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ARTICLE

Four minutes of in-class high-intensity interval activity improves selective attention in 9- to 11-year olds

Jasmin K. Ma, Lucy Le Mare, and Brendon J. Gurd

Abstract: The amount of time allocated to physical activity in schools is declining. Time-efficient physical activity solutions that demonstrate their impact on academic achievement-related outcomes are needed to prioritize physical activity within the school curricula. "FUNtervals" are 4-min, high-intensity interval activities that use whole-body actions to complement a storyline. The purpose of this study was to (*i*) explore whether FUNtervals can improve selective attention, an executive function posited to be essential for learning and academic success; and (*ii*) examine whether this relationship is predicted by students' classroom off-task behaviour. Seven grade 3–5 classes (n = 88) were exposed to a single-group, repeated cross-over design where each student's selective attention was compared between no-activity and FUNtervals days. In week 1, students were familiarized with the d2 test of attention and FUNterval activities, and baseline off-task behaviour was observed. In both weeks 2 and 3 students completed the d2 test of attention following either a FUNterval break or a no-activity break. The order of these breaks was randomized and counterbalanced between weeks. Neither motor nor passive off-task behaviour predicted changes in selective attention following FUNtervals; however, a weak relationship was observed for verbal off-task behaviour and improvements in d2 test performance. More importantly, students made fewer errors during the d2 test following FUNtervals. In supporting the priority of physical activity inclusion within schools, FUNtervals, a time efficient and easily implemented physical activity break, can improve selective attention in 9- to 11-year olds.

Key words: exercise, children, academic performance, school, in-class activities, students, executive function.

Résumé : Le temps alloué à l'activité physique à l'école est en déclin. Des solutions en matière d'activité physique, rentables dans le temps et démontrant leur impact sur les résultats scolaires, sont requises afin de prioriser l'activité physique dans le cursus scolaire. Les *FUNtervalles* consistent en un intervalle de 4 minutes d'activités de forte intensité mobilisant tout le corps et s'inscrivant en complémentarité dans un thème. Cette étude se propose (*i*) d'explorer la possibilité selon laquelle les FUNtervalles améliorent l'attention sélective, une fonction opérationnelle jugée essentielle à l'apprentissage et au succès scolaire et (*ii*) d'examiner si cette association est prédite par le comportement non centré sur la tâche des élèves en classe. Sept classes de la 3e à la 5e année (n = 88) forment un seul groupe dans lequel on compare selon un devis croisé avec mesures répétées l'attention sélective de chaque élève dans des périodes sans activités à des périodes incluant des FUNtervalles. Durant la semaine 1, les élèves se familiarisent avec le test d'attention d2 et les activités de FUNtervalles et on observe les comportements non centrés sur la tâche comme mesure de base. Durant les semaines 2 et 3, les élèves passent le test d'attention d2 à la suite d'une pause des FUNtervalles ou des périodes sans activités. L'ordre des pauses est aléatoire et contrebalancé d'une semaine à l'autre. Les comportements moteurs ou passifs non centrés sur la tâche ne prédisent pas les variations de l'attention sélective à la suite des FUNtervalles, mais on observe une faible relation entre les comportements verbaux non centrés sur la tâche et l'amélioration des résultats au test d'attention d2. Fait important à noter : les élèves font moins d'erreurs au test d2 à la suite des FUNtervalles. À l'appui de la priorité de l'inclusion de l'activité physique dans les écoles, les FUNtervalles, qui sont des pauses rentables et faciles d'application, peuvent améliorer l'attention sélective des élèves de 9 à 11 ans. [Traduit par la Rédaction]

Mots-clés : exercice physique, enfants, succès scolaire, école, activités de classe, élèves, fonction exécutive.

Introduction

Despite evidence that physical activity promotes health in children (Biddle et al. 2004; Must and Tybor 2005), only 7% of Canadian youth are meeting current physical activity guidelines (Active Healthy Kids Canada 2014). While schools appear to represent an ideal site for increasing youth physical activity (Colley et al. 2011; Pate et al. 2006; Tomporowski et al. 2011), the perception that physical activity threatens academic achievement (Coe et al. 2006; Sallis et al. 1999) and the perceived lack of time available for physical activity (Tsai et al. 2009) have contributed to a lack of physical activity programming in schools. Contrary to these perceptions, time spent participating in physical activity in place of regular instruction time does not impair academic performance (Rasberry et al. 2011) and in fact may improve it (Ahamed et al. 2007; Carlson et al. 2008; Murray et al. 2007; Rasberry et al. 2011; Sallis et al. 1999; Trudeau and Shephard 2008, 2010).

To address the barrier of time and the associated threat to academic performance teachers perceive, we (Ma et al. 2014) and others (Grieco et al. 2009; Mahar et al. 2006; Tsai et al. 2009) have developed brief exercise breaks designed to be time efficient and feasibly implemented in the classroom. To further support the inclusion of physical activity in schools an emerging body of literature has begun to examine the impact of classroom exercise breaks on outcomes linked to learning and academic performance (Grieco et al. 2009; Ma et al. 2014; Mahar et al. 2006; Tsai

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et al. 2009). In particular the impact of exercise on selective attention, a cognitive function linked to learning (Yli-krekola et al. 2009), has received recent interest.

Selective attention, an executive function that encompasses the ability to attend to relevant stimuli and ignore irrelevant or distractor stimuli (Bedard et al. 2003; Carter et al. 1995), is an important determinant of literacy (Stevens et al. 2009) and mathematics ability (Blair and Razza 2007). There is limited evidence that exercise has positive effects on selective attention in school-aged children. For example, 10 min of both coordinative exercises (consisting of bouncing, throwing, and kicking balls while balancing) and participation in sport improved attentional performance in 13- to 16-year olds (Budde et al. 2008). Twelve minutes of sustained moderate- to high-intensity exercise (running on a track) also enhanced selective attention in elementary-aged children (Niemann et al. 2013; Tine and Butler 2012). While effective at improving selective attention, all of the above interventions required student relocation (i.e., to a gym or a track) and/or the use of equipment. It is currently unknown if time-efficient physical activity breaks designed to be implemented in classrooms are able to have similar beneficial effects on selective attention.

We have recently observed that 4 min of high-intensity interval exercise, FUNtervals, reduces off-task behaviour (i.e., disengagement from the learning task at hand) in grade 2 and 4 students (Ma et al. 2014). Interestingly, there is some evidence that off-task behaviour and selective attention are associated with one another. For example, children with attention-deficit hyperactivity disorder exhibit significantly less on-task behaviour than their typically developing counterparts (Kofler et al. 2008), and have associated problems with selective attention (Satterfield et al. 1990). Given this relationship, and our previous observation that improvements in off-task behaviour were positively associated with baseline off-task behaviour, it seems reasonable to hypothesize that FUNtervals would improve selective attention, and that the magnitude of this improvement would be predicted by baseline off-task behaviour.

Therefore, the purpose of this study is 2- fold: (*i*) to extend our previous examination of the effects of brief, high-intensity interval exercise (FUNtervals) on classroom behaviour to selective attention, a cognitive function associated with academic achievement; and (*ii*) to determine whether classroom off-task behaviour predicts changes in selective attention observed following exercise. It is hypothesized that FUNtervals will improve selective attention and that these improvements will be greatest in students with the highest rates of off-task behaviour on no activity days.

Materials and methods

Participants

The current study is a follow-up from a previously published report (Ma et al. 2014) and involved the recruitment of a new group of participants from 7 classrooms of students attending grades 3–5 (grade 3/4, 2 classes; grade 4, 2 classes; grade 4/5, 3 classes) from 5 different south eastern Ontario, Canada, elementary schools. Schools serviced primarily white, middle-class families with 12 students having ministry of education designations. Based on previous examinations of the effects of exercise on d2 test performance in children, a large effect size (Cohen's $f = 0.8$) was assumed (Budde et al. 2008; Niemann et al. 2013). Setting a power of 0.80, and an α level of 0.05, power analysis determined that 81 participants were required. Of a total 170 students contacted, 168 (99%) returned permission forms confirming informed consent. Participants excluded from analyses included those with missing data, dyslexia, or severe learning disabilities, and those in 1 class whose teacher intervened during an intervention as a result of excessively poor behaviour on a no-activity day. A total of 88 students (male, $n = 44$; female, $n = 44$) were included in the final d2 test data analysis and 68 were included in the behaviour analysis. Approval for this study was obtained from the General Research Ethics Board at Queen's University and the participating district school board.

Study design

The current study utilized a single-group, repeated cross-over design where we compared students' selective attention on no-activity days and FUNterval days. Off-task behaviour for each student was also evaluated on 2 occasions during the first week of the study. The intervention totaled 3 weeks in duration with all data collection being conducted in the classroom. In week 1, students were familiarized with the d2 test of attention and FUNterval activities, and off-task behaviour was assessed. In both weeks 2 and 3 students completed the d2 test of attention following either a FUNterval break or a no activity break. The order of these breaks was randomized in week 2 and then repeated in the opposite order in week 3.

Familiarization and quantification of off-task behaviour

The first day of week 1 was used as familiarization to both FUNterval activities and the d2 test of attention. Fifty minutes of observation of off-task behaviour was also completed on day 1 with the dual purpose of familiarizing the researchers with the observation tool and familiarizing students with the presence of researchers in the classroom. Student familiarization to the presence of researchers has previously been reported to be important to eliminate the reactivity effect on the teacher and students (Mahar et al. 2006). Data collected during the familiarization day was not used in subsequent analysis.

Days 2 and 3 of week 1 were used to quantify student off-task behaviour on no-activity days. Both of these days consisted of 50 min of classroom observation following a 10-min lecture break delivered by the primary researcher. The 10-min, no-activity break was separated from recess by at least 20 min on both days.

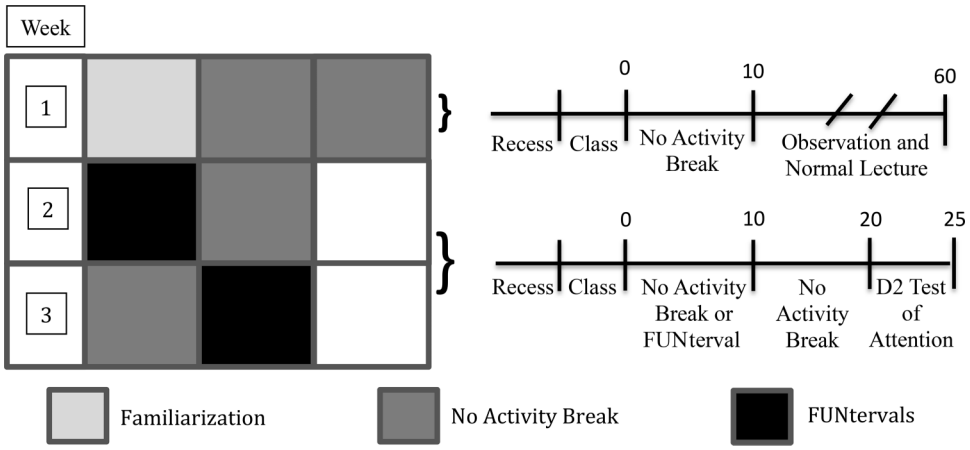
FUNterval and no activity interventions

During weeks 2 and 3, FUNterval and no-activity break interventions were delivered on 2 separate days in randomized order (FUNterval intervention on day 1, $n = 53$; no-activity intervention on day 1, $n = 35$). The order that these breaks were delivered in week 3 was opposite from the order that they were delivered in week 2. Each intervention break was 10 min in duration (FUNterval break, 4 min of exercise plus time required to prepare and to return to seats following activity; no activity, 10-min lecture) and was separated from recess by at least 20 min of normal classroom instruction. Every intervention break was followed by another 10-min, no-activity break, during which the researcher delivered a lecture unrelated to class content before the d2 test of attention was administered. The d2 test of attention was administered 10 min post-intervention as previous research has demonstrated that this is the time period at which the greatest effects of physical activity on executive function are present (Chang et al. 2012). Intervention days within a given week were separated by at least 24 h and the last visit of week 2 and the first of week 3 were separated by at least 5 days. Ideally a week separation occurred between weeks 2 and 3 in an attempt to reduce the learning effect on the d2 test (Budde et al. 2012); however, this scheduling commitment was not always feasible for teachers. A detailed schematic of the experimental design is presented in Fig. 1.

FUNterval activity intervention

FUNtervals are high-intensity interval activities that require only 4 min to complete. The protocol, adapted from the work of Tabata et al. (1996), consists of 20 s of high-intensity activity separated by 10 s of rest, repeated 8 times. This protocol was adapted for primary school classrooms to complement various storylines, which encourage students to complete large, whole-body movement

Fig. 1. Overview of study design. The order of interventions in weeks 2 and 3 was randomized and counterbalanced.



as fast as possible. Movements targeted included, for example, squats, jumping jacks, scissor kicks, jumping, and running on the spot. A different FUNterval was implemented on each activity day of the study. A booklet outlining the FUNterval activities utilized in this study, along with many additional activities, is available from the authors upon request. Although other physical activity breaks that are effective for school use are available (Whitt-Glover et al. 2013), FUNtervals are unique for their physical activity-specific break (no associated academic component) requirement of less than 10 min of class disruption, and no equipment or relocation from the classroom.

No-activity intervention

To isolate the effects of exercise from the effect of having a break in the lesson material, a lecture on a nonlesson-related topic was given on no-activity days. Lectures given did not require the students to be physically active in any capacity and included the primary researcher speaking about engaging topics related to the field of kinesiology.

Observation

Classroom observations took place during regular classroom instruction. Teachers were instructed to avoid group work and have students participate in the lesson from their desks. Although the proportion of time each class spent in each lesson activity varied, classroom lessons during the observation period consisted of either students completing independent worksheets and/or oral lectures followed by a question and answer period.

Off-task behaviour was identified using the Behavioral Observation of Students in Schools tool definitions (Shapiro 1996), with off-task behaviour being recorded using the partial interval method (Hintze et al. 2002) as we have described previously (Ma et al. 2014). Briefly, a rotating observation schedule allowed for a total observation time of 5 min per student per day. During each observation interval researchers noted the occurrence and duration of motor (i.e., fidgeting, drawing, restlessness), verbal (i.e., talking to classmate, speaking when not called upon), and passive (i.e., gazing off, not making eye contact to the speaker, head down on the table) off-task behaviour for 30 s (Hintze et al. 2002; Mahar 2011). Reliability of this observation technique was previously tested in grade 4 students and found to be high: 90% (range = 84%–94%), $\kappa = 0.795$ (Ma et al. 2014).

d2 test of attention

The d2 is a standardized pen and paper assessment of individual attention and concentration that is related to academic performance (Brickenkamp 2002). The test consists of 14 lines of 47 characters (658 total items) comprising the letters "p" and "d" with 1–4 dashes arranged individually or in pairs above or below the character. The students are required to scan the characters and mark all "d"s with 2 dashes either above or below. Students were given 20 s per line, or a total of 4 min and 40 s to complete the test and the tests were scored for the total number of characters processed (TN; sum of total characters processed for each line), errors of omission (E_{Omis}; the number of mistakes made by missing relevant symbols), errors of commission (E_{Comm}; the number of mistakes made by including irrelevant symbols, the percentage of errors (E%; the proportion of both errors of commission and omission made within all of the processed items), the total number of items scanned minus error scores (TN-E), and concentration performance (CP; number of correctly crossed out relevant items minus errors of commission) (Brickenkamp and Zillmer 2002). The test–retest internal reliability coefficients of the d2 test have been reported to be high (0.9–0.95) for all parameters (Brickenkamp 2002), with test values for criterion, construct, and predictive validity remaining stable over a period of up to 23 months after initial testing (Brickenkamp 2002). The d2 test of attention has been used to measure selective attention in previous childhood studies (Budde et al. 2008; Niemann et al. 2013; Tine and Butler 2012) and was selected as its short time for set up and completion make it minimally disruptive for the classroom.

Statistical analysis

Values for d2 test performance for each student were obtained by averaging the daily collections in each condition. Repeated measures, 2-way ANOVAs were used to compare d2 performance scores between no-activity and FUNterval days. Where the assumption of sphericity was violated, the Greenhouse–Geyser adjustment was reported. Independent samples *t* tests were used to assess gender differences in d2 test performance. Effect sizes (ES) for change in d2 test scores were calculated using Cohen's *d* to demonstrate the size of mean differences. Classroom off- task behaviour was averaged over the 2 days and linear regression analysis was used to examine each individual component of classroom off-task behaviour as a predictor of mean changes in selective attention. Mean changes in d2 test performance were calculated by averaging scores between weeks 2 and 3, then taking the difference between average FUNterval and no-activity data. Independent samples *t* tests were used to compare off-task behaviour of boys and girls.

Results

Sex differences

A comparison of the d2 test performance on no-activity days demonstrated that males made a higher number of total errors (E) and E_{Omis} than females (Table 1). Males were also found to partic-

Table 1. Participant characteristics.

Performance measure	Male (n = 44)	Female (n = 44)	t	df	p
Behaviour					
% Passive	29±3	19±2	–3.03	67	<0.01*
% Motor	25±3	18±2	–1.24	67	<0.01*
% Verbal	5±1	5±1	–0.53	67	0.97
Selective attention					
TN	381±13	359±13	1.26	86	0.21
E	19±2	12±2	2.22	86	0.03*
E_{Omis}	12±2	6±2	2.60	86	0.01*
E_{Comm}	7±1	6±1	0.38	86	0.70
E%	5.0±0.6	3.8±0.6	1.35	86	0.18
TN-E	362±13	347±13	0.86	86	0.39
CP	143±6	140±6	0.45	86	0.65

Note: Values are means ± SE of the percentage of off-task behaviour and d2 test performance on No Activity days. CP, concentration performance; E, total errors; E%, percent errors; E_{Comm}, errors of commission; E_{Omis}, errors of omission. TN, total number of characters processed; TN-E, total number of characters minus total number of errors.

*Indicates significant ($p < 0.05$) differences between males and females.

ipate in a greater percentage of passive and motor off-task behaviour than females (Table 1).

Intervention effects on attention

Repeated measures ANOVAs revealed nonsignificant sex × intervention and week × intervention interaction effects, but a significant ($p < 0.05$) main effect of intervention (i.e., FUNtervals) on d2 test performance. Specifically, following no activity there was a greater TN (no activity = 370, FUNtervals = 361, $F_{[1,87]} = 4.40$, $p = 0.04$, ES = 0.12; Fig. 1A) while following FUNtervals there were fewer E (no activity = 15, FUNtervals = 11, $F_{[1,87]} = 11.54$, $p < 0.01$, ES = 0.29), E_{Omis} (no activity = 9, FUNtervals = 6, $F_{[1,87]} = 6.65$, $p = 0.01$, ES = 0.18; Fig. 1B), E_{Comm} (no activity = 7, FUNtervals = 5, $F_{[1,87]} = 4.64$, $p = 0.03$, ES = 0.16; Fig. 1C), and E% (no activity = 4.4%, FUNtervals = 3.4%, $F_{[1,87]} = 12.08$, $p < 0.01$, ES = 0.23; Fig. 1D). All measures of the d2 test (TN, E, E_{Omis}, E_{Comm}, E%, TN-E, and CP) improved from week 1 to week 2 (p's < 0.05). A significant effect of test day order was also found from day 1 to day 2 in all d2 test outcomes as well as between days 3 and 4 for TE, E_{Omis}, and E% (data not shown).

Off-task behaviour and selective attention

Neither baseline passive or motor off-task behaviours were found to predict the change in d2 test outcomes (i.e., the difference between FUNterval and no activity d2 test performance) in simple linear regression tests ($p > 0.05$; Table 2). However, weak relationships between baseline verbal off-task behaviour and change in E_{Comm} ($R = 0.27$, $t(67) = –2.20$, $p = 0.03$), E% ($R = 0.27$, $t(67) = –2.33$, $p = 0.02$), and CP ($R = 0.24$, $t(67) = 2.00$, $p = 0.05$) as well as a weak relationship between baseline verbal off-task behaviour and no activity E_{Comm} ($R = 0.06$, $t(67) = 2.09$, $p = 0.04$) were observed (Table 2). Moreover, independent t test revealed the improvement in selective attention following FUNtervals was not significantly different between the highest quartile (HQ) and lowest quartile (LQ) of motor or passive off-task behaviour (data not shown); however, the HQ for verbal off-task behaviour demonstrated a significantly greater improvement following FUNtervals than the LQ for E (HQ = –7.7, LQ = –2.0, $p = 0.04$), E_{Comm} (HQ = –2.6, LQ = –0.3, $p = 0.03$), E% (HQ = –2.2, LQ = –0.5, $p = 0.04$), and CP (HQ = 7.8, LQ = –1.3, $p = 0.01$; Fig. 2).

Discussion

The current study is the first to examine a classroom feasible intervention and its effects on selective attention. In the present study we examined the acute effects of brief, high-intensity interval activities, or FUNtervals, on selective attention in students in grades 3–5. Whether the impact of exercise on selective attention could be predicted by baseline classroom behaviour was also examined. The major findings of the current study were (*i*) brief, high-intensity interval exercise (FUNtervals) improved selective attention in 9- to 11-year olds, and (*ii*) verbal off-task classroom behaviour weakly predicted the changes in selective attention induced by FUNtervals but a similar relationship was not observed for either passive or motor off-task behaviour. These results demonstrate that FUNtervals, which are easily implemented in primary school classrooms, can increase performance on a selective attention test, suggesting that they may also improve the in-class learning environment.

Table 2. Regression R values of average off-task behaviour as a predictor of d2 test performance.

Performance measure	Passive off-task behaviour	Motor off-task behaviour	Verbal off-task behaviour
TN			
R	0.05	0.09	0.06
p	0.70	0.47	0.65
E			
R	0.01	0.11	0.20
p	0.91	0.38	0.10
E_{Omis}			
R	0.00	0.08	0.12
p	0.99	0.52	0.32
E_{Comm}			
R	0.05	0.10	0.26
p	0.72	0.42	0.03*
E%			
R	0.03	0.10	0.27
p	0.81	0.41	0.02*
TN-E			
R	0.06	0.13	0.12
p	0.66	0.29	0.31
CP			
R	0.06	0.17	0.24
p	0.65	0.17	0.05*

Note: CP, concentration performance; E, total errors; E%, percent errors; E_{Comm}, errors of commission; E_{Omis}, errors of omission; TN-E, total number of characters minus total number of errors; TN, total number of characters processed.

*Indicates significant ($p < 0.05$) correlation.

Fig. 2. Comparison of the highest and lowest quartile of mean off-task verbal behaviour on change in d2 test performance from no activity days to FUNterval days. A greater negative change is desirable for total errors (E), errors of commission (E_{Comm}), and % errors (E%), while a greater positive change is desirable for concentration performance (CP). *, Significantly different from the highest quartile ($p < 0.05$).

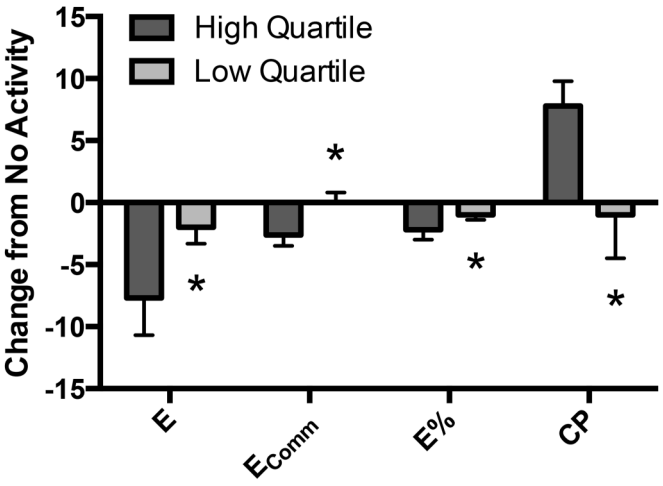
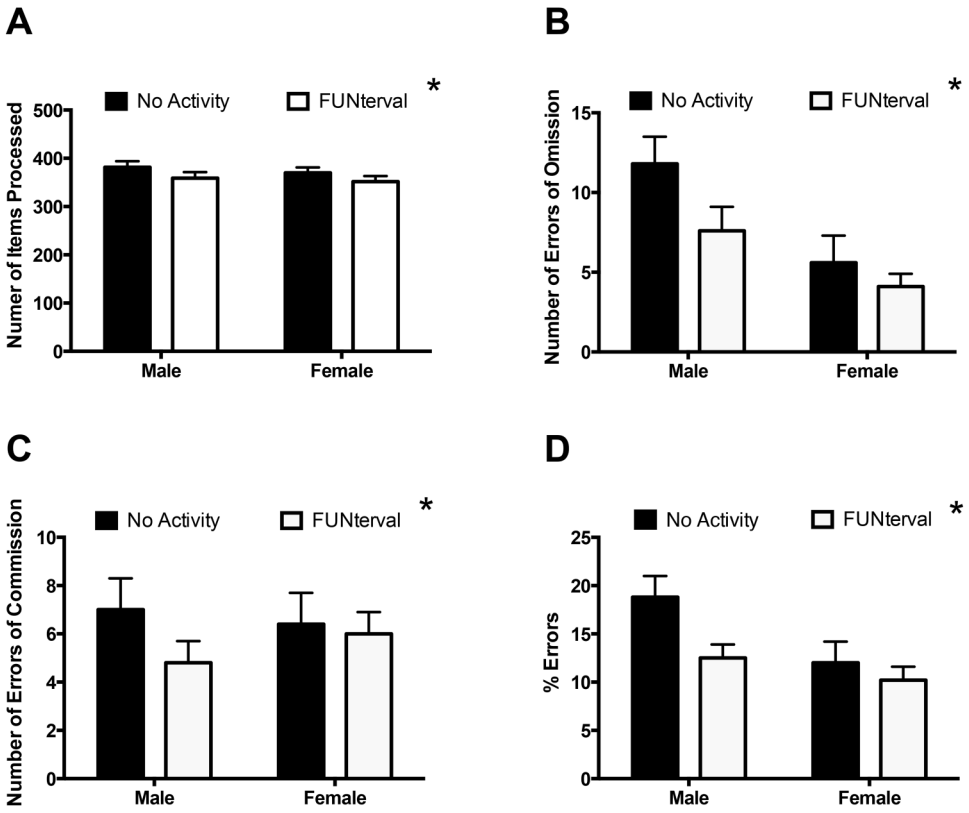


Fig. 3. Effects of FUNtervals on d2 test of attention outcomes. Comparison of FUNterval with no activity days in males and females on total number of items processed (A), errors of omission (B), errors of commission (C), and % errors (D). *, Significant ($p < 0.05$) main effect of intervention.



FUNtervals and selective attention

The most important finding of the current study is the observation that 4 min of high-intensity interval activity improves selective attention in elementary school children (Fig. 3). The observation that fewer errors were made during the d2 test following FUNtervals is consistent with improved accuracy, quality of work, and degree of carefulness compared with no-activity days. Performance on the d2 test is also predictive of academic performance (Brickenkamp and Zillmer 2002), suggesting that the observed improvements on the d2 test following FUNtervals may be associated with improvements in academic achievement were FUNtervals to be implemented on a long-term basis. These assertions are speculative, however, and further research is needed to confirm the long-term effects of regular participation in FUNterval activities on academic achievement.

Our observations are consistent with previous studies demonstrating positive acute effects of exercise on selective attention. For example, running at both moderate (Tine and Butler 2012) and high intensities (Niemann et al. 2013) resulted in greater d2 test performance with this effect being particularly strong in students from low-income families (Tine and Butler 2012). Additionally, both coordinative exercises and normal sport lessons improve CP, with greater effects seen following coordinative exercises (Budde et al. 2008). Unlike the latter study, where a counterbalanced order, no-activity control was absent, the current study utilized a randomized within-subject repeated crossover design, which provides greater confidence that the observation of improved selective attention was an effect of exercise per se, rather than an effect of learning. Further, unlike previous studies where the intervention activities required that students leave the classroom and/or utilize equipment, the current study demonstrates that brief, high-intensity physical activity breaks implemented in classrooms are capable of improving selective attention. Thus, the impact of in-class physical activity breaks on selective attention appears to be similar to that of exercise breaks completed outside the classroom.

Interestingly, after exclusion of students with incomplete data sets (see Materials and methods section for details), a greater percentage of students participated in an order of conditions that would favour improvements in the no-activity condition in week 1 (60% completed the FUNterval condition first during the first week of testing) as test-taking strategies may be developed when the test is repeated from day to day. This may explain the observation that no-activity days resulted in a slightly higher number of characters processed than FUNterval days and suggests that the positive effects of FUNtervals reported may actually have been underestimated in the current data set. In summary, FUNtervals are an extremely brief physical activity break with benefits extending beyond their ease of implementation to the classroom learning environment through improved selective attention.

Selective attention and off-task behaviour relationship

In addition to demonstrating that classroom-based high-intensity physical activity can improve selective attention, the current study is also one of the first to examine the relationship between off-task behaviour and improvements in selective attention following physical activity breaks. More specifically, we examined whether baseline off-task classroom behaviour predicted the magnitude of improvement in selective attention following FUNtervals. Previous studies have observed that students with the highest off-task behaviour benefited the most from physical activity interventions (Ma et al. 2014; Mahar et al. 2006). Based on these observations, and the proposed mechanistic links between behaviour and selective attention (Kercood and Grskovic 2009), we hypothesized a positive correlation between baseline off-task behaviour and the change in selective attention induced by exer-

cise. Contrary to our hypothesis, neither passive nor motor off-task behaviour predicted the change in d2 test performance following FUNtervals (Table 2), and while a statistically significant correlation was observed between verbal off-task behaviour and improvements in d2 test performance (concentration performance, %E, and E_{Comis}; Table 2), this effect was small ($r \sim 0.25$). While it is difficult to comment with certainty why verbal and not passive or motor off-task behavior was related to the improvements in d2 test following exercise, there is some evidence that that socializing (i.e., verbal interaction) can help students focus in the classroom (Jarrett et al. 1998). Interestingly, there is also evidence that physical activity can improve classroom focus and reduce the need for verbal social interactions in students who normally use this behavior to achieve classroom focus (Pellegrini and Smith 1993). Regarding the absence of a relationship between motor and passive off-task behaviour, it is possible that a relationship would have been observed if improvements in off-task behaviour were compared with improvements in selective attention following FUNtervals, i.e., observations of off-task behaviour were taken on FUNtervals days in addition to control days. These measures were not included in the current study in an attempt to reduce classroom disruption.

To our knowledge, no study to date has specifically tested the relationship between classroom off-task behaviour and selective attention in children of normal learning ability, but behaviour and selective attention have been linked in children with attentional dysfunction (Barkley 1997; Hallahan et al. 1979). There is also evidence that strategies targeted to improve selective attention also result in improved classroom behaviour in students with attention disorders (Kercood and Grskovic 2009). Our data provides preliminary evidence that verbal off-task behaviour is associated with selective attention improvements; however, further research evaluating children with normal learning abilities using randomized control trials are needed to better understand the classroom behaviour and selective attention relationship.

Limitations and future directions

In an effort to encourage teacher participation, the current study was designed to be as minimally disruptive to normal class activities as possible, and thus the primary researcher led the activity interventions in classrooms. To better generalize the feasibility of FUNtervals, future studies should involve teachers in the activity implementation. Additionally, although the d2 test of attention is shown to be related to academic outcomes (Brickenkamp 2002), we did not demonstrate an effect of FUNtervals on academic performance. Future research should test the long-term effects of FUNtervals on academic performance and achievement by assessing the impact of regular participation in FUNtervals on standardized test results or grade point average. Finally, while the protocol used in FUNtervals has consistently demonstrated improvements in adult fitness when done on a bicycle (Ma et al. 2013; Tabata et al. 1996) or using whole-body movements (McRae et al. 2012), the efficacy of FUNtervals specifically for improving fitness in children is currently not known. Perhaps the greatest strength of the current study is the demonstration that a high-intensity interval protocol, which was proven to be effective in a laboratory setting, can be translated to a classroom setting. There is a need for future research to continue to take a translational approach and apply the exercise techniques that are known to be effective in our labs to real-world settings.

Conclusion

FUNtervals address both the barrier of time teachers face and supports the positive role activity breaks play in the learning environment. Further, we have demonstrated that verbal off-task behaviour weakly predicts changes in d2 test performance following FUNtervals, and more importantly, we demonstrated that d2 test performance (i.e., selective attention) is improved by participation in 4 min of high-intensity, classroom-based interval activity. These data suggest the inclusion of FUNtervals in elementary school classrooms may be utilized as both a means of increasing physical activity and improving focus and attention in the classroom. In summary, this study demonstrates that time-efficient physical activity breaks that require no equipment, and can be completed in the classroom, are both feasible to implement and can improve selective attention. It is hoped that these results will be utilized to help prioritize the inclusion of physical activity within school curricula.

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