

# Jump Around or Sit Still and Read: Physical Activity and Reading in Primary School

Corretear o quedarse quieto y leer: Actividad física y lectura en la escuela primaria

Saltironejar o quedar-se quiet i llegir: Activitat física i lectura a l'escola primària

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## Abstract

Previous research has shown positive impacts of physical activity interventions on academic achievement. To complement existing research, we aimed to study two grade 4 school classes, and without any interventions, examine the relationships between students' physical activity during the school day, their reading comprehension, attitudes towards reading, and reading media preferences. A group of 50 students (grade 4, ages 10–11) were recruited using purposive sampling. The results showed a weak negative correlation between physical activity and reading comprehension. Furthermore, individuals with higher levels of physical activity demonstrated a more negative attitude towards reading. The study also unveiled a negative correlation between physical activity and enjoyment of silent reading of traditional books, while a positive correlation was observed between physical activity and enjoyment of reading on electronic screens. We conclude that reading requires disciplining your body and attention to focus on the text, and comprehension was lower for the physically more active students. Overall, however, the students enjoyed reading.

**Keywords:** physical activity, reading comprehension, attitudes towards reading, reading media preferences, reading education.

## Resumen

Estudios anteriores han demostrado impactos positivos de la actividad física en el rendimiento académico. Para complementar estos estudios, el objetivo de esta investigación ha sido estudiar dos clases de cuarto de primaria y, sin ninguna intervención, examinar las relaciones entre la actividad física de los estudiantes durante el día escolar y su comprensión lectora, actitudes hacia la lectura y preferencias de medios de lectura. Se reclutó a un grupo de 50 estudiantes (cuarto grado, de 10 a 11 años) mediante muestreo intencional. Los resultados muestran una leve correlación negativa entre la actividad física y la comprensión lectora. Además, los estudiantes con el nivel más alto de actividad física demuestran una actitud más negativa hacia la lectura. El estudio también revela una correlación negativa entre la actividad física y el disfrute de la lectura silenciosa de libros convencionales, mientras que se observa una correlación positiva entre la actividad física y el disfrute de la lectura en pantallas electrónicas. Concluimos que la lectura requiere disciplinar el cuerpo y la atención para centrarse en el texto. La comprensión lectora es menor para los estudiantes físicamente más activos. Sin embargo, en general, los estudiantes expresan que disfrutaban leyendo.

**Palabras clave:** actividad física, comprensión lectora, actitudes hacia la lectura, preferencias de medios de lectura, educación lectora.

### Resum

Estudis anteriors han demostrat impactes positius de l'activitat física en el rendiment acadèmic. Per complementar aquests estudis, l'objectiu d'aquesta investigació ha estat estudiar dues classes de quart de primària i, sense cap intervenció, examinar les relacions entre l'activitat física dels estudiants durant el dia escolar i la seua comprensió lectora, actituds cap a la lectura i preferències de mitjans de lectura. Es varen reclutar un grup de 50 estudiants (quart grau, de 10 a 11 anys) mitjançant mostreig intencional. Els resultats mostren una lleugera correlació negativa entre l'activitat física i la comprensió lectora. A més, els estudiants amb el nivell més alt d'activitat física demostren una actitud més negativa envers a la lectura. L'estudi també revela una correlació negativa entre l'activitat física i el gaudi de la lectura silenciosa de llibres convencionals, mentre que s'observa una correlació positiva entre l'activitat física i el gaudi de la lectura en pantalles electròniques. Concloem que la lectura requereix disciplinar el cos i l'atenció per centrar-se en el text. La comprensió lectora es menor pels estudiants físicament més actius. Tot i això, en general, els estudiants expressen que gaudeixen llegint.

**Paraules clau:** activitat física, comprensió lectora, actituds envers la lectura, preferències de mitjans de lectura, educació lectora.

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## 1. Introduction

It is common to think of reading as an intellectual and emotional activity; that is, reading requires decoding and comprehension, and it gives rise to some sort of emotional response. However, it is undeniable that reading is also a physical and embodied activity (Mangen & Weel, 2016; McLaughlin, 2015). It is also a socio-material activity where the social aspects and the material aspects of reading are entangled and transformed in spatial as well as temporal shifts (Kucirkova, 2021). This formed the foundation for our investigation as we embarked on a field study in two primary school classrooms

(grade 4, ages 10–11) to examine relationships between everyday reading activities and students' physical activity during the schooldays.

## 2. Background

Earlier research has demonstrated a positive correlation between physical activity and cognitive and academic performance in children (Sattelmair & Ratey, 2009; Sibley & Etnier, 2003). Neuroscientific studies have associated physical fitness with the same frontoparietal network as used in reading, leading to suggestions that increased physical activity might yield benefits for school performance (Hillman, Erickson, & Kramer, 2008). The implementation of a physical education programme comprising an intervention of 30 minutes of high-intensity activity three days a week demonstrated also positive impacts on reading scores in the Metropolitan Achievement Tests (MAT6 and MAT7) (Sallis et al., 1999). Additionally, a study examining the relationship between physical activity and academic grades reported favourable outcomes specifically linked to vigorous activity (Coe, Pivarnik, Womack, Reeves, & Malina, 2006). Intervention studies offer possibilities to draw conclusions about cause and effect, but they say less about actual everyday situations and relations in the classroom today, which is the focus of the present study.

Incorporating moderate to vigorous physical activity during the school day can indeed contribute to a more tranquil and focused classroom environment and thereby enhance concentration (Lindgren, Haraldsson, & Håman, 2019). Not surprisingly, a noisy background is a source of distraction, which hampers learning (Klatte, Bergström, & Lachmann, 2013). The level of disruption varies between individuals; people with lower working memory capacity are more prone to distraction (Kane, Bleckley, Conway, & Engle, 2001). Working memory, sustained attention (i.e., the ability to keep focusing on the task), and cognitive inhibition (i.e., the ability to suppress irrelevant thoughts) directly affects reading comprehension (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014). Moreover, working memory and response inhibition also have direct effects on decoding (Arrington et al., 2014).

The effect of a noisy environment also varies by task. Surprisingly and perhaps counterintuitively, reading in a hard-to-read font makes it easier to block out surrounding auditory noise (Halin, 2016; Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014; Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013). The perceptual load produced by hard-to-read fonts can also lead to less mind-wandering (Faber, Mills, Kopp, & D'Mello, 2017). The harder it is to read the more you must focus your attention on the task at hand. Furthermore, the type of background noise matters for the level of disruption. Specifically, speech that is semantically relevant and content-related to the reading impairs performance more than, for example, traffic noise (Halin et al., 2014; Hao & Conway, 2022). Connecting back to physical activity, being physically tired could potentially make it easier to sit still, make less noise, and focus on

reading, thus producing a calmer classroom (Lindgren et al., 2019). A systematic review of existing studies on classroom-based physical activity interventions suggests that exercise has a positive impact on students' attention and on-task behavior (Ruhland & Lange, 2021). However, there appears to be significant individual differences. A study where adolescents played football before testing information processing, inhibitory control, and working memory showed that higher levels of physical fitness were beneficial for cognitive function, but the physical activity intervention was only beneficial for already high-fit participants (Williams et al., 2020).

Additionally, earlier research has shown that boys are more physically active than girls, which can be influenced by individual, family, school, and environmental factors (Telford, Telford, Olive, Cochrane, & Davey, 2016). If there was a generally applicable positive relationship between physical activity and reading, then boys would be better at reading. This is however not the case. For example, a study in Finland shows that girls in primary school have better reading skills and a more positive attitude towards reading compared to boys (Merisuo-Storm & Aerila, 2018). Girls are more positive towards reading than boys are, and they also hold stronger competency beliefs in reading, which is positively related to reading comprehension (Katzir, Lesaux, & Kim, 2009; Orellana García & Baldwin Lind, 2018). In the present study, we have not used any preconceived categorisation of our participants into boys and girls. Furthermore, we can conceive that students, both boys and girls, who struggle to sit still may encounter difficulties in disciplining their bodies to the degree necessary for engaged and meaningful reading (McLaughlin, 2015). Difficulties in creating a favourable reading situation could also lead to negative experience, which in turn affects attitudes towards reading and thus also willingness to engage in reading. Several studies (Katzir et al., 2009; Merisuo-Storm & Aerila, 2018) have shown strong correlations between reading attitudes, self-esteem, self-efficacy, and reading comprehension skills. Amounts of engaged reading and reading volume has also been shown to predict reading proficiency (Allington & McGill-Franzen, 2021; Guthrie, Schafer, & Huang, 2001; Lee, Jang, & Conradi Smith, 2021)

**Therefore, the aim of this non-experimental field study (i.e., without interventions) in two Swedish primary schools is to examine the relationships between grade 4 students' physical activity during the school days and three aspects related to their reading: a) comprehension level, b) attitudes towards reading, and c) attitudes towards reading different media.**

Moreover, to further understand the complexity of reading, Mangen's and van der Weel's (2016) framework is useful. The framework encompasses not only intellectual but also physical and situational aspects of reading, covering both print and onscreen substrates and reading media. Their model spans the stages of preparing for reading, the act of reading, and the effects of reading.

*Preparing for reading* is categorized into the text, the reader, and the environment. The text includes considerations of substrate affordances (modalities and online/offline), genre and complexity, length, text design (type design, graphic design, and textual structuring), and interface characteristics. The reader is conceptualized in terms of profile (age, socio-cultural background, gender, expert level), purpose and motivation (phenomenologically, as personally meaningful and goal-oriented, and socio-culturally, as socially meaningful). The environment is divided into infrastructure, accessing text (selecting, locating, and navigating), and choosing a location.

*The act of reading* in Mangen's and van der Weel's model is divided into embodied interaction, mental interaction, and environmental factors. Embodied interaction covers substrate affordances (sensorimotor, ergonomic, experiential, modal, and online/offline). Mental interaction comprises mental resources (attentional, perceptual, and cognitive), comprehension level (cognitive, social, situational, cultural), and immersion level. Environmental factors include aloud vs. silent reading and location (noise level and distraction).

Finally, *the effects of reading* in this model comprise personal and social effects. Personal effects include evaluation, learning new knowledge, modification of existing knowledge, retention (short-term vs. long-term), and pleasure. Social effects involve information, education, cohesion, and manipulation.

Mangen's and van der Weel's model of embodied reading offers a comprehensive framework for describing various aspects of reading and evaluating and exploring the aspects of reading supported by different technologies.

As indicated in previous paragraphs, earlier studies point in different directions regarding the relationship between physical activity and reading. The aim of this non-experimental field study in two Swedish primary schools is to examine the relationships between grade 4 students' physical activity during the school days and three aspects related to their reading: a) comprehension level, b) attitudes towards reading, and c) attitudes towards reading different media. Consequently, we formulated the following three research questions (RQ):

- RQ1: What is the relationship between students' level of physical activity during the school day and their reading comprehension levels?
- RQ2: What is the relationship between students' level of physical activity during the school day and attitudes towards reading?
- RQ3: What is the relationship between students' level of physical activity and their preferences of reading media?

### 3. Method

The participants were 50 fourth-grade students (ages 10–11) recruited using purposive sampling. We contacted the education office in a mid-sized Swedish city that facilitated the recruitment of teachers interesting in teaching methods in reading. Three teachers signed up for participation. One of the teachers withdrew due to organizational issues. We then recruited students through the other two teachers. This means that we had teachers from two primary schools participating and students from two grade four classes were offered to participate. All students who wanted to take part and whose parents gave consent were included. All participants and their legal guardians gave their written consent to participate. Participants could withdraw their consent at any time. The Swedish Ethical Review Authority decided that the research project did not require ethical approval (Etikprövningsmyndigheten, registration number 2021-03319).

The researchers had no prior relations with the schools, the teachers, or the participating children. The three researchers who gathered data largely took a passive role in the classroom, even though they sometimes acted as assistants to the teacher.

Each student was equipped with a Polar E-Unite physical activity tracker to measure their level of physical activity by counting the number of steps they took during the school day. Reading comprehension levels were measured by the teachers, as part of regular teaching, using one part of the DLS 4–6 test, which is a Swedish diagnostic material for the analysis of reading and writing skills in grades 4 to 6 (Järpsten & Taube, 2010). The reading comprehension part reported here covers three texts with 29 accompanying tasks. The test scores are scaled using the Stanine method on a nine-point standard scale with a mean of five and standard deviation of two, based on previous norm data (Baumann & Stevenson, 1982).

Each student was also provided with a logbook for reading activities. There are two background questions in the logbook that are relevant for this paper:

1. Underline one or several words that apply for what you think about reading (I think reading is... terrible, difficult, unnecessary, tough, boring, necessary, important, easy, fun, wonderful).
2. Circle the number that applies best to you for each statement (scale 1–5, don't know). (I like... to read silently in a book, to read silently on a screen/online, to read aloud for someone else, to listen when someone else reads for me from a book, listen to an audiobook).

The data collection procedure started with one week for the participants to get familiar with the physical activity tracker. After that we started recording how many steps they took per day. They put on the activity tracker in the morning when they got to school and took it off before going home. The

reading comprehension test was managed by the teachers as part of their regular teaching. The participants filled out the background questions in their logbooks during the first days of the study, which lasted two weeks in both school classes. Researchers also took field notes during visits in the schools.

The mean number of steps per school day was calculated for each participant. Days with physical education or a field trip had a larger number of steps, and short school days had a smaller number of steps. Some days were not included in the data for some participants, such as when a participant forgot to take the tracker off before going home from school and when one participant constantly shook his tracker to get more steps. The number of steps were corrected on days of transportation, since steps were recorded when the trackers were carried in a bag, at which the researcher's number of steps were deducted from the steps for that day.

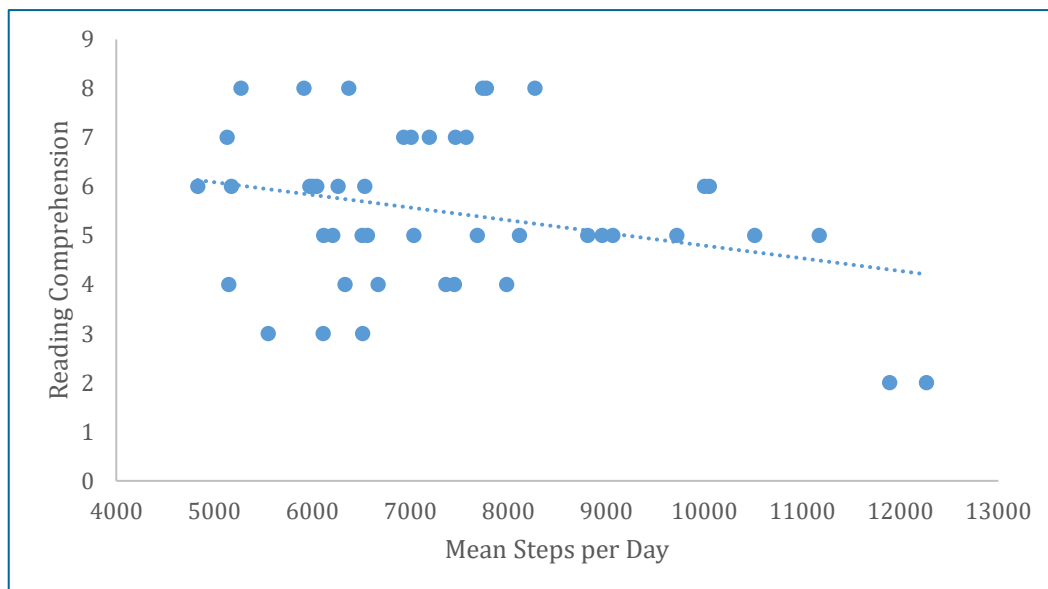
Data were analysed using descriptive statistics (frequencies, medians, means, and standard deviations) and correlations. Non-parametric tests, chosen due to non-normal distributions, were used to test if observed differences were statistically significant. Qualitative data in logbooks and field notes were used in the interpretation of the quantitative results.

## 4. Results

The results are reported in three sections that each answer one of the three research questions.

### 4.1. Physical Activity and Reading Comprehension

Pearson's  $r$  revealed a weak negative correlation between physical activity (mean number of steps per school day) and reading comprehension among the participating students,  $r(43) = -.29$ ,  $p = .053$ . The findings show significance at  $p < .10$ . Notably, a significant portion of the negative correlation in the data is influenced by the two participants located in the bottom right of the scatter plot (see Figure 1), both displaying a considerable number of steps and low scores in reading comprehension. However, these are formally not considered outliers, given a definition of outliers as less than  $Q1 - 1.5 \times IQR$  or greater than  $Q3 + 1.5 \times IQR$ . They are however different from the others, and therefore worthwhile taking a closer look at.



**Figure 1.** Correlation between level of physical activity during the school day and reading comprehension.

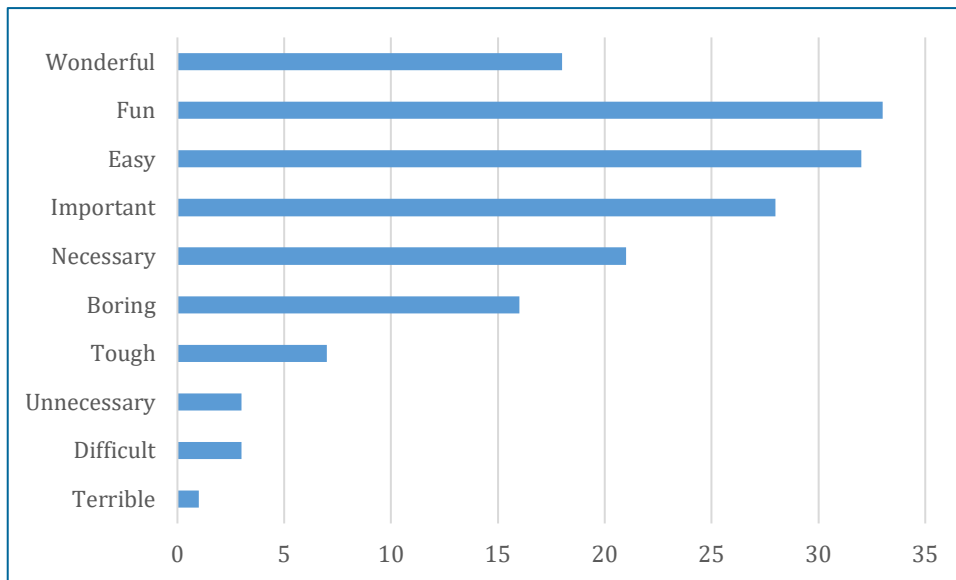
The logbooks reveal that one of the two participants with low reading comprehension score and high physical activity, reports reading sometimes and reading well. Reading is for this participant both difficult and easy, boring but important. At the same time, the participant reports to like reading. The field notes show that this participant sometimes sit in a smaller room outside the classroom to work. The other participant finds reading boring and hard but at the same time easy. This participant seldomly reads, but reports reading well and likes reading onscreen, listening to audiobooks, and listening to someone else reading. The logbook from this participant also reports that he often finds the readings interesting but difficult to read and understand. The field notes reveal that this participant struggles with getting started, with focusing on the reading, and with sitting still without talking or fiddling with things. What emerges from the accounts in the logbooks is an ambivalent view of the two participants' reading experience and performance, and the field notes indicates that the teachers particularly attended these students.

Overall, instances of non-comprehension of a text were noted in the field notes, and they were experienced as frustrating and sometimes gave rise to anger. Such reactions and attitudes are further explored in the following section of the results.

#### 4.2. Physical Activity and Attitudes towards Reading

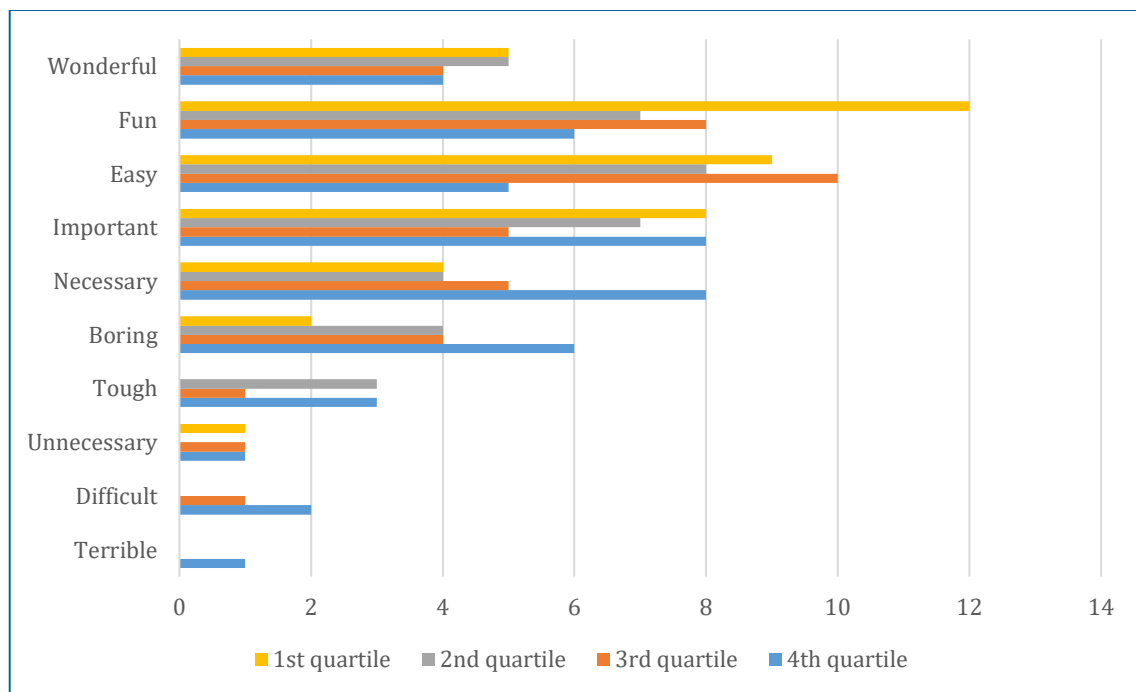
Overall, the attitudes towards reading were positive as illustrated in Figure 2. Most of the students found reading fun, easy, or important. A large proportion of them thought of reading as wonderful, and a large proportion found it necessary. However, a large proportion also thought of it as boring. A few found it tough, unnecessary, difficult, or terrible.





**Figure 2.** Attitudes towards reading.

To facilitate an analysis of how students with varying level of physical activity perceived reading the students were subsequently grouped into quartiles, ranging from 1) low, 2) low – medium, 3) medium, and 4) medium – high levels of physical activity during the school days. The attitudes towards reading among students in different quartiles of physical activity are depicted in Figure 3.



**Figure 3.** Attitudes towards reading for the 1st to 4th quartile of physical activity level.

For the students in the 1st quartile (low physical activity), the majority perceived reading as fun, easy, or important. Several found it wonderful or necessary, and only a few found it boring. One student deemed it unnecessary, while none considered reading to be tough, difficult, or terrible.

Among students in the 2nd quartile (low to medium physical activity), most regarded reading as easy, fun, or important. Several considered it wonderful or necessary. Although, several also found it boring. A few found reading to be tough, but none saw it as unnecessary, difficult, or terrible.

Within the 3rd quartile (medium to high physical activity), most students found reading to be easy and fun. Several perceived it as wonderful. However, several also found it important, necessary, or boring. A few considered reading to be tough, while one student deemed it unnecessary, and another found it difficult.

Regarding students in the 4th quartile (high physical activity), they predominantly viewed reading as important or necessary, while many also found it fun, or easy. Many moreover thought of it as boring. Several considered reading to be wonderful, and a few perceived it as tough or difficult. One student found reading unnecessary and terrible.

A potential source of confusion is that a participant could mark, for example, that reading was both wonderful and boring. When asked about this one student said that reading subtexts to a film was wonderful, but reading a book was boring.

In the logbooks, the students expressed generally a positive feeling in relation to reading activities. However, they often expressed that they were tired, which sometimes was related to poor sleep and sometimes to late evening activities, such as away games or cups in football. Some students furthermore expressed physical education or being on breaks outside prior to reading as a reason for a positive reading experience. A quiet environment was also mentioned as contributing to good reading experiences.

The field notes from observations in the classroom show that the teachers put in physical activities and games during and between sedentary sessions. One of the teachers also used a wheel of fortune application projected onto the wall to randomize bodily reading positions (e.g., sit on the floor, stand up, sit on the table, walk around) that the students could choose to make. When asked about the randomized reading positions, the teacher says:

It seems as those who have difficulties when nothing happens reads more. But the focus on reading in the class as a whole goes down a little. (translated from Swedish)

Many children expressed explicitly that they enjoyed the randomized reading positions. We could observe that longer sedentary sessions, meant that some students got difficulties to sit still and focus on reading. When the tablet was used this meant that some participants instead started taking photos

or making funny faces on a photo app. This was noted by the teacher who then introduced some sort of physical activity game.

In this classroom, the children often moved around or sat on their tables, stood up, or sat on the floor, instead of only sitting on their chairs while reading. Yet, the atmosphere was overall peaceful and quiet, except for during group work when the sound level was high. Sometimes, some students wore earmuffs during reading to reduce distraction from background noise. Another physical aspect of reading is the choice of reading substrate and mode of reading. This is covered in the following section.

### 4.3. Mode of Reading Preferences and Physical Activity

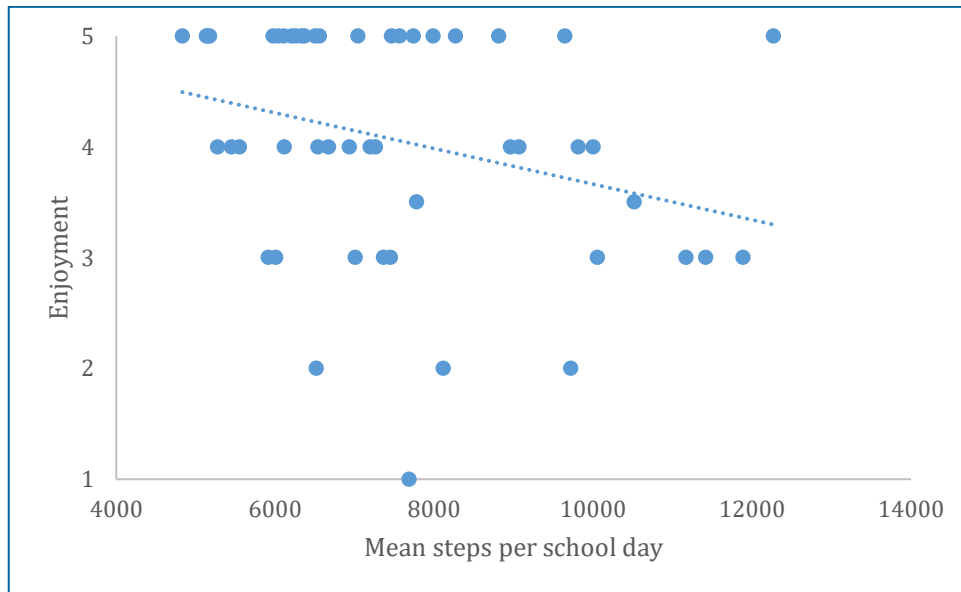
Overall, the attitudes towards reading were positive as illustrated in Figure 2. Most of the students found reading fun, easy, or important. A large proportion of them thought of reading as wonderful, and a large proportion found it necessary. However, a large proportion also thought of it as boring. A few found it tough, unnecessary, difficult, or terrible.

In general, the students displayed a preference for silent reading in a book ( $M = 4.06$ ,  $SD = 1.02$ ,  $90\% CI [3.82, 4.30]$ ), listening to someone else read to them ( $M = 3.96$ ,  $SD = 0.99$ ,  $90\% CI [3.71, 4.20]$ ), and listening to an audiobook ( $M = 3.84$ ,  $SD = 1.05$ ,  $90\% CI [3.56, 4.12]$ ) over reading on screen ( $M = 3.15$ ,  $SD = 1.18$ ,  $90\% CI [2.86, 3.44]$ ) or reading aloud to others ( $M = 2.92$ ,  $SD = 1.14$ ,  $90\% CI [2.65, 3.19]$ ). The Kruskal-Wallis H test, chosen due to the non-normal distribution of the data, revealed a significant difference in enjoyment levels across various reading media,  $H(4) = 36.64$ ,  $p < .001$ , with mean rank scores of 145.82 for Books, 93.83 for Screens, 81.86 for Reading Aloud to Others, 138.92 for Listening to Someone Read, and 132.85 for Audiobooks. The Post-hoc Dunn's test, using a Bonferroni corrected alpha of .01, indicated significant differences in the mean ranks for the following pairs (i.e., differences between other pairs were not statistically different):

- Silent reading in a book was preferred over reading on a screen.
- Listening to someone reading was preferred over reading on a screen.
- Listening to an audiobook was preferred over reading on a screen.
- Silent reading in a book was preferred over reading aloud to others.
- Listening to someone read was preferred over reading aloud to others.
- Listening to an audiobook was preferred over reading aloud to others.

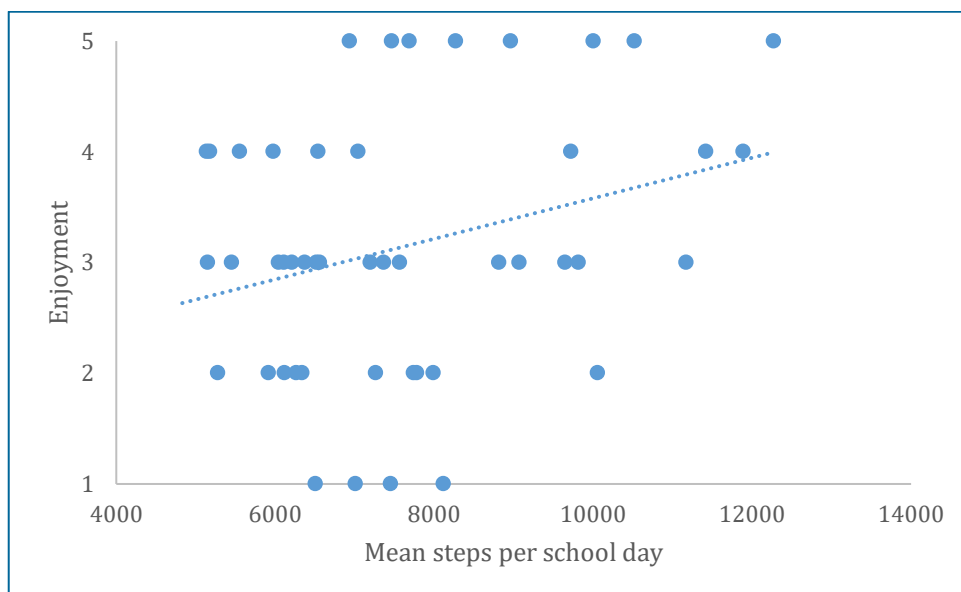
Figure 4 displays the correlation scatterplot depicting the relationship between physical activity (mean number of steps per school day) and the enjoyment of silent reading in a book. Pearson's  $r$  indicated a

weak, but statistically significant, negative correlation between physical activity and the enjoyment of silent reading in a book,  $r(48) = -.30, p = .038$ .



**Figure 4.** Correlation between physical activity (mean number of steps per school day) and the enjoyment of silent reading in a book.

The relationship between physical activity and the enjoyment of reading on the screen or online is illustrated by the correlation scatter plot in Figure 5. A weak positive correlation, as determined by Pearson’s  $r$ , was observed between physical activity and the enjoyment of silent reading on a screen or online,  $r(45) = .29, p = .048$ . The finding is considered statistically significant at  $p < .05$ .



**Figure 5.** Correlation between level of physical activity during the school day and enjoyment of silent reading on a screen/online.

There were no statistically significant correlations between physical activity and the enjoyment of reading aloud for someone else ( $r(47) = -.18, p = .221$ ), listening to someone else read from a book ( $r(47) = .03, p = .826$ ), or listening to an audiobook ( $r(39) = .24, p = .133$ ).

One would expect that it would be the same, or at least very similar, to listen to someone read and to listen to an audiobook, but one participant who rated listening to someone read with a 4 and listening to an audiobook with a 1, said that the voice in audiobooks could be very annoying and she had not listened to an audiobook since grade 1. This indicates that there are subtle differences in the media and interaction design that potentially can have large effects on reading experience.

We took note of substantial differences between individuals in the field notes. Even though reading aloud for other was generally not preferred, a student that came in late to such a session asked the teacher for something to read aloud since everybody else had read aloud. The teacher then gave the student the task of reading the figure caption in the text that they worked on.

The teachers also explicitly managed the students' attention. During joint reading activities, for example, one student would read a small part of the text, and the next student would continue. The teacher would then ask the students to follow along in the text in front of them. When the teacher read aloud, she would direct their attention to specific parts of specific pages in the book, including certain headlines. However, in individual silent reading sessions, this level of intervention was not possible. As a result, some students occasionally did not accomplish much reading during these sessions. In such cases, the teacher needed to intervene with individual students by sitting down next to them, positioning the book, pointing, and jointly starting the reading with the student.

## 5. Discussion

The purpose of this study was to examine relationships between physical activity and reading in two

**Firstly, we observed a weak negative correlation between physical activity and reading comprehension. Secondly, most students found reading fun, easy, or important. Many of them thought of reading as wonderful, but many also found it necessary or boring. Only a few of them found it tough, unnecessary, difficult, or terrible.**

Swedish primary schools. Three main findings correspond to the three research questions posed. Firstly, we observed a weak negative correlation between physical activity and reading comprehension. Secondly, most students found reading fun, easy, or important. Many of them thought of reading as wonderful, but many also found it necessary or boring. Only a few of them found it tough, unnecessary, difficult, or terrible. It was also observed that students with lower levels of physical activity expressed more

positive attitudes towards reading than those with higher levels, and there were more negative sentiments among those with higher levels of physical activity. Thirdly, the students liked to engage in silent reading with a book, listen to someone read, or listen to an audiobook, whereas they expressed less enjoyment for reading silently on a screen or reading aloud to others. We also observed a weak negative correlation between physical activity and enjoyment of silent reading of a book, and a weak positive correlation between physical activity and enjoyment of reading on a screen.

The negative correlation between physical activity and reading comprehension observed in this study stands in contrast to earlier studies, which have shown a positive correlation between physical activity of different kinds and cognitive and academic performance in children (Hillman et al., 2008; Sattelmair & Ratey, 2009; Sibley & Etnier, 2003). Positive impacts have in particular been shown for moderate to vigorous activity (Coe et al., 2006; Lindgren et al., 2019; Sallis et al., 1999). Our study did not have any physical activity intervention and we recorded the students' number of steps during the school day. It is quite possible that their regular everyday physical activity did not reach a high-enough level required to make the students physically tired and thus produce positive effects documented in previous research. What we observe in this study is that students who were more physically active also scored lower on a reading comprehension test, and they had more negative attitudes towards reading. It is difficult to say anything about cause and effect based on our study, but this result lends support to the idea that students may find it challenging to control their bodies and attention to the extent required for focused and meaningful reading (McLaughlin, 2015).

This should not be seen as evidence that refutes that moderate to vigorous physical activity in preparing for reading can be beneficial for some readers. Especially students with high levels of physical fitness benefit directly from classroom-based physical activity prior to cognitively demanding activities (Williams et al., 2020). However, integrating physical activity can also contribute to a quieter and more focused classroom (Lindgren et al., 2019; Ruhland & Lange, 2021). This benefits not only the physically fit students, but all students, since a noisy environment is a source of distraction (Klatte et al., 2013). Some students are even more prone to distraction due to attention difficulties and lower working memory capacity, which also are associated with decoding and reading comprehension (Arrington et al., 2014; Kane et al., 2001). A tranquil reading environment would particularly benefit these students. Furthermore, since some noise is more distracting than other (Halin et al., 2014; Hao & Conway, 2022), the exact design of the reading activity also matters (e.g., the choice of reading substrate, the sequencing of individual reading and writing, small group reading and discussion, and full class reading and discussion).

It is positive that most of the students found reading fun, easy, or important, even though a large proportion of them thought of reading as necessary or boring, since reading attitudes and reading comprehension abilities are strongly correlated (Katzir et al., 2009; Merisuo-Storm & Aerila, 2018). However, if you only read because it is necessary, and you find reading boring or even unnecessary and terrible, then it becomes unlikely that you read a lot. Reading achievement has also been demonstrated to be predicted by the amount of engaged reading (Guthrie et al., 2001). This means that motivation to read is central to becoming a proficient reader (Eriksson Barajas & Aronsson, 2009; Orellana Garcv#a & Baldwin Lind, 2018).

**Our results also show a negative correlation between physical activity and enjoyment of silent reading of a book, and a positive correlation between physical activity and reading on a screen.**

The last part of our results relates to the act of reading and the preference of reading media or substrate. Even though on-screen reading is convenient and offers for example search functionality, our participants liked to read offline silently in a physical book, listening to someone read, or listening to an audiobook. This can be due to drawbacks such as distraction and affordances to skim rather than read closely, awkward handling, or visual fatigue, which on one hand has been shown to be associated with decreased narrative coherence, transportation, and empathy (Baron, 2015; Benedetto, Draizerbib, Pedrotti, Tissier, & Baccino, 2013; Mangen & Kuiken, 2014). On the other hand, visually demanding text design and fonts have been shown to make it easier to block out surrounding auditory noise and avoid mind-wandering (Faber et al., 2017; Halin, 2016; Halin et al., 2014; Hughes et al., 2013). Design considerations for reading activities and reading media based on these potentially contradictory forces remain unclear.

Our results also show a negative correlation between physical activity and enjoyment of silent reading of a book, and a positive correlation between physical activity and reading on a screen. A possible interpretation of this result is that it is a halo effect of the more physically active student liking his or her tablet with effects on enjoyment to read on the screen. The halo effect, originally coined by Thorndike (Thorndike, 1920) is the inclination to skew assessments of someone's or something's attributes, based on a generally superior or inferior view of that someone or something. However, an explanation could also be that someone who is not immersed in the text might be immersed by the tight interaction loops with the tablet.

## 5.1. Limitations

We recruited participants from two primary schools, grade 4 classes in a medium-sized Swedish city. As a result, the generalizability of our findings may be limited. However, our focus is on describing the relationships between physical activity and reading during regular school days for these participants. This study is non-experimental, descriptive, and correlational, which means that we cannot draw conclusions regarding cause and effect. There may have been confounding variables. Physical activity has been operationalized as steps per school day, but there is also physical activity outside of school hours. Additionally, there is small physical activity that occurs without any steps recorded, such as standing up instead of sitting down or shifting balance from one leg to the other. Finally, a limitation is that we in this study do not discriminate what texts the students have in mind when answering questions about how they feel about reading.

## 5.2. Future Research

Two of our participants were particularly active while scoring low on the reading test. The qualitative data showed an ambivalent view of how they experienced reading, and the field notes indicated that these two participants struggled with focusing on the reading, requiring attention from the teachers. This may indicate the beginning of a cluster of students with a particularly large need to be physically active, and who struggle with both attention and reading. They might very well benefit from moderate to vigorous physical activity before reading. It is also possible that they would benefit from moving around often and not sitting still for too long, or constantly moving during the act of reading.

Qualitative studies of physical aspects of reading are necessary to understand different contexts as well as individual differences. For example, qualitative comparisons between the reading experiences of students who are more sedentary compared to those who are more physically active would be worthwhile. Another issue for similar research is that we do not know why children enjoy reading physical books more than reading on the screen. We also do not know why there is a correlation between physical activity and enjoyment of reading on the screen.

The results from this study are working hypotheses. A quasi-experimental study design is necessary for drawing conclusions about causality. An interrupted time series design with a control group would provide empirical evidence for such arguments. Using a mixed-methods approach would allow for also studying also how reading activities are experienced and socially and bodily performed.



## 6. Conclusions

This study contributes with a nuanced understanding of the relationships between physical activity and reading during the school day. Observed correlations are weak, but multiple data point in the same direction: Firstly, the physically more active students from the two participating school classes were not as strong readers and did not have as positive attitudes towards reading as the less physically active ones. We observed that the act of reading requires disciplining your body to focus on the text, which is well in line with McLaughlin (2015). Secondly, connecting back to Mangen and van der Weel (2016), physical activity when preparing to read could help some students to focus. Looking finally at what Mangen and van der Weel call ‘the effects of reading’, that is for example, evaluation, learning, pleasure, and cohesion, comprehension was lower for the physically more active students, but generally, the students still enjoyed reading. Overall, it is worth emphasizing that the students had positive attitudes towards reading physical books and listening to books. Even the students who were not very positive to reading thought of it as important. Yet, it is pivotal to remember that there are individual and contextual differences to consider between students-this is something mean values tend to hide.

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