the content of the text through the systematic classification process of coding and identifying categories which represented similar meanings/patterns of communication (organising phase), and reporting the analysis process and results through categories and a story line (reporting phase) (Elo & Kyngas, 2008; Vaismoradi et al., 2013). Moreover, category development was influenced by the frequency of occurrence of a topic, which was important in relation to the research question, within the data, and included an intensive examination of language and meaning (Vaismoradi et al., 2016, 2019). This analysis method was deemed most appropriate due to its (post)positivist underpinning with the analysis seeking to develop categories which are truly representative of the perspectives of the participants (Braun & Clarke, 2020; Vaismoradi et al., 2013). Furthermore, this inductive analysis approach is valuable for exploratory work in an area where not much is known (Green & Thorogood, 2004). To develop methodological rigor, a critical friend approach was adopted. This approach is not based on forming a consensus between colleagues regarding the data, but instead supports a rigorous interpretation of the results through group reflection and critical feedback, that is both plausible and defendable (Smith & McGannon, 2018).

Results

Cognitive Function data:

Response time and accuracy data at each time point, across the exercise and resting trials, for each cognitive function test (including data split by sex and fitness) are displayed in Table 2.

Stroop test

Response times, simple level. Overall, there was no difference in response times between the exercise and resting trials; main effect of trial, $p = 0.605$. Moreover, the pattern of change in response times across the morning was similar between the exercise and resting trials; trial by time interaction, $p = 0.104$. Overall, response times were faster in boys (881 $\pm$ 22 ms), compared to girls (968 $\pm$ 24 ms); main effect of sex, $F_{(1, 86)} = 6.0$, $p = 0.016$, $\eta_p^2 = 0.065$. Response times were also faster in high-fit (885 $\pm$ 24 ms) compared to low-fit (978 $\pm$ 24 ms) participants; main effect of fitness, $F_{(1, 86)} = 7.8$, $p = 0.007$, $\eta_p^2 = 0.083$. However, the effect of exercise on response times was not influenced by sex or fitness; trial by time by sex interaction, $p = 0.635$; trial by time by fitness interaction, $p = 0.738$.

Response times, complex level. There was no difference in response times between exercise and resting trials; main effect of trial, *p* = 0.520. However, response times tended to be slower immediately following exercise compared to resting; trial by time interaction, $F_{(2, 186)} = 3.0$, $p = 0.057$, $\eta_p^2 = 0.031$, Figure 2. Response times were similar between boys and girls; main effect of sex, *p* = 0.120. Additionally, sex did not influence the effect of exercise on response times; trial by time by sex interaction, *p* = 0.674. Response times were faster in the high-fit (1143 ± 32 ms), compared to low-fit (1283 ± 32 ms) group; main effect of fitness, $F_{(1, 86)} = 9.5$, $p = 0.003$, $\eta_p^2 = 0.100$. However, fitness did not influence the effect of exercise on response times; trial by time by fitness interaction, *p* = 0.484.

Figure 2.

*Response Times (ms) across the Morning on the Complex Level of the Stroop Test, for Exercise (The Daily Mile) and Control (Resting) trials (trial * time interaction, p = 0.057).*

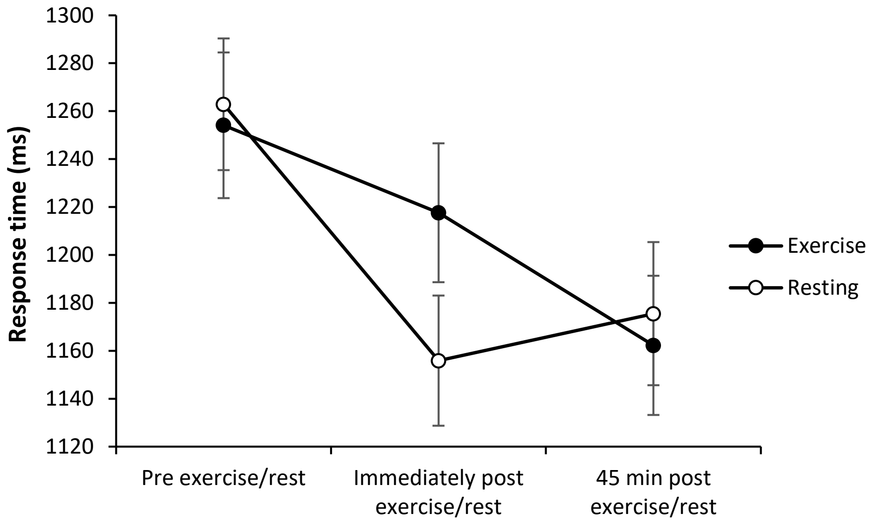


Table 2. *Cognitive Function across Exercise and Rest Trials for the Whole Sample and Split by Participant Sex and Fitness. Data are presented as mean±SEM.*

Test	Level	Variable	Participant Group	Resting trial			Exercise trial			
				Pre-resting	Immediately post	45 min post	Pre-exercise	Immediately post	45 min post	
Stroop test	Simple	Response times (ms)	Overall	952 ± 21	883 ± 22	915 ± 23	928 ± 22	923 ± 22	924 ± 22	
			Girls	1025 ± 31	914 ± 32	963 ± 35	980 ± 30	963 ± 34	963 ± 38	b
			Boys	890 ± 27	858 ± 30	875 ± 30	884 ± 30	889 ± 29	891 ± 25	
			Low Fit	1013 ± 35	956 ± 35	958 ± 33	982 ± 37	985 ± 33	975 ± 39	c
			High Fit	919 ± 24	833 ± 25	903 ± 34	887 ± 25	879 ± 31	888 ± 26	
		Accuracy (%)	Overall	97.2 ± 0.4	94.5 ± 0.8	93.8 ± 0.9	97.1 ± 0.4	95.2 ± 0.8	93.0 ± 0.8	
			Girls	98.6 ± 0.4	95.3 ± 1.0	94.3 ± 1.3	96.6 ± 0.7	95.2 ± 1.0	93.4 ± 1.3	
			Boys	96.0 ± 0.6	93.8 ± 1.2	93.4 ± 1.1	97.5 ± 0.6	95.2 ± 1.1	92.6 ± 1.1	
			Low Fit	96.8 ± 0.6	95.8 ± 0.9	94.0 ± 1.3	97.3 ± 0.6	95.5 ± 0.9	92.2 ± 1.5	
			High Fit	97.8 ± 0.5	93.4 ± 1.3	94.4 ± 1.1	96.9 ± 0.7	94.7 ± 1.3	93.9 ± 1.0	
	Complex	Response times (ms)	Overall	1263 ± 27	1156 ± 27	1176 ± 30	1254 ± 30	1218 ± 29	1162 ± 29	
			Girls	1306 ± 41	1214 ± 43	1228 ± 45	1291 ± 47	1256 ± 46	1165 ± 53	
			Boys	1227 ± 37	1107 ± 34	1131 ± 39	1223 ± 40	1185 ± 37	1160 ± 30	
			Low Fit	1335 ± 39	1246 ± 45	1261 ± 48	1332 ± 51	1290 ± 44	1235 ± 47	c
			High Fit	1215 ± 38	1081 ± 28	1128 ± 35	1185 ± 37	1159 ± 41	1090 ± 37	
		Accuracy (%)	Overall	93.7 ± 0.7	90.9 ± 0.8	91.5 ± 0.9	93.5 ± 0.7	92.6 ± 0.09	90.3 ± 1.0	
			Girls	95.1 ± 0.9	92.5 ± 1.3	92.8 ± 1.2	93.7 ± 0.9	92.9 ± 1.0	90.1 ± 1.8	
			Boys	92.5 ± 1.0	89.6 ± 1.3	90.4 ± 1.3	93.2 ± 0.9	92.4 ± 1.1	90.4 ± 1.2	
			Low Fit	93.2 ± 1.0	91.0 ± 1.5	91.8 ± 1.4	93.6 ± 0.9	92.8 ± 1.0	90.1 ± 1.8	
			High Fit	94.7 ± 0.9	91.1 ± 1.2	92.0 ± 1.2	93.6 ± 1.0	92.2 ± 1.3	90.1 ± 1.4	
Sternberg paradigm	One-item	Response times (ms)	Overall	644 ± 15	612 ± 16	603 ± 18	632 ± 15	619 ± 16	621 ± 16	
			Girls	676 ± 18	656 ± 26	623 ± 26	664 ± 25	660 ± 22	635 ± 26	b
			Boys	618 ± 22	577 ± 18	587 ± 25	606 ± 18	586 ± 23	610 ± 19	
			Low Fit	653 ± 19	627 ± 26	629 ± 23	648 ± 26	641 ± 24	656 ± 25	
			High Fit	646 ± 24	606 ± 21	596 ± 30	616 ± 17	612 ± 25	594 ± 22	
		Accuracy (%)	Overall	95.7 ± 0.6	91.9 ± 1.2	93.4 ± 1.0	95.1 ± 0.8	94.7 ± 0.8	93.7 ± 0.9	
			Girls	96.9 ± 0.7	93.0 ± 1.6	93.9 ± 1.5	95.2 ± 1.2	95.1 ± 1.1	93.6 ± 1.6	
			Boys	94.7 ± 0.9	91.0 ± 1.7	92.9 ± 1.4	95.0 ± 1.0	94.5 ± 1.2	93.8 ± 1.0	
			Low Fit	96.6 ± 0.7	91.1 ± 1.8	93.5 ± 1.3	94.7 ± 1.2	93.8 ± 1.3	93.8 ± 1.3	
			High Fit	95.6 ± 0.9	93.5 ± 1.6	94.9 ± 1.2	95.0 ± 1.1	95.2 ± 1.1	93.5 ± 1.3	
	Three-item	Response times (ms)	Overall	811 ± 16	803 ± 20	777 ± 19	832 ± 30	819 ± 18	803 ± 18	
			Girls	841 ± 18	781 ± 26	779 ± 25	810 ± 27	835 ± 26	804 ± 27	d
			Boys	786 ± 24	820 ± 29	776 ± 28	849 ± 50	806 ± 25	803 ± 24	
			Low Fit	828 ± 26	845 ± 36	826 ± 32	849 ± 31	871 ± 27	854 ± 27	c
			High Fit	803 ± 20	772 ± 19	746 ± 22	818 ± 56	782 ± 25	764 ± 25	

Test	Level	Variable	Participant Group	Resting trial			Exercise trial			
				Pre-resting	Immediately post	45 min post	Pre-exercise	Immediately post	45 min post	
		Accuracy (%)	Overall	94.8 ± 1.2	92.6 ± 0.7	90.1 ± 0.9	93.8 ± 0.6	93.2 ± 0.8	91.3 ± 0.9	
			Girls	95.3 ± 0.8	93.2 ± 1.2	91.1 ± 1.3	94.0 ± 1.2	93.7 ± 0.9	91.4 ± 1.5	
			Boys	94.5 ± 0.9	92.1 ± 1.1	89.3 ± 1.3	93.6 ± 1.9	92.8 ± 1.0	91.2 ± 1.0	
			Low Fit	94.2 ± 1.0	91.8 ± 1.2	89.3 ± 1.5	95.4 ± 0.9	93.3 ± 0.9	91.1 ± 1.3	
			High Fit	95.7 ± 0.7	94.0 ± 0.7	91.7 ± 1.1	91.7 ± 2.3	92.8 ± 1.2	91.8 ± 1.1	
	Five-item	Response times (ms)	Overall	981 ± 23	932 ± 23	890 ± 24	990 ± 23	980 ± 25	939 ± 21	a
			Girls	981 ± 28	938 ± 33	877 ± 30	995 ± 34	959 ± 34	921 ± 35	
			Boys	982 ± 35	928 ± 33	901 ± 37	987 ± 30	997 ± 35	954 ± 25	
			Low Fit	1009 ± 40	959 ± 39	917 ± 42	1028 ± 36	1038 ± 41	959 ± 31	
			High Fit	966 ± 27	920 ± 27	878 ± 27	949 ± 30	924 ± 30	915 ± 31	
		Accuracy (%)	Overall	89.7 ± 1.1	84.3 ± 1.4	83.1 ± 1.4	89.2 ± 0.9	87.1 ± 1.3	84.9 ± 1.3	
			Girls	91.1 ± 1.4	84.9 ± 2.1	83.9 ± 2.0	89.4 ± 1.4	87.4 ± 1.8	85.6 ± 2.1	
			Boys	88.5 ± 1.7	83.8 ± 1.8	82.5 ± 1.9	89.1 ± 1.1	86.6 ± 1.8	84.3 ± 1.8	
			Low Fit	87.7 ± 1.9	82.2 ± 2.4	81.8 ± 2.5	89.3 ± 1.3	84.9 ± 2.0	84.7 ± 2.1	
			High Fit	91.3 ± 1.4	86.6 ± 1.5	85.7 ± 1.2	89.0 ± 1.3	88.6 ± 1.7	85.4 ± 1.8	
Flanker task	Congruent	Response times (ms)	Overall	657 ± 15	649 ± 15	630 ± 15	676 ± 15	662 ± 15	651 ± 14	
			Girls	701 ± 23	697 ± 24	665 ± 25	707 ± 24	678 ± 22	682 ± 23	b
			Boys	620 ± 18	609 ± 18	601 ± 18	649 ± 18	649 ± 21	626 ± 18	
			Low Fit	686 ± 21	701 ± 25	676 ± 21	711 ± 23	702 ± 23	693 ± 22	c
			High Fit	647 ± 21	612 ± 17	599 ± 22	643 ± 20	629 ± 20	611 ± 19	
		Accuracy (%)	Overall	97.5 ± 0.4	95.1 ± 0.8	95.5 ± 0.8	98.0 ± 0.3	97.5 ± 0.5	96.4 ± 0.6	a
			Girls	97.5 ± 0.5	95.6 ± 1.4	95.8 ± 1.1	98.3 ± 0.5	97.3 ± 0.8	96.1 ± 1.0	
			Boys	97.6 ± 0.5	94.7 ± 0.9	95.2 ± 1.0	97.7 ± 0.5	97.6 ± 0.4	96.7 ± 0.7	
			Low Fit	97.4 ± 0.5	94.7 ± 1.1	96.3 ± 0.9	98.6 ± 0.4	97.4 ± 0.6	96.1 ± 1.0	
			High Fit	97.8 ± 0.5	96.9 ± 0.5	95.4 ± 1.1	97.5 ± 0.6	97.4 ± 0.6	96.5 ± 0.8	
	Incongruent	Response times (ms)	Overall	715 ± 21	708 ± 20	676 ± 18	720 ± 16	714 ± 16	689 ± 16	
			Girls	771 ± 38	762 ± 34	707 ± 30	759 ± 29	739 ± 27	720 ± 24	b
			Boys	668 ± 21	664 ± 21	650 ± 20	688 ± 16	693 ± 20	664 ± 21	
			Low Fit	759 ± 34	766 ± 32	733 ± 27	772 ± 26	766 ± 23	733 ± 24	c
			High Fit	693 ± 25	671 ± 22	636 ± 23	675 ± 19	674 ± 23	651 ± 22	
		Accuracy (%)	Overall	92.4 ± 1.4	91.6 ± 1.0	92.6 ± 0.8	94.7 ± 0.6	93.6 ± 0.7	93.4 ± 0.8	a
			Girls	91.1 ± 2.9	92.0 ± 1.8	93.5 ± 1.2	95.5 ± 0.7	92.9 ± 1.1	93.0 ± 1.5	
			Boys	93.5 ± 1.0	91.3 ± 1.0	91.9 ± 1.1	94.0 ± 0.8	94.2 ± 0.8	93.7 ± 0.9	
			Low Fit	92.8 ± 1.8	91.4 ± 1.3	93.1 ± 0.9	95.1 ± 0.9	93.0 ± 1.1	93.5 ± 1.4	
			High Fit	92.0 ± 2.3	92.9 ± 1.4	93.0 ± 1.3	94.1 ± 0.8	93.9 ± 0.8	93.2 ± 1.0	

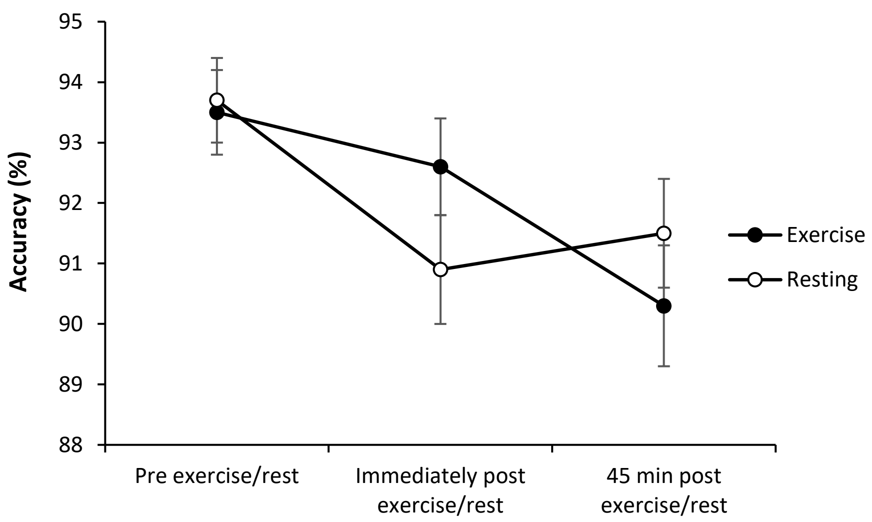
Note. [a] Main effect of trial. [b] Main effect of sex. [c] Main effect of fitness. [d] Trial*time*sex interaction.

Accuracy, simple level. Overall, accuracy was similar between the exercise and resting trials, main effect of trial, p = 0.873. Moreover, the pattern of change in accuracy across the morning was similar between exercise and resting trials; trial by time interaction, p = 0.406. There was no difference in accuracy between the sexes or between fitness groups; main effect of sex, p = 0.348; main effect of fitness, p = 0.951. Furthermore, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, p = 0.357; trial by time by fitness interaction, p = 0.389.

Accuracy, complex level. There was no difference in accuracy between exercise and resting trials; main effect of trial, p = 0.885. However, accuracy tended to be higher immediately following exercise compared to resting, but this did not reach statistical significance; trial by time interaction, $F_{(2, 186)} = 3.0$, p = 0.057, $\eta_p^2 = 0.031$, Figure 3. There was no difference in accuracy between the sexes or between the fitness groups; main effect of sex p = 0.205; main effect of fitness, p = 0.871. Moreover, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, p = 0.972; trial by time by fitness interaction, p = 0.891.

Figure 3.

*Accuracy across the Morning on the Complex Level of the Stroop Test, for Exercise (The Daily Mile) and Control (Resting) Trials (trial * time interaction, p = 0.057).*



Sternberg paradigm

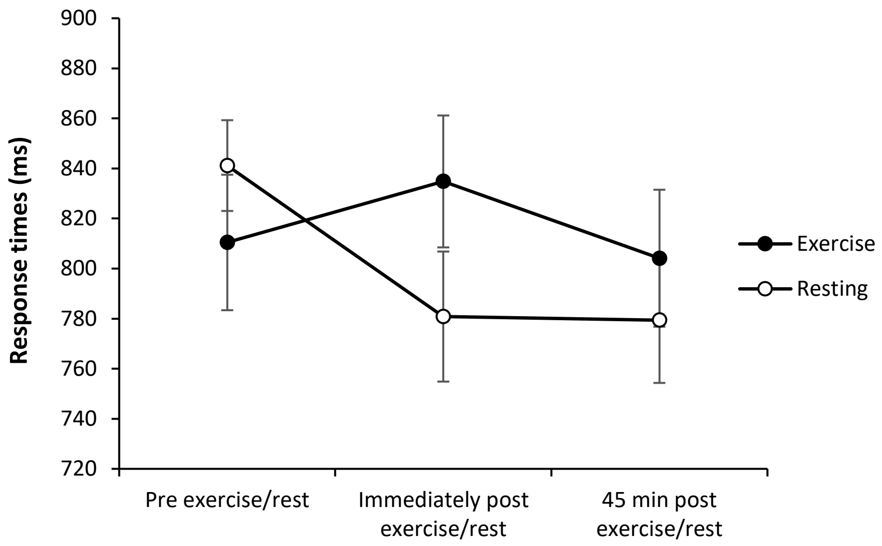
Response times, one-item level. Overall, there was no difference in response times between exercise and resting trials; main effect of trial, p = 0.661. There was also no difference in the pattern of change in response times across the morning between trials; trial by time interaction, p = 0.430. Boys (597 $\pm$ 14 ms) had faster response times compared to girls (652 $\pm$ 16 ms); main effect of sex, $F_{(1, 86)}$ = 4.9, p = 0.030, η_p^2 = 0.053. However, the effect of exercise on response times was not influenced by sex; trial by time by sex interaction, p = 0.967. Moreover, there was no difference in response times between fitness groups, and fitness did not influence the effect of exercise on response times; main effect of fitness, p = 0.185; trial by time by fitness interaction, p = 0.888.

Response times, three-item level. There was no difference in response times between exercise and resting trials; main effect of trial, p = 0.143. There was also no difference in the pattern of change across the morning between trials; trial by time interaction, p = 0.914. There was no difference in response times between boys and girls; main effect of sex, p = 0.952. However, sex influenced the effect of exercise on response times; trial by time by sex interaction, $F_{(1, 86)}$ = 4.0, p = 0.027, η_p^2 = 0.042. Specifically, there was a significant trial by time interaction for girls, $F_{(2, 80)}$ = 4.3, p = 0.017, η_p^2 = 0.097, but not for boys, p = 0.317; whereby girls' response times got slower immediately following The Daily Mile and faster following resting (Figure 4). The high-fit group (845 $\pm$ 22 ms) presented faster response times compared to the low-fit group (781 $\pm$ 22 ms); main effect of fitness, $F_{(1, 86)}$ = 4.3, p = 0.041, η_p^2 = 0.048. However, the effect of exercise on response times was not influenced by fitness; trial by time by fitness interaction, p = 0.974.

Response times, five-item level. Response times were slower during the exercise (972 $\pm$ 19 ms) compared to resting (937 $\pm$ 20 ms) trial; main effect of trial, $F_{(1, 92)}$ = 4.9, p = 0.030, η_p^2 = 0.050. However, the pattern of change in response times across the morning was similar between the exercise and resting trials; trial by time interaction, p = 0.314. There was no difference in response times between the sexes or between fitness groups; main effect of sex, p = 0.728; main effect of fitness, *p* = 0.119. Moreover, neither sex nor fitness influenced the effect of exercise on response times; trial by time by sex interaction, *p* = 0.615; trial by time by fitness interaction, *p* = 0.540.

Figure 4.

*Girls' Response Times (ms) across the Morning on the Three-item Level of Sternberg Paradigm for Exercise (The Daily Mile) and Control (Resting) Trials (trial * time interaction, p = 0.017).*

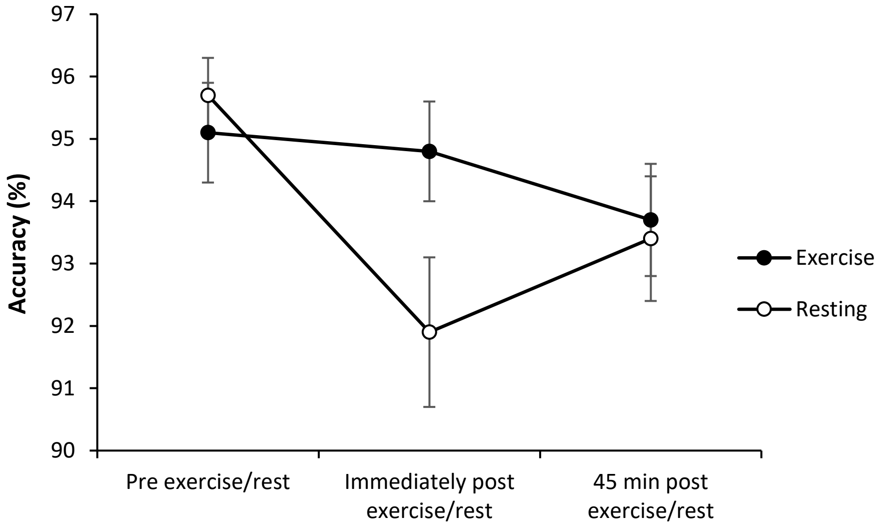


Accuracy, one-item level. Overall, accuracy was similar between exercise and resting trials; main effect of trial, *p* = 0.235. Accuracy tended to be higher immediately following exercise compared to rest, but statistical significance was not met; trial by time interaction, $F_{(2, 186)} = 2.7$, *p* = 0.073, $\eta_p^2 = 0.028$, Figure 5. There was no difference in accuracy between the sexes or between fitness groups; main effect of sex, *p* = 0.376; main effect of fitness, *p* = 0.529. Moreover, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, *p* = 0.972; trial by time by fitness interaction, *p* = 0.627.

Accuracy, three-item level. There was no difference in accuracy between exercise and resting trials; main effect of trial, *p* = 0.700. Moreover, the pattern of change in accuracy across the morning was similar between the exercise and resting trials; trial by time interaction, *p* = 0.283. There was no difference in accuracy between the sexes or between fitness groups; main effect of sex, *p* = 0.426; main effect of fitness, *p* = 0.175. Furthermore, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, *p* = 0.860; trial by time by fitness interaction, *p* = 0.484.

Figure 5.

*Accuracy across the Morning on the One-item Level of Sternberg Paradigm, for Exercise (The Daily Mile) and Control (Resting) Trials (trial * time interaction, p = 0.073)*



Accuracy, five-item level. Accuracy tended to be higher during the exercise (87.1 ± 0.9 %), compared to the resting (85.7 ± 1.1 %) trial, however this did not reach statistical significance; main effect of trial, $F_{(1, 93)} = 2.8$, $p = 0.099$, $\eta_p^2 = 0.029$. Moreover, there was no difference in the pattern of change in accuracy across the morning between the exercise and resting trials; trial by time interaction, *p* = 0.119. There was no difference in accuracy between the sexes or between fitness groups; main effect of sex, *p* = 0.524; main effect of fitness, *p* = 0.179. Moreover, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, *p* = 0.722; trial by time by fitness interaction, *p* = 0.601.

Flanker task

Response times, congruent level. There was no difference in response times between the exercise and resting trials; main effect of trial, *p* = 0.980. There was also no difference in the pattern of change in response times across the morning between trials; trial by time interaction, *p* = 0.865.

Response times were faster in boys (626 $\pm$ 16 ms) compared to girls (688 $\pm$ 18 ms); main effect of sex, $F_{(1, 91)} = 7.0$, $p = 0.010$, $\eta_p^2 = 0.071$. Response times were also faster in high-fit (624 $\pm$ 17 ms) compared to low-fit (690 $\pm$ 17 ms) participants; main effect of fitness, $F_{(1, 88)} = 7.8$, $p = 0.006$, $\eta_p^2 = 0.082$. However, the effect of exercise on response times was not influenced by sex or fitness; trial by time by sex interaction, $p = 0.474$; trial by time by fitness interaction, $p = 0.326$.

Response times, incongruent level. There was no difference in response times between exercise and resting trials; main effect of trial, $p = 0.537$. Moreover, there was no difference in the pattern of change across the morning between the trials; trial by time interaction, $p = 0.881$. Response times were faster in boys (671 $\pm$ 19 ms) compared to girls (743 $\pm$ 21 ms); main effect of sex, $F_{(1, 91)} = 6.2$, $p = 0.015$, $\eta_p^2 = 0.063$. Response times were also faster in high-fit (666 $\pm$ 21 ms) compared to low-fit (755 $\pm$ 21 ms) participants; main effect of fitness, $F_{(1, 86)} = 9.2$, $p = 0.003$, $\eta_p^2 = 0.096$. However, the effect of exercise on response times was not influenced by sex or fitness; trial by time by sex interaction, $p = 0.387$; trial by time by fitness interaction, $p = 0.437$.

Accuracy, congruent level. Accuracy was higher on the exercise (97.3 $\pm$ 0.3 %) compared to resting (96.0 $\pm$ 0.5 %) trial; main effect of trial, $F_{(1, 92)} = 6.7$, $p = 0.011$, $\eta_p^2 = 0.068$. However, the pattern of change in accuracy across the morning was similar between exercise and resting trials; trial by time interaction, $p = 0.202$. There was no difference in accuracy between sexes or between fitness groups; main effect of sex, $p = 0.784$; main effect of fitness, $p = 0.796$. Moreover, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, $p = 0.578$; trial by time by fitness interaction, $p = 0.217$.

Accuracy, incongruent level. Accuracy was higher on the exercise (93.9 $\pm$ 0.5 %) compared to resting (92.2 $\pm$ 0.8 %) trial; main effect of trial, $F_{(1, 92)} = 5.3$, $p = 0.023$, $\eta_p^2 = 0.055$. However, there was no difference in the pattern of change across the morning between exercise and resting trials; trial by time interaction, $p = 0.529$. There was no difference in accuracy between sexes or between fitness groups; main effect of sex, $p = 0.937$; main effect of fitness, $p = 0.973$. Moreover, the effect of exercise on accuracy was not influenced by sex or fitness; trial by time by sex interaction, $p = 0.070$; trial by time by fitness interaction, $p = 0.976$.

Focus groups

Participants highlighted a number of factors which shaped their perception and enjoyment of The Daily Mile. Specifically, six categories were developed: enjoyment of the core components of The Daily Mile, valued social context, perceived benefits from participation, perceived/actual exercise ability influences enjoyment of The Daily Mile, weather preferences influence enjoyment of The Daily Mile, and how The Daily Mile could be improved (Table 3). Illustrative quotes are presented in the table and text, with a focus within the text on sub-categories which were most prevalent in the focus groups and/or most significant in terms of their impact on participants.

Enjoyment of the core components of The Daily Mile

This category refers to specific features of The Daily Mile initiative that were fundamental to children's enjoyment of it. Within this category, four sub-categories were developed: The Daily Mile supports desire to exercise regularly, children enjoy running, exercising outside is desirable, and self-paced nature promotes autonomy (Table 3).

The Daily Mile supports desire to exercise regularly. Participants expressed a desire exercise more in school and noted that The Daily Mile provides an opportunity to exercise regularly. Consequently, children voiced positive feelings towards the initiative being introduced or continued in their school.

Exercising outside is desirable. Almost all participants emphasised their enjoyment of exercising outside. Participants frequently mentioned that when inside they feel "claustrophobic" (participant 31) and discussed the satisfaction gained from having space, fresh air and being closer to nature when participating in The Daily Mile outside: "It gives you fresh air and also…you're nearer to nature and it makes you more engrossed in what you are trying to do" (participant 24). One participant noted that it felt healthier as a result of this: "it's...healthier because you're getting fresh air and oxygen" (participant 55).

Table 3: *Higher-order and Sub- categories representing Factors Affecting Participants' Perceptions and Enjoyment of The Daily Mile, with exemplar quotes.*

Higher-order category	Sub-category	Quotes
Enjoyment of the core components of The Daily Mile	The Daily Mile supports desire to exercise regularly	"I did enjoy it because it's more exercise" (participant 92)
	Children enjoy running	"I enjoyed it because I really like running" (participant 10)
	Exercising outside is desirable	"I enjoyed it, I liked it being outside because we had more space than inside, and it was fresh air" (participant 33)
	Self-paced nature promotes autonomy	"Even though I kind of struggle…I could always walk a little bit and…the sporty people can just go around and around and around" (participant 26)
Valued social context	Engaging with peers is fun	"It was quite fun because you can run around with your friends"(participant 2)
	Peers provide distraction from exercise demands	"I liked how you could talk, because I was talking and didn't notice how I walked so far" (participant 19)
	Peers provide motivation & support	"If you're feeling tired, your friends can motivate you, so you can keep going." (participant 29)
Perceived benefits from participation	Perceived benefits to health	"I like it because…everyone can go and get fit and they'll be good at sport" (participant 105)
	Perceived benefits to learning	"I like The Daily Mile because it...can help you concentrate quite a lot" (participant 42)
Perceived/actual exercise ability influences enjoyment of The Daily Mile		"I don't really enjoy it, because it tires me out quite a lot and it's hard" (participant 41)
		"I liked it…it got really tiring, but it was still fun." (participant 32)
Weather preferences influence enjoyment of The Daily Mile		"it depends how hot it is outside. If it's really warm, I don't think I will enjoy it, but if it's cool I'm going to enjoy it more." (participant 43)
How The Daily Mile could be improved	Children desire variety within exercise	"I did enjoy it because it's more exercise but I didn't enjoy it 'cause it's a bit boring, you just run around a simple track for 20 minutes, but we could, like, put some obstacles in it" (participant 92)
	Potential for a discretionary competitive element	"It would be nice to run around with our friends and also, like, challenge yourself and race other people" (participant 96)

Self-paced nature promotes autonomy. The majority of participants confirmed that they enjoyed the self-paced nature of The Daily Mile, with many explaining that this was the most significant factor in their enjoyment of The Daily Mile as an exercise intervention. Participants appreciated that The Daily Mile enabled them to have autonomy over their exercise intensity: “I think it was good, because you get to choose, because instead of making us run the whole thing round, like jog, you could get your breath and you could have a chance to walk and then get your energy back” (participant 14). Moreover, participants acknowledged that everyone has different physical abilities and that The Daily Mile facilitated an environment where they could each feel comfortable exercising to their own. “Some people run faster than others, and some people will want to stop and start a bit, if they go too far they might want to slow down” (participant 33).

Valued social context

Although it is a characteristic of The Daily Mile initiative, the social context is considered as a higher-order category here, as participants discussed extensively the social context (i.e. the opportunity to walk/jog/run alone and/or with others) when asked what they enjoyed about participating in The Daily Mile. Accordingly, three sub-categories were developed, which represent the main reasons behind their enjoyment of the social context: engaging with peers is fun, peers provide distraction from exercise demands, and peers provide motivation and support (Table 3).

Engaging with peers is fun. Participants discussed that being able to complete The Daily Mile with peers was fun (Table 3). Some participants explained that part of the ‘fun’ was being able to chat with classmates/friends, with The Daily Mile fostering informal social interaction which is not feasible during other types of exercise, such as team sports: “In a sport...you might have to have a serious chat with someone, like, say, dodge this or there’s someone else there, but with The Daily Mile, you just have the chance to talk and not to worry about anything else” (participant 14).

Peers provide distraction from exercise demands. Several participants explained that they felt the social context was a good distraction from the demands of the exercise: “I think that was good, because if you were struggling, then it takes your mind off things" (participant 15). "I think it's good because you're distracted, you're not really focusing on actually running" (participant 31).

Perceived benefits from participation

This category highlights participant's perceptions of the benefits that can be gained from participating in The Daily Mile. Within this category, two sub-categories were developed: perceived benefits to health and perceived benefits to learning (Table 3).

Perceived benefits to learning. Many participants, when asked what they enjoyed about The Daily Mile, suggested the benefits that can be gained from participation. For example, several children expressed that participation in The Daily Mile provides a much needed "brain break" (participant 93) during lessons, and that this benefits subsequent concentration and learning: "It's quite good to be outside, instead of being in a room all the time for the whole morning and, as well, it makes people concentrate on their work more" (participant 30). "I like it because...it helps you learn" (participant 105).

Perceived/actual exercise ability influences enjoyment of The Daily Mile

Perceived and/or actual exercise ability (e.g. fitness) played a key role in determining participant's feelings towards The Daily Mile initiative. For example, while several participants expressed that they would happily extend the duration of The Daily Mile as it would enable them to challenge themselves, other participants expressed that they would not be capable of exercising for longer, with a few suggesting that The Daily Mile should be shorter because it is too tiring. Moreover, many participants recognised that participating in The Daily Mile regularly would improve their ability and fitness: "If we did do it every day, this is a good thing. We'll get more used to it and then get better at it" (participant 18). However, others portrayed a lack of enthusiasm and confidence in ability: "I don't want to do it every day because like you might get tired, like your body might start aching" (participant 10). For a few participants, perceived/actual exercise ability ultimately determined the level of enjoyment they experienced during participation in The Daily

Mile: “I don’t really enjoy it, because it tires me out quite a lot and it’s hard” (participant 41) and “I liked it…it got really tiring, but it was still fun” (participant 32).

Weather preferences influence enjoyment of The Daily Mile

Although many participants noted that they would enjoy participating in The Daily Mile in any weather conditions, some participants’ enjoyment of The Daily Mile was largely influenced by the weather during participation: “I didn’t like it ‘cause it was cold but...if it wasn’t, if it was warmer I would have” (participant 87). For some participants, these preferences influenced their feelings regarding other aspects of the initiative. For example, a few participants stated that they felt The Daily Mile was too long in duration, however when discussing why they felt this way, participants frequently noted the weather i.e. that the conditions were too hot/too cold: “I didn’t like the amount of time because if it’s outside and it’s cold then you get cold really easily” (participant 92).

How The Daily Mile could be improved

This category refers to suggestions from participants of ways in which The Daily Mile could be improved in order to enhance enjoyment in participation. Two sub-categories were developed: children desire variety within exercise and potential for a discretionary competitive element.

Children desire variety within exercise. When asked, some participants confirmed that there were other types of exercise (e.g. athletics, circuits, team sports) that they would prefer to do regularly in school. These participants explained that although they find running enjoyable, they prefer exercise that involves a variety of activities. Consequently, they found The Daily Mile to be repetitive: “It was a bit boring. You’re not really doing anything you’re just running” (participant 102). From further discussion, it was discovered that almost all participants expressed a preference for variety within exercise and a desire to participate in activities that incorporate running as well as other exercise components regularly at school. Gaining agreement from the other participants in the focus group, one participant suggested incorporating other components into The Daily Mile: “I did enjoy it because it’s more exercise but I didn’t enjoy it ‘cause it’s a bit boring, you just run around a simple track for 20 minutes, but we could, like, put some obstacles in it” (participant 92).

Potential for a discretionary competitive element. A few participants suggested incorporating a competitive element into The Daily Mile. They felt that it's enjoyable to challenge themselves and that competition can provide a good distraction from exercise demands: "It would be nice to run around with our friends and also, like, challenge yourself and race other people" (participant 96). However, some participants highlighted that they already participate in competitive sports at school and thus enjoy having the opportunity to participate in an activity that is non-competitive: "I prefer not competitive...because our school...we do other competitive stuff whereas it's nice after you're doing lessons just to have a chat. 'Cause sometimes when you get back to your class you can be really tired from trying really hard" (participant 105).

Discussion

Overall, the findings of the present study show that The Daily Mile did not significantly affect subsequent cognition, compared to resting. However, there was a tendency for improved accuracy on tasks of inhibitory control and visual working memory immediately following participation in The Daily Mile. Moreover, another key finding of the present study was that boys displayed faster response times than girls on the simple level of all cognitive tests, and high fit participants displayed faster response times than low fit participants on both the simple and complex levels of cognitive tests. During the focus groups, participants reported positive perceptions of The Daily Mile and the self-paced, social nature and outdoor location were considered particularly enjoyable components. The findings of the present study provide some clarity to the limited and ambiguous evidence regarding the acute effects of The Daily Mile on children's cognition. Furthermore, this study has enabled novel understanding of the factors which influence children's enjoyment of The Daily Mile.

The present study is the first crossover, order-balanced, randomised control trial to examine the acute effects of The Daily Mile on children's cognition. The results from the sample as a whole demonstrate that The Daily Mile does not significantly affect immediate or delayed (45 min) cognition, across the domains of inhibitory control, cognitive flexibility, and visual working memory. There was, however, a tendency towards improved accuracy on the one-item level of the Sternberg paradigm (visual working memory) and the complex level of the Stroop test (inhibitory control) immediately following The Daily Mile, compared to rest. This was coupled with a tendency for slower response times on the complex level of the Stroop test, suggesting that children tended to be slower but more accurate in inhibitory control and working memory tasks following The Daily Mile. The effect size of these trends were small ($\eta_p^2 < 0.06$), though small effect sizes are typical within exercise-cognition literature (e.g. Booth et al., 2020; Cooper et al., 2018; Ludyga et al., 2016; Verburgh et al., 2014).

Interestingly, Booth et al. (2020) reported significant improvements in working memory following participation in The Daily Mile, compared to rest. According to Baddeley and Hitch's (1974) model, working memory is comprised of the visuo-spatial sketchpad, which processes visual/spatial information, and the phonological loop, which processes auditory/verbal information. The present study measured visual working memory using the Sternberg paradigm test, tapping into the visuo-spatial sketchpad, while Booth et al. (2020) measured verbal working memory using the reading span task, activating the phonological loop. The discrepancy between the findings of the present study and Booth et al.'s (2020) may thus be, in part, due to the specific type of working memory assessed. However, Morris et al. (2019) utilised the digit recall test, which similarly taps the phonological loop component of working memory and found no effect of The Daily Mile. Moreover, Booth et al. (2020) also observed enhanced inhibitory control following The Daily Mile, while Morris et al. (2019) did not, suggesting that other factors, such as the timing of the cognitive testing, may be responsible for the difference in results between the studies. In Booth et al.'s (2020) study, teachers were instructed to administer cognitive measurements within 20 min of The Daily Mile; whereas the cognitive tasks in the present study, and in the study by Morris et al. (2019), were completed within 5 min of completion of The Daily Mile. Exercise-induced effects on cognition are both domain and time sensitive, with enhancements to some domains presenting immediately and others presenting after a delay (Williams et al., 2019). The different effects of The Daily Mile on cognitive function observed between these studies could, therefore, be due to the time at which the cognitive tasks were administered following participation. The present study extends previous work by reporting no effects of The Daily Mile on children's cognition 45 min following participation. However, it must also be noted that The Daily Mile did not have any negative effects on subsequent cognition, which coupled with the previously reported benefits on physical activity (Chesham et al., 2018) and fitness (de Jonge et al., 2020), still suggests that The Daily Mile is an effective school-based physical activity intervention.

In the present study, boys presented faster response times than girls on the simple levels of all cognitive tasks, with a small ($\eta_p^2 < 0.06$; Sternberg paradigm test) to medium ($\eta_p^2 < 0.14$; Stroop and Flanker test) sized effect. Interestingly, however, there are no differences in performance between sexes on the complex levels of the Stroop or Sternberg paradigm tests, which elicit higher cognitive demands. Similar findings have been reported in previous research with both children and adults, demonstrating that males, compared to females, are consistently faster on simple, but not complex, reaction time tasks (Dykiert, Der, Starr & Deary, 2012). Additionally, there was no effect of sex on the cognitive responses to exercise, with the exception of the three-item level of Sternberg paradigm whereby girls' response times got slower following exercise and got quicker following resting. However, this effect was not observed on the one-item or five-item level of the test, nor did sex influence the effect of The Daily Mile on inhibitory control or cognitive flexibility; in line with previous findings across cognitive domains (Booth et al., 2020).

Moreover, in the current study participants with a higher cardiorespiratory fitness presented faster response times on both the simple and complex levels of the Stroop test and Flanker task, and on the three-item level of Sternberg paradigm. Effect sizes ranged from small ($\eta_p^2 < 0.06$; Sternberg paradigm test) to medium ($\eta_p^2 < 0.14$; Stroop and Flanker test). These findings likely represent the effect of chronic exercise participation on cognition, a relationship supported by the literature (Hillman et al., 2011; Ludyga et al., 2020). It would, therefore, be valuable for future research to explore whether effects to cognition are gained with chronic participation in The Daily Mile, particularly as chronic exercise interventions which improve young people's fitness lead to improvements in cognitive function (Xue et al., 2019) and improvements to cardiorespiratory fitness are observed following 12 weeks of participation in The Daily Mile (de Jonge et al., 2020). However, the findings of the present study suggest that the cognitive effects of acute participation in The Daily Mile are similar for young people of all fitness levels, which is in line with previous research on The Daily Mile (Booth et al., 2020). Interestingly, these findings are in contrast to a number of studies within the wider exercise-cognition literature, which suggest that young people with high cardiorespiratory fitness gain greater post-exercise enhancements to cognitive function (Cooper et al., 2018; Jäger et al., 2015). The contrast in findings may be due to the fact that The Daily Mile is a self-paced activity and has been shown to elicit a similar relative exercise intensity in children of all fitness levels (Hatch et al., 2021); thus participation in The Daily Mile is more likely to produce similar cognitive responses in children of differing fitness levels than exercise of a set absolute intensity, which is likely to elicit varying relative intensity between participants and thus varying cognitive responses.

The present study is the first to investigate the specific factors which influence children's enjoyment of participating in The Daily Mile. The findings respond to the need for evidence regarding children's enjoyment of physical activity initiatives, which is essential not only for engagement in the initiative but for the development of positive perceptions of exercise and thus life-long physical activity participation (Cardinal et al., 2013; Humbert et al., 2008). Overall, participants expressed positive feelings towards the core principles of The Daily Mile and a desire to participate in The Daily Mile regularly at school. In particular, children found participation in The Daily Mile enjoyable due to its social context, outdoor location and self-paced nature. These findings support previous research which has recognised children's value of social connections during exercise (Harris et al., 2019; Kinder et al., 2019) and extend upon them by detailing the factors which promoted an enjoyable social context during The Daily Mile; specifically, the informal environment which enabled fun, supportive and motivational interactions while exercising. Moreover, the findings of the present study demonstrate that children enjoyed the self-paced nature of The Daily

Mile as it enabled them to have choice over their exercise intensity and thus exercise to their own ability. Together these findings suggest that The Daily Mile facilitates social relatedness and autonomy, which according to Self Determination Theory (Ryan & Deci, 2000), are fundamental psychological needs that when satisfied promote internal motivation for long-term physical activity participation (Sebire et al., 2013). Therefore, for most children participation in The Daily Mile is likely to elicit long-term engagement in the initiative and promote positive perceptions and motivations towards exercise more generally.

Importantly, however, children expressed a desire for variety in the exercise they engage in at school and a few children reported feeling bored during The Daily Mile due to its repetitive nature. This is of some concern, given that boredom during exercise is cited as a primary reason for young people not wanting to participate in physical activity in school (Department for Education, 2013). Moreover, some children suggested that The Daily Mile could be made more enjoyable by incorporating other activities and/or a competitive element. Similarly, teachers implementing The Daily Mile report that some children are motivated by competition and seek it during The Daily Mile (Harris et al., 2019). Therefore, future research could consider making minor modifications to The Daily Mile (e.g. introducing discretionary competitive elements and/or opportunities to vary the nature of activity) and investigate how these affect children's enjoyment and effects to cognition and health.

Among the many strengths of this study are its robust design and control of variables (e.g. dietary intake) which have the potential to impact the exercise-cognition relationship (Cooper et al., 2011, 2015; Hoyland et al., 2009), and yet have not been controlled in previous Daily Mile-cognition research. However, a potential limitation of the present study is that the effects of acute participation in The Daily Mile on cognition were only examined up to 45 min following participation; and thus the effects across the remainder of the school day, for example, remain unknown. Additionally, the majority of the schools were implementing The Daily Mile at the time of participation in the study. While the length of implementation at these schools ranged from 2 to 12 months, prior engagement will have impacted the novelty of the exercise, and thus may have influenced children's perceptions of it (e.g. whether they found it boring or repetitive). Children were instructed, however, to comment exclusively on their experience of participating in The Daily Mile within the study, and not on their experiences of the initiative more generally. Nevertheless, the focus group data should be interpreted with this in mind. Moreover, as with all studies of this nature, it is possible that the schools that agreed to participate in the study are not representative of all schools; with a possibility being that schools who are more active were more likely to participate. However, anecdotally, this was not the case in the present study and is partly supported by the fact that two of the schools had never previously implemented The Daily Mile. Additionally, although children were asked to refrain from exercise 24 h prior to each trial, transport to school was not controlled or measured. Furthermore, due to logistical challenges and the number of children who volunteered to participate within each school, group sizes during participation in The Daily Mile were smaller (5–16 children) than they typically are when The Daily Mile is implemented in school. Children's activity patterns and/or enjoyment may differ when participating in larger groups (e.g. whole class), thus the results of this study should be interpreted with this in mind.

Future research could expand on this study, and other qualitative work on The Daily Mile, by examining how teacher and pupil perceptions of the initiative interact to influence implementation success, as teacher's perceptions of exercise interventions can impact pupil's perceptions, and vice versa (Marchant et al., 2020; McMullen et al., 2014). Furthermore, future research should seek to examine the chronic effects of participation in The Daily Mile on children's cognition, which remain unknown.

Conclusions

This is the first within-subjects, counterbalanced, randomised control trial to explore the acute effect of The Daily Mile on cognition in children. The findings demonstrate that The Daily Mile has no significant effect on inhibitory control, cognitive flexibility or visual working memory measured immediately or 45 min post exercise. However, there was a tendency for children to be more accurate immediately following The Daily Mile on a simple visual working memory and complex inhibitory control task. Another key finding was that children enjoyed participating in The Daily Mile, particularly due to its social context and self-paced nature; although some children reported feeling bored due to its repetitiveness. Future research should examine the exact time course of any changes in cognition following acute participation in The Daily Mile; alongside considering the effects of chronic participation in The Daily Mile. Furthermore, future research could examine the effect of a modified Daily Mile, which includes a discretionary competitive element, for example, on children's enjoyment of the initiative, which is important for long-term adherence and any subsequent benefits for cognition and health.

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