The Effect of Multiple Recesses on Listening Effort: A Preliminary Study

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Purpose: **This study investigates the relation between a multiple-recess intervention and change in listening effort in early elementary-aged students at the beginning and end of the school day. Method: Kindergarten and first-grade (n = 167) students participating in a larger study, the LiiNK™ project, completed a dual task paradigm designed to measure listening effort via reaction time in the morning and afternoon of a school day. Students attended either an intervention school, participating in four 15-minute recess periods during the school day, or a control school, participating in one 15-minute recess period, usually at the end of the day. Change in reaction time from morning to afternoon was compared across groups. Results: Children in the intervention schools, on average, demonstrated decreased listening effort in the afternoon, as measured by the secondary task, whereas children in the control schools demonstrated increased listening effort. Differences between groups were not the result of between-district differences and did not change from the fall to the spring semester. Conclusion: Preliminary evidence indicates that unstructured play, in the form of multiple recesses during the day, may decrease listening effort in elementary-aged children with normal hearing. Future work should consider how a decrease in listening effort could lead to increased academic learning, particularly in the afternoon.**

Introduction

Despite recommendations from the Society of Health and Physical Educators (SHAPE America) that children receive at least 20 minutes of recess daily in the school setting, scheduling of unstructured play continues to decline in the United States (Murray & Ramstetter, 2013; SHAPE America, 2016). State lawmakers and school personnel have been minimizing unstructured, outdoor play that can strengthen academic scores in order to provide more direct instruction (Pelligrini & Bohn-Gettler, 2013; RWJF, 2013). The removal or minimization of recess in a daily school schedule has had unintended negative consequences not only on physical fitness (CDC, 2011; 2014) but also on cognitive skill development (Biddle & Asare, 2011; Ickes, Erwin, & Beighle, 2013; Verburgh, Konigs, Scherder, & Oosterlaan, 2013).

Play contributes to learning in elementary school aged children (pre-K through grade 5; Piaget, 1965; 1983; Vygotsky, 1967). Unstructured play prompts changes to the behavior in ways that promote cognitive understanding (e.g., paying attention) through interactive, manipulative experiences (Barros, Silver, & Stein, 2009; Pelligrini & Bohn-Gettler, 2013). Students who engage in extended listening activities throughout the day without breaks may experience an increase in listening effort, the cognitive resources required to perceive and process the speech signal, as the day goes on (e.g., Hicks & Tharpe, 2002). Increased listening effort may lead to decreased learning as the day goes on. Although there is a link between attention, memory and learning (e.g., Baddeley, 2003; Cowan, Elliott, Saults, Morey, Mattox, Hismajtullina, et al., 2005), listening effort may represent an additional construct that should be considered in classroom learning. The purpose of this preliminary study was to consider the effects of a multiple recess intervention on kindergarten and first grade students' listening effort throughout the day.

Physical Activity and Learning

Regular physical activity leads to better mental acuity, including brain development (Biddle & Asare, 2011; Verburgh et al., 2013). Neurological research has shown consistently that regular physical activity increases oxygen flow to the brain (Ickes et al., 2013; Ratey, 2013; Verburgh et al., 2013) and increases production of neurotrophins, which stimulates the development of beneficial new neural pathways (Medina, 2008).

Physical activity helps memory and thinking through both direct and indirect means (Hillman, Pontifex, Raine, Castelli, Hall, et al., 2009; Tomporowski, Davis, Miller, & Naglieri, 2008). The benefits of exercise come directly from its ability to reduce insulin resistance, reduce inflammation, and stimulate the release of growth factors—chemicals in the brain that affect the health of brain cells, the growth of new blood vessels in the brain, and even the abundance and survival of new brain cells. Indirectly, physical activity improves mood and sleep, and reduces stress and anxiety. Problems in these areas frequently cause or contribute to cognitive impairment.

Among children, unstructured play prompts changes in the prefrontal cortex, the critical region of the brain's executive control center, responsible for regulating emotions, making plans, and solving problems (Barros et al., 2009; Medina, 2008; Pellegrini & Bohn-Gettler, 2013). This not only moves children along the path toward normal social development, it makes them better thinkers and therefore better learners (Ickes et al., 2013; Subramanian, Sharma, Arunachalam, Radhakrishnan, & Ramamurthy, 2015). Research shows that given 15 minutes of unstructured play, children will spend a third of this time engaged in spatial, mathematical, and architectural activities (Ness, & Farenga, 2016).

When physical activity and recess are performed outside, studies have shown the elements of nature and daylight can additionally enhance the quality of the classroom performance (Biddle & Asare, 2011; Louv, 2008; Medina, 2008; Verburgh et al., 2013). The brain was designed to set the timing of circadian rhythms from extensive exposure to daylight (Medina, 2008). When individuals remain inside for extended periods of time, circadian rhythms lose their timing, leading to abnormal sleep patterns. Exposure to daylight also improves the immune system through the natural absorption of the D3 hormone (Louv, 2008). Natural sunlight can also improve eye health and stress levels (Ratey, 2013). Overall, these different components of health have shown a strong relationship with longer attentional focus, improved reading skills, and verbal fluency (Pellegrini & Bohn-Gettler, 2013; Ratey, 2013; Pettersen, 2016; Tomporowski et al., 2008).

Attention, Memory and Learning

If recess serves to increase a student's ability to sustain attention and learning in the classroom, then the ability to attend throughout the day may be improved by offering multiple recesses daily. At a minimum, a child must attend to new information process and store it (i.e., to learn new information; e.g., Baddeley, 2003; Cowan, Elliott, Saults, Morey, Mattox, Hismajtullina, et al., 2005). According to Baddeley (1996), the central executive, also termed working-memory, is the system responsible for controlling attention. Therefore, the central executive plays an important role in academic learning. For example, tasks thought to measure central executive performance, such as sentence span and auditory digit sequencing tasks, significantly contribute to reading comprehension and word-level reading of 4th and 9th grade students (Swanson & Howell, 2001).

The central executive is a limited-capacity system. If information cannot be held and integrated in the central executive, as when attention resources are diminished, information will be lost and successful learning will not occur (Cowan et al., 2005). In other words, there is a limited amount of processing a person can engage in at a given time, and the cognitive resources, including attention and working memory, available to an individual person will affect the amount he or she can learn.

In a classroom, children must perceive, store, and interpret the speech signal produced by the teacher. Listening effort, or the cognitive resources required to perceive and process the speech signal, represents a construct that could explain a relation between attentional control/resources and learning (e.g., Picou & Ricketts, 2014; Hornsby, 2013; Hua, Karlsson, Widen, Moller, & Lyxell, 2013). If a child is experiencing a high level of listening effort (e.g., having to use a greater proportion of attention resources to perceive and store a speech signal), he or she may have difficulty learning new or complex information. Most researchers have measured the association between learning and skills associated with the central executive with tasks such as sentence span and digit sequencing; however, it is possible that measuring children's listening effort also provides information about children's attention and learning.

Increasingly, researchers are linking listening effort with listening fatigue (e.g., Hornsby, 2013; Hicks & Tharpe, 2002). Fatigue associated with listening may decrease one's ability to attend to or concentrate on new material (e.g., Kennedy, 1988; Leavitt & DeLuca, 2010). Evidence from adults and children with hearing loss indicates that sustained speech processing can lead to increased mental fatigue (Hornsby, 2013, Hornsby, Werfel, Camarata & Bess, 2014; Werfel & Hendricks, 2016). Although listening fatigue has not been fully explored, it is important to consider that fatigue could be an effect of sustained listening effort throughout the school day. If recess allows a child to diminish fatigue as a result of sustained listening, it is possible that children will learn more in the classroom.

Measuring Listening Fatigue

Dual-task paradigms have been used successfully by many researchers to measure listening effort, (e.g., Downs, 1982; Hicks & Tharpe, 2002; Howard, Munro, & Plack, 2010; Rakerd, Seltz, & Whearty, 1996; Sarampolis, Kalluri, Edwards, & Hafter, 2009). These tasks require a listener to simultaneously complete two tasks: a primary task and a secondary task (Feuerstein, 1992). The primary task, a listening and speech-processing task, places increasing demand on a participant's cognitive resources (in a way that could mirror classroom learning). The secondary task, in this case, a reaction-time task, measures any remaining cognitive resources available to the participant. Thus, changes in secondary task performance are indicative of changes in cognitive resources (i.e., changes in listening effort).

Multiple studies have successfully used reaction time in a secondary task to measure the listening effort of adults with and without normal hearing (Sarampalis et al., 2009; Fraser, Gagne, Alepins, & Dubois, 2010; Picou & Ricketts, 2014). Listening effort has also been successfully measured in children. Hicks and Tharpe (2002) measured the reaction time performance of 28 children with and without hearing loss using a primary speech-recognition in background noise task and determined that children with hearing loss expended more effort listening than children with normal hearing. Howard, Munro and Plack (2010) measured reaction time performance of 31 children with normal hearing and determined that, as background noise level increased, secondary task performance decreased. This finding indicated that a dual-task paradigm can be sensitive to changes in listening effort, even in children.

If elementary school children participate in sustained periods of academic instruction without breaks (e.g., recess), it would be reasonable to assume that those children expend increasing amounts of listening effort as the day goes on. Thus, increased academic instruction without breaks may have diminishing returns: as listening effort increases, children may have fewer resources, such as attention, available to them to learn. On the other hand, if children experience frequent breaks throughout the day, it is possible they do not expend as much listening effort during afternoon instruction. The goal of this preliminary study was to determine if participation in frequent physical activity decreased listening effort at the end of the school day. This study represents the first step in a line of inquiry to determine if recess could enhance learning in the classroom by decreasing overall fatigue experienced by students as a result of sustained academic instruction.

This preliminary research study addressed the following question: Do children who participate in more recesses throughout the day demonstrate a faster reaction time performance in a dual task paradigm than children who participate in fewer recesses?

METHODS

Participants

Participants from this study are part of the larger LiiNK™ Project. The LiiNK™ Project includes a teacher and administrator training to implement a character development curriculum called Positive Action® (2007) and to increase the amount of time allotted for unstructured, outdoor play (Rhea, Rivchun, & Pennings, 2016; Rhea, 2016).

For the current study, a stratified random sample of students was selected from two intervention and two control schools matched for district and socioeconomic status distribution. Two males and two females were randomly selected from 43 Kindergarten and 1st grade classrooms totaling 172 students per grade across each school each semester. Teachers were given the opportunity to identify any students that were considered unable to receive English instruction or had a learning disability. Also accounting for absences and inability to participate in the task, 270 total students were asked to participate in the dual-task paradigm (fall and spring). Students who were unable to complete the practice experimental task (described below), students who did not complete all reaction time trials, and students who did not complete the task in the morning and the afternoon of the same day were excluded from analysis. Following removal of students from that original pool, data was taken from a total of 163 students. Data from the North Texas intervention schools and control schools represented a range of socio-economic statuses as indicated in Table 1.

LiiNK™ Project Intervention

In this study, students in intervention schools (n = 88 across both districts) participated in the character development curriculum and in unstructured outdoor play. The amount of time allotted during the school day for unstructured, outdoor play included four, 15-minute recesses throughout the day, totaling 60 minutes each day. Adherence to the outdoor play schedule was monitored by a weekly self-report electronic survey that was sent to the teachers. LiiNK team members also completed visits to the schools to confirm that the teachers were adhering to the LiiNK program. Overall recess adherence was .94, meaning that 94% of scheduled (four 15-minute recesses daily) recess times were attended. The control schools maintained their original school day schedule. For the control schools, the daily schedule consisted of one 15 to 20 minute recess daily.

Experimental Task

To measure listening effort in this project, a dual-task listening paradigm where students simultaneously completed a primary task and a secondary task was created based on the task described by Hicks and Tharpe (2002). The primary attention task speech-recognition stimuli consisted of number series from the Memory for Digits subtest of the Comprehensive Test of Phonological Processing- Second Edition (Wagner, Torgesen, Rashotte, & Pearson, 2013). This subtest measures a participant's ability to repeat increasingly long strings of numbers accurately, and has been validated for use with Kindergarten and first-grade children. Because this project was designed to measure changes in listening effort over time, signal-to-noise ratio was not manipulated in the primary attention task – all children performed this task in quiet.

The secondary attention task consisted of a reaction-time task wherein participants were asked to push an arrow key corresponding to a right or left facing arrow that appeared on a laptop computer screen. Stimuli for the secondary task were designed and controlled by the E-Prime 2.0 software program (Psychology Software Tools, 2012). Arrows appeared in a randomized order at pre-set, at variable time intervals. Participants were instructed to push the correct corresponding arrow as fast as possible when it appeared on the screen.

The timing of the primary and secondary task variables was not consistent across children because the child's responses to the reaction-time task dictated how quickly he or she moved through the task. Thus, if a child reacted very quickly, he or she would

Table 1. LiiNK Cohort 1 Campus Demographics

Campus	Number of Students	% Hispanic	% African American	% White	% Other Ethnicity	% Economic Disadvantaged	% Special Education	% ELL
District 1								
Intervention	879	55.1%	26.1%	6.8%	12.0%	83.6%	6.8%	47.1%
Control	793	41.1%	41.9%	8.3%	8.7%	78.9%	6.8%	32.4%
District 2								
Intervention	593	13.2%	2.6%	81.5%	2.7%	28.4%	7.7%	1.1%
Control	676	26.5%	5.9%	59.5%	8.1%	24.2%	11.6%	5.8%

Source: School District One 2013-2014 report. Texas Academic Performance Report 2013-2014 School District Two complete fewer trials of the primary task. Presentation of the primary task stimuli therefore corresponded to the reaction time trials at varying intervals (sometimes presented at the beginning of a reaction time trial, sometimes in the middle, sometimes at the end).

Procedures

Participants in this study completed the experimental task twice during one school day in the fall and one school day in the spring. Within each day, students in the control and intervention groups completed the task at the beginning of the school day prior to any participation in recess (at the very beginning of the school day) and in the afternoon after several recesses for students in the intervention group or after at least one recess for the students in the control group. Prior to beginning the experimental task, participants were introduced to both tasks and given the chance to practice the primary and secondary task for 20 reaction time trials and 5 number lists (simultaneously). Children who demonstrated understanding of the task were invited to continue the experimental task. Participants were told that accurately repeating numbers was the main task they should focus on, and that the examiner would show the participant his or her scores on the number task when the participant was finished.

In the experimental task, children completed 60 reaction-time trials in the secondary task and as many trials in the primary tasks as possible in the time taken to complete the secondary task. An examiner recorded the child's primary-task responses on-line. Secondary task reaction-time responses were recorded by E-Prime 2.0 software, measured as the time between the appearance of the arrow stimulus and hitting the correct corresponding button.

Analysis

For purposes of analysis, primary task responses were maintained but not used as a measure of listening effort, consistent with other studies of listening effort (e.g., Hicks & Tharpe, 2002). Secondary task responses that were correct (i.e., the correct corresponding button was selected) were measured and reaction times were averaged within each child (i.e., an average reaction time was recorded in the morning and again in the afternoon for each child). Any child who was unable to obtain a correct answer on either the primary or secondary task, or who performed below chance levels on the secondary task was excluded from data analysis.

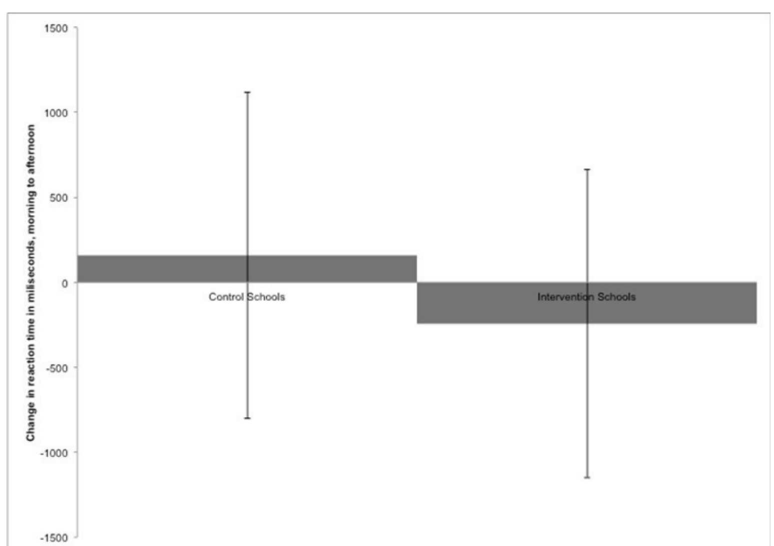
Consistent with other reaction time studies, outlier performances were removed (item by item) from each participant's correct response data pool prior to assessing an individual child's reaction time average. Each participant's performance distribution was consistent with expected distributions (left modal skew of normal distribution) for reaction times. To correct for extreme outlier performance, those data points that were more than 2 standard deviations above each participant's mean and constituted fewer than 5% of the data points for the participant were removed from analysis.

Data were recorded from each kindergarten and first-grade student as reaction time between onset of the stimulus and correct item (arrow direction) selection in both the morning and afternoon testing sessions. The dependent variable, change in reaction time between the first and second session, was calculated for each eligible participant.

RESULTS

Our research question addressed whether children who participated in the LiiNK program would demonstrate a smaller change in morning to afternoon reaction time performance in a dual task paradigm than children not participating in the LiiNK program. Because reaction time data tend to be skewed, parametric statistics were not an appropriate planned analysis. Instead, a nonparametric Mann-Whitney U test was applied with change in reaction time from morning to afternoon as the dependent variable and group membership (control or LiiNK intervention school) as the independent variable. The Mann-Whitney U test revealed a main effect of group $U = 2048.00$, $Z = -4.079$, $p < .001$ with a mean rank of 95.46 for control schools and 65.31 for intervention schools. This analysis indicated that reaction time changes more for students in the control schools ($M = 159.23$, $SD = 959.48$) than in the intervention schools ($M = -242.422$, $SD = 906.57$). Thus, it appeared that students in control school expended a greater amount of listening effort (as measured by secondary task reaction time) in the afternoon than in the morning. Students in the intervention schools appeared, on average, to complete the task more quickly in the afternoon than in the morning. Thus, these students appeared to expend more effort in the morning than in the afternoon. See Figure 1 for representations of results.

Figure 1. Overall change in reaction time by intervention or control school



Two additional analyses were conducted to ensure the appropriate variables were included in the primary analysis to answer our research question. First, a Mann-Whitney test using district as an independent variable was necessary to rule out pre-existing differences in reaction times between school districts tested. Results indicated no main effect of district $U = 2866.00$, $Z = -1.261$, $p = .207$ with a mean rank for the first district of 76.31 and a mean rank for the second district of 85.66. This finding indicates that school district did not affect our main effect of intervention versus control school (and that the intervention schools followed a similar pattern of performance across districts).

Second, an analysis of performance in fall versus spring was conducted to determine whether longitudinal differences existed in reaction time. The Mann-Whitney test indicated no main effect of semester $U = 2961.00$, $Z = -.940$, $p = .347$ with a mean rank of 78.40 in fall and 85.38 in spring. This indicates that students, whether in control or intervention school, tended to exhibit the same pattern of performance in the fall as in the spring. This would indicate that there are not cumulative effects of daily recess on listening effort throughout the year. The lack of main effects of district and semester confirmed the original analysis, which combined data across districts and across semesters for intervention and control schools.

DISCUSSION

The purpose of this preliminary study was to consider how participation in multiple recesses during the day would change listening effort exerted in the morning versus the afternoon in elementary-school children. Listening effort, as measured by a dual-task paradigm, increased in control schools (who participated in one recess during the day) from morning to afternoon. Conversely, listening effort decreased in intervention schools (who participated in four recesses during the day) from morning to afternoon. These differences in performance did not change in magnitude or direction from fall to spring semesters, and the patterns of performance were similar across the two districts tested. Thus, participation in multiple episodes of unstructured play appeared to influence a child's ability to respond quickly in a secondary reaction time task.

In a dual-task paradigm, reaction time during the secondary task is thought to reflect changes in the cognitive resources available to a student after engaging in a primary speech-perception task (Feurenstein, 1992; Picou & Ricketts, 2014). In this case, the primary speech perception task required a student to perceive a speech signal, understand that signal, and form words (numbers) to repeat back to the examiner. This simple speech perception task should engage a child's auditory attention and auditory working memory, as well as tapping requiring simple verbal skills (i.e., verbal repetition). These skills are necessary for basic communication throughout one's day. If performance on the secondary task does reflect the additional attentional resources available to a student, one could infer that children in control school have fewer additional attentional resources available to them in the afternoon for learning tasks. In other words, children in control schools seemed to be exhibiting increased effort just to listen to a speech signal in the afternoon. Children in intervention schools, on the other hand, actually appeared to have more attentional resources available to them in the afternoon for learning tasks.

Studies have suggested that listening effort may be associated with listening fatigue (Hornsby, 2013; Hicks & Tharpe, 2002). Results of this study fit that idea: it is possible that children who engage in sustained attention activities throughout the day (as children in control schools who participated in extended academic instruction time) experience fatigue as the day goes on. Children in intervention schools, alternatively, were able to break-up engagement in activities involving sustained attention and may have experienced less fatigue. This interpretation is a possible explanation of our results: children who do not participate in recess frequently throughout the day may experience more fatigue (and have access to fewer cognitive resources, such as attention) than children who do participate in recess.

The Baddeley (2003) model that links limited-capacity working memory, attention, and learning provides additional hypotheses about a relation between listening effort and learning in the classroom setting. If children experience limitations on the amount of information that can be processed by their working memories, and must expend more listening effort as the day goes on, one could hypothesize that those children will learn less in the afternoon than in the morning. If we are able to diminish listening effort via intervention (e.g., via recess), then researchers might expect children who participate in the Liink project to exhibit more learning throughout the day than children who participate in a more traditional recess model. This relation between listening effort, attention, working memory and learning needs to be further explored. A link between these skills would have strong implications for recess policies in educational institutions.

The findings of this study, that increased recess in the form of unstructured outdoor play through the day allowed students to exhibit less listening effort in the afternoon, are consistent with other studies describing the benefits of recess. The benefits of physical activity for cognitive processing, including attentional focus, may be reflected in the construct of listening effort. These preliminary findings would indicate that recess is important for more than just physical development, but also for academic growth in the classroom.

Limitations and Future Directions

Findings from this preliminary study provide avenues for future directions. First, there were many students invited to complete the task who were unable to do so. It is possible that altering the parameters of the experimental task (e.g., identifying a less demanding primary task or using a switch button as compared to keyboard keys) would capture the performance of a larger number of students. Future works should explore how the parameters of the dual-task reaction time paradigm affect performance.

Second, there was a large amount of variability in change in reaction time from morning to afternoon across both schools.

This variability is likely the result of many extraneous variables that were not measured in this study. For example, it is possible that some children did not really experience a "break" in attention during recess. Children in some families may have also engaged in sustained attention tasks before school. It is also possible that some children in this sample experienced events during class time or during play that would adversely affect afternoon task performance. A future study may consider the effects of other variables on change in reaction time from morning to afternoon.

Third, individual data on child profiles were not collected. Consequently, it is unclear if children with less obvious learning difficulties, such as language impairment, were included in the sample of children who participated. It is also possible, and perhaps even likely (Bess, Dodd-Murphy, & Parker, 1998), that some children in this sample had minimal hearing loss. Even a very low degree of hearing loss may have affected task performance. Thus, this preliminary data cannot evaluate the effects of child characteristics on reaction time. Future works should more thoroughly define individual participants to identify if some children "need" breaks more than others.

This study represents preliminary findings that participation in multiple recesses throughout the day may decrease listening effort in Kindergarten and first-grade children. Future studies should consider how a decrease in listening effort could directly contribute to increased learning in the classroom. If listening effort decrease is associated with an increase in learning, it is possible that recess contributes academic instruction by shorting quantity of instruction but increasing quality of learning experience.

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