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Preschoolers exhibit greater on-task behavior following physically active lessons on the approximate number system

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Objective: To determine how the dual-task nature of incorporating physical activity with instructional activities immediately impacts acuity of the approximate number system and on-task behavior in preschoolers.

Methods: Using a randomized within-participants repeated-measures crossover design, 51 children completed an approximate number system task before and after either 20-min of physically active instruction corresponding to 38% heart rate reserve (HRR; light-to-moderate intensity) or conventional sedentary instruction at corresponding to 21% HRR (very light intensity).

Results: Findings revealed that preschool-aged children exhibited similar learning and greater on-task behavior following a single bout of physically active instruction relative to conventional sedentary instruction. Overall, preschoolers accrued 931.3 ± 8.2 more steps and an additional 9 minutes at or above light-intensity activity during the physically active instruction.

Conclusion: Accordingly, these findings suggest that the dual-task nature of physically active learning does not compromise learning, reduces the need for redirecting off-task behavior, and ultimately allows children to avoid sedentary behavior in educational contexts.

KEYWORDS

approximate number system, attention, dual-task, numeracy, physical activityacute exercise, preschool, time-on-task

1 | INTRODUCTION

Physical activity recommendations suggest that intervening during the school day may be an ideal means of increasing physical activity given that children spend between 25 and 32 hours weekly in out-of-home early childcare settings[1]—with a vast majority of their time spent in sedentary activities[2]—and classroom lessons have been identified as the least active segment of a child's day.[3] Integrating physical activity with instruction of core curriculum content has emerged as a way to address the growing trend of children adopting a predominantly sedentary lifestyle. Although such approaches are effective for enhancing physical activity and on-task behavior, and extant evidence demonstrates enhancements in cognition and attention following single bouts of physical activity,[4] a critical limitation is our understanding of how the dual-task nature of incorporating physical activity within academic instruction may immediately impact learning.

Providing greater opportunities to engage in physical activity during the school day—even in short bouts—enhances scholastic outcomes, on-task behavior, and attentional control.[5-8] In contrast to concerns regarding difficulty getting students to re-engage with academics following physical activity, children exhibit improved on-task behavior and complete more arithmetic problems following 10- and 20-min classroom activity breaks relative to a 10-min sedentary break.[6] Similarly, enhancements in reading, arithmetic, and neural indices of attention have been observed following a 20-min bout of physical activity.[8] Given that these acute physical activity interventions have observed improvements in attention and academic achievement in school-aged children, recommendations to implement physical activity breaks during the school day to increase overall levels of physical activity appear to be well-justified. Further, such interventions appear to relate to immediate and long-term benefits for cognition and scholastic achievement, particularly in reading and mathematics. Though, a critical limitation to the current literature is the degree to which physically active instruction impacts cognitive functioning in children younger than age five; the influence of single bouts of physical activity on cognition in this population has been understudied.[4]

However, physical activity integrated within instructional contexts could conceptually be implemented in ways that may offer negligible benefits or may even hinder learning. For instance, implementing short physical activity opportunities (shorter than 10 minutes) as placeholder or transition activities within instructional contexts (ie, having students march while spelling words until an instructor can rotate around to the group of students) was not associated with improvements in scholastic performance relative to sedentary periods.[7] Similarly, although such activities eventually would amass over the course of the day, the accumulation of physical activity over the course of a 12-hour period (even within particular intensities) is unrelated to long-term memory and in some cases may even be detrimental to the consolidation of long-term memory during that period.[9] Promisingly, an emerging body of evidence has suggested that full integration of physical activity and instruction may provide long-term benefits to scholastic performance. Namely, daily physically active lessons lasting from 4 weeks to 6 months have been associated with improved retention on assessments of literacy, foreign language, geography, science, and math in preschool-aged children relative to sedentary lessons immediately and up to 6 weeks following cessation of the intervention.[10-14] Although these studies suggest that such approaches are feasible in preschool-aged children, the acute effects of a single bout of physically active instruction on academic constructs and on on-task behavior—which provides insight into possible implications for classroom behavior and scholastic performance—remain underspecified in preschool-aged children.

Given such findings, however, it is important to acknowledge the positive effects of physically active lessons observed across longer periods of time may reflect the enhancements of other mental processes—including attention, classroom behavior, and cognitive control—that enable greater scholastic performance even if the implementation of physically active instruction is actually detrimental. Full integration of physical activity and instruction inherently results in a dual-task situation in which students must manage cognitive (academic instruction) and energetic demands (physical activity) concurrently. In such an instance, the load theory of attention[15] suggests that when the cognitive and energetic demands are high, the resource-limited nature of attention would result in focusing on only one aspect of the instructional activity (ie, either the physical activity or the instructional content). Such dual-task situations lead to trade-off patterns in task prioritization, with children more vulnerable to trade-offs in the cognitive domain. For example, when performing a motor task (eg, balancing) while memorizing a list of words, children exhibit performance decrements in only the cognitive domain whereas adults show decrements in both task domains.[16] Consequently, fully integrating physical activity with instruction may actually hinder to what extent children can engage cognitively with academic content. However, others have argued that cognitively engaging physical activity may result in greater cognitive gains than those observed when participating in non-cognitively engaging physical activities because brain regions controlling higher-order cognitive processes are activated.[17] To this end, preadolescents reported increased enjoyment concomitant with no decrements in performance on a flanker task following a 10-min bout of aerobic physical activity integrated with math instruction relative to seated math instruction.[18] In this way, integrating physical activities with learning could result in impairments (through cognitive load) or improvements (through cognitive engagement) to cognition. Thus, further research is necessary to better understand the immediate effects of physically active lessons on scholastic performance to ensure that such approaches are not detrimental to educational outcomes, especially in preschool-aged children who may be particularly susceptible to cognitive decrements during dual-task performance.

Highlights

- Effect of physically active lessons on the approximate number system.
- Rigorous randomized within-participants repeated-measures crossover design.
- Physical activity does not impede learning of the approximate number system.
- Time-on-task was increased following physically active lessons.

Thus, the present investigation sought to address these limitations in the literature by determining the extent to which incorporating physical activity within instructional periods impacts scholastic performance and on-task behavior in preschool-aged children. Although the vast majority of literature has focused upon preadolescent populations,[10] changes induced by physically active lessons could be masked or prompted as a by-product of other compensatory cognitive operations given the complexity of academic performance. Accordingly, focusing on a preschool-aged population offers an ideal opportunity to assess changes in scholastic performance free of potential confounds associated with high-level cognitive operations that are not yet fully operational.[19] Using a rigorous randomized within-participants repeated-measures crossover design with a sample of preschool-aged children, the present investigation assessed changes in acuity of the approximate number system and on-task behavior prior to and following a 20-min bout of either conventional sedentary instruction or physically active instruction. The approximate number system is involved with the mental representation of numerosity (ie, thinking about quantities, such as determining which container holds more grapes—regardless of grape size), is functionally distinct from the symbolic representation of numbers,[20] and serves as an important predictor of later mathematics and overall academic achievement.[21] Given the considerable evidence supporting enhancements in academic achievement following physically active lessons alongside the extant literature demonstrating improvements in attention and on-task behavior following single bouts of physical activity—with greater effects observed for cognitively engaging forms of physical activity—it was hypothesized that physically active instruction would improve precision of the approximate number system (ie, shorter reaction time and increased response accuracy) and on-task behavior relative to conventional sedentary instruction.

2 | METHOD

2.1 | Participants

A final sample of 51 preschool-aged children (M = 4.7 ± 0.8 years, 25 females; 24% nonwhite) participated in this investigation at Michigan State University. An initial sample of 60 participants was recruited; however, nine children were excluded for noncompliance (ie, not participating in any of the intervention activities and/or not performing the approximate number system task). See Figure S1A for a CONSORT flow diagram of enrollment. The present study was approved by the Institutional Review Board at Michigan State University. Parents/guardians of all participants provided written informed consent, and participants provided verbal and written assent prior

TABLE 1 Participant demographics (mean ± SD)

Measure	All participants	Females	Males
N	51	25	26
Age (years)	4.7 ± 0.8	4.7 ± 0.9	4.6 ± 0.7
Nonwhite (%)	24	12	12
Weight-for-stature (percentile)	55.0 ± 29.2	50.1 ± 28.7	59.3 ± 29.5

Note: Weight-for-stature based on child growth standards ages 2-5 y.[35]

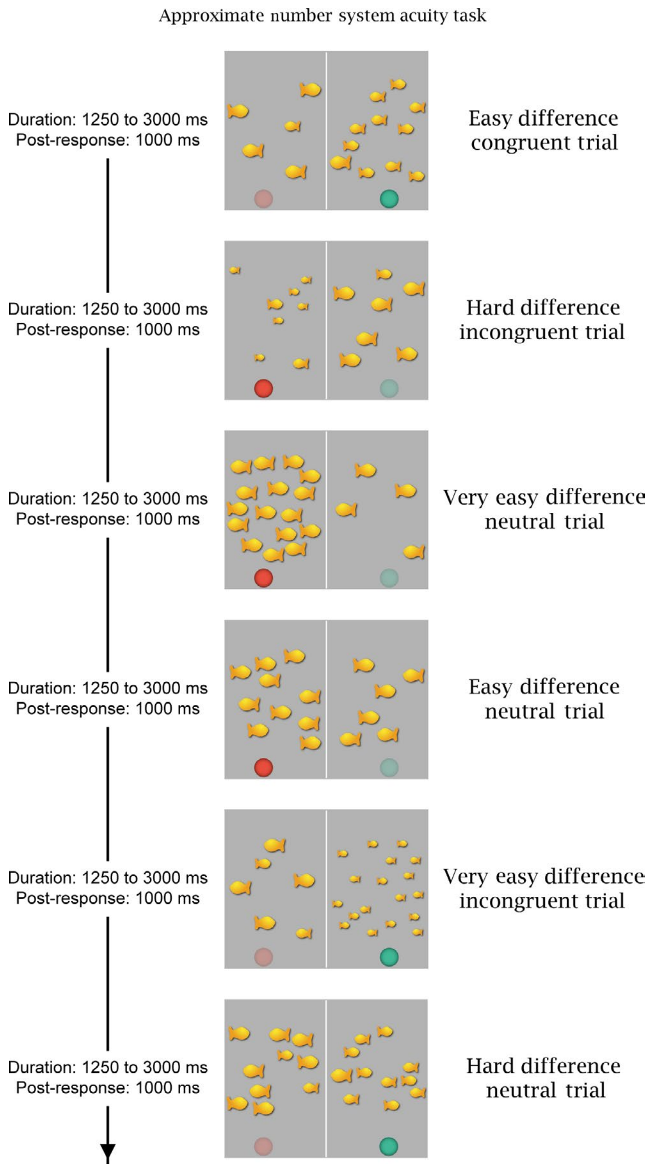

FIGURE 1 Illustration of the approximate number system task. For reference, the correct response to each stimulus is depicted. Comparisons were equally distributed across very easy difference ratios (≤0.30), easy difference ratios (0.33-0.5), and hard difference ratios (≥0.67) where the ratio is smaller/larger quantity and across congruent (greater surface density for the greater quantity), incongruent (greater surface density for the smaller quantity), and neutral (matching surface density between comparisons) trials

to participation. All parents/guardians reported participants being free of neurological disorders or physical disabilities and indicated normal or corrected-to-normal vision. Participant demographic characteristics are provided in Table 1.

2.2 | Approximate number system acuity task

Acuity of the approximate number system was assessed using a nonsymbolic magnitude comparison paradigm.[22] Participants were instructed to respond as accurately as possible with a button press to indicate which of two schools of fish contained a greater number of fish. The two schools of fish were presented simultaneously on a gray background with button-response mappings appearing below the arrays to alleviate working memory demands (see Figure 1). A number of task parameters were controlled to maintain consistency with prior work using this task in preschoolers (see Appendix S1 Methods).[22,23] The task was performed on a laptop using PsychoPy, 1.83.4[24] using a variable stimulus duration ranging from 1250 to 3000 ms and a fixed 1000 ms post-response interval.[22] At each measurement period, children completed 12 practice trials followed by 72 task trials. Reaction time was quantified using median speed of responding following the onset of the stimulus only for correct trials, ensuring a more representative measure of reaction time in pediatric populations by reducing the effect of trials with outlying times.[25] Response accuracy was quantified as the proportion of correct responses relative to the number of trials administered (excluding practice trials).

2.3 | Experimenter redirection

On-task behavior was quantified by a trained observer separate from the experimenter. Experimenters provided verbal redirection for participants by reminding participants to "press the button for the side with more fish." Experimenter redirection was contingent on participants exhibiting an easily observable off-task behavior defined as verbal or motor behavior that was not relevant to the learning situation (ie, pressing both buttons at the same time, diverting eye contact away from the laptop screen, and talking to the experimenter).[5] Both experimenter and observer were blind to the experimental condition at pretest, and observers were trained undergraduate research assistants blind to the experimental objectives. Such an approach was used to maintain external validity with classroom practices—in which teachers frequently redirect students for exhibiting behaviors that do not follow class rules or do not support the learning situation—and to reduce the time and training burden associated with other direct observation momentary sampling techniques.

2.4 | Physical activity measurement

During both sessions, children wore a heart rate monitor (Model: H7; Polar Electro) to continuously record heart rate as an objective physiological index of the intensity of the lessons. Additionally, physical activity was measured using a uni-axial spring-levered pedometer (Model: Yamax Digi-Walker SW-200; Yamasa Tokei Keiki Co Ltd.) worn on the right hip to record number of steps. Total number of steps and minutes spent at or above 30% HRR (ie, light-to-moderate intensity)[26] were quantified as the present investigation aimed to optimize physical activity engagement within this range. Detailed processes for preparation and analysis of heart rate data are provided in the Appendix S1.

2.5 | Procedure

Using a randomized within-participants crossover design (see Figure S1B), participants visited the laboratory on two separate days (mean days apart 6.9 ± 5.9; mean time of day difference 33.7 ± 156.0 minutes). During the first visit, following consent/assent, participants' parents/guardians completed the Physical Activity Readiness Questionnaire.[27] Children were then counterbalanced into two different session orders (Day 1: conventional sedentary instruction, Day 2: physically active instruction or Day 1: physically active instruction, Day 2: conventional sedentary instruction, see Figure S1B) to ensure any observed effects were unrelated to the order in which participants received the experimental conditions.[4] The approximate number system task was performed on a laptop before and immediately following cessation of each 20-min experimental condition (see Table S1). During both sessions, instructions emphasized accuracy, equal emphasis was placed on physical and cognitive task domains (ie, children were not told to run faster), and experimenters helped children correct any counting errors during instructional activities. Additional detail regarding experimenter feedback and activity descriptions is provided in Appendix S1.

2.5.1 | Conventional sedentary instruction

To maximize the external validity of the present investigation, sedentary instruction replicated activities previously used to strengthen the acquisition of approximate number representations and aligned with Michigan Early Learning Standards.[25,28,29] During the 20-min conventional sedentary instruction condition (M = 20.2 ± 1.7 minutes), participants accumulated 4.5 minutes [95% CI: 2.0-6.9] of activity at or above a light intensity (at or above 30% HRR); mean heart rate = 107.0 [95% CI: 103.9-110.1], and heart rate reserve = 20.9 Percent [95% CI: 17.7-24.1], see Figure 2A.

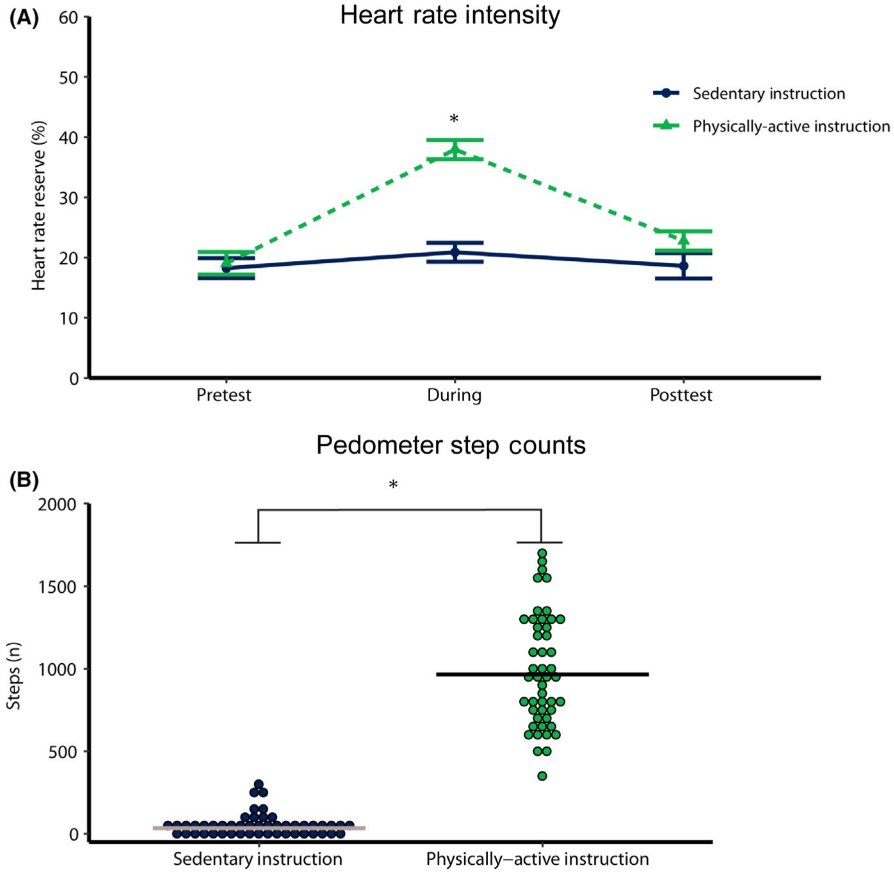

FIGURE 2 Illustration of (A) heart rate intensity and (B) pedometer step counts during each experimental condition. Mean step count for each condition is noted with a gray line for the sedentary instruction and black line for the physically active instruction

2.5.2 | Physically active instruction

Participants engaged in similar activities to those used in sedentary instruction with the incorporation of physically active components. During the 20-min physically active condition (M = 20.1 ± 1.2 minutes), participants accumulated 13.5 minutes [95% CI: 11.6-15.3] of activity at or above a light intensity (at or above 30% HRR); mean heart rate = 127.8 bpm [95% CI: 124.6-131.0], and heart rate reserve = 37.9 Percent [95% CI: 34.7-41.2], see Figure 2A.

2.6 | Statistical analysis

To determine how acuity of the approximate number system was differentially impacted by physically active instruction relative to conventional sedentary instruction, analysis of median reaction time and response accuracy was conducted separately by examining main and interaction effects of a 2 (Mode: conventional sedentary instruction, physically active instruction) × 2 (Time: pretest, post-test) × 3 (Ratio: very easy, easy, hard) univariate multilevel model including a random intercept for Participant, Participant × Mode, Participant × Time, and Participant × Ratio interactions. Analysis of frequency of experimenter redirection was conducted by examining main and interaction effects of a 2 (Mode: conventional sedentary instruction, physically active instruction) × 2 (Time: pretest, post-test) univariate multilevel model including a random intercept for Participant, Participant × Mode, and Participant × Time interactions. All analyses used the lme4, lmerTest, and emmeans packages in R version 3.6[30] using Kenward-Roger degrees of freedom approximations, $\alpha = .05$, and Benjamini-Hochberg false discovery rate control = 0.05 for post-hoc breakdowns. For each inferential finding, Cohen's f^2 and d with 95% confidence intervals were computed as standardized measures of effect size, using appropriate variance corrections for repeated-measures comparisons (d_{rm}).

3 | RESULTS

3.1 | Reaction time

Analysis of median reaction time[††] revealed no main effects or interactions with Mode, $F's$ (2,49) ≤ 0.6, $p's \geq 0.434$, $f^{2'}s \leq 0.02$ [95% CI: 0-0.08] (see Figure 3A; Table S2), suggesting no difference between physically active and sedentary instruction. A main effect of Time was observed for median reaction time indicating that learning occurred; participants responded faster at post-test

[††]Results similar to those reported here were obtained from analyses of mean reaction time following outlier removal.

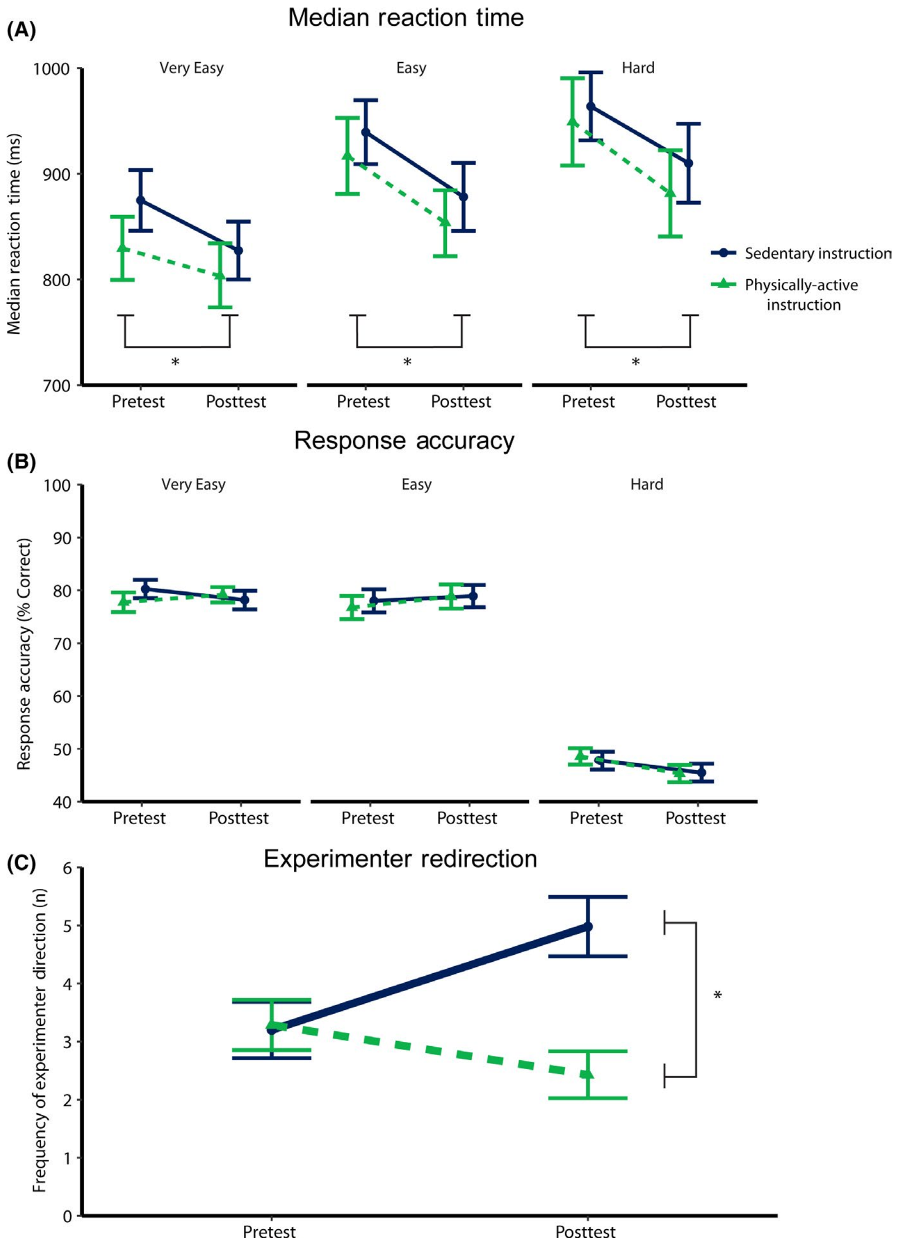

FIGURE 3 Illustration of the effects of mode and time for (A) median reaction time, (B) response accuracy, and (C) experimenter redirection

(859.6 ± 235.1 ms) relative to pretest (912.3 ± 238.3 ms), F(1, 50) = 15.1, $P < .001$, $d_{rm} = 0.29$ [95% CI: 0.13-0.44]. A main effect of Ratio was observed, F(2, 99) = 23.9, $P < .001$, $f^2 = 1.15$ [95% CI: 0.60-2.27], with median reaction time slowing with increased task difficulty: very easy ratios exhibited the fastest reaction time (834.1 ± 203.9 ms), followed by easy (897.5 ± 228.9 ms), then hard (926.3 ± 268.4 ms) ratios, $t's$ (99) ≥ 2.1, $p's \leq 0.037$, $d_{rm's} \geq 0.17$ [95% CI: 0.01-0.75].

3.2 | Response accuracy

Analysis of response accuracy revealed no main effects or interactions with Mode, $F's$ (2,49) ≤ 1.0, $p's \geq 0.38$, $f^{2'}s < 0.01$ [95% CI: 0-0.03] (see Figure 3B; Table S2), suggesting no difference between physically active and sedentary instruction. A main effect of Ratio was observed, F (2, 100) = 499.9, $P < .001$, $f^2 = 1.97$ [95% CI: 1.15-3.82], which was superseded by a Time × Ratio interaction, F (2, 338) = 3.5, $P = .03$, $f^2 = 0.01$ [95% CI: 0.00-0.07]. Post-hoc decomposition of this interaction revealed that response accuracy was maintained from pretest to post-test for very easy and easy ratios, $t's(155) = 0.3$, $p's \geq 0.3$, $d_{rm's} = 0.03$ [95% CI: −0.16-0.28], whereas a slight reduction in response accuracy for the hard ratio—which did not remain significant following false discovery rate control (Benjamini-Hochberg critical alpha = 0.022)—was observed at post-test (45.4 ± 11.6%) relative to pretest (48.2 ± 11.3%), t (155) = 2.1, $P = .037$, $d_{rm} = 0.35$ [95% CI: 0.02 to 0.68].

3.3 | Experimenter redirection

Analysis of experimenter redirection revealed a main effect of Mode, $F(1, 48) = 10.2$, $P = .003$, $f^2 = 0.30$ [95% CI: 0.06-0.69], which was superseded by a Mode × Time interaction, $F(1, 49) = 20.7$, $P < .001$, $f^2 = 0.61$ [95% CI: 0.24-1.29] (see Figure 3C; Table S2). Post-hoc decomposition of this interaction revealed that participants required similar frequency of redirection at pretest for both physically active (3.3 ± 3.0) and sedentary instruction (3.2 ± 3.4) conditions, $t(91) = 0.3$, $P = .8$, $d_{rm} = 0.04$ [95% CI: −0.26-0.34]. Following sedentary instruction, participants required greater frequency of redirection (5.0 ± 3.6) relative to pretest, $t(97) = 4.3$, $P < .001$, $d_{rm} = 0.50$ [95% CI: 0.26-0.74]. Following physically active instruction, participants required fewer redirections (2.5 ± 2.8) relative to pretest, $t(97) = 2.0$, $P = .043$, $d_{rm} = 0.29$ [95% CI: 0.01-0.58], though this difference did not remain significant following false discovery rate control (Benjamini-Hochberg critical alpha = 0.040). Relative to sedentary instruction (5.0 ± 3.6), fewer redirections were required following physically active instruction (2.5 ± 2.8), $t(91) = 5.3$, $P < .001$, $d_{rm} = 0.70$ [95% CI: 0.42-0.97].

4 | DISCUSSION

The present study aimed to provide new insight into how the dual-task environment presented by integrating physical activity with early numeracy instruction interferes with or enhances acquisition of approximate number representations in preschoolers. Findings revealed that following a single 20-min bout of physically active instruction at low-to-moderate intensity, preschoolers exhibit enhanced on-task behavior relative to following conventional sedentary instruction. Although physically active instruction did not significantly enhance approximate number system acuity relative to conventional sedentary instruction (contrary to our *a* priori hypothesis), physically active instruction was not detrimental to learning, improved on-task behavior, and allowed children to spend approximately half the lesson period at low-to-moderate intensity activity; these results suggest the dual-task environment did not result in decrements in the cognitive domain.

Findings from the present investigation are consistent with the notion that physically active lessons create a substantive change in physical activity by reducing sedentary behavior.[5,11-14] Mahar and colleagues[5] observed that school-aged children who engaged in the energizers' classroom-based physically active lessons accumulated almost 800 additional steps over the course of an entire school day relative to students engaged in conventional lessons. Mavilidi and colleagues[14] integrated movement with number knowledge, which resulted in preschoolers accruing about 2 minutes of moderate-to-vigorous activity. Although physical activity was only assessed throughout the 20-min intervention period within the present study, physically active instruction provided preschoolers with an additional 931.3 ± 8.2 steps (see Figure 2B) and 9 minutes at or above light intensity. Viewed within the framework of recommendations that preschool-aged children accumulate at least 10 000 steps per day, integrating physical activity with academic learning accounted for 10% of the daily recommended steps and represented an approximately 1600% increase in steps [((physically active steps – sedentary steps)/sedentary steps)*100] in a very brief session. Overall, children accumulated just over nine additional minutes of physical activity and spent 68% of the lesson at or above light intensity (at or above 30% of heart rate reserve) as a result of integrating physical activity with instruction. This finding suggests that single bouts of physical activity at lower intensities may offer similar attentional enhancements to those observed following higher intensities (ie, moderate-to-vigorous), which are widely supported in the extant acute physical activity and classroom activity break literature.[4,10] Importantly, the physically active instruction intervention in the present study resulted in a greater duration (ie, seven more minutes of physical activity) of physical activity at higher intensity (low-to-moderate) relative to other physically active learning interventions in preschoolers[11,12,14]; and future research may seek to integrate similar activities to increase the likelihood that children accrue the many health-related benefits associated with greater amounts of moderate-to-vigorous activity during lessons. Taken together, the findings suggest that physically active instruction improves on-task behavior and reduces the time spent sedentary.

Novel to the present investigation was the assessment of the extent to which the dual-task environment presented by physically active instruction immediately impacts learning, specifically focusing upon changes in the acuity of the approximate number system—which serves as the foundation for later mathematical performance and overall academic achievement. Importantly, integrating physical activity with early numeracy instruction was not associated with any deleterious cognitive effects. Speculatively, such a finding may reflect the stability of neural mechanisms underlying the acquisition of such skills, which enable individuals during early childhood to be robust against the influence of interfering distractors. Alternatively, the low-to-moderate intensity of physical activity may have been insufficient to incur potential enhancements in cognition or the beneficial effects of the bout of physical activity on attentional control may have counteracted the negative influence presented by the dual-task environment. Unlike implementing short physical activity opportunities as placeholder or transition activities within instructional contexts, the present study's physically active lesson intentionally aligned with the learning goals (ie, engaging the approximate number system) and Michigan Early Learning Standards.[29] Consequently, physically active instruction may have resulted in the same performance gains because there was similar duration of direct instruction as in the conventional sedentary condition. Nevertheless, the present findings suggest that physically active learning does not detract from the acquisition of approximate number representations while offering attentional benefits and reducing sedentary behavior.

Although task performance was not selectively impacted by the physically active instruction, such approaches do appear to offer benefits relative to educational outcomes. Specifically, children exhibited greater on-task behavior following physically active instruction—as evidenced by reduced experimenter redirection. Accordingly, such findings align with the burgeoning body of literature demonstrating enhancements in attention following physical activity.[4] When viewed within the broader context of this literature, it may be that the enhancements in scholastic performance observed following long-term implementation of physically active lessons may not result from the lesson period per se, but rather reflect similar attentional control changes as those observed following classroom movement breaks, that is, following the activity period, children are able to engage attention towards subsequent instructional periods to a greater extent. Thus, acute bouts of physical activity enable subsequent transient enhancements in task engagement to optimize the learning environment, and over repeated bouts, structural, and functional neural adaptations are incurred to support enhanced brain function. Moreover, increased neurotrophic growth factors supporting structural and functional neural adaptations alongside improved cognition have been observed following interventions with greater moderate-to-vigorous physical activity.[31] Because intensity may influence acute changes in neurotrophic factors following physical activity engagement,[32] further research is necessary to examine the benefit of accumulating bouts of physical activity at very light intensity for physical and brain health—through physically active instruction—relative to the health-enhancing potential of greater amounts of moderate-to-vigorous intensity activity accumulated through classroom movement breaks.[7]

4.1 | Study limitations

Physical activity-induced changes in number sense may be more readily apparent in populations exhibiting low behavioral self-regulation, which is a predictor of early math skills, [33] or in lower-performing individuals.[34] Although exploratory analyses did not reveal that change in acuity of the approximate number system was differentially impacted by physically active and sedentary instruction between higher- and lower-performers, results suggested that higher-performers exhibited greater learning following sedentary instruction and lower-performers exhibited increased accuracy whereas higher-performers exhibited a deterioration regardless of condition (see Appendix S1 Results). Such findings provide preliminary data to guide future research. The present investigation only focused upon changes in the acuity of the approximate number system within a very short period following the lesson; further research is necessary to understand the protracted effects of such a dual-task environment on retention of academic learning. As children participated in the lessons individually alongside the experimenter within a highly controlled laboratory setting, future research should determine the feasibility of implementing the same lessons in a classroom setting given that the present findings replicate the same beneficial after-effects of a single bout of physically active instruction on attention observed in classroom-based studies. Although performance gains in both physically active and sedentary instruction were consistent with those observed in studies using similar approximate number system training,[21,28] the present findings should be interpreted in light of the fact that the present study lacks a non-instruction control group (eg, seated coloring). Although the experimental design used in this study is suitable for detecting the differential effects of physically active and sedentary instruction, the lack of a control group with no instruction does not rule out the potential that both approaches have similarly little to no effects. Further, the systematic approach used to code off-task behavior—using experimenter redirection—in the present study has limitations. Namely, observers coding off-task behavior were not blind to the experimental condition at post-test and reliability of ratings is unknown. Although the rating approach required children to exhibit a well-defined, easily observable off-task behavior to elicit an experimenter redirection, participants may have achieved similar task performance levels following both lessons because more redirection at post-test occurred, which could have masked any possible differences between experimental conditions even though fewer experimenter redirections were observed following physically active instruction relative to sedentary instruction. Finally, the classification of physical activity intensity in the present investigation may underestimate the actual intensity of the lessons given the lack of prediction equations for children younger than 6 years old; nonetheless, the approach used in the present study will help determine intensity in preschoolers, serving to strengthen the design of future studies.[4]

5 | CONCLUSION

Findings indicate that preschoolers exhibit similar learning and greater on-task behavior following a single bout of physically active learning at low-to-moderate intensity. The results of the present study support the idea that integrating physical activity with instruction is an ideal means to reduce sedentary behavior and optimize classroom behavior. Future research should determine to what degree physically active instruction can be integrated with other academic content, at higher intensities, and longer time frames to support the development of physical literacy and school readiness.

5.1 | Perspective

Because educational administrators assert the primacy of performance on standardized achievement tests, physically active instruction is an appealing approach that reduces sedentary behavior and enhances classroom efficiency—by reducing the need to redirect off-task behavior and thereby increasing overall instruction time. Our data provide preliminary evidence to suggest that enhancements in cognition observed in longer physically active instruction interventions may stem from acute improvements in attentional control—rather than the academic lesson—thereby enhancing on-task behavior and enabling children to gain more from instructional periods that follow periods of physical activity.

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CONFLICT OF INTEREST

No conflicting financial interests exist.

AUTHORS' CONTRIBUTION

Amanda L. McGowan contributed to conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft, writing—review and editing, visualization, supervision, project administration, and funding acquisition. Hope K. Gerde contributed to resources, writing—review and editing, and supervision. Karin A. Pfeiffer contributed to resources, writing—review and editing, and supervision. David P. Ferguson contributed to writing—review and editing, and supervision. Matthew B. Pontifex contributed to methodology, resources, writing—original draft, writing—review and editing, and supervision.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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