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A short physical activity break from cognitive tasks increases selective attention in primary school children aged 10–11

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ABSTRACT

Importance: Evidence for an acute effect of physical activity on cognitive performance within the school setting is limited. The purpose of this study was to gain insight into acute effects of a short physical activity bout on selective attention in primary school children, specifically in the school setting.
Methods: Hundred and twenty three 10–11 years old children, 49.6% girls, engaged in four experimental breaks in random order: 1 h of regular cognitive school tasks followed by a 15 min episode with the following conditions 1) 'no break' (continuing a cognitive task), 2) passive break (listening to a story), 3) moderate intensity physical activity break (jogging, passing, dribbling) and 4) vigorous intensity physical activity break (running, jumping, skipping). Selective attention in the classroom was assessed by the TEA-Ch test before and after the 15 min break in each condition.
Results: After the passive break, the moderate intensity physical activity break and the vigorous intensity physical activity break attention scores were significantly better ($p < 0.001$) than after the 'no break' condition. Attention scores were best after the moderate intensity physical activity break (difference with no break = −0.59 s/target, 95% CI: −0.70; −0.49).
Conclusion: The results show a significant positive effect of both a passive break as well as a physical activity break on selective attention, with the largest effect of a moderate intensity physical activity break. This suggests that schools could implement a moderate intensity physical activity break during the school day to optimize attention levels and thereby improve school performance.
Trial registration: NTR2386.

1. Introduction

Because children spend a large part of their regular days in school, schools have been recognized as key settings for promoting physical activity (PA) in children (Naylor & McKay, 2009). However, the primary priority for schools is to provide a tailored curriculum in order to help children to develop their knowledge, understanding and cognitive skills. These two statements seem contradictory. However, research has shown that additional time for cognitive subjects does not necessarily lead to an improvement in academic performance (Ahamed et al., 2007). Interestingly, less time for cognitive subjects and more time allotted to PA also do not necessarily reduce academic performance (Leppo, Davis, & Crim, 2000). A recent review revealed evidence for a significant positive relationship between PA and academic performance (Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012).

In addition to the described positive relationship between PA and academic performance, the literature on the acute effect of PA on cognition is expanding. A meta-analysis by McMorris and Hale (2012) showed positive significant effects of moderate intensity exercise and a possible negative effect of high intensity exercise. Also in children, acute and chronic exercise has shown positive effects on cognition (Best, 2010; Hillman, Kamijo, & Scudder, 2011). However, there is a lack of knowledge about the effects of different PA intensities on cognition in children.

There are several mechanisms which could explain an effect of acute aerobic types of PA on cognition, such as increased blood and

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oxygen flow to the brain (Jorgensen, Nowak, Ide, & Secher, 2000), and increased hormone levels (Fleshner, 2000) argued to lead to stress reduction.

However, the evidence from the acute effect of PA on central executive tasks (e.g. selection, initiation, and termination of processing routine) is more robust than the effect on attention tasks (McMorris & Hale, 2012). Attention is defined as the ability to resist distraction. Selective attention is the ability to process specific target information while ignoring irrelevant information (Heaton et al., 2001), resulting in increased efficiency, improved sensory discrimination and is helpful for memory.

Attention is important for several aspects of learning and memory storage; attention is required when learning something (to encode the information), but also when recalling a memory (Hillman, Snook, & Jerome, 2003). Deficits in attention are associated with poorer academic performance (Aronen, Vuontel, Steenari, Salmi, & Carlson, 2005).

Moreover, the acute effect of PA on attention in a school setting is limited, due to differences in study design, and different study samples (Hillman et al., 2011; Janssen, Toussaint, Van Mechelen, & Verhagen, in press). In addition, as mentioned above, there is a lack of knowledge about the effects of different PA intensities on cognition in children. Therefore, the purpose of this study was to gain insight into acute effects of experimental PA breaks of different intensity on selective attention in 10–11 year old primary school children, in which aerobic fitness was measured as a covariate.

2. Methods

2.1. Procedure

Between September and December 2011, a convenience sample of seven classes from four primary schools ($n = 123$ children) participated in a randomized cross-over experiment, with a within-design. All experimental breaks took place between 09.30 and 10.00 after an hour of regular cognitive tasks that were scheduled at that moment. The measurements were conducted with one week intervals. Each participating class was visited five times. At the first visit, children completed the selective attention test three times. The purpose of this first measurement was to acquaint children with the test and the test protocol, and to reduce potential test-learning effects. On the subsequent visits the different experimental breaks (no break, passive break, moderate intensity PA break, vigorous intensity PA break) were administered, in random order (Fig. 1).

Each experimental break lasted 15 min and was supervised by two researchers and the classroom teacher. Selective attention was assessed before and after each experimental break in the classroom.

2.2. Participants

The sample included 123 children from the 5th grade, aged 10–11. The participants were recruited from 4 schools (7 classes) that also participated in the PLAYgrounds study (Janssen, Twisk, Toussaint, van Mechelen, & Verhagen, 2013). Schools were located in the urban area of Amsterdam in neighborhoods with a relatively large part of the population of immigrant origin and low socio-economic status. The school register provided demographic information (age and gender). Similar to a previous school-based study (Collard, Chinapaw, Verhagen, Bakker, & van Mechelen, 2010), parents of the participating children received a passive informed consent form that explained the nature and procedures of the study allowing them to withdraw their child if they objected to study participation. The Medical Ethics Committee of the VU

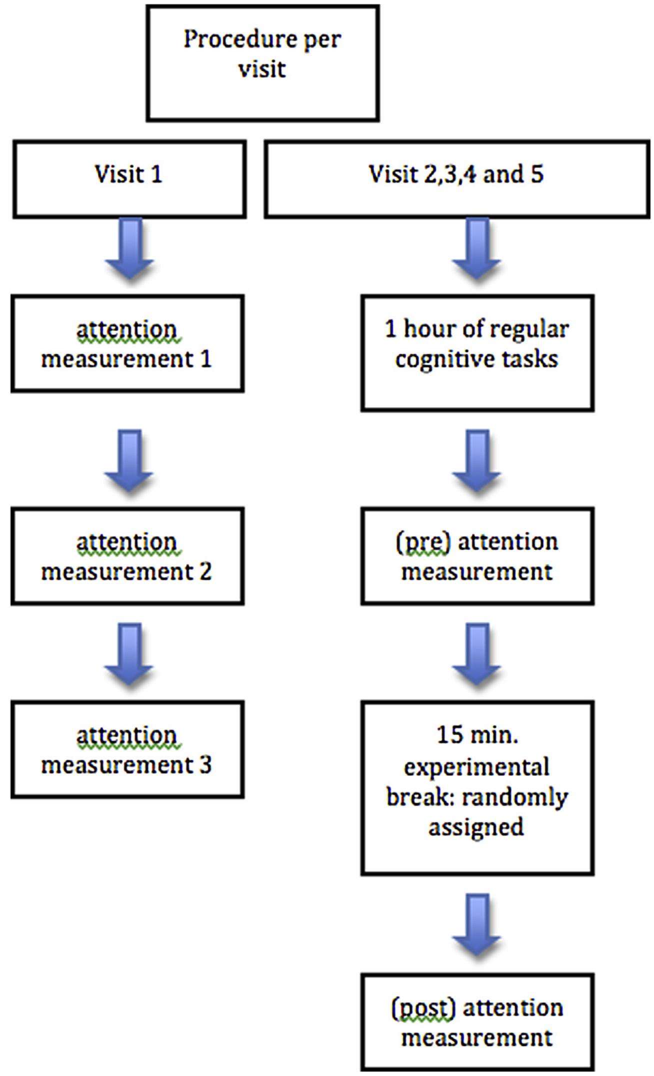

Fig. 1. Flow diagram of the procedure.

University Medical Centre approved the study design, protocols and passive consent procedure (NTR2386).

2.3. Experimental breaks

Each experimental break lasted 15 min in total, which equals a morning break in Dutch primary schools. The experimental breaks were administered in a random order.

The first experimental condition was ‘no break’, in which children continued their cognitive tasks (i.e. mathematics or language exercises) instead of a ‘real’ break. They were not allowed to ask the teacher for help or go to the toilet.

The second experimental break was a passive break. The teacher read out aloud a story to the children. Children were neither physically active nor performing difficult cognitive tasks.

The third experimental break was an exercise break consisting of moderate intensity PA and included walking to and from the PE classroom. All exercises in the PE classroom were instructed by the researcher and consisted of a combination of jogging, passing of the ball and dribbling with the ball. For example, the children worked in groups of three and had to pass the ball to another child who stood opposite them and then run in the same direction. The next child did the same toward the third child, and so on.

The fourth experimental break was an exercise break consisting of vigorous intensity PA and included running to and from the PE classroom. All exercises in the PE classroom were instructed by the researcher and consisted of a combination of running, jumping and rope skipping. For example, the children had to perform different rope skipping exercises, exercises with jumping over the rope when it was placed on the floor, and relay races.

The physical activity breaks were performed in the PE classroom. Instructions for each next exercise were given during the previous exercise in order to keep the desired intensity level of PA. The PA breaks were designed in concordance with PE teachers and tested in a pilot setting in order to achieve the predefined PA intensity level. The intensity levels were monitored by Actitrainer (Actigraph) accelerometers exclusively during the PA breaks.

2.4. Measurements

2.4.1. Selective attention

The outcome measure of this study was selective attention. Selective attention was assessed by the 'Sky Search' subtest of the Test of Every day Attention for Children (TEA-Ch) (Manly et al., 2001). In the Sky Search subtest, children have to find pairs of identical space crafts as quickly as possible among distracting pairs of non-identical space crafts. In every test 20 pairs were present and finding 15 or more correct pairs was needed to calculate a valid attention score (Manly, Roberston, Anderson, & Nimmo-Smith, 2004). Different configurations of the test were used to present a new pattern of the space crafts in each test. At each measurement different versions of the Sky Search were used in random order to reduce a learning effect.

The children were instructed to circle as many identical pairs as they could find, scanning the document, as quickly as possible. In order to measure the individual time, each child received a timer, which each child started him/herself on command and stopped as soon as the search had finished. During the learning day, each researcher timed half of the children in a class, in order to check how well the children were able to time themselves. No significant differences were found between the reported times from researcher and children.

After each test, time to perform the circling task (motor performance) was measured. This motor performance test consisted of the same 20 pairs without the distracting pairs of non-identical space crafts.

The final score was calculated as the time needed to identify a pair minus the time for the motor performance test. A lower score indicates better selective attention. The reliability (0.80) and validity (0.90) of the subtest have been reported as moderate to high (Manly et al., 2001). The correlations with IQ, reading, spelling and arithmetic abilities are 0.14, 0.09, 0.13 and 0.10 respectively, indicating that Sky Search scores are not related with IQ, nor with academic performance (Manly et al., 2001).

2.4.2. Physical activity

PA intensity was monitored using accelerometers (Actitrainer, Actigraph) in order to determine the intensity level during the physically active breaks. The accelerometer was securely attached to the child's right hip by an elastic waist belt. The epoch length was 1 s and the display was turned off in order to minimize distraction. Data was downloaded using ActiLife 5 software, and average counts per minute were calculated. The following cut-off points were used to determine PA intensity: moderate PA between 2000 and 2999 counts/min and vigorous PA over 3000 counts/min (Ekelund et al., 2004). These cut-off points correspond with approximately 3–6 and >6 metabolic equivalent of the respective tasks (METs). A minimum of 12 out of 15 min at the intended intensity level was required to include a child in the analysis.

2.4.3. Aerobic fitness

Aerobic fitness was assessed on a separate day in the second week during a scheduled physical education (PE) lesson. Aerobic fitness was assessed using the 20-mSRT (Leger & Lambert, 1982). The children had to run between two lines, set 20 m apart, exactly at a prescribed pace, dictated by sound beeps. The running speed started at 8.0 km/h and increased every minute by 0.5 km/h (Léger, Mercier, Gadoury, & Lambert, 1988). The test stopped when a child was unable to follow the pace and missed the line in time for two consecutive times. The score on the 20-mSRT was the last full stage the child completed. A higher score on the 20-mSRT indicates better aerobic fitness. The 20-mSRT scores were categorized as bad, poor, fair, good or excellent, based on scores of normative samples that are representative for this age group (Vrijkotte, De Vries, & Jongert, 2007). These scores were dichotomized into high (fair, good or excellent) or low (bad or poor).

2.4.4. Statistical analysis

The difference between the different experimental breaks was analyzed by a linear multilevel regression analysis to account for the clustered nature of the data. In the multilevel analysis, a four-level structure was applied, with the measurements ($n = 492$) at first level, the children ($n = 123$) at second level, the class ($n = 7$) at third level and the school ($n = 4$) at fourth level. Pre-measurements of attention were included in the model as a covariate. Aerobic fitness (dichotomous) was identified a priori as a potential covariate. To evaluate the influence of this covariate on the results of the experiment, effect modification was assessed by constructing interaction terms between the different breaks and the covariate aerobic fitness. All multilevel analyses were performed using MLwiN (version 2.21) and a two-tailed significance level of $p < 0.05$ (for effect modification: $p < 0.10$) was considered statistically significant. Finally, sensitivity analyses were performed excluding children who had scored less then 15 correct pairs (i.e. the minimum score to calculate a valid selective attention score).

3. Results

3.1. Participants

The mean age of the children in the study was 10.4 (SD = 0.59) years old with 50% boys. The average score on the shuttle-run test was 6.3 (SD = 2.0). Based on the shuttle-run scores, a total of 37 (30.1%) children were classified with a low physical fitness and 77 (62.6%) children with a high physical fitness. Table 1 shows the baseline characteristics of the participants.

When either the pre-measurement or the post-measurement of a break was incomplete, the participant was excluded from the analysis for that specific break. A total of 57 data points were missing. From the remaining 435 measurements (from 123 children), 15 measurements were excluded from the analyses due to not reaching the required physical activity intensity level. In total, 97% of the children had reached the required average intensity level

Table 1
Baseline characteristics of the participants.

$n = 123$	
Age in years [mean (sd)]	10.4 (0.59)
Gender [n (%) boys]	62 (50)
Shuttle-run [mean (sd) score]	6.3 (2.0)
Physical fitness [n (%) low]	37 (30.1)

n; Number of children, sd; standard deviation.

Table 2
Mean attention scores (standard deviation) of selective attention in seconds/target for the pre- and post-measurement and differences (*B*; 95% CI) in attention scores between the experimental breaks. The differences are a comparison of the post-measurements, in which the post-measurements are corrected for the pre-measurements.

	No break (NB)	Passive break (PB)	Moderate intensity PA break (MPAB)	Vigorous intensity PA break (VPAB)
n	112	108	111	89
Pre-measurement [mean (sd)]	2.7 (0.78)	2.6 (0.82)	2.5 (0.77)	2.5 (0.68)
Post-measurement [mean (sd)]	2.9 (0.78)	2.5 (0.71)	2.1 (0.58)	2.4 (0.62)
B [95% CI]	[Reference]	−0.27 [−0.35; −0.18][a]	−0.59 [−0.70; −0.49][a,b]	−0.29 [−0.39; −0.19][a]

n; Number of children in the analysis, sd; standard deviation, PA; physical activity.
[a] Significantly different from no break.
[b] Significantly different from vigorous and passive break.

of physical activity during the moderate intensity PA break and 91% had reached the intended average intensity level of physical activity during the vigorous intensity PA break. Children who had not reached the intended PA level were excluded from the analyses for that specific break. In the end 420 (84.8%) measurements from 123 children were available for the analyses. Finally, a two-level structure has been used in the analysis, with the measurements at first level and the children at second level. There was no correction required for class or school. Table 2 shows the mean selective attention scores pre- and post-measurement as well as the difference in selective attention scores between the experimental breaks.

Test scores were significantly lower (improved selective attention) after the passive break (−0.27, 95% CI: −0.35; −0.18) than after the 'no break'. Test scores after the vigorous intensity PA break were significantly lower than the 'no break' (−0.29, 95% CI: −0.39; −0.19) but not the passive break. After the moderate intensity PA break, the test scores were lowest, and significantly lower than after the 'no break' (−0.59, 95% CI: −0.70; −0.49), the passive break and the vigorous intensity PA break.

When excluding children who had scored less than 15 correct pairs for that specific break, the results were similar, but less pronounced (Table 3). There was no significant effect modification by aerobic fitness.

3.2. Discussion

A significant beneficial effect of both a passive break as well as physical activity breaks on selective attention was found with the strongest effect after a moderate intensity PA break. The larger effect of the moderate intensity PA break is in line with the inverted-U-hypothesis (Yerkes & Dodson, 1908). This hypothesis states that cognitive performance is optimally enhanced at a moderate level of arousal (McMorris & Graydon, 2000). The optimal level of arousal for attention in adults is reached after moderate intensity PA (Brisswalter, Collardeau, & Rene, 2002). This hypothesis was supported by a meta-analysis, concluding that acute, moderate intensity exercise has a strong beneficial effect on speed of response (McMorris, Sproule, Turner, & Hale, 2011). Arguably, this optimal level is the same in children because attentional control is fully developed by the age of 7 (Rueda, Posner, & Rothbart, 2005). A recent review, focused on the acute effect of a short PA bout on attention in school-aged children, concluded that also in children intensity level of PA may influence the effect of PA on attention (Janssen et al., in press). Overall all the included studies that found an effect of acute PA on attention contained a short bout of moderate intensity PA. In studies with a more strenuous (>65% HRmax) PA bout no effect of PA on attention was found. The lack of an effect of vigorous intensity PA on attention could be explained by the transient hypofrontality theory (Dietrich, 2003, 2006), which states that a decrease in cognitive performance is caused due to brain activation which is required to perform dynamic movements. A reduction in cerebral blood flow (and thereby oxygen) during the vigorous intensity PA break could explain the smaller effect on selective attention, which equaled the effect after a passive break. In addition, cognitive performance possibly remains decreased for approximately 20 min after vigorous intensity PA, because the brain needs time to return tot homeostasis (Del Giorno, Hall, O'Leary, Bixby, & Miller, 2010).

Two other explanations can explain the significantly improved attention after the moderate intensity PA break. Firstly, the exercises in the moderate intensity PA break were of coordinative character. Budde (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008) concluded that coordinative exercises might lead to pre-activation of parts of the brain, which are also responsible for mediating functions like attention. In addition, a recent study from Chang, Tsai, Cheng, and Hung (2013) revealed that coordinative exercise intervention, regardless of intensity, resulted in better attention. This explanation is further supported by a study on cognitive flexibility, which demonstrated that cortical transcranial magnetic stimulation manipulates subcortical cognitive functions (van Schouwenburg, O'Shea, Mars, Rushworth, & Cools, 2012).

Secondly, motivation or mood state could have played a role. Participating in enjoyable activities may improve mood (Berger, Owen, & Man, 1993). Maybe the exercises in the moderate intensity PA break were more enjoyed than the more exhausting exercises during the vigorous intensity PA break. Further research should compare the effect of coordinative versus non-coordinative PA on selective attention, as well as the potential moderating effect of 'enjoyment'.

The improved attention after the passive break is in line with other studies that found that taking a mental break from cognitive tasks can already improve selective attention; breaks during periods of sustained cognitive work may reduce cognitive interference (Toppino, Kasserman, & Mracek, 1991) and even brief breaks helped to stay focused on the task (Ariga & Lleras, 2011).

Table 3
Differences in attention scores between the experimental conditions excluding children who found less then 15 correct pairs. The differences are a comparison of the post-measurements, in which the post-measurements are corrected for the pre-measurements.

n = 316 Measurements; 108 cases	No break (NB)	Passive break (PB)	Moderate intensity PA break (MPAB)	Vigorous intensity PA break (VPAB)
B [95% CI]	[Reference]	−0.22 [−0.29; −0.15][a]	−0.43 [−0.50; −0.35][a,b]	−0.21 [−0.29; −0.14][a]

[a] Significantly different from no break.
[b] Significantly different from vigorous and passive break.

3.3. Limitations

PA intensity during the breaks was monitored by accelerometers and generalized to an average PA level for children of 10 years old. Nevertheless, it might be that the vigorous intensity PA break was not vigorous for the fittest children and the moderate intensity PA break was too vigorous for the least fit children. In contrast to previous studies (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Hillman, Castelli, & Buck, 2005), this study found no significant effect modification by aerobic fitness. The general cut-off points for PA intensity could have obscured a modifying role of aerobic fitness. For future research it is recommended to tailor the intensity of the experiment to the actual level of aerobic fitness of the participant, based on their individual maximal heart rate and maximal oxygen consumption.

Despite a practice run of the Sky Search test at visit 1 (to acquaint the children with the test), the use of different versions of the Sky Search test for every measurement, and the random order of the different versions, a learning effect could have occurred. Additional analyses of the differences between employed versions of the Sky Search showed a significant difference between outcomes of the different versions. Although the order of versions was randomized, one version that had been used mainly in the moderate intensity PA break and the outcome of this version differed significantly from the other versions. This could have led to an overestimation of the effect of the moderate intensity PA break.

The results of this study showed a positive effect from a short break – especially the moderate intensity PA break – on selective attention. However more research is needed to define the optimal dosage of PA breaks. Also, the relevance of the improvement of selective attention on total academic performance is questionable. The improvement in selective attention found in this study equals 0.6 s per target. Although selective attention is highly important for academic performance (Baddeley, 2001) and that selective attention impacts language, literacy, and math skills (Stevens & Bavelier, 2012), the actual contribution of the observed improvement in selective attention on academic performance is unknown and needs further research longitudinally.

An important strength of this study is that a robust methodology within a real-life setting (school) was employed. The children were their own controls, the experimental breaks and the respective versions of the selective attention tests were randomly assigned. In addition, the data was analyzed with a linear multilevel analysis to account for the clustered nature of the data. Also, the effect of different PA intensities compared to no break as well as to a 'non-active' break was examined.

4. Conclusions

Selective attention, one of the executive functions of cognitive performance, significantly improved in 10–11 year old children after a 15 min (exercise) break, with the largest improvement after a moderate intensity PA break. These findings suggest that schools should consider to implement (PA) breaks during the school day to optimize selective attention levels and support learning.

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Janssen and Rauh had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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