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Physically Active Lessons Improve Lesson Activity and On-Task Behavior: A Cluster-Randomized Controlled Trial of the "Virtual Traveller" Intervention

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Abstract

Background. Physically active lessons have not often been assessed with randomized controlled trials. *Aims*. Evaluate the effects of the "Virtual Traveller" (VT) intervention delivered using classroom interactive whiteboards on physical activity, on-task behavior, and student engagement. *Methods*. Participants were 219 children aged 8 to 9 years from 10 schools in Greater London, assessed in a cluster-randomized controlled trial between March 2015 and May 2016. For 6 weeks, intervention children received 10-minute VT sessions three times a week during math and English lessons (VT group: n = 113). Children in control schools received regular teaching (COM group: n = 106). Outcomes were school-day, weekend-day, and lesson-time sedentary behavior (SB), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA), and on-task behavior and student engagement, assessed at baseline (T0), 2 weeks (T1), and 4 weeks (T2) during the VT intervention and 1 week (T3) and 3 months (T4) postintervention using multilevel modeling. *Results*. VT pupils engaged in significantly more school-day MVPA at T1 only, with no other significant differences between groups in overall school-day or weekend-day activity. VT pupils engaged in significantly less SB and more MVPA during lesson time than COM pupils. More on-task behavior was shown in VT pupils than COM pupils but there was no difference in student engagement. *Discussion*. VT reduced sedentary behavior and increased physical activity during lesson time but not across overall school or weekend days. It improved on-task behavior but had no effect on student engagement. *Conclusion*. Physical activity can be integrated into teaching using interactive whiteboards with no detriment to educational outcomes.

Keywords

intervention, on-task behavior, physical activity/exercise, physically active lessons, school-based health care, student engagement

Physical activity has been shown to be beneficial to children's cardiometabolic health (Cesa et al., 2014; Stamatakis et al., 2015), mental health (Biddle & Asare, 2011), cognitive function (Carson et al., 2015), and academic achievement (Efrat, 2011; Fedewa & Ahn, 2011). However, the majority of children's time is sedentary, with up to 8.6 hours a day spent in obligatory seated school lessons (LeBlanc et al., 2015). As childhood levels of physical activity (Telama, 2009) and sedentary behavior (SB; Biddle, Pearson, Ross, & Braithwaite, 2010) have been shown to track into later life, it is vital that interventions are developed to help encourage active lifestyles at an early age (Weiler, Allardyce, Whyte, & Stamatakis, 2013). Various interventions have been developed to add physical activity into the school environment (Dobbins, Husson, DeCorby, & LaRocca, 2013), including during break times (Engelen et al., 2013) and educational sessions (Turner & Chaloupka, 2017). However, teachers, typically, describe a lack of time as the primary barrier for the physical activity provision (Naylor et al., 2015), with such interventions often requiring time to be drawn away from other academic objectives.

To address low activity levels and maintain maximal teaching time, lessons that incorporate physical activity in

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the teaching of academic content have recently been developed and tested (Mullender-Wijnsma et al., 2016; Norris, Shelton, Dunsmuir, Duke-Williams, & Stamatakis, 2015a). Physically active lesson interventions have typically reported increases to school time physical activity (Mullender-Wijnsma et al., 2015b; Riley, Lubans, Holmes, & Morgan, 2016); however, follow-up is often limited, and the activity measurement used is usually poor (Norris et al., 2015a). Only the "Physical Activity Across the Curriculum" randomized controlled trial has assessed activity levels beyond school time only (Donnelly et al., 2009; Norris et al., 2015a), finding weekday and weekend accelerometer-assessed activity to be increased at 3-year follow-up (Donnelly et al., 2009). There is hence an unclear evidence base as to whether physically active lessons have effects on activity beyond school time.

Promising educational benefits are evident in initial physically active lesson research (Norris et al., 2015a). For example, the recent "Fit & Vaardig op School" (Fit and Academically Proficient at School [F&V]) intervention found significant improvements in math and spelling tests at a 2-year follow up, equating to 4 months of increased learning gains compared with control group (Mullender-Wijnsma et al., 2016). However, wider educational outcomes that influence academic achievement test scores (J. D. Finn & Zimmer, 2012; Howie & Pate, 2012) have largely not been robustly assessed. For example, student engagement (behavior, cognitions, and emotions in pupils that reflect their interest in learning and school; J. D. Finn & Zimmer, 2012; Fredricks et al., 2011) has been relatively underresearched in relation to physically active lessons. On-task behavior during lesson times (a measure of behavioral student engagement: motor and verbal behavior appropriate to learning situations; Grieco, Jowers, & Bartholomew, 2009) is not commonly assessed in active-lesson randomized controlled trials (Mullender-Wijnsma et al., 2015a; Norris et al., 2015a). Aspects of cognitive student engagement (level of perceived capability and investment toward education; Fredricks et al., 2011) have been assessed in terms of attitudes (Riley et al., 2016) and competence toward the taught subject (Vazou & Skrade, 2016), although affective student engagement (emotional connectedness to the school environment) remains unexplored. This means that a picture on important pupil emotions and cognitions toward learning in the context of physically active lessons is still unclear.

Previous physically active lesson research has also been lacking in other areas. Interventions have mostly not described their behavior change techniques (BCTs; Martin & Murtagh, 2015)—that is, the "active ingredients" of intervention content included to encourage a change in behavior (Michie, Fixsen, Grimshaw, & Eccles, 2009; Michie et al., 2013). They have also been largely atheoretical (Norris et al., 2015a)—giving no indications for the proposed mechanisms of change behind interventions. Also, physically active lesson research has largely not utilized existing classroom equipment of interactive whiteboards (Norris et al., 2015a, 2015c), available in more than 70% of U.K. classrooms (Futuresource Consulting, 2010). This is despite other research showing physical activity to be increased with the provision of other digital technologies, such as Active Video Games (Norris, Hamer, & Stamatakis, 2016; Peng, Crouse, & Lin, 2013).

The aim of this study was to test the effect of the "Virtual Traveller" (VT) intervention on children's physical activity and SB, on-task behavior, and student engagement. The VT intervention was developed as a series of sessions to incorporate physical activity into primary school math and English teaching (Norris, Dunsmuir, Duke-Williams, Stamatakis, & Shelton, 2016). It featured a package of preprepared PowerPoint sessions delivered by classroom teachers on existing classroom interactive whiteboards. The study embedded the COM-B model of behavior change: designed to facilitate *C*apability, *O*pportunity, and *M*otivation *B*ehavior in pupils and teachers to improve physical activity and student engagement outcomes (see Norris, Dunsmuir, et al., 2016 for full details). Following recommendations for the development and evaluation of complex health interventions by the Medical Research Council (2013), VT was developed following iterative feasibility work in the form of a pilot study (Norris et al., 2015c) and qualitative teacher interviews and pupil focus groups (Norris et al., 2015b). It was hypothesized that VT would (1) increase children's light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) and reduce SB during school time, (2) increase LPA and MVPA and reduce SB during lesson time, and (3) improve on-task behavior during lesson time (Norris, Dunsmuir, et al., 2016). This study is reported in accordance with the Consolidation Standards of Reporting Trials guidelines (Schulz, Altman, & Moher, 2010).

Method

Design and Recruitment

A summary of the study protocol is presented here, with a full version available in the published protocol paper (Norris, Dunsmuir, et al., 2016). The study was a cluster-randomized controlled trial of a physically active lesson intervention delivered on a rolling basis between March 2015 and May 2016. Year 4 (aged 8-9 years) classes in primary schools in the Greater London region were approached to participate in the VT study. Schools were recruited by contact with local Public Health and School Sport Partnership organizations and through enquiries elicited from the study website (www.virtualtravellerstudy.wordpress.com). One Year 4 class in each of the 10 recruited schools was informed about the project by the lead author, with informed consent—signed by parents/carers and pupils themselves—received from 87.1% (n = 264/303; Figure 1). Nonconsenting pupils participated in VT or comparison (COM) sessions with their class, but no data were collected from them.

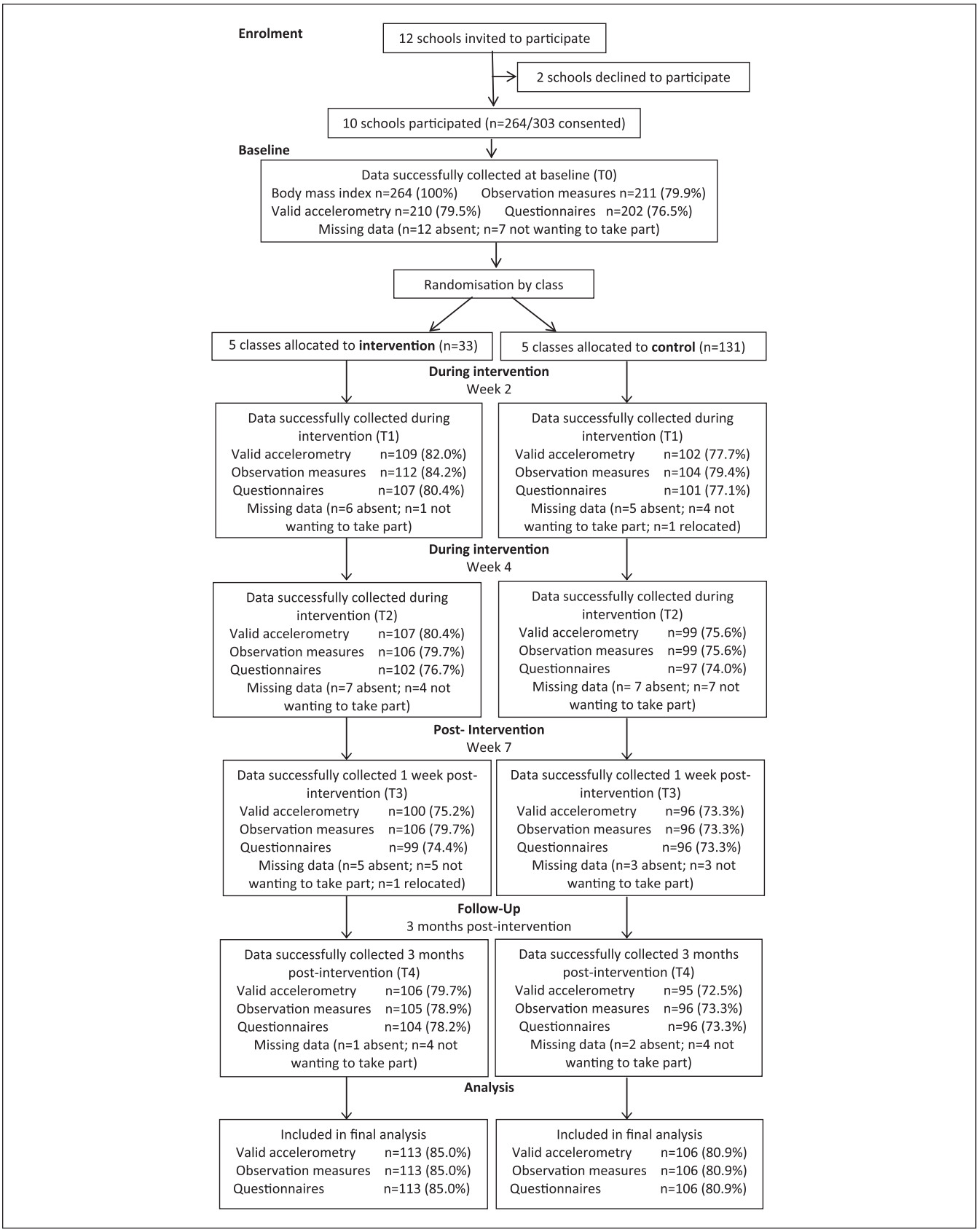

Figure 1. Sample flowchart.

Following initial recruitment, all participants completed baseline assessments (T0). Classes were then randomized to intervention (VT; 5 classes) or comparison (COM; 5 classes) groups via computer program. Measures were repeated at the second (T1) and fourth week (T2) of the 6-week intervention period and at 1 week (T3) and 3 months postintervention (T4). COM classes received typical teaching, with the full VT program supplied to use at the end of the study period (waiting list control). Ethical approval was granted by the UCL Research Ethics Committee (Ref: 3500-004).

Intervention

VT was a program of preprepared physically active lesson sessions, developed following feasibility work (Norris et al., 2015b, 2015c). It consisted of 3 × 10-minute physically active VFTs a week over a 6-week period (18 sessions in total). VT was designed to be integrated into Year 4 (8-9 years) National Curriculum math and English teaching (Department for Education, 2013) and was developed with consultation from teachers with recent Year-4 teaching experience (Norris, Dunsmuir, et al., 2016). After an initial 30-minute training session, VT was provided as PowerPoint sessions via a USB stick, to be delivered by teachers on existing classroom interactive whiteboards. COM teachers received this training after study data collection.

Sessions included embedded Google Earth videos showing transitions between different global locations. Accompanying text provided questions on session content and prompted children to simulate appropriate on-the-spot movements of moderate-to-vigorous intensity as they "travelled" to and interacted with locations. For example, children ran on-the-spot as they travelled between London and New York City when learning about explanation texts, before performing jumping jacks or high kicks to show whether the quiz questions on the topic were true or false (Session E4: Explanation texts). Students stood behind their desks to complete these movements. Behaviour Change Techniques from the Behaviour Change Technique Taxonomy—version 1 (BCTTv1; Michie et al., 2013) were embedded throughout teacher training and the intervention itself (Norris, Dunsmuir, et al., 2016). For example, goal-setting (BCT 1.1) was used during teacher training where teachers agreed to deliver three VT sessions a week. An overview of the whole VT program and detailed descriptions of example math and English sessions and the BCTs used can be seen in the study protocol (Norris, Dunsmuir, et al., 2016).

Measures

Demographic Measures. Pupil and teacher demographics were assessed by a questionnaire at baseline (T0). Weight was assessed at baseline to the nearest 0.1 kg (Weight Watchers 8961U electronic scales, Milton Keynes, UK) and height to the nearest millimeter (2-meter tape measure) to calculate body mass index (kg/m^2). Underweight, overweight, and obesity prevalence was estimated using the 2nd, 85th, and 95th percentiles of the 1990 U.K. reference curves (Cole, Freeman, & Preece, 1995).

Outcome Measures. Outcome measures to assess the effectiveness of VT were assessed at T0 (baseline), at weeks 2 (T1) and 4 weeks (T2) of the 6-week intervention and at 1 week (T3) and 3 months (T4) postintervention. Primary outcome measures were SB, LPA, and MVPA during school and weekend days. Secondary outcome measures were SB, LPA, and MVPA during lessons, on-task behavior, and student engagement. All data collection was administered by trained researchers, unblinded to classes' allocation to VT and COM groups (Norris, Dunsmuir, et al., 2016).

Physical activity outcomes were assessed using Actigraph GT1M accelerometers, shown to be highly valid and reliable in children (Kim, Beets, & Welk, 2012). At each data collection phase, accelerometers were worn for 4 consecutive days including 2 school and 2 weekend days. A device was attached to each participant's waist on their right hip with an adjustable elastic strap. Accelerometers were activated at 09:00 on Day 1 when accelerometers were distributed at the start of school and deactivated at 23:59 on Day 4. This provided a total of 86 hours of maximum wear time for each data collection phase (Norris, Dunsmuir, et al., 2016). A valid accelerometer day was defined as at least 500 minutes wear time between 07:00 and 00:00 (Ekelund et al., 2012). Participants were included in the analysis if they provided at least 2 days of valid accelerometer wear time (including 1 VT day in intervention pupils; Figure 1). Data were collected in 5-second epochs (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013) and analyzed using Pulsford cut points (Pulsford et al., 2011) to classify activity as sedentary: (<100 counts per minute [CPM]), LPA (100-2240 CPM), moderate (2241-3840 CPM) or vigorous (≥3841 CPM). Nonwear was defined as 60 minutes of consecutive 0s (Troiano et al., 2008). Using all valid days, a daily average for time in SB, LPA, and MVPA was calculated in minutes per day. Raw data were extracted from each Actigraph and analyzed using ActiLife software (Actigraph, LLC, Fort Walton Beach, FL, USA).

Lesson physical-activity outcomes were assessed firstly via 20-minute accelerometry assessments of VT and COM sessions and also via 20-minute observed assessments using the well-validated Children's Activity Rating Scale (CARS: K. J. Finn & Specker, 2000; Puhl, Greaves, Hoyt, & Baranowski, 1990). Participating pupils were observed in turn for 4 seconds (Merrett & Wheldall, 1986) using a prerecorded audio file during VT and COM lessons, with data recorded on a standardized score sheet. Pupils' movements were rated from 1 = *stationary* to 5 = *fast movement* across the observation period to provide a mean score for each individual (Norris, Dunsmuir, et al., 2016; Puhl et al., 1990). One session in each participating class ($n = 10$ sessions, 20% of all sessions observed) was observed by two researchers to allow

for reliability assessments. Inter-rater reliability across all CARS observations was high (ICC = 0.75) (Cicchetti, 1994).

On-task behavior was assessed simultaneously alongside CARS observation using the Observing Teachers and Pupils in Classrooms (OPTIC) tool (Merrett & Wheldall, 1986)—a well-validated within-education research (Robertson & Dunsmuir, 2013). Pupil's on-task behavior was rated as either 1 (on-task: making eye contact with teacher, following teacher's instructions, etc.) or 2 (off-task). Interrater reliability across all OPTIC observations was good (ICC = 0.66) (Cicchetti, 1994).

Student engagement was assessed immediately after assessed control and intervention sessions using the pupil-completed Student Engagement Instrument—Elementary version (SEI-E) questionnaire (Carter, Reschly, Lovelace, Appleton, & Thompson, 2012): a recent adaption of the well-validated Student Engagement Instrument (Appleton, Christenson, Kim, & Reschly, 2006) for primary school–aged children. The SEI-E features 24 items and assesses four constructs: Teacher–Student Relationships (TSR; 9 items), Peer Support for Learning (PSL; 6 items), Future Goals and Aspirations (FGA; 5 items), and Family Support for Learning (FSL; 4 items) (Carter et al., 2012). All items are 4-point Likert-type scales, with the questionnaire taking 15 to 20 minutes to complete. Validation of the SEI-E has been performed in pupils of the same age as the VT intervention (Carter et al., 2012). A full process evaluation of the VT intervention was also performed (Norris, Dunsmuir, et al., 2016), to be reported in a subsequent article.

Data Analysis

Independent *t* tests comparing VT and COM groups were performed for each outcome and assessment period. As the SEI-E (Carter et al., 2012) has not yet been tested in a U.K. sample, principal components analysis was used to assess its structure across all completed questionnaires (Supplemental Appendix available with the article online) using SPSS for Windows (Version 19.0). This study was a cluster-randomized controlled trial, with randomization to intervention groups done by class rather than by individual pupils. Multilevel modelling was hence used to reflect the hierarchical relationships between assessment point, pupils, and classes (Campbell, Mollison, Steen, Grimshaw, & Eccles, 2000). A priori sample size analysis was run to reflect this analysis (Maas & Hox, 2005), with calculations based on baseline posttest correlation scores of $r = 0.30$ (Riley et al., 2016), 80% power, a levels set at $p < .05$, an intraclass correlation coefficient (ICC) = 0.15, and a maximum number of classes of $J = 10$, with $n = 140$ required overall (Norris, Dunsmuir, et al., 2016). With $n = 219$ in the analytic sample, this study exceeded this minimum sample size requirement.

Multilevel regression analyses were conducted using Stata (Version 12.0), with analyses performed in accordance with past physically active lesson intervention studies (de Greeff et al., 2016; Mullender-Wijnsma et al., 2015b). Three-level models were constructed, with measurements at each time point (Level 1), nested within individual pupils (Level 2), and nested within classes (Level 3). Random intercept models were developed to assess the differences between levels in impact of intervention (VT or control) and time point (baseline [T0], during [T1 and T2], and posttest [T3 and T4]) and the group-by-time interaction. Outcomes at T4 were used as the dependent variables, with three models for each outcome built to investigate the effects of the intervention. The covariates model contained sex, ethnicity (White pupils coded as 0, and non-White pupils coded as 1), and measurement period (categorical: comparing scores of baseline [T0] with the intervention periods [T1 and T2] and follow-up periods [T3 and T4]) as fixed effects. Model 1 added condition as a fixed effect: to investigate whether the VT group differed from the control group. Model 2 contained Model 1 and condition × measurement period interactions as additional fixed effects. Results of Model 2 are presented in all reporting and tables to show the most adjusted version of analysis. The model fit was evaluated by comparing the deviance of the covariates model with the deviance of Models 1 and 2. Alpha levels were set at $p < .05$.

Results

Ten Year 4 (aged 8-9 years) classes from 10 different primary schools were recruited to the study. Of the initial 264 pupils that were recruited (Figure 1), 133 (5 schools) were allocated to the VT intervention group, and 131 (5 schools) were allocated to the COM group. No classes dropped out during the study. A total of 219 pupils (83.0% of those recruited) provided valid data in at least one measurement period and were included in the analytic sample (Table 1). At T0, 211 pupils produced valid data for at least one outcome variable, falling to 209 pupils at T4 (3-month follow-up; 79.2% of recruited pupils; Figure 1). Absenteeism and no longer wanting to participate were common reasons for attrition. If they wished, participants could continue their involvement in subsequent data collection points if they had been absent at any time point. In all, 50.7% of the analytic sample were male, with 52.1% from ethnic minority groups and 30.6% from low household income backgrounds (<£15,000; Table 1). There were no significant differences in demographic variables between VT and COM groups (Table 1).

Table 2 presents pupils' mean scores of physical-activity outcomes. No intervention effects were seen for the primary study outcomes of school- and weekend-day SB, school-day LPA, and weekend-day MVPA (Table 3). However, for the remaining primary study outcomes, multilevel modelling analysis found higher school-day MVPA in the VT group at T1 only (first intervention period: 60.8 minutes [$SD = 8.31$] in VT group vs. 56.1 minutes [$SD = 10.38$] in COM group; $B = 6.02$ [1.90]; 95% CI [2.30, 9.74]; $p < .01$; Table 3), with no differences at either follow-up period. Also, a significant

Table 1. Pupil Demographics.

Demographics	Overall sample (n = 219), n (%)	Intervention group (n = 113), n (%)	Control group (n = 106), n (%)	p
Sex				
Male	111 (50.7)	52 (46.1)	59 (55.7)	.16
Female	108 (49.3)	61 (54.0)	47 (44.3)	
Age, years, M (SD)	8.6 (0.49)	8.6 (0.49)	8.6 (0.49)	.88
Ethnicity				
White	105 (47.9)	60 (53.1)	45 (42.5)	.27
Mixed	15 (6.8)	5 (4.4)	10 (9.4)	
Asian or Asian British	88 (40.2)	42 (37.2)	46 (43.4)	
Black or Black British	11 (5.0)	6 (5.3)	5 (4.7)	
Chinese	0 (0.0)	0 (0.0)	0 (0.0)	
Born in the United Kingdom	167 (76.3)	89 (78.8)	78 (73.6)	.37
English as a first language	170 (77.6)	88 (77.9)	82 (77.4)	.93
Body mass index category				
Underweight	3 (1.4)	2 (1.8)	1 (0.9)	.99
Normal	134 (61.2)	68 (60.2)	66 (62.3)	
Overweight	66 (30.1)	35 (31.0)	31 (29.2)	
Obese	16 (7.3)	8 (7.1)	8 (7.5)	
Special educational needs	3 (1.4)	2 (1.8)	1 (0.9)	.60
Physical difficulties	3 (1.4)	1 (0.9)	2 (1.9)	.53
Free school meals	50 (22.8)	28 (24.8)	22 (20.8)	.48
Total household income (£)				
<15,000	67 (30.6)	33 (29.2)	34 (32.1)	.47
15,000-19,999	82 (37.4)	47 (41.6)	35 (33.0)	
20,000-29,999	61 (27.9)	31 (27.4)	30 (28.3)	
30,000-39,999	8 (3.7)	2 (1.8)	6 (5.7)	
40,000-49,999	1 (0.5)	0 (0.0)	1 (0.9)	

Note. Independent t tests found no significant differences for any demographic variables between intervention groups. M = mean; SD = standard deviation.

difference between intervention groups was observed for weekend-day LPA at T3 only (1 week follow-up period: 49.6 minutes [SD = 9.66] in VT group vs. 47.2 minutes [10.52] in control group; B = 10.33 [5.17]; 95% CI [0.21, 20.46]; p = .045), showing greater LPA in the VT group than in the COM group (Table 3).

All lesson-time physical activity outcomes showed significant differences between study groups during the intervention period (T1 and T2; Table 3), with the VT group demonstrating significantly less accelerometer-assessed SB (−6.00 minutes at T1, −6.60 minutes at T2; Table 2), more LPA (+4.20 minutes at T1, +4.60 minutes at T2), and more MVPA (+1.68 minutes at T1, +2.00 minutes at T2). Greater activity was also observed with the CARS tool (Table 3). Overall, VT lessons contributed 3.6% (SD = 1.91) of daily MVPA compared with 0.5% (SD = 0.57) in COM lessons. There were no significant differences in VT pupils' activity levels during the intervention (T1 and T2). Maintained effects of the intervention were not seen for any lesson physical activity outcome at either follow-up period (T3 and T4).

Table 2 presents pupils' mean scores of on-task behavior and student engagement outcomes. Multilevel modelling analysis found significantly higher on-task behavior in the VT compared with COM group at both intervention points (T1: 1.86/2 [SD = 0.06] in VT group vs. 1.77 [SD = 0.07] in COM group; B = 0.08 [0.01]; 95% CI [0.06, 0.11]; p < .001; T2: 1.85/2 [SD = 0.08] in VT group vs. 1.76 [SD = 0.06] in COM group; B = 0.09 [0.01]; 95% CI [0.06, 0.11]; p < .001) (Table 4). There were no significant differences in VT pupils' on-task behavior during the intervention (T1 and T2). However, this intervention group difference was not maintained at either follow-up period (T3 and T4). No differences in any SEI-E student engagement outcomes were observed at any time point (Tables 2 and 4).

Discussion

The results of this study are a unique contribution to the literature on physically active lesson interventions in various ways. First, by assessing physical activity across full days with accelerometry it was shown that VT did not have any clear effect on overall school and weekend activity levels, rejecting Hypothesis 1. Significantly, greater school-day MVPA in the VT group was seen at T1 only, although the difference was small (4.7 minutes). This contrasts with previous results showing physically active teaching to have

Table 2. Outcome Scores at all Time Points.

	T0		T1		T2		T3		T4	
Outcomes	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*
Physical activity outcomes										
Primary outcomes										
School-day MVPA (minutes)										
Intervention	60.6 (10.26)	108	60.8 (8.31)***	105	59.0 (10.03)	103	59.4 (9.04)	99	58.8 (7.03)	101
Control	62.0 (13.27)	96	56.1 (10.38)	99	58.3 (11.04)	98	59.9 (9.88)	94	58.6 (6.53)	92
Weekend-day MVPA (minutes)										
Intervention	51.1 (18.69)	89	49.6 (9.66)	77	47.7 (11.46)	83	50.1 (9.03)	75	49.5 (9.36)	84
Control	49.9 (12.03)	82	47.2 (10.52)	83	50.3 (13.33)	72	49.1 (9.70)	74	50.2 (9.09)	71
Secondary outcomes										
School-day SB (minutes)										
Intervention	654.8 (43.79)	108	652.6 (42.19)	105	647.8 (46.04)	103	654.4 (34.31)	99	651.5 (29.12)	101
Control	647.4 (39.32)	96	654.2 (43.20)	99	647.5 (45.59)	98	648.1 (45.15)	94	649.6 (30.58)	92
School-day LPA (minutes)										
Intervention	145.1 (24.77)	108	139.2 (24.98)	105	143.2 (22.31)	103	144.1 (19.77)	99	137.9 (11.98)*	101
Control	149.4 (27.43)	96	141.1 (26.42)	99	145.4 (25.84)	98	149.0 (37.40)	94	144.6 (24.18)	92
Weekend-day SB (minutes)										
Intervention	633.1 (58.77)	89	638.9 (41.68)	77	630.8 (38.61)	83	636.6 (52.63)	75	639.6 (53.34)	84
Control	645.3 (51.74)	82	641.4 (44.99)	83	641.6 (36.51)	72	627.9 (76.56)	74	638.6 (51.16)	71
Weekend-day LPA (minutes)										
Intervention	128.9 (30.08)	89	121.6 (29.12)	77	120.9 (18.61)	83	119.3 (16.62)	75	116.5 (14.28)	84
Control	134.1 (28.94)	82	122.4 (32.71)	83	129.5 (35.15)	72	115.1 (18.37)	74	117.8 (14.08)	71
Lesson SB (minutes)										
Intervention	16.4 (1.28)	108	10.3 (1.86)***	107	10.0 (1.75)***	104	15.6 (2.52)*	99	16.3 (1.37)	101
Control	16.5 (1.31)	96	16.3 (1.56)	99	16.6 (1.42)	98	16.4 (1.36)	93	16.6 (1.20)	92
Lesson LPA (minutes)										
Intervention	3.4 (1.17)	108	7.7 (1.50)***	107	7.7 (1.39)***	104	3.6 (1.81)	99	3.4 (1.33)	101
Control	3.2 (1.23)	96	3.5 (1.43)	99	3.1 (1.28)	98	3.4 (1.25)	93	3.2 (1.30)	92
Lesson MVPA (minutes)										
Intervention	0.3 (0.31)	108	1.9 (1.14)***	107	2.3 (0.98)***	104	0.7 (0.97)***	99	0.3 (0.31)	101
Control	0.26 (0.31)	96	0.22 (0.29)	99	0.3 (0.32)	98	0.3 (0.28)	93	0.3 (0.27)	92
CARS lesson to PA										
Intervention	1.4 (0.10)	108	3.6 (0.22)***	107	3.6 (0.20)***	104	1.5 (0.15)	99	1.4 (0.12)	101
Control	1.4 (0.13)	96	1.4 (0.11)	99	1.4 (0.13)	98	1.42 (0.11)	93	1.4 (0.10)	92
Educational outcomes										
Secondary outcomes										
On-task behavior										
Intervention	1.77 (0.07)	108	1.86 (0.06)***	107	1.85 (0.08)***	104	1.76 (0.07)	99	1.77 (0.07)	101
Control	1.77 (0.06)	96	1.77 (0.07)	99	1.76 (0.06)	98	1.77 (0.06)	93	1.76 (0.07)	92
Teacher–Student Relationships (TSR)										
Intervention	23.3 (2.82)	103	24.3 (2.39)**	102	23.8 (2.83)**	101	22.9 (3.26)	97	22.9 (2.89)	100
Control	23.4 (2.89)	92	23.6 (2.84)	96	22.9 (3.08)	97	22.8 (2.84)	93	22.9 (2.91)	92
Peer Support for Learning (PSL)										
Intervention	20.4 (3.23)	103	20.6 (3.03)	102	20.7 (2.97)	101	20.4 (3.05)	97	20.4 (2.87)	100
Control	20.3 (3.85)	92	20.3 (2.98)	96	20.3 (2.91)	97	20.3 (2.95)	93	20.3 (2.66)	92
Future Goals and Aspirations (FGA)										
Intervention	16.9 (2.88)	103	16.9 (2.80)	102	16.8 (2.77)	101	16.8 (2.81)	97	16.9 (2.75)	100
Control	16.8 (2.74)	92	16.7 (2.66)	96	16.7 (2.53)	97	16.7 (2.58)	93	16.8 (2.46)	92
Family Support for Learning (FSL)										
Intervention	13.5 (1.91)	103	13.6 (1.81)	102	13.6 (1.75)	101	13.5 (1.92)	97	13.4 (1.88)	100
Control	13.6 (1.89)	92	13.5 (1.86)	96	13.5 (1.82)	97	13.4 (1.83)	93	13.5 (1.76)	92

Note. All physical activity outcomes reported in minutes except CARS; CARS stands for Children's Activity Rating Scale, rated between 1 = *stationary* and 5 = *fast movement*; Lesson time is a 20-minute period; TSR (maximum score of 28), PSL (maximum score of 24), FSL (maximum score of 16), and FGA (maximum score of 20) are all constructs from the Student Engagement Instrument–Elementary version (SEI-E). OPTIC stands for the Observing Pupils and Teachers in the Classroom tool assessing on-task behavior, with behavior rated overall during 20-minute lessons as between off-task (1) or on-task (2). *SD* = standard deviation; MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior; LPA = light physical activity; PA = physical activity. *$p < .05$. **$p < .01$. ***$p \leq .001$.

Table 3. Multilevel Modeling Predicting 3-Month Follow-Up (T4) Scores for Physical-Activity Outcomes.

Effects	School-day SB (minutes)	School-day LPA (minutes)	School-day MVPA (minutes)	Weekend-day SB (minutes)	Weekend-day LPA (minutes)	Weekend-day MVPA (minutes)	Lesson SB (minutes)	Lesson LPA (minutes)	Lesson MVPA (minutes)	CARS
Fixed effects (SE)										
Intercept	652.59 (4.84)***	152.63 (8.20)***	60.66 (1.23)***	642.43 (9.03)***	134.32 (5.22)***	47.66 (1.44)***	16.47 (0.21)***	3.18 (0.16)***	0.34 (0.08)***	1.44 (0.03)***
Sex[a]	−3.17 (2.59)	−1.38 (1.25)	2.27 (0.62)***	2.56 (3.68)	1.47 (1.71)	3.16 (0.84)***	0.06 (0.10)	−0.04 (0.09)	−0.02 (0.04)	0.00 (0.01)
Ethnicity[b]	−6.27 (2.65)*	0.88 (1.33)	0.15 (0.65)	0.19 (3.90)	0.32 (1.82)	0.43 (0.84)	0.03 (0.11)	0.08 (0.09)	−0.10 (0.04)*	−0.02 (0.01)*
T1[c]	6.82 (5.75)	−9.30 (2.74)***	−5.83 (1.37)***	−4.12 (7.73)	−10.09 (3.58)**	−2.45 (1.80)	−0.25 (0.23)	0.29 (0.20)	−0.05 (0.09)	−0.01 (0.02)
T2[c]	0.21 (5.78)	−5.63 (2.75)*	−3.57 (1.38)**	−4.08 (8.02)	−4.02 (3.72)	0.61 (1.87)	0.11 (0.23)	−0.14 (0.20)	0.01 (0.09)	−0.01 (0.02)
T3[c]	0.74 (5.82)	−1.23 (2.78)	−1.97 (1.39)	−15.90 (7.96)*	−20.38 (3.69)***	−0.57 (1.86)	−0.17 (0.23)	0.18 (0.20)	−0.01 (0.09)	−0.01 (0.02)
T4[c]	2.24 (5.86)	−5.82 (2.80)*	−3.28 (1.40)*	−5.13 (8.05)	−17.70 (3.73)***	0.52 (1.88)	0.07 (0.23)	−0.02 (0.20)	−0.01 (0.09)	−0.01 (0.02)
Intervention	6.14 (6.06)	−5.24 (11.50)	−0.98 (1.57)	−12.12 (11.99)	−5.50 (7.09)	1.92 (1.78)	−0.14 (0.26)	0.17 (0.21)	−0.04 (0.10)	−0.03 (0.04)
T1 * Intervention	−9.19 (7.94)	3.58 (3.80)	6.02 (1.90)**	7.49 (10.94)	3.81 (5.06)	0.70 (2.55)	−5.86 (0.31)***	4.06 (0.27)***	1.74 (0.12)***	2.24 (0.03)***
T2 * Intervention	−6.97 (7.99)	3.43 (3.81)	1.96 (1.91)	0.85 (11.03)	−3.73 (5.11)	−4.07 (2.57)	−6.45 (0.32)***	4.43 (0.27)***	2.02 (0.12)***	2.20 (0.03)***
T3 * Intervention	−1.05 (8.06)	0.45 (3.85)	0.68 (1.93)	19.70 (11.14)	10.33 (5.17)*	−0.76 (2.60)	−0.55 (0.32)	0.08 (0.28)	0.44 (0.12)***	0.05 (0.03)
T4 * Intervention	−5.40 (8.06)	−1.30 (3.85)	1.45 (1.93)	11.48 (11.04)	5.38 (5.12)	−2.31 (2.58)	−0.11 (0.32)	0.02 (0.27)	0.05 (0.12)	0.02 (0.03)
Random effects (SE)										
Variance between classes	3.46 (2.25)	17.67 (4.02)	1.27 (0.52)	14.60 (3.95)	9.71 (2.38)	1.16 (8.07)	0.21 (0.07)	0.12 (0.06)	0.07 (0.29)	0.05 (0.01)
Variance within classes	40.02 (0.90)	19.15 (0.43)	9.57 (0.22)	49.60 (1.26)	22.99 (0.58)	11.58 (0.29)	1.59 (0.04)	1.37 (0.03)	0.62 (0.01)	0.14 (0.01)
Model deviance	−5075.38	−4371.55	−3664.54	−4215.32	−3615.78	−3055.77	−1883.09	−1728.75	−938.65	562.53

Note. SB = sedentary behavior; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; CARS = Children's Activity Rating Scale. *B* coefficients are presented with standard error (SE) in parentheses.
[a]Boys coded as 0 and girls coded as 1. [b]White pupils coded as 0 and non-White pupils coded as 1. [c]Indicates comparison of scores between given time point and T0 (baseline).
*$p < .05$. **$p \leq .01$. ***$p \leq .001$.

Table 4. Multilevel Modeling Predicting 3-Month Follow-up (T4) Scores for On-Task Behavior and Student Engagement Outcomes.

Effects	On-task behavior	Teacher-Student Relationships (TSR)[a]	Peer Support for Learning (PSL)[a]	Future Goals and Aspirations (FGA)[a]	Family Support for Learning (FSL)[a]
Fixed effects (SE)					
Intercept	1.77 (0.01)***	23.76 (0.34)***	19.49 (0.34)***	17.22 (0.31)***	13.92 (0.23)***
Sex[b]	0.00 (0.00)	−0.70 (0.18)***	0.84 (0.19)***	−0.89 (0.17)***	−0.15 (0.11)
Ethnicity[c]	0.00 (0.00)	0.06 (0.19)	0.63 (0.19)***	0.17 (0.17)	−0.49 (0.12)***
T1[d]	0.00 (0.01)	0.14 (0.41)	0.03 (0.43)	−0.16 (0.39)	−0.03 (0.26)
T2[d]	−0.01 (0.01)	−0.52 (0.41)	−0.04 (0.42)	−0.18 (0.39)	−0.08 (0.26)
T3[d]	0.00 (0.01)	−0.58 (0.42)	0.02 (0.43)	−0.17 (0.39)	−0.19 (0.27)
T4[d]	0.00 (0.01)	−0.55 (0.42)	−0.01 (0.43)	−0.07 (0.39)	−0.08 (0.27)
Intervention	0.00 (0.01)	−0.18 (0.42)	0.30 (0.42)	−0.02 (0.38)	−0.19 (0.29)
T1 * Intervention	0.08 (0.01)***	0.88 (0.57)	0.14 (0.59)	0.13 (0.54)	0.15 (0.36)
T2 * Intervention	0.09 (0.01)***	1.00 (0.57)	0.26 (0.59)	0.13 (0.54)	0.24 (0.36)
T3 * Intervention	−0.01 (0.01)	0.15 (0.60)	−0.15 (0.59)	0.15 (0.54)	0.27 (0.37)
T4 * Intervention	0.00 (0.01)	0.20 (0.58)	−0.12 (0.59)	0.09 (0.54)	0.08 (0.37)
Random effects (SE)					
Variance between classes	0.01 (0.01)	0.18 (0.14)	0.06 (0.31)	4.78 (3.58)	0.20 (0.08)
Variance within classes	0.07 (0.01)	2.83 (0.06)	2.91 (0.07)	2.65 (0.06)	1.81 (0.04)
Model deviance	1289.22	−2397.22	−2421.12	−2330.04	−1959.45

Note. *B* coefficients are presented with standard error (SE) in parentheses.
[a]TSR, PSL, FGA, and FSL indicate subscales from the Student Engagement Instrument–Elementary (SEI-E) version. [b]Boys coded as 0 and girls coded as 1. [c]White pupils coded as 0 and non-White pupils coded as 1. [d]Indicates comparison of scores between given time point and T0 (baseline).
*$p < .05$. **$p \leq .01$. ***$p \leq .001$.

effects on overall school time activity (Donnelly et al., 2009; Norris et al., 2015a; Riley et al., 2016) and also with the only previous study to assess weekend activity, which found positive, sustained benefits (Donnelly et al., 2009). VT improved lesson time physical activity as assessed by accelerometers and observations, confirming Hypothesis 2 and concurring with the majority of previous physically active lesson research (Norris et al., 2015a; Riley et al., 2016).

It may be that the dose of VT sessions (3 × 10-minute sessions a week) was insufficient to elicit significant activity increases across the full-school day. As VT was performed using on-the-spot actions (Norris, Dunsmuir, et al., 2016), it may be that these movements did not elicit sufficient MVPA to increase overall activity. Also, according to the "ActivityStat Hypothesis" (Rowland, 1998), it may be that the extra exertion from VT sessions was biologically compensated with reduced subsequent activity.

Second, this study assessed activity twice during the intervention period to track any potential change with repeated session exposure. Importantly, no significant changes were seen in lesson time SB, LPA, or MVPA levels within the intervention group during the intervention (T1 and T2). This suggests that VT sessions did not have depreciating effects on lesson activity over time, opposing concerns from teachers in qualitative feasibility work that pupils may become less active during exposure to sessions (Norris et al., 2015b). However, as previously discussed, this increased lesson time activity did not produce any significant differences in overall activity levels due to potential issues with dose and the on-the-spot movement prompted.

Our study was the first to examine a wide range of student engagement outcomes (J. D. Finn & Zimmer, 2012; Fredricks et al., 2011) in relation to physically active lessons (Norris, Dunsmuir, et al., 2016; Norris et al., 2015a). On-task behavior (behavioral student engagement) was shown to be greater in the VT group during both intervention assessments (T1 and T2). This confirms Hypothesis 3 and concurs with previous physically active lesson research (Grieco et al., 2009). No reduction in mean on-task behavior scores was seen during the VT intervention, suggesting sustained benefits during exposure to the sessions. A lack of maintained effect on on-task behavior beyond the intervention period (T3 and T4) suggests that continued VT session provision is required to give sustained benefits.

No effects of VT were seen on any of the four SEI-E subscales (assessing affective and cognitive student engagement). Hence, although pupils arguably experienced a novel teaching experience with VT (Norris et al., 2015b), this did not have any impact on their emotions or cognitions surrounding learning and the school environment. This study has hence shown that physical activity can be integrated into academic lessons using existing classroom interactive whiteboards with positive (on-task behavior) or no detrimental effects (student engagement) to educational outcomes. This extends previous physically active lesson research that found no detrimental effects to activity in interventions not using classroom technologies (Donnelly et al., 2009; Mullender-Wijnsma et al., 2016; Norris et al., 2015a). Future work is needed to assess whether longer term physically active lessons of greater dose have effects on children's' physical-activity and educational outcomes.

Strengths and Limitations

A limitation of this study, and indeed all physically active lesson interventions, is the lack of blinding (Norris et al., 2015a). Changes to the teaching environment are very obvious to pupils and are necessary for teachers to deliver the sessions. Academic achievement was not assessed, due to the time and resources required to assess classroom grades and administer standardized testing. Also, the SEI-E engagement questionnaire used has not been used in the U.K. samples specifically and may have produced measurement error.

Strengths of this study were its design as a cluster-randomized controlled trial, its low attrition rate, and its use of behavior change theory (COM-B model). It also featured a sample of ethnically diverse and disadvantaged pupils, whereas most other physically active lesson interventions have predominantly featured White, middle-class participants (Neelon, Hesketh, & van Sluijs, 2016).

Conclusion

The VT physically active lesson intervention did not produce significant changes to school-day or weekend-day physical activity levels during the intervention or at 1-week or 3-month follow-ups. However, significantly less sedentary behavior and more physical activity were produced during VT lessons compared with control lessons. The intervention was also associated with greater on-task behavior but showed no differences to student engagement. These findings suggest that physically active lessons using existing classroom interactive whiteboards can be used to initiate activity within math and English curriculums with positive effects (on-task behavior) or at least with no detriment (student engagement) to educational outcomes.

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Supplemental Material

Supplemental Appendix is available in the online version of this article at http://journals.sagepub.com/home/heb.

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