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Smart-device related thoughts among pupils and their relationship with motivation for participation in activities

Research paper

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Running head: Device engagement and participation motivation

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Õpilaste nutiseadmetega seotud mõtted ning nende seos osalusmotivatsiooniga

Kokkuvõte

Nutiseadmete kasutamise mõju laste seas on varasemates uuringutes käsitletud peamiselt enesearuande meetodite abil. Käesoleva uuringu eesmärk oli rakendada objektiivset mõõtmismeetodit, et registreerida õpilaste nutiseadmetega seotud mõtteid kahes erinevas keskkonnas ja uurida nende seost osalusmotivatsiooniga. Kasutati sega-disaini, kogudes andmeid spetsiaalselt loodud seadme ja veebipõhise küsimustiku abil. Andmeanalüüsi kaasati 151 Eesti 3.-9. klassi õpilast. Tulemused näitasid, et vaimne hõivatus nutiseadmetest esines sõltumata keskkonnast, kuid erines vanuse ja soo lõikes. Nooremad õpilased osutusid keskkonnatundlikumaks ja poisid raporteerisid üldiselt rohkem seadmetega seotud mõtteid. Seos osalusmotivatsiooniga ilmnes ainult koolikeskkonnas. Lisaks arutletakse saadud tulemusi asjakohaste muutujate kohta, mis on seotud isikliku seadme omamisega, kasutusharjumustega, tajutava akadeemilise mõjuga ja uuringus kasutatud eksperimentaalse seadme kasutatavusega.

Märksõnad: õpilased, nutiseadmed, motivatsioon, osalemine, vaimne hõivatus

Smart-device related thoughts among pupils and their relationship with motivation for participation in activities

Abstract

The impact of smart device use among children has been addressed in previous studies mainly through self-reported methods. This study aimed to apply an objective method to record smart-device related thoughts among pupils in two different environments and to examine their association with participation motivation. A mixed design was employed, using a specially designed experimental device and a web-based questionnaire. Data analysis included 151 Estonian pupils in grades 3-9. Results indicated that mental engagement with smart devices occurred regardless of environment but differed by age and gender. Younger pupils were more environment-sensitive and boys registered more device-related thoughts overall. Association with participation motivation emerged only in the school context. Additionally, background variables related to device ownership, usage patterns, perceived academic impact and experimental device usability are discussed.

Keywords: pupils, smart devices, motivation, participation, mental engagement

Smart-device related thoughts among pupils and their relationship with motivation for participation in activities

In September 2024, education experts and parents wrote an open letter to the Estonian state asking it to develop clear rules for schools regarding the use of smart devices in the school environment (ERR, 2024). The letter highlights how research shows negative links between the use of smart devices and children's mental and physical health, development, well-being and academic performance. In a more specific example, studies show that although technology offers certain advantages, children at different stages of development require carefully controlled use of smart devices (Panjeti-Madan & Ranganathan, 2023). Studies show that screen time has increased across all age groups and can have a negative impact on both mental and physical health, increasing stress levels, reducing physical activity, disrupting sleep, causing emotional changes, and affecting social relationships and behaviour (Panjeti-Madan & Ranganathan, 2023).

This study aims to examine the frequency of device-related thoughts among pupils in two environments objectively and to investigate whether these thoughts are related to motivation to participate in activities. The first parts of this work focus on the visible effects of smart device use. The discussion begins with the impact on physical health, addressing issues such as decreased physical activity, back pain, and hand discomfort. Secondly, the impact on cognitive development and academic performance is discussed, considering how long-term digital exposure affects cognitive functions such as attention span and learning ability. The overview then turns to the impact on mental health and behaviour, emphasising the role in psychopathology and mental well-being. Before introducing specific models and theories of why problematic smartphone use persists, relationships with the motivational aspects are explored based on previous findings and the perspective of self-determination theory. The dependence is then examined more closely from the perspective of cost-benefit analysis and novelty preference, which helps explain why technological interactions are so effective at capturing attention. Additionally, a perspective through opponent-process theory is discussed. Finally, the main patterns and conceptual links between different factors and theories are highlighted, and previous research approaches are presented, which in turn lead to the present study and its objective. It is essential to acknowledge that smart device use has its benefits (for example, see Ubben et al., 2023), but for this paper, the negative links of excessive use are highlighted.

Before turning to the scientific overview, it is worth noting that in the literature, the consensus on whether excessive internet and smart device use constitutes a behavioural addiction has yet to be decided (Billieux et al., 2015; Panova & Carbonell, 2018). It has been suggested that alternative terms should be used instead of “addiction” to avoid misleading research and diminishing the perceived severity of clinically recognised addiction disorders (Panova & Carbonell, 2018). One of the suggested terms is Problematic Smartphone Use (PSU), which is interpreted as excessive use of smart devices associated with functional disturbances and symptoms similar to substance addiction disorders (Billieux et al., 2015; Panova & Carbonell, 2018). This is something to keep in mind to avoid misunderstandings, as the following studies have used different terms.

Impact on physical health

A correlational analysis of neck, shoulder, and lower back pain in high school students found that digital products (personal computers, tablets, mobile phones) are significantly associated with the prevalence of the previously named pains (Shan et al., 2013). Among medical students, neck and hand discomfort and disability were likewise found to have a strong positive correlation with smartphone addiction (Rafiyan et al., 2025). An overall negative relationship between cell phone use and fitness has been found in a sample of college students (Lepp et al., 2013). Alarmingly, increased exposure to smartphones and tablets has been linked to reduced physical activity and poorer sleep patterns in children as young as 5 to 10 years old (Bacil et al., 2024). The overall trend between reduced physical activity and smartphone addiction has been shown among children, adolescents, and young adults in a 2025 systematic review and meta-analysis, emphasising the need to address excessive smartphone use in public health strategies (Nambirajan et al., 2025).

Impact on cognitive development and academic performance

A systematic review reveals that among children under the age of two, who have access to smart devices, excessive screen time has a negative impact on speech development, suggesting that early exposure may compromise cognitive development (Massaroni et al., 2024). The authors point out that what is done on a smart device plays a role, using terms passive and active screen time, defined by the cognitive and physical resources spent on the activity. For example, the authors refer to a publication by the Canadian Paediatric Society, which highlights the role of passive screen time as a form of play in front of a television. From passive screen time, young children have been observed to experience resulting impairments in attention, language, executive functioning, cognitive abilities, and play (Ponti et al., 2017).

In terms of academic performance, PSU and the use of social media in lectures have been found to be associated with a more superficial approach to learning (Rozgonjuk et al., 2018). Amez and Baert (2020) conducted a systematic review to assess the relationship between smartphone use and academic performance and found that the empirical results support the negative relationship between the frequency of smartphone use and academic success. However, the authors highlight that literary results may be related to socially desirable responses, as results differ between studies based on whether the data is gathered online or on a paper-and-pencil form, and whether self-reported or actual grades are used. The authors point out that scientific literature would benefit from objectively tracked data on smartphone use instead of self-reported measures. Notably, Boase and Ling (2013) found that self-reported data on mobile phone use correlates only moderately with server-logged data (actual behaviour), proving that self-reported information may be misleading when measuring the frequency of smart device use.

Impact on mental health and behaviour

A 2016 systematic review examined the association of PSU with the psychopathology of anxiety and depression (Elhai et al., 2016). The review confirmed that the severity of depression and anxiety was consistently associated with PSU. Furthermore, a smaller association with higher stress levels was present, and a more inconsistent association was found with self-esteem. Twenge and Martin (2020) examined gender differences in the relationship between digital media use and psychological well-being. They found that heavy users of digital media were more likely to experience mental health issues than light users, regardless of gender. Alongside, the study revealed that adolescent girls spend more time texting and using social media, whereas boys devote more time to gaming. Furthermore, the association between low well-being and digital media use was stronger among girls than boys, suggesting that girls may be at greater risk for mental health issues related to digital media use. Another analysis of smartphones, social media use and mental health has concluded that social media use in youth has a dose-response relationship with mental distress, self-injurious behaviour and suicidality (Abi-Jaoude et al., 2020). Early digital media exposure has been tied to behavioural problems as well, with a study showing that an earlier first use of YouTube and a higher frequency of usage correlate with greater difficulties in Korean children aged 8-11 years (Kim et al., 2024).

To understand these behavioural and emotional outcomes, we must first examine what motivates people to engage with digital technology and how motivation is impacted by the excessive use of smart devices. The following sections attempt to explain why smart devices have such a powerful influence, mainly focusing on psychological factors.

Motivational aspects

Lin et al. (2022) reported that smartphone addiction decreases self-efficacy and proposed that this relationship may serve as a potential barrier to participation in physical activity. Furthermore, their study revealed that smartphone addiction negatively predicts intrinsic motivation to engage in physical activity while positively predicting extrinsic motivation. Aligül and Tolukan (2024) confirmed a negative relationship between smartphone addiction and motivation to participate in physical activity.

Similarly, in a longitudinal study, digital dependence and the frequency of smartphone use were found to be associated with lower academic motivation (Machado de Oliveira et al., 2023). The study investigated PSU and its associated negative outcomes among university students through the lens of self-determination theory, drawing on the foundational work of Ryan and Deci (2017). According to self-determination theory, optimal human development and well-being are fostered in environments that support three basic psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2017). When these needs are satisfied, individuals are more likely to develop autonomous (intrinsic) motivation, which is associated with positive outcomes. Conversely, when these needs are thwarted, motivation becomes controlled (extrinsic) and results in negative outcomes. The study of Merchán Tamayo et al. (2023) found a negative association between autonomous academic motivation and PSU, suggesting that enhancing autonomous and reducing controlled motivation may help mitigate excessive smartphone use and its related negative outcomes. Specifically, it revealed that controlled motivation and amotivation were positively associated with PSU, as well as higher levels of anxiety, insomnia, and stress. In contrast, autonomous motivation was linked to lower levels of PSU and fewer psychological difficulties.

Collectively, these findings indicate that excessive and early smartphone use can have a negative impact by altering individuals' motivational patterns, and motivation can, in turn, influence the use of smart devices. The causal relationship is yet to be studied. Various models of PSU, in addition to the motivational perspective, have been proposed to systematically describe this phenomenon. The following provides a selected overview of models and theories, which all offer a more complex insight into the problem and its origin. However, this overview is not definitive, and terminology and definitions vary, as the field remains under active research.

Models of problematic smartphone use

Most of the models and theories have grown out of trying to understand excessive internet use, but they also work for explaining problematic behaviours associated with excessive smartphone or digital technology use (Rozgonjuk, 2019). The field draws on several foundational models.

Davis (2001) proposed one of the most influential models to explain pathological internet use, adding a cognitive component to it, which was previously mostly associated with behaviour. The Cognitive-Behavioral Model of Pathological Internet Use distinguishes distal and proximal causes of problematic behavioural symptoms of pathological internet use. The model also differentiates specific and generalised pathological internet use, in which the latter describes a more general use of the internet and has to do with social isolation and/or lack of social support in real life. Meanwhile, specific pathological internet use is described through a dependency on a specific function on the internet. In distal causes of problematic behaviour, the model highlights reinforcement carried on by situational cues, meaning that an individual will be reinforced by the ensuing response of trying a new internet feature. Furthermore, the individual becomes conditioned to perform the activity more often to achieve the associated response. Other distal causes include introduction to the internet and the individual's psychopathology. The most central in this model are maladaptive cognitions that act as proximal causes of pathological internet use. Maladaptive cognitions include thoughts about the self and about the world. For example, self-conscious individuals can think of the internet as a safe place, and individuals with a ruminative cognitive style tend to have more reinforced memories about the internet. The behavioural symptoms of pathological internet use add to the maladaptive cognitions, making it a vicious cycle.

One of the most comprehensive theories is the Interaction of Person-Affect-Cognition-Execution model (I-PACE; Brand et al., 2016). The model is an elaboration of the Model of Internet Addiction by Brand et al. (2014) that is influenced by the Cognitive-Behavioral Model by Davis (2001). It is proposed as a process model that tries to explain the development and maintenance of specific internet use disorders. The I-PACE model highlights a person's core characteristics (personality, social cognitions, biopsychological constitution, psychopathology, specific motives for using), which affect the way an individual subjectively perceives situations and, in addition, influence one's coping style and internet-related cognitive biases. These factors influence an individual's affective and cognitive responses, which in turn influence the decision to use a certain application. The decision to use a certain application leads to gratification, which reinforces previous factors (for example, internet-related cognitive bias and coping style), and the result is problematic digital technology behaviour. The model notes a hypothesised shift from resulting gratification to compensation in the process of addiction.

To conclude, the Cognitive-Behavioral Model of Pathological Internet Use and the I-PACE model provide a comprehensive understanding of how problematic digital technology use develops and persists. The Cognitive-Behavioral Model highlights the interaction of causes such as situational reinforcement and individual psychopathology, maladaptive cognitions about oneself and the world, leading to either generalised or specific pathological internet use (Davis, 2001). Building on this, the I-PACE model emphasises how a person's core characteristics shape cognitive biases and coping styles, which in turn influence affective and cognitive responses, reinforcing the cycle of excessive technology use (Brand et al., 2016). Suggesting that over time, this cycle may shift from seeking gratification to using the internet as a means of compensation, ultimately contributing to the development and maintenance of digital technology addiction.

The overview now turns to theories relying on the idea that the brain's reward system performs a cost-benefit analysis that favours novelty and immediate gratification, thereby reinforcing the use of a smart device.

The brain's bias toward novelty and cost-benefit analysis perspective

It has been claimed that the brain likes novelty. For example, Bunzeck and Düzel (2006) found that novel stimuli trigger dopamine-related signals in the substantia nigra/ventral tegmental area that help enhance learning and memory. A 2007 study found that the brain responds similarly when expecting a reward or novel stimuli, which seems to create a motivational signal that encourages exploring new things (Wittmann et al., 2007). Schomaker and Meeter (2015) have found that a novel stimulus initiates a cascade of brain responses that activate multiple systems. As a result of these brain responses, novelty influences cognition through improved perception and action, increased motivation, enhanced exploratory behaviour, better memory, and learning. From the perspective of excessive smartphone use, a study examining frontostriatal connectivity in adolescents with excessive smartphone use found that such use is associated with altered functional connectivity between brain regions involved with cognitive control and reward prediction (Chun et al., 2018).

Together, these findings suggest that persistent exposure to digital novelty may contribute to functional changes in brain regions, potentially reshaping neural pathways over time. This form of cognitive engagement can be further illustrated by phenomena such as phantom vibration and ringing syndromes, which are characterised by false sensations of a phone vibrating or ringing when it is not (Mangot et al., 2018). Studies have shown that increased smartphone use is a significant predictor of these experiences (Mangot et al., 2018;

Ramasubramani et al., 2022). The syndromes suggest that the brain remains attuned to device-related cues even in their absence, indicating modified neural pathways.

Likewise, one of the more specific and individual proposals in terms of explaining problematic smart device use focuses on the brain's cost-benefit analysis and the novelty of stimulus offered by smart devices (Aru & Rozgonjuk, 2022). Aru and Rozgonjuk have proposed the idea that the use of smart devices may be a harmful habit, the main consequence of which is the inability to cope with prolonged mental effort. They explain how smart devices always offer something new and thus interfere with the cost-benefit analysis performed by the brain, where the benefits from the smart device (with minimal perceived cost) outweigh the benefits from other activities. Activities that appear to have a lower benefit level are interpreted as costly, and the smart device with a readily available high benefit level wins. The authors highlight how children may not be aware of the cost of smart device use. Therefore, it would be important to inform them about it by making the cost more transparent.

As can be seen next, this imbalance between reward and regulation in the nervous system can likewise be interpreted through psychological frameworks, such as the opponent-process theory, which explains the cyclical nature of pleasure and withdrawal.

Opponent-process theory perspective

A study by Tian et al. (2023) examined the effects of TikTok short videos on users within the framework of opponent-process theory. The authors concluded that while viewing short videos elicits positive emotions, these emotions are replaced by negative affect once viewing stops. Consequently, users tend to engage in repeated viewing to either sustain positive emotions or alleviate negative ones. As emotions function as a reinforcement mechanism, where stronger positive emotions lead to stronger subsequent negative emotions, this cycle may ultimately contribute to the development of addictive patterns of use.

Essential insights

Synthesising different perspectives reveals several essential insights into how biological, cognitive, and motivational mechanisms interact to sustain digital dependence. Based on prior discussions, it is reasonable to assume that the negative impact of smart device use is multifaceted and warrants further investigation, with a need for more objective and specific measurements to better understand the necessity and potential methods of intervention. While most researchers agree that excessive smart device use is an emerging health concern across age groups requiring intervention, the underlying reasons why people become dependent on these devices and the best approaches to study this phenomenon remain topics of active debate. Consequently, researchers have used various methodological approaches. The next section will present some of the main instruments used in the field to introduce the methodology of this study.

Approaches to studying associations with smart devices

Despite the range of theories explaining excessive technology use and the ongoing debate over whether it qualifies as an addiction, many empirical studies continue to rely on measurement tools influenced by internet addiction-related disorders research (Rozgonjuk, 2019). One commonly used instrument is the Smartphone Addiction Scale (SAS) and its abbreviated version, the Smartphone Addiction Scale Short Version (SAS-SV), designed specifically for teenagers (Kwon et al., 2013a; Kwon et al., 2013b). The original SAS includes 33 items, while the SAS-SV comprises 10 items (Kwon et al., 2013a). Responses are collected on a 6-point Likert scale ranging from 1 “strongly disagree” to 6 “strongly agree” (Kwon et al., 2013a). These tools assess six dimensions: daily life disturbance, positive anticipation, withdrawal, cyberspace-oriented relationship, overuse, and tolerance (Kwon et al., 2013b). Another widely used measure is the Mobile Phone Problem Use Scale (MPPUS), which consists of 27 items rated on a 10-point Likert scale, where 1 corresponds to “not true at all” and 10 to “extremely true” (Bianchi & Phillips, 2005). The questions cover aspects of problematic use like escaping from other problems, withdrawal, craving, negative life consequences, and loss of control.

Overall, these self-reported scales aim to capture the psychological and behavioural engagement with smartphones, often highlighting the mental engagement users develop with their devices. Even though these instruments offer valuable insights, they primarily rely on subjective self-report data, typically gathered through single-response questionnaires. However, as previously referenced, research has shown that self-reported smartphone use only moderately correlates with actual usage (Boase & Ling, 2013) and that the method of data collection can significantly influence conclusions (Amez & Baert, 2020). To address these limitations, some studies have incorporated objective smartphone use data. For instance, Felisoni and Godoi (2018) employed a mobile app to track actual behaviour and compared it with self-reported data. Similarly, Rosen et al. (2018) used a smartphone app to log device unlocks and daily use duration, finding that over half of the participants were surprised by their technology use, underestimating the actual use. Kim et al. (2019) developed a mobile app and web-based portal to track usage while also collecting self-reported data, including SAS responses. Their findings indicated that students substantially underestimated their in-class smartphone use.

Present study

As reviewed above, scientific literature consistently highlights the negative consequences of excessive digital technology use across multiple domains. Explanations for dependency on smart devices have drawn on a variety of theoretical perspectives. Collectively, these theories suggest that excessive use can lead to a persistent and problematic mental engagement with smart devices through many different situational as well as individual factors. Current research in this field has largely relied on measurement instruments that typically gather self-reported and single-response data (such as asking participants how much they believe they thought about or used their devices over a recent period), while operating on the premise that excessive smartphone use resembles substance addiction through mental engagement. While these measures provide a valuable foundation, self-reported data are prone to reliability issues, prompting calls for more objective approaches. For example, objective data collection has been attempted by tracking phone unlock frequency and time spent with an open screen. However, research has yet to extensively examine the real-time occurrence of thoughts about smart devices during everyday activities.

The present study addresses this gap by investigating the extent to which pupils think about smart devices during two distinct educational contexts. One is a regular school day with traditional lessons, and the other is an educational program provided by AHHAA Science Centre. Drawing from literature, it is proposed that excessive smart device use is linked to mental engagement that occurs even in the absence of direct device interaction, and that the frequency of such thoughts is related to motivation for participating in ongoing activities. In addition, the study explores previously suggested potential gender differences, for example, in the primary activities undertaken on smart devices. To achieve these aims, a mixed-method design is employed, incorporating self-reported survey data alongside data from a specially developed device, able to record how many times participants think about smart devices in real time, based on the number of times they press a button. As a result, this study could add to the field by introducing a novel way to collect objective data about mental engagement with smart devices and study its possible associations.

To achieve said aims, the following research question has been created: To what extent do pupils think about smart devices in two different environments, and is the number of smart-device related thoughts recorded related to motivation to participate in activities? Furthermore, three more specific hypotheses were formed. The first hypothesis stated that pupils' thoughts about smart devices significantly differ between two environments (AHHAA and school), with pupils reporting more smart-device related thoughts in school. The second hypothesis stated that there is a negative correlation between pupils' participation motivation and their smart-device related thoughts (mental engagement), with pupils reporting more frequent thoughts about smart devices in activities where participation motivation is lower. The third hypothesis stated that boys, on average, tend to use smart devices for gaming more, while girls primarily use them for social interactions.

Method

Participants

The sample for this study consisted of pupils in grades 3-9 participating in educational programs at the AHHAA Science Centre (Tartu, Estonia). The students were contacted through the school's contact person, who forwarded information to the class teacher, or directly through the class teacher (according to the information provided to AHHAA while booking the educational program visit). All groups without special needs and speaking Estonian who could be accommodated with the available testing equipment from grades 3-9 were offered the opportunity to participate. As a result, a total of 208 pupils participated in the main study (10 groups), deciding to take the experimental device after hearing about the opportunity to participate. The exact number of pupils to whom the study was introduced was not tracked, but the number was approximately 300 in September-November (main study) and 160 in May (pilot testing). The results of 151 pupils were included in the final data analysis. This reduction in sample size resulted from eight pupils denying informed consent, sixteen being absent on one of the study days, one providing unreliable questionnaire responses, one being excluded to meet the desired data analysis requirements, and thirty-one experiencing technical issues with the experimental device on at least one study day.

Variables

The main variables in this study are the number of smart-device related thoughts, which were objectively collected using a specially developed device (clicker), and the test subjects' subjective assessment of motivation during the activities they participated in on the test days (in AHHAA hall tasks and either workshop or planetarium, and in school context lessons) through a multiple-choice online questionnaire. In addition, the questionnaire examined gender, grade, ownership of a personal smart device, the most common activity on smart devices, subjectively assessed average time spent on a device, the occurrence of schoolwork being disrupted by the smart device, the accuracy of clicker use, and whether the clicker disturbed the test subjects at the science centre or school. The test subjects were additionally given an opportunity to provide feedback or ask questions at the end of the online questionnaire through a single open-ended question.

Procedure

The plan was agreed upon with the management of the AHHAA Science Centre, and information about the experiment was communicated to all employees via internal email. For procedure and material testing, pilot studies were conducted and are briefly described in the following subchapter. The pilot studies took place in May, and the main study took place from September to November 2025. The research was conducted in Estonian, thus the results have been translated for this paper and original materials can be seen in the appendices. The main study consisted of two conditions. Under the standard condition, pupils' thoughts of smart devices were recorded by asking them to press the button once for each thought. In the control condition, participants were asked to press the button when they had a thought of rather being at home right now. Other than that, the two conditions did not differ. Every third group was automatically assigned to the control condition, while also paying attention to the group size. Since the groups participating varied from 10 to over 50 students at a time, situations where the control group would be larger than the experimental group were avoided, and if necessary, every third group was replaced with, for example, every fourth group.

With the permission of AHHAA, the school groups that had booked an educational program were contacted by the provided email approximately two weeks before. The first email introduced the opportunity to participate in the study, its purpose, and a brief overview of the experiment with a short introduction that teachers could share with pupils. The email asked for a response indicating whether the teacher (speaking for the class) refuses or agrees to participate. If the first email was answered with a refusal, an appreciation email followed. If the teacher agreed, an appreciation email was sent with further instructions, a proposed date and time for the start of the study, and a request to forward an attached information letter to the parents. The letter included instructions to notify the class teacher if they did not agree to their child participating (the teacher would then forward the refusal anonymously to the researcher). It was explained that if no response was received, the default assumption was agreement. Teachers had to confirm sharing the information with the parents at the beginning of the first study day via an informed consent questionnaire, in addition to confirming the agreement to participate. The original informed consent questionnaire for teachers can be seen in Appendix A. The structures of the study days are explained next. Note that study day is a term used in this paper to describe up to three astronomical hours spent either at school or AHHAA. This time frame was chosen in accordance with the schedule of the science centre's educational program, thus enabling the harmonisation of data collection between the two environments. For data analysis, two hours (120 minutes) from each study day were used.

On the first day of the experiment, verbal information about the study was provided to the children and teachers, including a withdrawal possibility at any time during the study. An opportunity to ask additional questions at any time was emphasised throughout. Each test subject was then given a clicker and asked to confirm participation via an informed consent form by completing an online questionnaire, which can be seen in Appendix B. The questionnaire asked pupils to enter the code on the clicker (therefore, the whole study was anonymous) and then confirm their agreement to participate. The main points of the previous verbal instructions were included in writing before the agreement option. Additionally, each group got assigned a letter (based on the alphabet), which was asked to be added to the clicker code. For example, the first group of the study got the letter “A”, and so a pupil with clicker 62 had to insert “62A” into the questionnaires. This allowed different groups to be distinguished anonymously within the data analysis. Teachers had to give informal consent by inserting their name in accordance with the contact info used previously, instead of the clicker code. Those whose parents did not agree with participating were given the exact same treatment as others, but the teacher was asked to find out the corresponding code and forward it to the researcher during the day, without singling out the pupil. The data associated with these codes was immediately deleted after each study day. The pupils were additionally informed of the option not to participate by not taking the clicker at all (those who did not take the device were not included in the sample). After completing the agreement questionnaires, the test subjects were reminded of how to use the clicker, and a first test click was performed together. Then the group was left to continue their day until the agreed-upon time. At the end of the first study day, the clickers were collected, and the children were asked to keep in mind or write down the individual codes, so that each test subject could take their device on the following day. In the case of writing down names, it was done by the teacher and not shared with the researcher. It was likewise made clear that the teacher cannot ask for data based on the device codes, thus ensuring the confidentiality of the test subjects. Lastly, information about the following study day was shared and agreed upon.

On the second day, the participants met at the agreed time and place to receive the devices and be reminded of the main principles of participating. The test subjects were then left to use the clickers independently and met again at the agreed time, approximately three astronomical hours later. To finish the participation, each pupil had to fill out an online questionnaire and once that was done, return the clicker. The questionnaire can be seen in

Appendix C. The form asked for the clicker code and group letter, whether the pupils owned an individual smart device, their gender and grade, how long the pupils think they spend in a smart device daily, what is the most common activity on the device, how much they wanted to participate in AHHAA's hall tasks and workshop or planetarium, and how much in school lessons, whether the pupil has ever felt a smart device disturbing schoolwork, how accurately the clicker was used, and whether the clicker was disturbing. Lastly, it was possible to write or ask anything anonymously in an open-form question. The clicker code was used to link together the informed consent, the number of smart-device related thoughts reported, and the questionnaire responses. Once the clickers were returned, it was possible to ask any remaining questions. If someone wished to receive individual feedback, they had the opportunity to provide personal contact details, but in that case, it was emphasised that the anonymity would be compromised.

Pilot experiments

The first pilot experiment was conducted to check the survey questionnaire with the children of AHHAA Science Centre employees (four children from grades 3, 6, and 9). Parents were asked to complete the questionnaires together with their children and provide feedback on the comprehensibility and clarity. No modifications followed.

In the second pilot experiment, the clickers were tested with two 6th-grade children, who were asked to spend two astronomical hours in AHHAA and provide feedback on the comprehensibility, memorability, and whether the device was distracting. As a result, the experimental devices were modified to be worn around the neck instead of around the wrist.

The third pilot experiment consisted of groups that participated in May (141 pupils), which were originally planned to be included in the main study sample. This decision was made due to a number of technical and methodological problems that made it impossible to assess the reliability of the collected data and the comparability of the study days with sufficient certainty. Following the groups that participated in May, the following main changes were made: instead of leaving the devices with the teacher overnight, the researcher collected them at the end of the day to avoid data loss due to technical problems and devices being forgotten; the introduction to the study was clarified to explain how the devices work and to allay children's fears about being filmed or eavesdropped on; an explicit warning was added that the devices are not to play with, to prevent inappropriate clicks; the number of examples of what is considered as a thought about smart devices was increased; the response option of not participating was added to the questions assessing motivation, as it became apparent that some were absent from activities; the initial plan to have teachers and instructors wear the device was abandoned, as it proved unnecessary and it was impossible to ensure a consistency across different groups; 25 experimental devices were renewed to save time, cost and improve reliability; a control condition was added to the study design and the proportion of randomization was increased to rule out the effect of the order of environments on the results.

Apparatus

To conduct the study, experimental devices were created in collaboration with the owner of Good Sounds OÜ, working at AHHAA Science Centre. Example devices are shown in Appendix D. The purpose of the device was to record the date and time when the button was pressed. The clicker was developed based on the following assumptions: the clicker has its own identification code, visible to the child; the button is as quiet as possible; the clicker does not have a screen; each click can be identified by time and date; the data can be transferred to a computer; the device is small and attracts as little attention as possible; battery life is at least two days for use, longer for data retrieval. A total of 50 devices were manufactured in cooperation with the University of Tartu for May, and 25 of those were updated for September. The device was a small black or grey 3D-printed rectangle that attaches to a neck strap, which has a partly hidden rectangular button on top, with a small green LED light and an individual code. Pressing the button turns on the light, followed by a small flash after a 1-2 second delay, confirming that the click got registered, and preventing nervous clicking every second. Data was saved to a MicroSD card and transferred to the computer as a CSV file, titled with the individual code.

The questionnaires were distributed via printed QR codes, which could be opened on a personal smart device, or if necessary, on devices provided. The questionnaires were created in the LimeSurvey environment of the University of Tartu, and the responses to the questions were analysed based on the principles of the Likert scale in the program JASP. The main questionnaire involved 13 questions, out of which 1 was open-ended for the clicker code and 1 voluntary for any feedback. The remaining 11 questions had multiple-choice answers. The informed consent questionnaires had one open-ended question for either the code or name, an overview of principles, followed by a mandatory agree or deny option.

In terms of writing, artificial intelligence, such as ChatGPT, Grammarly, and DeepL, was used for linguistic editing. Artificial intelligence was asked for suggestions on how to improve the existing text or used to improve Estonian to English translations.

Ethical considerations

Participation in this study was entirely voluntary and coordinated in collaboration with teachers and parents. Teachers were informed of the study procedures in advance, after which parents received an information letter. Parents who declined their child's participation notified the teacher, who informed the researcher using only device codes and all corresponding data was deleted. Thus, the whole process was completely anonymous. Prior to data collection, pupils received a verbal explanation of the procedure and were informed of their right to withdraw at any time, including through a private withdrawal option to avoid peer awareness. To minimise perceived pressure, it was emphasised that teachers had no authority to influence participation, assign grades related to the study, or access individual data. No variables were manipulated, and no personal identifiers were collected. Data was linked solely by device codes, with age group being determined by grade, ensuring anonymity. Therefore, the study minimised physical, psychological, or social risk to the children. Pupils were encouraged to ask questions throughout the study and confirm their understanding of the procedure regularly. Parents and teachers were provided with the researcher's contact details and could raise questions at any time. All data was stored anonymously on the researcher's personal laptop within the secure University of Tartu cloud service or LimeSurvey. Only aggregated results were shared with teachers, and all data was used exclusively for this research and not shared with third parties.

Data analysis

Data from the clickers was collected from MicroSD cards as CSV files. To balance the differences between the results of groups, the data used in analyses included the number of registered thoughts during two astronomical hours (out of the approximate three hours of the study day itself). The questionnaire responses were exported from LimeSurvey straight to a JASP file. Informed consent form answers were kept only in LimeSurvey. Eventually, the JASP file consisted of timed clicks recorded by the experimental devices and questionnaire answers distributed by participants in a fully anonymous form. A separate JASP file was made for the control condition and another one for extreme values.

Repeated Measures Analysis of Variance (RM-ANOVA) was used as the main analytical approach in this study to examine the effect of environment on the smart-device related thoughts registered and their interactions with age group and gender, with overall motivation included as a covariate. Prior to this, descriptive statistics and correlation analyses were performed to summarise the data and explore relationships between variables. Differences between control and standard conditions were assessed using an Independent

Samples T-Test. Additionally, a Paired Samples T-Test was used to assess data from only those test subjects who fell outside the outlier limit in the main analyses. This analysis plan was developed due to the mixed design of the study, since it was necessary to use both within- and between-subjects variables. Of the assumptions for RM-ANOVA, the assumption of normality was violated when considering the extreme data, while the other assumptions are met. However, after removing extreme data, the assumption of normality was no longer violated.

First, analyses were performed separately for each experimental condition, using data from the standard and control conditions. Second, participants whose data fell outside the outlier limits were excluded from the primary analyses and explored separately. Outlier thresholds were determined using Tukey's method (interquartile range), based on the 25^{th} and 75^{th} percentiles. Consequently, excluded were test subjects who clicked in AHHAA more than 29 times or school more than 38 times, or on average more than 35 times. As a result, 16 pupils' data were removed from the standard condition and 6 from the control condition. This method was chosen in alignment with the default analytical procedures of the JASP software used. In addition, for the RM-ANOVA model to work, the data of one test subject who chose the response option "prefer not to say" instead of disclosing their gender was removed from the analyses, as this made the RM-ANOVA model too complex to work. The primary conclusions of the study are based on analyses conducted after the removal of extreme values. However, a section presents analyses based exclusively on the extreme data.

Results

Descriptives

The total sample consisted of 151 pupils, out of whom 135 (89.4%) participated in the standard condition and 16 (10.6%) in the control condition. Out of the sample, 64 were boys, 87 girls. In grade four were 30 pupils, grade five 44, grade six 20, grade eight 23 and grade nine 34. For the following data analyses, two age groups based on said grades were made. The younger group included pupils from grades 3-5 ($n = 64$ in standard condition, $n=10$ in control condition), and the older group included students from grades 6-9 ($n = 71$ in standard condition, $n = 6$ in control condition). The standard conditions' registered smart-device related thoughts in each environment can be seen in Figures 1 and 2, including extreme values ($n = 135$).

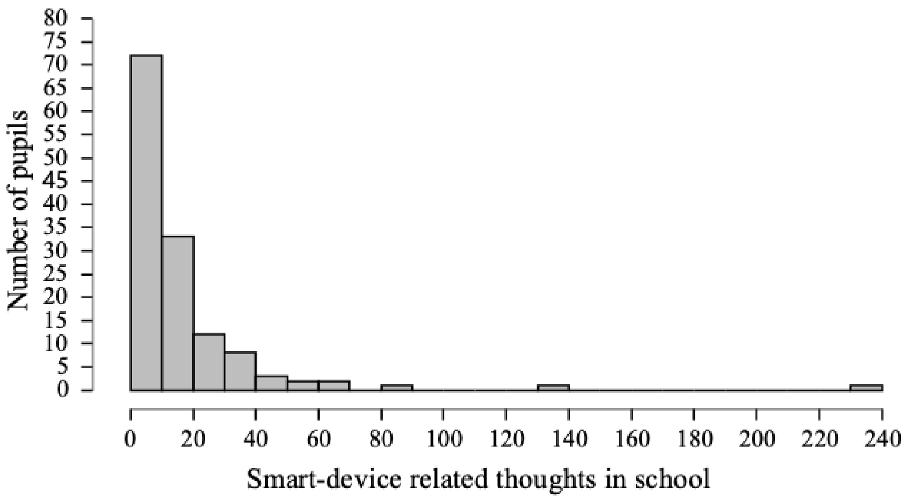

Figure 1. Descriptive plots for the registered smart-device related thoughts in school.

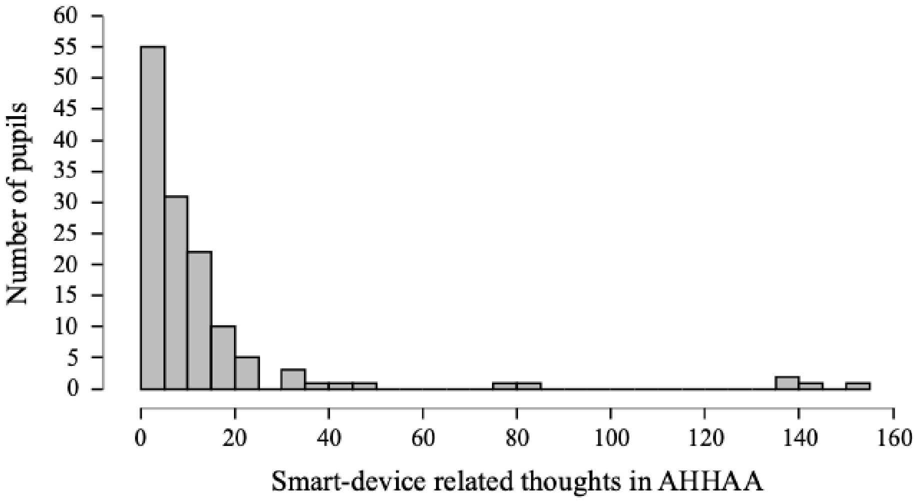

Figure 2. Descriptive plots for the registered smart-device related thoughts in AHHAA.

Out of the 151 pupils, 148 (98%) reported having their own personal smart device, whereas 3 pupils (2%) reported not owning one. When asked whether they have ever felt smart devices disrupting their schoolwork, 46 (30.5%) agreed, 71 (47%) disagreed, and 34 (22.5%) chose “I don’t know”. Almost half of the pupils (47%) reported that the experimental device used in this study did not disturb their days, that being 71 pupils. Meanwhile, 46 (30.5%) reported that the device did disturb them, and 34 (22.5%) answered “I don’t know”. The average time spent on a smart device daily was reported to be 3-5 hours (mean = 2.7, SD = 1.03). The most popular activity on a smart device was “I watch short videos (TikTok, Instagram/Facebook Reels…)”. The popularity of each given activity that the pupils got to choose from can be seen in Table 1.

Table 1

Popularity of Activities Performed on Smart Devices Among Pupils

Proposed activity	Frequency	Percentage
I play (Roblox, Brawl Stars, Candy Crush, Block Blast...)	31	20.53
I don't use smart devices	4	2.65
I use it for schoolwork (ChatGPT, Stuudium, E-kool, Google, Safari...)	7	4.64
I watch short videos (TikTok, Instagram/Facebook Reels...)	54	35.76
I watch longer videos, movies/series (YouTube, Netflix...)	30	19.87
I communicate (Messenger, Snapchat, Discord, calls, messages...)	23	15.23
I search for information that doesn't involve schoolwork (Google, Safari, ChatGPT...)	2	1.33
Total	151	100.00

Note. Frequency shows the number of pupils who chose the given activity on a smart device as their most popular.

Taken by gender, watching short videos was the most popular choice for both boys (33%) and girls (38%). Second for boys was watching longer videos, movies, or series (25%), while for girls, second place went to communication (19.5%). The third most popular option for boys was playing (23.4%), and for girls, watching longer videos (16.1%). In comparison, only 9.4% of the boys chose communication, and 18.4% of the girls chose gaming as the most popular activity.

After the corrections for extreme data, the standard condition consisted of 119 pupils, of whom 54 belonged to grade group 3-5 and 65 to grade group 6-9, 44 were boys, and 75 were girls. In the control condition, the sample consisted of 10 pupils, out of whom 4 belonged to grade group 3-5 and 6 to grade group 6-9, 4 were boys, and 6 were girls. In the following, the main results are presented based on the samples without extreme values.

Based on the age groups, the younger group registered on average 7 smart-device related thoughts in AHHAA and 10 in school, meanwhile the older group registered 9 smart-device related thoughts in AHHAA and 10 in school. Taken together, the data in both environments, both age groups registered on average 9 smart-device related thoughts. Table 2 shows descriptive statistics about the registered smart-device related thoughts, specifically by grade.

Table 2

Main Statistics of Registered Smart-device Related Thoughts by Environment and Grade

Environment	Grade	Valid	M	SD	Minimum	Maximum
AHHAA	4.	18	6.17	4.66	1.00	16.00
	5.	36	7.83	5.86	0.00	21.00
	6.	18	11.72	6.53	2.00	25.00
	8.	20	8.00	6.25	1.00	25.00
	9.	27	7.74	4.89	1.00	18.00
School	4.	18	4.67	4.26	1.00	19.00
	5.	36	12.81	9.92	0.00	36.00
	6.	18	9.61	9.07	1.00	29.00
	8.	20	8.85	6.81	1.00	30.00
	9.	27	10.67	8.47	0.00	35.00

The results taken by gender showed that boys registered on average 11 smart-device related thoughts and girls 8. Based on the environment, boys' mean score in AHHAA was 9 and girls' 7. In school mean score for registered smart-device related thoughts was 12 for boys and 9 for girls.

Motivation was assessed separately for participation in AHHAA activities and in school activities. An overall motivation score for each participant was calculated by averaging these two scores for use in the statistical analyses. The assessed motivation was in general "I rather wanted to participate" both in younger ($M = 3.94$, $SD = 0.65$) and older ($M = 3.74$, $SD = 0.72$) age groups. Between environments, the only exception was the older age group in the motivation to participate in school activities, with the average answer being "I don't know" ($M = 3.32$, $SD = 0.95$). The differences between boys ($M = 3.80$, $SD = 0.71$) and girls ($M = 3.85$, $SD = 0.69$) were minimal, with all mean scores rounding up to "I rather wanted to participate". Small differences between the motivation to participate in either school or AHHAA were found when looking at the overall motivation scores. The mean for motivation in AHHAA was 4.15 ($SD = 0.79$), in school 3.51 ($SD = 0.97$); nevertheless, both still rounded up to "I rather wanted to participate".

All test subjects gave a subjective assessment of the average time spent on a smart device. Differences emerged by age groups, with the younger age groups' average answer being 1-3 hours ($M = 2.43$, $SD = 1.08$), whereas the older age groups' average answer was 3-5 hours ($M = 3.03$, $SD = 0.85$). There were no gender differences, as both indicated that they spend on average 3-5 hours on a smart device daily; the mean for girls was 2.77 ($SD = 0.86$) and for boys 2.73 ($SD = 1.21$). Taking the subjective assessment of one's accuracy of using the clicker, the average reported score in the standard condition was "I clicked almost always when the thought occurred" ($M = 3.91$, $SD = 1.24$).

Correlations

Since some of the variables were assessed on a 5-point Likert Scale, Spearman's correlations were used. The correlations found were interpreted based on Cohen's criteria. Three statistically significant correlations emerged. First, between the smart-device related thoughts registered in both environments, with the relationship being strong and positive ($\rho = 0.54$, $p < .001$). Second, between the smart-device related thoughts registered in school and the motivation to participate in school activities, with the relationship being small and negative ($\rho = -0.19$, $p = 0.043$). Third, between a motivation to participate in either of the environment's activities, with the relationship being moderate and positive ($\rho = 0.27$, $p = 0.003$). The relationship between smart-device related thoughts registered in AHHAA and the motivation to participate in AHHAA's activities was statistically insignificant ($\rho = 0.08$, $p = 0.380$). Similarly, the relationship between smart-device related thoughts registered in school and the motivation to participate in AHHAA's activities was statistically insignificant ($\rho = 0.01$, $p = 0.890$). The same applied to the relationship between the smart-device related thoughts registered in AHHAA and the motivation to participate in school activities ($\rho = -0.17$, $p = 0.068$). Taken together, reported smart-device related thoughts and motivation independent of the environment did not show a significant correlation between the two ($\rho = -0.13$, $p = 0.146$). The subjective assessment of one's time spent on a smart device daily did not correlate in a statistically significant way with the overall smart-device related thoughts recorded by the experimental device without (ρ = -0.01, $p = 0.908$) nor with the extreme values (ρ = 0.01, $p = 0.910$).

Repeated Measures ANOVA

Within-subjects analysis results showed the main effect of environment to be statistically insignificant, $F(1, 114) = 1.46$, $p = 0.230$, $\omega^2 = 0.001$. A statistically significant interaction was found between environment and age group, $F(1, 114) = 4.47$, $p = 0.037$, $\omega^2 = 0.008$. The interaction between environment and gender was not statistically significant, $F(1,114) = 1.33$, $p = 0.251$, $\omega^2 < 0.001$. Similarly, the interaction between environment and the overall motivation was not significant, $F(1,114) = 0.40$, $p = 0.527$, $\omega^2 = 0.000$. However, a statistically significant three-way interaction was revealed between environment, age group, and gender, $F(1,114) = 4.37$, $p = 0.039$, $\omega^2 = 0.008$. The interaction between age group and environment can be visually seen in Figure 3. The figure shows that the average number of registered smart-device related thoughts differed across environments and age groups, with an increase from AHHAA to school. The number of thoughts was overall higher in school than in AHHAA for both age groups, but grades 3-5 showed a more pronounced increase. To assess this difference more closely, an additional Wilcoxon signed-rank test was conducted only on the younger age group, which showed a statistically significant difference between the smart-device related thoughts registered in AHHAA and school, $W = 360.5$, $p = 0.007$.

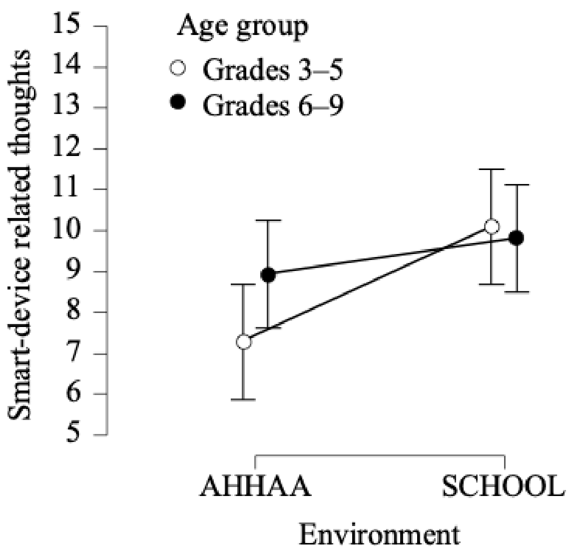

***Figure 3*.** Interaction between age group and environment in registered smart-device related thoughts with 95% confidence intervals.

Results for the between-subjects analysis showed that the main effect of age group was statistically insignificant, $F(1,114) = 0.25$, $p = 0.615$, $\omega^2 = 0.000$. Similarly, the main effect of overall motivation was not statistically significant, $F(1,114) = 0.23$, $p = 0.636$, $\omega^2 = 0.000$. In contrast, a statistically significant main effect of gender was revealed, $F(1,114) = 6.51$, $p = 0.012$, $\omega^2 = 0.023$. Furthermore, a statistically significant interaction between age group and gender was revealed, $F(1,114) = 8.05$, $p = 0.005$, $\omega^2 = 0.030$. The interaction between gender and environment can be seen in Figure 4. The figure shows that the number of reported smart-device related thoughts was overall higher in school for both genders. Besides, boys exhibited a slightly more pronounced increase between the environments and a higher number of smart-device related thoughts overall.

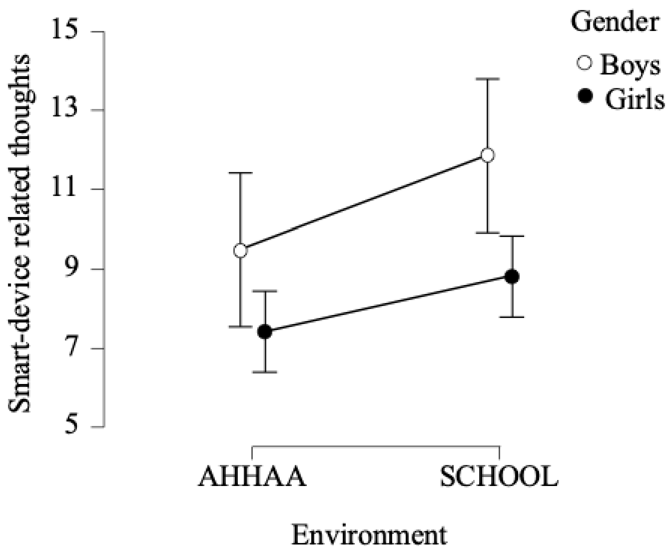

Figure 4. Interaction between gender and environment in registered smart-device related thoughts with 95% confidence intervals.

Control condition

In the control condition (n = 10), the mean for registered home-related thoughts was 12 in AHHAA and 11 in school. Taken together, the overall mean score for home-related thoughts was 11. Since the control condition had a small sample, no statistics were reported by age group or gender. Likewise, other variables were not analysed separately in this condition as this was not relevant to the purpose of the study. Relevant data from this group was analysed together with the standard condition previously.

Table 5 shows the main statistics in smart-device or home-related thoughts in each environment, taken together, and an overall motivation level by experimental conditions.

Table 5

Main Statistics of Reported Thoughts and Motivation Between Experimental Conditions

	Group	N	M	SD	SE	Coefficient of variation
Smart-device or home-related thoughts in AHHAA	Standard	119	8.18	5.80	0.53	0.71
	Control	10	11.60	3.92	1.24	0.34
Smart-device or home-related thoughts in school	Standard	119	9.94	8.60	0.79	0.87
	Control	10	11.30	9.90	3.13	0.88
Overall smart-device or home-related thoughts	Standard	119	9.06	6.33	0.58	0.70
	Control	10	11.45	5.79	1.83	0.51
Overall motivation	Standard	119	3.83	0.69	0.06	0.18
	Control	10	3.45	0.81	0.26	0.23

Note. The units for thoughts are shown in counts, whereas motivation was assessed on a 5-point Likert Scale, 0 meaning “I didn´t participate”, 1 “I really didn’t want to participate”, 2 “I rather didn’t want to participate”, 3 “I don’t know”, 4 “I rather wanted to participate”, 5 “I really wanted to participate”.

An Independent Samples T-test was conducted to explore the differences between control and standard conditions. The results are reported in Table 6, showing no statistically significant differences between the two conditions in either the number of registered thoughts or motivation.

Table 6

Independent Samples T-Test Results for the Comparison of Experimental Conditions

	t	df	*p*	Cohen's d	SE Cohen's d
Smart-device or home-related thoughts in AHHAA	-1.83	127	0.070	-0.60	0.33
Smart-device or home-related thoughts in school	-0.47	127	0.636	-0.16	0.33
Overall smart-device or home-related thoughts	-1.15	127	0.251	-0.38	0.33
Overall motivation	1.64	127	0.103	0.54	0.33

Note. Based on the Levene's Test of Equality of Variances results, Student's T-test was used for all variables.

Extreme values

The outlier sample in the control condition consisted of only 6 pupils, and the reported home-related thoughts were unrelated to smart devices, which are the focus of this study. Consequently, no substantive analyses were performed on this sample. In standard condition, 16 pupils reported extreme values in comparison with others, of whom 10 belonged to grade group 3-5, and 6 to grades 6-9, 12 were boys and 4 girls. Figure 5 shows all registered smart-device related thoughts that fell outside the outlier limit by the environments.

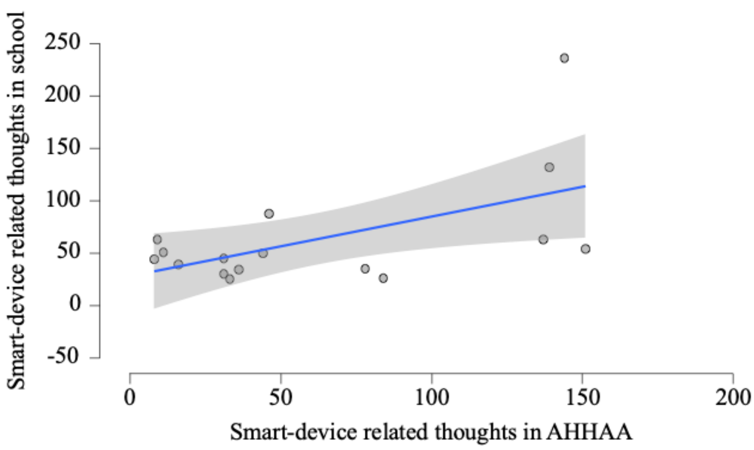

Figure 5. Registered smart-device related thoughts that fell outside the outlier limits.

In this group, the average score for registered smart-device related thoughts was 78 in the younger age group and 38 in the older one. Boys registered on average 73 smart-device related thoughts and girls 34. Taken together, the mean score for registered smart-device related thoughts independently of the environments was 63.

Taking the subjective assessment of one's time spent on a smart device daily, the average mean score was 2.81 (SD = 1.11), interpreted as 3-5 hours. The average motivation was reported as "I don't know" (M = 3.19, SD = 0.79). Mean score for motivation was 3.75 (SD = 0.91), that is "I rather wanted to participate", in AHHAA and 2.63 (SD = 1.03), that is "I don't know", in school. Results for the assessment of using the device precisely showed a mean score of 4.38 (SD = 1.03), interpreted as "I clicked almost every time the thought occurred". Due to the small sample size, no gender or age group differences were assessed in these variables.

Correlational analyses revealed a statistically significant correlation between smart-device related thoughts registered in AHHAA and the participation motivation in AHHAA ($\rho = -0.64$, $p = 0.008$). Statistically insignificant were relationships between the smart-device related thoughts registered in AHHAA and school ($\rho = 0.35$, $p = 0.187$), smart-device related thoughts registered in AHHAA and the participation motivation in school ($\rho = -0.14$, $p = 0.602$), smart-device related thoughts registered in school and motivation to participate in AHHAA ($\rho = -0.34$, $p = 0.194$), smart-device related thoughts registered in school and motivation to participate in school activities ($\rho = -0.32$, $p = 0.230$) and the motivation to participate in AHHAA and school ($\rho = 0.33$, $p = 0.218$). The relationship between subjectively assessed time spent on a smart device daily and the registered smart-device related thoughts was found to be statistically insignificant ($\rho = 0.04$, $p = 0.884$). Taken together, the overall smart-device related thoughts registered and motivation levels independently from the environments, there was a statistically significant negative and strong relationship between the two ($\rho = -0.51$, $p = 0.045$).

Since the sample was small (n = 16), RM-ANOVA turned out to be inconvenient, and so a Wilcoxon signed-rank test was used instead to assess whether the registered smart-device related thoughts differed in two environments. The mean score for registered smart-device related thoughts in AHHAA (M = 62.4, SD = 52.53) did not differ in a statistically significant way from the thoughts registered in school (M = 63.45, SD = 53.23), W = 66.00, $p = 0.940$.

Discussion

The main purpose of this study was to examine the extent to which pupils think about smart devices in two different environments, one being a regular day at school and the other in Science Centre AHHAA. In addition, it was investigated how these thoughts about smart devices relate to the participation motivation in different ongoing activities. Based on relevant literature, three specific hypotheses were formulated. Relevant data about gender, grade, ownership of a personal smart device, subjectively assessed average time spent on a device, the most common activity on smart devices, the occurrence of schoolwork being disrupted by the smart device, the accuracy of clicker use, and whether the clicker disturbed the test subjects, were collected. To achieve this goal, an experimental device was used to register smart-device-related thoughts, as well as an online questionnaire for all the other variables. To evaluate the potential impact of the experimental device, a control condition was included in which pupils registered thoughts related to the desire to be at home. Data was analysed by standard and control conditions, with the main analyses excluding extreme values. The main statistical analysis used was Repeated Measures ANOVA, complemented by descriptive statistics, correlations, and T-tests. The following sections present the main conclusions of the study in relation to the research question and hypotheses and compare them with previous findings in the literature.

The first question, concerning the extent to which pupils think about smart devices in two environments, was addressed using descriptive comparisons by age group and gender. Results showed that both age groups registered on average 9 smart-device related thoughts in each environment, while boys reported more thoughts on average (11) than girls (8). Although there were some differences in the mean scores, environmental differences turned out to be statistically insignificant, and no main effect of environment emerged. This means that the environment alone did not influence the frequency of smart-device related thoughts. Consequently, the first hypothesis of this paper, which proposed a statistically significant difference between the two environments and more thoughts appearing in school, was rejected. However, the results revealed a significant interaction between environment and age group, suggesting that younger and older pupils responded differently to the two environments. Younger pupils showed a pattern of smart-device related thoughts that depended more on the environment compared to older pupils, implying greater sensitivity to contextual cues. This pattern is underscored by the statistically significant difference between registered smart-device related thoughts in AHHAA and school, while analysing only the younger age group. Younger pupils reported more smart-device related thoughts in school. A similar pattern was observed for gender, with a main effect indicating that boys reported more smart-device related thoughts than girls, regardless of environment, potentially reflecting gender differences in overall engagement with smart devices. Furthermore, a significant three-way interaction between environment, age group, and gender indicated that the combined influence of age and gender further shapes how contextual factors affect smart-device related thoughts. Although the effect size was small, this finding highlights the importance of individual characteristics in understanding environmental effects. This has practical implications for interventions, as the effect can be age and gender sensitive, so uniformly applied interventions might not be beneficial. These results align with the I-PACE model (Brand et al., 2016), which emphasises the role of individual characteristics over situational factors. Overall, these findings suggest that context can influence smart-device related engagement, but not uniformly for all pupils.

Additionally, the results identified a small group of pupils who reported substantially more smart-device related thoughts than the rest. That being 16 pupils in the standard condition of this study out of 135 total. Within this group, younger pupils reported on average 78 thoughts compared to 38 among older pupils, while boys reported an average of 73 and girls 34. As with the main sample, no statistically significant differences between the two environments were found, indicating that smart-device related thoughts did not differ between school and AHHAA. For the main data analysis, this group was excluded as exceeding the calculated extreme value threshold. One possible explanation is that these values reflect unreliable data, such as a misunderstanding of the instructions or random use of the clicker without actual smart-device related thoughts. This interpretation is partly supported by auditory feedback after the study days from some pupils and teachers, who reported that certain pupils pressed the button for fun. However, subjective ratings of clicker use accuracy in this group indicated that most pupils reported using the clicker almost every time or always when a relevant thought occurred, suggesting an alternative explanation. It is therefore possible that these extreme values represent a small group of pupils with excessive engagement with smart devices. Unfortunately, the present study is unable to determine the actual cause for these values, and this issue should be examined in future research.

The second and primary interest of the study was to examine whether registered smart-device related thoughts were associated with motivation to participate in activities. Previous research has suggested that excessive smartphone use may have a negative impact on motivational patterns (Aligül & Tolukan, 2024; Machado de Oliveira et al., 2023; Merchán Tamayo et al., 2023; Lin et al., 2022). Accordingly, the second hypothesis proposed a negative correlation between smart-device related thoughts and motivation to participate. Overall, no statistically significant relationship was found between pupils' total participation motivation and the number of smart-device related thoughts reported across both environments. This indicates that the number of thoughts about smart devices did not correlate with the self-assessed motivation to participate, contrary to what previous literature has proposed. In addition, RM-ANOVA revealed no significant interactions involving overall motivation, suggesting that motivational differences did not meaningfully influence pupils' smart-device related thoughts across environments. Consequently, the second hypothesis was rejected. However, a small but significant negative correlation between the smart-device related thoughts registered in school and the motivation to participate in school activities emerged. This indicates that increased device related thoughts were associated with lower participation motivation in that context. This environment-specific relationship may be explained by Merchán Tamayo et al. (2023), who proposed that the type of motivation might play a role, with there being a stronger relationship between smartphone use and controlled motivation rather than autonomous motivation. Since school attendance is mandatory and routine, whereas participation at AHHAA is more voluntary and novel, motivational types for these environments could differ. Therefore, this would explain why the relationship surfaced only in school, where the motivation could presumably be more controlled. This idea is partly supported by slightly higher overall motivation ratings at AHHAA than at school. However, this difference disappears once results are interpreted based on the Likert scale used. Nevertheless, this study did not find a general relationship between smart-device related thoughts and participation motivation, but the results suggest a more nuanced pattern. The presence of a relationship in one environment but not the other raises questions for future research. One possible explanation is that these results excluded the data of extreme values, thereby omitting pupils with potentially excessive smart device use. This is interesting since analyses including only extreme values showed a strong negative relationship between the smart-device related thoughts and participation motivation. This could indicate that the pupils used in the main analyses did not have an excessive smart device use problem, since the previous findings apply to the ones that do, and in that case, the results appear to be in accordance. These findings suggest that the negative motivational effects proposed in previous literature may primarily apply to pupils with excessive smart device engagement.

A third hypothesis, based on previous literature findings, suggested that girls spend more time texting and social media, whereas boys on gaming (Twenge & Martin, 2020). To assess this proposal, a question was formed with 7 different activities, and pupils were asked to select their most frequently used activity. Results showed that for both boys and girls, the most popular activity was watching short videos (e.g., TikTok). Beyond this, gender differences appeared. Boys most commonly selected watching longer videos, movies, or series as their second preference, followed by gaming in third place. In contrast, girls most frequently chose communication-related activities as their second preference, with watching longer videos ranking third. Communication was selected by only 9.4% of boys but 19.5% of girls, while gaming was chosen by 23.4% of boys and 18.4% of girls. Consequently, the results of this study support the results of previous literature, with the indication that girls favour social media, whereas boys favour gaming. This distinction may be relevant to understanding whether different types of smart-device activities contribute differently to mental engagement, potentially explaining the observed main effect of gender in the number of registered smart-device related thoughts in this study. This is based on the idea of Massaroni et al. (2024), highlighting the difference between active and passive screentime. Furthermore, the most popular activity being watching short videos, could support the notion that novelty has a central role in smart device dependence, as such videos provide perceived high reward at low cost (Aru & Rozgonjuk, 2022; Wittmann et al., 2007). Short videos offer constant novelty and may thus explain the development of mental engagement with one's smart device found in this study. From the perspective of opponent-process theory (Tian et al., 2023), short-video consumption elicits positive emotions followed by negative affect once the viewing stops, thereby sustaining engagement as users attempt to maintain or alleviate said emotions. In practice, this is another example of the need for specific intervention tactics, as boys and girls use their devices in different ways. The discussion will now turn to additional relevant data collected beyond the main research questions and hypotheses.

The current paper is based on the growing need for clear guidelines in academic contexts regarding smart-device use (ERR, 2024). In this study, 98% of the pupils claimed to possess a personal smart device, and 30.5% admitted having felt the device disrupting their schoolwork. Average daily smart-device use was estimated at 3-5 hours. The data analysed about smart-device related thoughts covered a time period of only 2 astronomical hours (120 minutes). In those two hours, the pupils had either activities offered by school (mainly lessons of different subjects) or AHHAA (either a workshop, planetarium show, or worksheets that had to be filled while exploring different exhibits). Regardless of the continuous attention-demanding activities, on average, 9 smart-device related thoughts were registered across environments, equating to approximately one thought every 13 minutes. Looking at the group of pupils that registered extreme values of smart-device related thoughts, the results showed a mean score of 63 smart-device related thoughts, suggesting a frequency of roughly one every two minutes. These findings indicate notable mental engagement with smart devices. Unfortunately, information on school-level intervention strategies was not collected objectively, but it was later verbally assessed that most of the schools participating did not allow pupils to use their smart devices in school at all. Nevertheless, mean levels of smart-device related thoughts showed little variation across grades or environments. This suggests that even without direct exposure to devices or within contexts where their use is habitually restricted, device-related thoughts persist. This finding challenges Davis's (2001) model, which highlights the reinforcement carried on by situational cues as the reason for excessive smartphone use. The results from this study could indicate that the smart-device related thoughts are evoked even in the absence of situational cues. Instead, the results align with literature, suggesting persistent exposure to digital novelty may contribute to functional changes in brain regions potentially reshaping neural pathways over time (Aru & Rozgonjuk, 2022; Bunzeck & Düzel, 2006; Chun et al., 2018; Schomaker & Meeter, 2015; Wittmann et al., 2007). At a certain point, situational cues may no longer be necessary to activate these pathways. This interpretation is further supported by the absence of statistically significant differences in smart-device related thoughts between AHHAA and school, despite the situational cues offered being quite different. These findings warrant further investigation. Since schools have started regulating smart-device use, it would be beneficial to assess how each regulation impacts the number of smart-device-related thoughts and which situational cues in school may provoke said mental engagement.

Previous research has mainly relied on various self-reported scales to capture psychological and behavioural engagement with smartphones, often highlighting mental dependence users develop with their devices and arguing for more objectively tracked data (Amez & Baert, 2020; Bianchi & Phillips, 2005; Kwon et al., 2013a; Kwon et al., 2013b; Rozgonjuk, 2019). In the present study, self-assessed daily smart-device use did not correlate in a statistically significant way with the actual number of smart-device related thoughts registered. This aligns with Boase & Ling (2013), who found that self-reported smartphone use only moderately correlates with actual usage. Several results illustrate this discrepancy. For example, younger pupils reported spending 1-3 hours daily on their devices, while older pupils reported 3-5 hours. However, both age groups reported the same average number of smart-device related thoughts, indicating that actual usage time may not differ substantially. This interpretation must be taken with caution, as thoughts and actual behaviour do not necessarily coincide. Similarly, within the group displaying extreme values, younger pupils reported lower daily device use (1-3 hours) than older pupils (5-7 hours), yet registered more smart-device related thoughts, thus revealing a contradictory pattern. The overall findings suggest that mental dependency on smart devices can be captured in a more objective manner. Therefore, the current study introduces a potential novel approach by combining self-assessed data and real-time reporting of smart-device related thoughts. This allows the test subjects to report their thoughts immediately as they are noticed, eliminating the exaggeration or understatement that can result from errors in recall. For future purposes, pupils were asked whether the experimental device was disruptive. Reassuringly, 47% of the pupils reported no disturbance, whereas 30.5% did and 22.5% were unsure. These results alleviate concerns about the practical use of such methods. Finally, the feedback and interest about the study were surprisingly positive, with teachers expressing interest in discussing the findings and broader literature with pupils, and pupils themselves showing curiosity and engagement by asking questions.

Limitations

Despite its contributions, this study has several limitations. The primary limitation concerns the insignificant difference between the standard and control conditions in the number of smart-device and home-related thoughts registered. One possible explanation is that the experimental device itself acted as a situational cue, potentially eliciting the very thoughts it aimed to measure. However, this issue may as well be exacerbated by the small size of the control group, which constituted only 10.6% of the total sample, thereby limiting statistical power. Another explanation is the potential overlap between the selected constructs. In an academic context, thoughts about smart devices and the desire to be at home may reflect similar psychological processes, which could account for the lack of differentiation between conditions. However, the data collected does not allow for a definitive interpretation of this issue. Future research should therefore consider alternative control constructs and larger, more balanced samples. Additional limitations relate to the use of the experimental device since group effects may have occurred. For example, seeing a classmate use the device might be a situational cue to use it as well, thus bringing up the smart-device related thought and starting a chain reaction. Moreover, it cannot be ensured that all relevant thoughts were reported or that all registrations were intentional. Even though subjective self-assessments and pilot testing were used to partially control for these issues, prior research suggests that self-reports may be unreliable. Finally, structural and sample-related limitations must be acknowledged. An early start to data collection resulted in substantial data loss, with a large portion retrospectively treated as pilot data. Nevertheless, that was a great learning experience for trying out a method that had not knowingly been used before and thus did not go to waste. Furthermore, the sample consisted of pupils attending an academic program at

Science Centre AHHAA, which may limit generalizability. Future studies should therefore aim to replicate the findings using more diverse samples.

Conclusions

This study addressed a gap in the literature by proposing a novel approach to examining pupils' mental engagement with smart devices across two academic environments. Mental engagement was assessed through the number of smart-device related thoughts and relationships explored with the help of self-reported data on device ownership, perceived disruption to schoolwork, and daily device use. The results showed no significant overall differences between the environments in the number of smart-device related thoughts, nor a general association with participation motivation. However, a small negative correlation emerged in the school context, suggesting that the relationship between motivation and mental engagement with smart devices may be context dependent. Gender differences in device use indicated that watching short videos was the most common activity for both boys and girls, while boys reported more gaming and girls more social interaction. Across all groups, device-related thoughts were more frequent in the school environment than in AHHAA, particularly among younger pupils. Boys reported a higher number of smart-device related thoughts than girls in both settings, with this difference being more pronounced at school. Together, these findings suggest that the effect of environment on mental engagement with smart devices is moderated by age and gender, highlighting the limited effectiveness of uniform intervention approaches. Despite these contributions, the study is limited by its design, which restricts generalizability and causal interpretation. Future research should therefore be conducted.

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References

Abi-Jaoude, E., Naylor, K. T., & Pignatiello, A. (2020). Smartphones, social media use and youth mental health. *Canadian Medical Association Journal*, *192*(6), E136–E141. https://doi.org/10.1503/cmaj.190434

Aligül, B., & Tolukan, E. (2024). The Relationship of Smartphone Addiction with Motivation to Participate in Physical Activity: A Study in Sports Sciences Faculty Students. *Mediterranean Journal of Sport Science*, *7*(2), 320–329. https://doi.org/10.38021/asbid.1476185

Amez, S., & Baert, S. (2020). Smartphone use and academic performance: A literature review. *International Journal of Educational Research, 103.* https://doi.org/10.1016/j.ijer.2020.101618

Aru, J., & Rozgonjuk, D. (2022). The effect of smartphone use on mental effort, learning, and creativity. *Trends in Cognitive Sciences*, *26*(10), 821–823. https://doi.org/10.1016/j.tics.2022.07.002

Bacil, E. D. A., da Silva, M. P., Martins, R. V., da Costa, C. G., & de Campos, W. (2024). Exposure to Smartphones and Tablets, Physical activity and Sleep in Children From 5 to 10 Years Old: A Systematic Review and Meta-Analysis. *American Journal of Health Promotion*, *38*(7), 1033–1047. https://doi.org/10.1177/08901171241242556

Bianchi, A., & Phillips, J. G. (2005). Psychological Predictors of Problem Mobile Phone Use. *CyberPsychology & Behavior*, *8*(1), 39–51. https://doi.org/10.1089/cpb.2005.8.39

Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D. J., & Griffiths, M. D. (2015). Can Disordered Mobile Phone Use Be Considered a Behavioral Addiction? An Update on Current Evidence and a Comprehensive Model for Future Research. *Current Addiction Reports, 2*(2), 156–162. https://doi.org/10.1007/s40429-015-0054-y

Boase, J., & Ling, R. (2013). Measuring Mobile Phone Use: Self-Report Versus Log Data. *Journal of Computer-Mediated Communication*, *18*(4), 508–519. https://doi.org/10.1111/jcc4.12021

Brand, M., Young, K. S., & Laier, C. (2014). Prefrontal Control and Internet Addiction: a theoretical model and review of neuropsychological and neuroimaging findings. *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00375

Brand, M., Young, K. S., Laier, C., Wölfling, K., & Potenza, M. N. (2016). Integrating psychological and neurobiological considerations regarding the development and maintenance of specific Internet-use disorders: An Interaction of Person-Affect-

Cognition-Execution (I-PACE) model. *Neuroscience & Biobehavioral Reviews*, *71*, 252–266. https://doi.org/10.1016/j.neubiorev.2016.08.033

Bunzeck, N., & Düzel, E. (2006). Absolute Coding of Stimulus Novelty in the Human Substantia Nigra/VTA. *Neuron*, *51*(3), 369–379. https://doi.org/10.1016/j.neuron.2006.06.021

Chun, J.-W., Choi, J., Cho, H., Choi, M.-R., Ahn, K.-J., Choi, J.-S., & Kim, D.-J. (2018). Role of Frontostriatal Connectivity in Adolescents With Excessive Smartphone Use. *Frontiers in Psychiatry*, *9*. https://doi.org/10.3389/fpsyt.2018.00437

Davis, R. A. (2001). A cognitive-behavioral model of pathological Internet use. *Computers in Human Behavior*, *17*(2), 187–195. https://doi.org/10.1016/s0747-5632(00)00041-8

Elhai, J. D., Dvorak, R. D., Levine, J. C., & Hall, B. J. (2016). Problematic smartphone use: A conceptual overview and systematic review of relations with anxiety and depression psychopathology. *Journal of Affective Disorders, 207,* 251-259. https://doi.org/10.1016/j.jad.2016.08.030

ERR. (2024, September 24). *Avalik kiri: Nutiseadmete kasutamine koolides vajab reguleerimist.* https://www.err.ee/1609469623

Felisoni, D. D., & Godoi, A. S. (2018). Cell phone usage and academic performance: An experiment. *Computers & Education*, *117*, 175–187. https://doi.org/10.1016/j.compedu.2017.10.006

Kim, D., Lee, S., Kim, H., & Shin, Y. (2024). From temperament to YouTube: exploring the link between childhood temperament, YouTube usage patterns, and emotional/behavioral problems among children. *BMC Public Health*, *24*(1), 1-11. https://doi.org/10.1186/s12889-024-19011-w

Kim, I., Kim, R., Kim, H., Kim, D., Han, K., Lee, P. H., Mark, G., & Lee, U. (2019). Understanding smartphone usage in college classrooms: A long-term measurement study. *Computers & Education*, *141*. https://doi.org/10.1016/j.compedu.2019.103611

Kwon, M., Kim, D.-J., Cho, H., & Yang, S. (2013a). The Smartphone Addiction Scale: Development and Validation of a Short Version for Adolescents. *PLoS ONE*, *8*(12), 1-7. https://doi.org/10.1371/journal.pone.0083558

Kwon, M., Lee, J.-Y., Won, W.-Y., Park, J.-W., Min, J.-A., Hahn, C., Gu, X., Choi, J.-H., & Kim, D.-J. (2013b). Development and Validation of a Smartphone Addiction Scale (SAS). *PLoS ONE*, *8*(2), 1-7. https://doi.org/10.1371/journal.pone.0056936

Lepp, A., Barkley, J. E., Sanders, G. J., Rebold, M., & Gates, P. (2013). The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. *International Journal of Behavioral Nutrition and Physical Activity*, *10*, 79-87. https://doi.org/10.1186/1479-5868-10-79

Lin, B., Teo, E. W., & Yan, T. (2022). The Impact of Smartphone Addiction on Chinese University Students' Physical Activity: Exploring the Role of Motivation and Self-Efficacy. *Psychology Research and Behavior Management*, *15*, 2273–2290. https://doi.org/10.2147/prbm.s375395

Machado de Oliveira, M. M., Lucchetti, G., da Silva Ezequiel, O., & Lamas Granero Lucchetti, A. (2023). Association of Smartphone Use and Digital Addiction with Mental Health, Quality of Life, Motivation and Learning of Medical Students: A Two-Year Follow-Up Study. *Psychiatry: Interpersonal & Biological Processes*, *86*(3), 200–213. https://doi.org/10.1080/00332747.2022.2161258

Mangot, A. G., Murthy, V. S., Kshirsagar, S. V., Deshmukh, A. H., & Tembe, D. V. (2018). Prevalence and Pattern of Phantom Ringing and Phantom Vibration among Medical Interns and their Relationship with Smartphone Use and Perceived Stress. *Indian Journal of Psychological Medicine*, *40*(5), 440–445. https://doi.org/10.4103/ijpsym.ijpsym_141_18

Massaroni, V., Delle Donne, V., Marra, C., Arcangeli, V., & Chieffo, D. P. R. (2024). The Relationship between Language and Technology: How Screen Time Affects Language Development in Early Life—A Systematic Review. *Brain Sciences, 14*(1), 27. https://doi.org/10.3390/brainsci14010027

Merchán Tamayo, J. P. M., Rocchi, M. A., St-Denis, B., Bonneville, L., & Beaudry, S. G. (2023). A motivational approach to understanding problematic smartphone use and negative outcomes in university students. *Addictive Behaviors*, *148*. https://doi.org/10.1016/j.addbeh.2023.107842

Nambirajan, M. K., Vidusha, K., Kailasam, J. G., Kannan, S., Govindan, D., Ganesh, K., U, S., Priyan, S., & Krishnamoorthy, Y. (2025). Association between smartphone addiction and sedentary behaviour amongst children, adolescents and young Adults: A Systematic Review and meta-analysis. *Journal of Psychiatric Research*, *184*, 128–139. https://doi.org/10.1016/j.jpsychires.2025.02.049

Panjeti-Madan, V. N., & Ranganathan, P. (2023). Impact of screen time on children's development: cognitive, language, physical, and social and emotional domains. *Multimodal Technologies and Interaction, 7*(5), 52. https://doi.org/10.3390/mti7050052

Panova, T., & Carbonell, X. (2018). Is smartphone addiction really an addiction? *Journal of Behavioral Addictions*, *7*(2), 252–259. https://doi.org/10.1556/2006.7.2018.49

Ponti, M., Bélanger, S., Grimes, R., Heard, J., Johnson, M., Moreau, E., Norris, M., Shaw, A., Stanwick, R., Van Lankveld, J., & Williams, R. (2017). Screen time and young children: Promoting health and development in a digital world. *Paediatrics & Child Health, 22*(8), 461-468. https://doi.org/10.1093/pch/pxx123

Rafiyan, M., Azadchehr, M. J., Fazeli, A. M., & Jalalati, N. (2025). Examining the prevalence of neck and hand disorders and its relationship with smartphone addiction in medical students. *BMC Musculoskeletal Disorders*, *26*(1), 1-7. https://doi.org/10.1186/s12891-025-08809-3

Ramasubramani, P., Vengadessin, N., & Saya, G. K. (2022). Prevalence of Phantom Vibrations and Ringing Syndrome, and its Association with Smartphone Addiction among Medical Students of Teaching Hospital, South India. *Psychiatry: Interpersonal & Biological Processes*, *86*(2), 157–163. https://doi.org/10.1080/00332747.2022.2143143

Rosen, L. D., Carrier, L. M., Pedroza, J. A., Elias, S., O'Brien, K. M., Lozano, J., Kim, K., Cheever, N. A., Bentley, J., & Ruiz, A. (2018). The Role of Executive Functioning and Technological Anxiety (FOMO) in College Course Performance as Mediated by Technology Usage and Multitasking Habits. *Psicología Educativa*, *24*(1), 14–25. https://doi.org/10.5093/psed2018a3

Rozgonjuk, D. (2019). *Problematic smartphone use: behavioral, psychopathological, dispositional, and educational correlates*. http://hdl.handle.net/10062/64579

Rozgonjuk, D., Saal, K., & Täht, K. (2018). Problematic Smartphone Use, Deep and Surface Approaches to Learning, and Social Media Use in Lectures. *International Journal of Environmental Research and Public Health*, *15*(1). https://doi.org/10.3390/ijerph15010092

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness.* The Guilford Press. https://doi.org/10.1521/978.14625/28806

Schomaker, J., & Meeter, M. (2015). Short- and long-lasting consequences of novelty, deviance and surprise on brain and cognition. *Neuroscience & Biobehavioral Reviews*, *55*, 268–279. https://doi.org/10.1016/j.neubiorev.2015.05.002

Shan, Z., Deng, G., Li, J., Li, Y., Zhang, Y., & Zhao, Q. (2013). Correlational Analysis of neck/shoulder Pain and Low Back Pain with the Use of Digital Products, Physical

Activity and Psychological Status among Adolescents in Shanghai. *PLoS ONE*, *8*(10). https://doi.org/10.1371/journal.pone.0078109

Tian, X., Bi, X., & Chen, H. (2023). How short-form video features influence addiction behavior? Empirical research from the opponent process theory perspective. *Information Technology & People*, *36*(1), 387–408. https://doi.org/10.1108/itp-04-2020-0186

Twenge, J. M., & Martin, G. N. (2020). Gender differences in associations between digital media use and psychological well-being: Evidence from three large datasets. *Journal of Adolescence, 79,* 91-102. https://doi.org/10.1016/j.adolescence.2019.12.018

Ubben, M. S., Kremer, F. E., Heinicke, S., Marohn, A., & Heusler, S. (2023). Smartphone Usage in Science Education: A Systematic Literature Review. *Education Sciences*, *13*(4), 345. https://doi.org/10.3390/educsci13040345

Wittmann, B. C., Bunzeck, N., Dolan, R. J., & Düzel, E. (2007). Anticipation of novelty recruits reward system and hippocampus while promoting recollection. *NeuroImage*, *38*(1), 194–202. https://doi.org/10.1016/j.neuroimage.2007.06.038

Appendix A

Informal consent questionnaire for teachers

[] Palun sisesta oma ees- ja perekonnanimi: _______________

[] Käesolev uuring viiakse läbi Teaduskeskus AHHAA ja Tartu Ülikooli koostöös. Uurimistööd juhendab Jaan Aru ning viib läbi Ketlin Kolossov.

Uuringu eesmärgiks on kitsendada praegust teaduskirjanduses valitsevat lünka ning koguda objektiivseid andmeid selle kohta, kuivõrd mõtlevad lapsed nutiseadmete peale kahes erinevas keskkonnas ning kas registreeritud mõtete arv on seotud motivatsiooniga tegevuses osalemisel.

Uuringu käigus palutakse lastel kahes erinevad keskkonnas (AHHAA Teaduskeskus ja kool) kanda kaasas katseseadeldist nimega klikker, mis võimaldab salvestada nupule vajutuste arvu ja kellaaega. Lastele jagatakse juhised klikkeri nupule vajutada iga kord, kui a) mõttesse tekib nutiseade (näiteks tahe nutiseadet praegu kasutada) või b) mõttesse tekib tahtmine olla praegu kodus. Seadeldist palutakse kaasas kanda üks päev osaledes AHHAA õppeprogrammis ning teine päev koolis. Seejärel palutakse lastel vastata lühikesele veebiküsimustikule. **Ühtegi identifitseerimist võimaldavat tunnust katse jooksul ei koguta.** Kõik uuringus kogutud andmed seostatakse omavahel läbi katseseadeldise individuaalse koodi. Küsimustikule vastates ning katses osalemisega nõustumist kinnitades palutakse sisestada vaid klikkeri pealt leitav kood ning kogutud andmed viiakse hiljem tänu koodile omavahel vastavusse. **Õpetajal** palutakse informeerida lapsevanemaid, vajadusel abistada õpilasi ning informeerida uuringu läbiviijat tekkinud muredest ja takistustest. Katses osalemine on **vabatahtlik** ning alati on võimalus katse pooleli jätta. Katse käigus kogutud **andmed ei ole identifitseerimist võimaldavad** ning avaldatakse Tartu Ülikooli uurimistöö raames.

Uuringu käigus tekkinud küsimustega palume pöörduda: ketlin.kolossov@ahhaa.ee
Kinnitan, et olen nõus klassi katses osalemisega ja tutvunud uuringu läbiviimist puudutava informatsiooniga, teavitanud katses osalemisest lapsevanemaid, õpilasi ning kooli personali ja teavitanud katse läbiviijat juhul, kui mõni õpilane katses osaleda ei tohi.

Palun valige ainult üks järgnevatest:
() Jah () Ei

Appendix B

Informal consent questionnaire for pupils

[] Palun sisesta enda klikkeri peal olev kood: _______________

[] Uuring viiakse läbi Teaduskeskus AHHAA ja Tartu Ülikooli koostöös. Uurimistööd juhendab Jaan Aru ja viib läbi Ketlin Kolossov.

Uuringu eesmärk on koguda andmeid selle kohta, kui palju mõtlevad lapsed nutiseadmete peale koolis ja AHHAA-s ning kas see on seotud motivatsiooniga (tahtmisega midagi teha). Uuringus palun sul AHHAA Teaduskeskuses ja koolis kanda kaasas katseseadeldist nimega klikker, mis salvestab nupule vajutuste arvu ja kellaaega. Palun sul vastavalt antud juhistele päeva jooksul nupule vajutada. Seda palun teha üks päev AHHAA õppeprogrammis ning teine päev koolis. Seejärel palun sul vastata lühikesele veebiküsimustikule. Katses osalemine on anonüümne ehk **keegi ei saa teada, mida sina vastasid**.

Katses osalemine on **vabatahtlik** ning alati on võimalus katse pooleli jätta, kui annad sellest teada õpetajale või AHHAA töötajale. Katse käigus kogutud andmed avaldatakse Tartu Ülikooli uurimistöös.

Kui sul tekib uuringu käigus küsimusi, siis anna sellest julgelt märku õpetajale või AHHAA töötajale.

Palun vali "JAH", kui *kuulasid uuringu kohta räägitud informatsiooni ja oled nõus katses osalema.*
Palun vali "EI", kui *sa ei kuulanud või ei ole nõus katses osalema.*

Palun valige ainult üks järgnevatest:
() Jah () Ei

Appendix C

Questionnaire for motivation and relevant variables

1. Palun sisesta enda klikkeri peal olev kood: _______________
2. Palun vali enda sugu:
   - Poiss
   - Tüdruk
   - Ei soovi öelda
3. Palun vali, mis klassis sa käid:
   - 3. klass
   - 4. klass
   - 5. klass
   - 6. klass
   - 7. klass
   - 8. klass
   - 9. klass
4. Kas sul on oma isiklik nutiseade - näiteks telefon või tahvelarvuti?
   - Jah
   - Ei
5. Kui kaua sa arvad, et veedad keskmiselt päevas aega nutiseadmes?
   - rohkem kui 7 tundi
   - 5-7 tundi
   - 3-5 tundi
   - 1-3 tundi
   - vähem kui 1 tund
   - Ei ole nutiseadmes
6. Palun vali, mida sa nutiseadmes kõige rohkem teed:
   - Vaatan lühivideosid (TikTok, Instagram/Facebook Reels...)
   - Vaatan pikemaid videosid, filme/sarju (YouTube, Netflix...)
   - Mängin (Roblox, Brawl Stars, Candy Crush, Block Blast...)
   - Kasutan koolitööks (ChatGPT, Stuudium, E-kool, Google, Safari...)
   - Otsin informatsiooni, mis pole koolitööga seotud (Google, Safari, ChatGPT...)
   - Suhtlen (Messenger, Snapchat, Discord, kõned, sõnumid...)
   - Vestlen niisama tehisaruga (ChatGPT, Snapchat AI, Meta AI...)
   - Ei ole nutiseadmes

7. Palun vali, kui palju sa tahtsid AHHAA saaliülesandeid kaasa teha?
   - o Väga tahtsin kaasa teha
   - o Pigem tahtsin kaasa teha
   - o Ei oska öelda
   - o Pigem ei tahtnud kaasa teha
   - o Üldse ei tahtnud kaasa teha
   - o Ei osalenud
8. Palun vali, kui palju sa tahtsid AHHAA töötoas või planetaariumis kaasa teha?
   - o Väga tahtsin kaasa teha
   - o Pigem tahtsin kaasa teha
   - o Ei oska öelda
   - o Pigem ei tahtnud kaasa teha
   - o Üldse ei tahtnud kaasa teha
   - o Ei osalenud
9. Palun vali, kui palju sa tahtsid koolitundides kaasa teha? *
   - o Väga tahtsin kaasa teha
   - o Pigem tahtsin kaasa teha
   - o Ei oska öelda
   - o Pigem ei tahtnud kaasa teha
   - o Üldse ei tahtnud kaasa teha
   - o Ei osalenud
10. Kas sa oled tundnud, et nutiseade segab sinu koolitöö tegemist?

Näiteks peaksid õppima, aga oled hoopis telefonis.

   - o Jah
   - o Ei
   - o Ei oska öelda
11. Palun vali, kui täpselt sa enda arvates klikkerit kasutasid:
   - o Klikkisin alati, kui mõte tuli
   - o Klikkisin peaaegu alati, kui mõte tuli
   - o Ei oska öelda
   - o Klikkisin vahepeal, kui mõte tuli
   - o Unustasin üldse klikkida, kui mõte tuli
12. Kas klikker segas sinu päeva AHHAA keskuses või koolis?
   - o Jah segas

- Ei oska öelda
- Ei seganud

13. Siia saad kirjutada, kui tahaksid midagi veel öelda:

Kui ei taha midagi öelda, siis vajuta "ESITA".

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Appendix D

The experimental devices

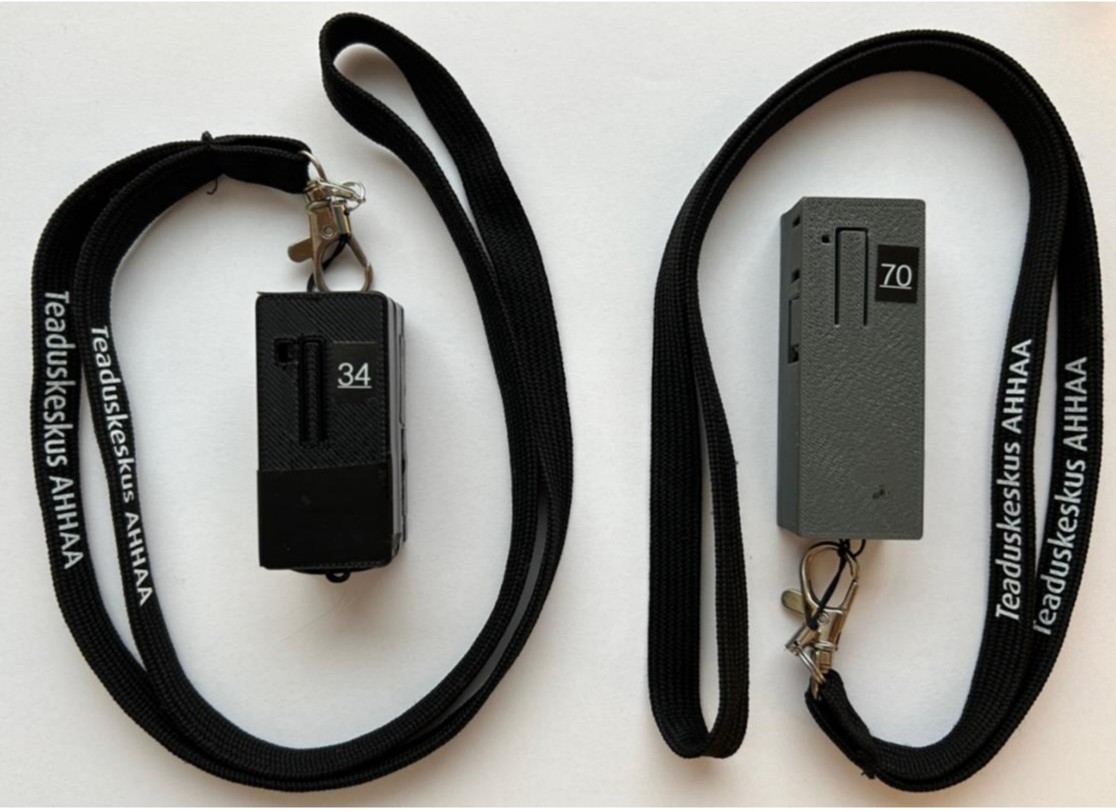

Figure D1. An example of the original experimental device (left) and the renewed experimental device (right).

Käesolevaga kinnitan, et olen korrektselt viidanud kõigile oma töös kasutatud teiste autorite poolt loodud kirjalikele töödele, lausetele, mõtetele, ideedele või andmetele.

Olen nõus oma töö avaldamisega Tartu Ülikooli digitaalarhiivis.

Ketlin Kolossov