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Does the Mere Presence of Smartphones Impact Cognition in the High School Classroom?

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Abstract

The regulation of smartphone use in high schools is a contentious issue. Among others, a key question is whether the location of learners' phones affects their cognitive performance in the classroom. While some studies have found that a smartphone's mere presence can impair cognition, others suggest that the evidence is weak, or that when separated from their phones, adolescents may experience anxiety which can also harm cognitive performance. We conducted two experimental studies at different high schools to test the effects of smartphone location on performance in a fluid intelligence task. Study 1 (n = 195; learner's desk: n = 96; schoolbag: n = 99) was conducted at a boys-only high school, while Study 2 (n = 115; learner's desk: n = 41; schoolbag: n = 49; teacher's desk: n = 25) was conducted a girls-only high school. Both studies were conducted in normal class settings and administered by teachers to enhance ecological validity. Across both studies, we found no clear evidence that having the phone on the desk impaired performance. In some comparisons, learners performed slightly worse when phones were in schoolbags and slightly better when phones were placed on the teacher's desk, but these effects were small and not robust. Learners did not report elevated anxiety when separated from their phones. Overall, our findings highlight the need for further research to clarify whether and how phone location influences cognitive performance in school settings, and to better understand the psychological and attentional mechanisms involved.

Keywords: smartphone; high school; smartphone vigilance; mere presence; separation anxiety; cognition; fluid intelligence

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Introduction

Over the past decade, smartphone ownership and use levels have increased significantly among adolescents (Böttger & Zierer, 2024; Otrel-Cass, 2022), with 95% of US teens reporting that they have access to a smartphone, and 45% reporting that they are constantly online (Anderson & Jiang, 2018). Similar trends have been reported for developing countries (le Roux & Parry, 2022a; Schwaiger & Tahir, 2022). Smartphones, through the key affordances of mobility and persistent online connection, have become constant companions for many adolescents, enabling them to continually monitor and respond to online events and communication (Hartanto & Yang, 2016; Vorderer et al., 2017). For many, these behavioural patterns have cultivated deep attachments to their smartphones which they perceive as a source of security and comfort (Parent et al., 2023).

An important and contentious question which has emerged from this revolution in adolescent communication practices concerns the management of smartphone use in school contexts (Ott, 2017). In recent years, this question has fuelled intense debate about the appropriate policies to be adopted, triggering protests (Rahman, 2024) and various forms of legal intervention (Wikström et al., 2024). On one extreme of the debate, prominent scholars like Jonathan Haidt call for phone-free schools (Haidt, 2023), citing factors like distraction (Anshari et al., 2017; Nikolopoulou, 2020), lower levels of in-person social interaction (Twenge et al., 2019), and problematic forms of social media use like cyberbullying (Cagirkan & Bilek, 2021) as key motivators. A growing list of countries, including France, Spain, Switzerland, Italy, Finland and The Netherlands, have or are in the process of adopting legislation which limits or bans smartphone use in schools.

Countering this position, others have adopted a techno-optimistic stance which values the potential role that smartphones can play in teaching and learning activities. This includes enabling learners to access online content relating to their schoolwork (Gao et al., 2014) and enabling teachers to adopt smartphone applications as part of teaching and learning activities (Grigic Magnusson et al., 2023). Supporting this line of argumentation, a recent systematic literature review found that, when appropriately designed, the adoption of screen-based content can lead to better reading comprehension outcomes than paper-based content (Díaz et al., 2024). Additionally, it has been argued that smartphones promote learner safety in schools by enabling them to stay in touch with parents (Gath et al., 2024). Other scholars have warned that smartphone bans can create an artificial environment in which adolescents fail to learn the important skill of self-regulating their attention and behaviour (Gath et al., 2024; le Roux & Parry, 2019). Between these two extremes exist a range of moderate policy positions in which, for example, learners are allowed to have smartphones on them, but interaction with phones is limited or discouraged by educators (Gao et al., 2014).

An important dimension of the debate concerns the physical location of learners' smartphones during the schoolday. For example, some schools allow learners to bring their phones to school but require them to be stored in a designated location (e.g., phone lockers or "cubbies"; Adams, 2019). The potential effectiveness of such policies should be considered in relation to two key themes in the literature. The first relates to the "mere presence" or "brain drain" effect (Thornton et al., 2014; Ward et al., 2017). This effect involves the potential impact that the mere presence of an individual's smartphone can have on their cognitive ability or performance. While the relevance of this effect for smartphone policy in schools has been acknowledged (Böttger et al., 2023), few studies have tested it in school settings. The second relates to smartphone vigilance which describes an individual's level of cognitive involvement with or orientation towards their online sphere, and the degree to which online events and communication occupy cognitive resources even when the individual is not actively using their phone (Reinecke et al., 2018). Arguably, individuals who display higher trait smartphone vigilance may experience a higher volume of phone-related thoughts when their phones are within their reach (Ward et al., 2017). Additionally, they may experience separation anxiety when their phones are in a removed location (Hartanto & Yang, 2016). Both these effects can potentially impact the individual's attention orientation and/or the availability of cognitive capacity in the moment.

In the present paper we aim to contribute to this literature by addressing the following primary research question: *Does the location of a learner's smartphone influence their cognitive performance in a high school class context?* To address this question, we performed two experimental studies that were conducted at two separate high schools in South Africa to test the effect of phone location on high school learners' (aged 13 to 18) performance in a fluid intelligence task – Raven's standard progressive matrices (RSPM; Raven et al., 1998). The task tests an individual's "capacity to think logically and solve problems in novel situations, independent of acquired knowledge" and performance has been shown to depend upon the current availability of attentional resources (Mani et al., 2013). In both studies, learners were given 20 minutes to solve a selection of 20 RSPM problems within their normal class setting and under the supervision of their teachers. In the first study, 99 learners completed the task with their phones placed on their desks, while 96 learners completed the task with their phones placed in their schoolbags next to their desks. In the second study, the same conditions were implemented with 41 and 49 learners in the desk and schoolbag conditions respectively, while a third group of 25 learners placed their phones in sealed envelopes that were stored on their teachers' desks.

The Mere Presence or “Brain Drain” Effect

Thornton et al. (2014) were the first to investigate whether the mere presence of a smartphone could impair cognitive performance. They proposed that a smartphone, even when not in use, might serve as a subtle cue, reminding individuals of the extensive social networks and information it provides access to. In the first of two experiments, participants completed cognitive tasks with the experimenter’s smartphone placed visibly on the desk in front of them, while a notebook was used in the control condition. In the second experiment, participants’ own smartphones were placed on the desk instead. In both experiments, those in the smartphone condition performed worse on assessments of attentional performance than those in the control conditions, particularly in cognitively demanding tasks.

Adapting Thornton et al. (2014)’s findings, Ward et al. (2017) coined the term “brain drain” to describe how the mere presence of one’s smartphone might attract the orientation of attention, occupy limited cognitive resources, and impair performance on working memory capacity and fluid intelligence tasks, even when the conscious allocation of attention to a primary task is sustained. Ward et al. (2017) argued that because smartphones are highly salient in daily life, individuals must exert cognitive effort to inhibit automatic attention toward them. This inhibitory process, in turn, diverts resources away from concurrent cognitive tasks. Specifically, since both working memory capacity and fluid intelligence depend on available attentional resources, the mental effort required to suppress thoughts about one’s smartphone—or the array of information and social connections it provides access to—can diminish performance on tasks that rely on these cognitive functions.

In two experiments Ward et al. (2017) manipulated the proximity of participants’ smartphones—either on the desk, in a pocket, or in another room—and assessed cognitive performance under these conditions using RSPM, OSpan and Go/No-Go as tasks. Confirming their prediction and supporting the notion that the presence of a smartphone can reduce cognitive capacity, the results showed that participants performed worse on cognitively demanding tasks assessing working memory capacity and fluid intelligence, but not on assessments of sustained attention, when their smartphones were visible.

Building on these papers, numerous studies have investigated the potential cognitive effects that may arise due to smartphone presence (see Hartanto et al., 2024 for a meta-analysis). While some studies have replicated and confirmed the performance impairments linked to smartphone presence, others have found null or conflicting results. In the past two years, three meta-analyses have synthesised the existing research on this topic. Hartanto et al. (2024) pooled 166 effect sizes from 33 studies that assessed performance across a wide variety of cognitive outcomes (e.g., working memory capacity, sustained attention, content retention, fluid intelligence, reading retention, short term memory, mathematics, etc.). Their meta-analysis revealed a small, non-significant effect ($d = -.02$). Although they examined various methodological moderators, none of which proved significant, they did not assess whether performance differed based on the cognitive domain. Similarly, Böttger et al. (2023) conducted a meta-analysis of 44 effect sizes from 22 studies “methodologically similar to the study design of Ward et al. (2017)” (p. 2). Their analysis revealed a small but significant negative effect of smartphone presence across all cognitive functions ($g = -0.14$). When considering particular aspects of cognitive performance, they found a negative pooled effect on memory ($g = -0.23$), but no significant effect for attention ($g = -0.07$) or general cognitive performance ($g = 0.10$).[1]

Finally, Parry (2024) conducted a meta-analysis of 66 effect sizes from 27 studies, focusing on cognitive outcomes that rely directly on limited capacity cognitive resources, such as working memory, sustained attention, fluid intelligence, and inhibitory control. Instead of calculating an overall pooled effect size, Parry (2024) conducted separate meta-analyses for each cognitive function. He found a statistically significant negative effect for working memory ($d = -0.20$) but not for sustained attention ($d = -0.14$) or inhibitory control ($d = 0.05$). While Parry also reported results for cognitive flexibility ($d = 0.09$) and fluid intelligence ($d = -0.18$), these analyses were based on only five and seven effects, respectively. For fluid intelligence, although the two largest studies found negative effects, several smaller studies did not find effects. Additionally, he assessed the evidential value of the existing body of literature on the mere presence effect in terms of statistical power using Quintana (2023)’s metameta approach. The findings indicated that most studies in this area are underpowered, with average power ranging from just 5% to 20% for the observed effect sizes in the meta-analysis.

Taken together, aside from small-to-medium negative effects on working memory capacity, these three meta-analyses suggest that there is only limited evidence supporting negative impacts on cognitive performance due to the mere presence of one’s smartphone. However, while this assessment reflects the current body of evidence, Parry (2024)'s meta-analytic power analyses also reveal that, with few exceptions (e.g., Ward, 2017) most research in this area involves samples far too small to generate informative findings (e.g., most studies involve total samples of between 20 and 50 participants). Additionally, as both Hartanto et al. (2024) and Parry (2024) note, for most cognitive domains, there are simply far too few studies to meaningfully interpret outcomes. For instance, only three studies have followed Ward et al. (2017) in assessing whether the mere presence of one's own smartphone "redirect[s] the orientation of conscious attention away from the focal task" (p. 142) to the extent that it affects performance on fluid intelligence tasks. Despite these limitations, and the absence of ecologically valid research designs, alongside research in other areas, this body of work has been used to motivate calls for bans on smartphones within schools (see e.g., Haidt, 2024). However, as these meta-analyses show, in its present form, it lacks the rigour and maturity to justify policy prescriptions in high school classroom settings.

In a rare study which tested for the effects of smartphone location in a school setting, McKay (2021) assigned 85 high school learners to one of three smartphone location conditions – in their schoolbags in an adjacent room, in their schoolbags next to their desks, or on their desks. While in these conditions, learners completed a reasoning and problem-solving task, a reading performance task, and a digit cancellation task. Her analysis controlled for academic performance, grade level, gender, phone use frequency, media multitasking, phone attachment, and phone dependence. Phone location did not predict performance on the reading and digit cancellation tasks. However, for the reasoning and problem-solving task, learners performed significantly worse when the phone was in their schoolbags next to their desks compared to when it was in another room. In considering her findings, McKay (2021) argues that a learner's familiarity with their phone's present location may be a more important factor than the physical proximity of their phones: "While visibility or proximity may influence conscious thinking about the student's smartphone, it is likely the familiarity of the phone location that generates automatic phone-related cognitions, requiring monitoring and controlled override" (McKay, 2021, p. 137).

Although McKay (2021) offers early insights into high school contexts, empirical evidence on the effects of smartphone presence or separation among learners remains limited. The precise nature, extent, and mechanisms of these potential effects are still unclear. As debates over smartphone use in schools persist, further research is needed to determine whether and how smartphones influence learners' cognitive performance. While lab-based studies provide valuable insights, ecologically valid research in real classroom settings is needed to inform evidence-based policy decisions.

Study 1

In Study 1 we adopted a between subjects design, using cluster randomization to manipulate the presence of participants' smartphones during the completion of a fluid intelligence task. Two smartphone presence conditions were implemented. In the *Bag* condition, participants placed their smartphones in their schoolbags which were placed next to their desks. In the *Desk* condition participants' smartphones were placed on their desks in the top-right corner. While in these conditions, participants completed a fluid intelligence assessment, followed by a short survey on their academic performance and smartphone vigilance. Given the overall trend in findings reported in literature on the mere presence effect, we hypothesised that:

H1: *The presence of participants' smartphones will affect available cognitive capacity to the extent that those in the smartphone absent condition (bag) will perform better than those in the smartphone present condition (desk) in the test of fluid intelligence.*

H2: *Individual differences in the personal relevance of one's phone, operationalized in terms of "smartphone vigilance," will moderate the effects of smartphone presence on fluid intelligence to the extent that individuals who display higher trait smartphone vigilance will be more affected by the presence of their smartphone.*

Method

Following approval by the relevant ethics board, prior to data collection, we preregistered our hypotheses and methods for Study 1 (https://osf.io/nu74q). All data processing and analysis procedures were conducted in R (v4.3.1; R Core Team, 2023). The survey and data processing and analysis scripts can be viewed via the OSF repository (https://osf.io/9h2vg/) but, due to institutional agreements, the underlying study data cannot be publicly shared.

Participants

The study was conducted in March 2024 at a single Afrikaans-medium, boys-only high school in South Africa with a total of around 1,500 learners. The school allows learners to bring their smartphones to school and have them on their person during the schoolday. However, learners are only permitted to use their phones in class with the permission or under the instruction of their teacher. Ten classes participated in the study, with each class having approximately 30 learners. These classes were evenly distributed across the five grade levels (8–12, with learners aged 13–18 in these grades). The study involved two classes from each grade, with one class per grade randomly assigned to each of the two experimental groups. No participant was part of more than one class. All-in, the study involved a potential sample of approximately 300 high school aged boys between the ages of 13 and 18. The total number of classes (clusters) and participants (individuals) was determined by feasibility, as well as the aim to produce informative results (Lakens, 2022).

Prior to the execution of the study, parental consent for learners' participation was obtained. Parents were provided with an information sheet that outlined the study's aims and procedures and were asked to indicate their permission for their child's participation in the study through the completion of an online form. Prior to their participation in the study, a verbal process was followed to obtain learners' consent. Teachers, in accordance with a script provided to them by the researchers, read a description of the study to the learners, and explained to them that their participation was both voluntary and anonymous. Only learners that agreed to participate and for whom parental consent had been obtained, were allowed to complete the study procedures. The final sample included n = 195 high school aged boys, with a mean of 38.8 boys (SD = 9.04) per grade (gr8: 21.65%; gr9: 21.13%; gr10: 11.86%; gr11: 23.71%; gr12: 21.65%) separated into ten classes (two per grade). The *Bag* condition included n = 99 boys and the *Desk* condition included n = 96 boys.

Procedure

On the day of the study's execution, prior to commencement of classes, the researchers met with the teachers responsible for the classes selected for participation in the study. The study procedures were explained to the teachers, and each received a set of written instructions to be followed in their class, together with a printed set of study materials. Upon the commencement of the schoolday, following a short assembly, learners gathered in their classes where the study was performed.

In the class, the teacher, in accordance with the instructions, explained the study procedures to the learners, before following the verbal learner consent procedure. Thereafter, learners that chose to participate in the study were instructed to switch their phones to silent mode with no vibration, or to aeroplane mode, and to then place their phones face-down on the top right corner of their desk (in the *Desk* condition), or in their schoolbags next to their desks (in the *Bag* condition). To ensure that learners' performance and behaviour were not influenced by their knowledge of the different conditions, the overall study goals were not disclosed. Participants were then provided with the study materials which included printed copies of the instructions for the fluid intelligence task, a question book with the RSPMs and a separate answer sheet that also contained the survey questions. Participants were given 20 minutes to complete the RSPMs, after which they were instructed to complete the survey.

Measures

All data was collected via pen-and-paper sheets, with all materials and instructions presented in Afrikaans.

Fluid Intelligence. Building upon previous work in this area (e.g., Ward et al., 2017), we used Raven's Standard Progressive Matrices (RSPM) to assess performance on a fluid intelligence task requiring limited capacity cognitive resources (Raven et al., 1998). Given the manner in which RSPM requires participants to simultaneously process, analyse, and integrate complex patterns and relationships, it exerts pressure on sustained attention, working memory, and problem-solving abilities, and has been shown to be sensitive to fluctuations in the availability of these resources (Ward et al., 2017). Additionally, it has been shown to be sensitive to the individual's ability to suppress extraneous thoughts (Brewin & Beaton, 2002). Ward et al. (2017) only used a 10-item subset of RSPMs, in this study participants were presented with 20 items: 3 each from sets A, B, C, 5 from set D, and 6 from set E. Participants had 20 minutes to complete all 20 items. For each item, the participant is provided with a sequence of shapes with one shape missing and asked to complete the sequence by selecting the correct shape from a set of alternatives. As the participant progresses from items in category A to those in category E, the level of difficulty increases. Scores were calculated as the total number of correctly solved items, with higher scores reflecting better performance on the matrices. The matrices were presented in the form of a “workbook”, with answers provided on a separate answer sheet, along with responses to all other items.

Smartphone Vigilance. To measure smartphone vigilance, we followed other studies (e.g., Koessmeier & Büttner, 2022) and adapted the 12-item Online Vigilance Scale (Reinecke et al., 2018) which assesses individuals’ cognitive preoccupation with their online interactions. In this study, given the target population and setting, we assumed that the participants’ smartphones mediated a majority of their online interactions. Participants rated each of the 12-items on a 5-point Likert scale ranging from 1 (*does not apply at all*) to 5 (*fully applies*). The scale demonstrated good internal consistency (α = .92) and, given Hu and Bentler (1999)’s recommendations and in-line with prior research (e.g., le Roux & Parry, 2022b; Reinecke et al., 2018), model fit was acceptable but not good; $\chi^2(51) = 107.64$, $p < .001$, CFI = 0.94, RMSEA = 0.08, 90% CI [0.06, 0.10] and SRMR = 0.05.

Typical Academic Performance. Participants provided an indication of their typical academic performance across all subjects by selecting the appropriate category between 30% and 90%, with 5% intervals.

Analysis Plan

Following the preregistration, we accounted for data clustering (participants within classrooms) with Linear Mixed Models using Maximum Likelihood estimation. Significance tests for the regression coefficients were calculated using Satterthwaite’s method (Luke, 2017) as implemented in the *lmerTest* package (Bates et al., 2015; Kuznetsova et al., 2017). For H1, we estimated a linear mixed effects model to test the effect of the experimental treatment on RSPM scores. For H2, we tested the interaction between the treatment and smartphone vigilance on RSPM scores with a linear mixed effects model. To control for any potential effects of educational attainment and general academic ability, both models included age and academic performance as control variables. Continuous predictors were centred, and the experimental group was dummy coded. Both models used random intercepts and fixed slopes, and we also estimated them using restricted maximum likelihood (REML) as a sensitivity test. Conditional R^2 was calculated using the *partR2* package (Stoffel et al., 2021) with bootstrapped confidence intervals.

In addition to our pre-registered analysis, we conducted exploratory sensitivity analyses to determine the robustness of the results against a series of alternative analytical specifications. These included multilevel modelling without the academic performance covariate, linear modelling with all covariates, and linear modelling without covariates. For the latter, we used a Welch Two Sample *t*-test and an equivalence test via the TOST procedure, with an alpha-level of .05 and a smallest effect size of interest (SESOI) of $d = .18$. This SESOI simultaneously corresponds to the meta-analytic effect size reported in Parry (2024) as well as the value indicated by the “small telescopes” method discussed by Simonsohn (2015) and Lakens et al. (2018) which involves specifying a SESOI as the effect that an earlier study would have had 33% power to detect. Here, this value corresponds to the effect that Ward et al. (2017) would have had 33% power to detect. This test was implemented using the *TOSTER* package (Caldwell, 2022) and assessed whether the mean difference was equal to 0 (NHST) or more extreme than −.18 and .18 (TOST).

Results

Table 1 provides descriptive statistics for the RSPM, smartphone vigilance scale, and typical academic performance across experimental conditions. Participants in both conditions scored an average of 12 to 13 out of 20 on the RSPMs (see Table 1 for means, and Figure 1 for RSPM distributions by condition and class). There were no significant differences between conditions for smartphone vigilance; $t(185.24) = -1.6$, $p = .110$ or typical academic performance; $t(187.11) = -0.32$, $p = .749$. In the full sample, typical academic performance was positively correlated with RSPM score, and academic grade was positively correlated with smartphone vigilance and negatively with academic performance. No other significant correlations were found (see Table 1).

Table 1. *Descriptive Statistics for Key Study Variables.*

Variable	*Bag* condition		*Desk* condition		Correlations		
	N	*M (SD)*	*N*	*M (SD)*	RSPM	OV	AP
RSPM Score	99	12.38 (2.22)	96	12.95 (1.58)			
Smartphone vigilance (OV)	99	2.01 (0.60)	95	2.16 (0.70)	.04		
Academic performance (AP)	99	70.44 (9.09)	96	70.90 (10.54)	.35***	−.00	
Grade					.12	.26***	−.31***

Note. *** $p < .001$. In the *Desk* condition one participant did not complete the smartphone vigilance scale. Thus, while they were included in the H1 analysis, they were excluded from the H2 analysis.

Figure 1. *Distributions of RSPM Scores for Each Group (Panel A) and Class (Panel B).*

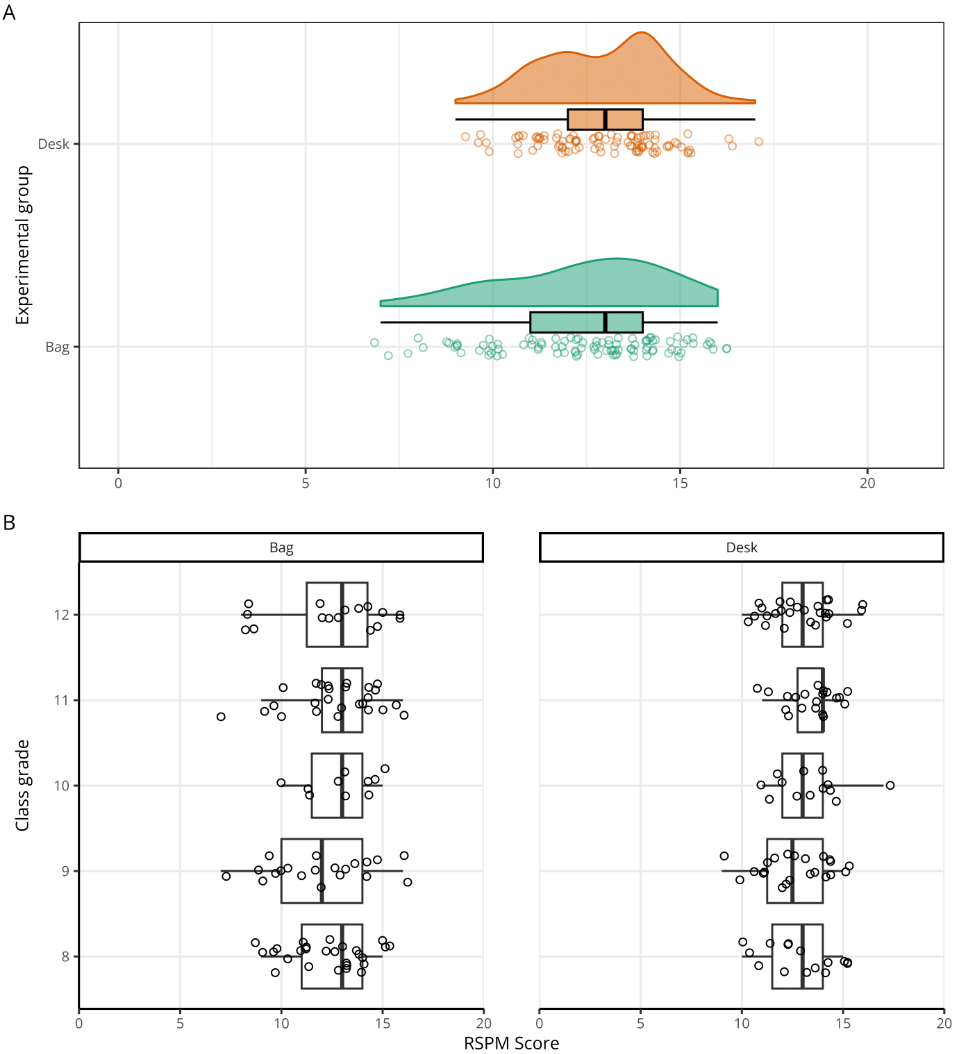


Table 2 summarises Model 1; conditional R^2 = .21, 95% CI [.12, .32], which tested the effect predicted in H1. In this model, only participants' grade level (academic year) and typical academic performance were significant predictors of RSPM scores. Contrary to H1, the experimental condition was not a significant predictor of RSPM score; β = .11, $t(191) = 1.68$, $p = .091$.

Table 2. *Multilevel Regression Predicting RSPM Score.*

Variable	Model 1 (H1)				Model 2 (H2)			
	b	*SE*	β	*p*	*b*	*SE*	β	*p*
Condition	.42	.25	.11	.091	.46	.25	.12	.067
Grade	.30	.09	.23	**.001**	.29	.09	.22	**.002**
Academic Performance	.09	.01	.45	**<.001**	.09	.01	.44	**<.001**
Smartphone vigilance					−.35	.29	−.12	.228
Condition x Smartphone vigilance					.44	.39	.11	.258

Note. β = standardised coefficient. Bold p-values are statistically significant.

In sensitivity analyses, this pattern of results was robust against all alternative analytical specifications assessed (e.g., multilevel modelling with REML estimators; multilevel modelling without the academic performance covariate: β = .13, *p* = .056; linear modelling with covariates: β = .11, *p* = .094). We also conducted an exploratory analysis focusing solely on the effect of condition without the grade and academic performance covariates, using the Welch Two Sample *t*-test (NHST) and an equivalence test via the TOST procedure with an alpha-level of .05 and a SESOI of *d* = .18. The equivalence test was not significant (*p* = .923), while the NHST procedure was significant, *t*(177.321) = −2.09, *p* = .038; mean difference = −0.574 90% CI [−1.03, −0.119]; Hedges's *g*(av) = −0.30 90% CI [−0.532, −0.061]. At the .05 error rate, these results suggest that the true mean difference between groups is not zero (NHST), but since the equivalence test did not confirm equivalence, the statistically significant difference is not practically significant within the specified effect range (equivalence bounds: *d* = 0.18).

To assess H2, we estimated an interaction model to test whether the effect hypothesised in H1 was moderated by smartphone vigilance; conditional R^2 = .22, 95% CI [.14, .34]. As shown in Table 2, the interaction between the experimental condition and smartphone vigilance was not statistically significant; β = .11, *t*(194) = 1.57, *p* = .258, providing no support for H2. This result was robust when assessed in four sensitivity analyses testing alternative model specifications (e.g., multilevel modelling with restricted maximum likelihood estimators; multilevel modelling without the academic performance covariate; linear modelling with covariates; and linear modelling without the academic performance covariate).

Discussion

In Study 1, both H1 and H2 were rejected using the pre-registered analytic strategy that accounted for cluster randomization. Sensitivity analyses confirmed that these results were robust across various analytical specifications. A significant effect of phone location was only found when all covariates (e.g., grade, academic performance, class) were excluded. However, this effect was in the opposite direction of the hypothesis in H1 and, as shown by our equivalence tests, was smaller than the smallest effect size of interest based on previous research (Parry, 2024; Ward et al., 2017). For H2, smartphone vigilance did not moderate the effect, regardless of the analytical approach.

Overall, the results of Study 1 suggest that the *visual* presence of smartphones did not reduce cognitive capacity to the extent that those in the *Bag* condition performed better on the fluid intelligence test than those in the *Desk* condition. However, since these hypotheses were only tested on adolescent boys, it is unclear if the findings would generalise to adolescent girls. Extant findings suggest that girls display higher smartphone attachment (Parent et al., 2023), which may lead to varying effects of phone proximity on cognitive performance. Therefore, further research is needed with a sample that includes adolescent girls to explore whether the observed patterns hold across genders.

The finding that participants in the *Bag* condition performed marginally worse than those in the smartphone-present condition, hints at a potential separation effect. It should be emphasised, however, that the degree of physical separation was low-learners' phones were within easy reach, in their bags next to their desks. Nonetheless, as was found by Hartanto and Yang (2016), the difference in performance may be explained by the negative impact of smartphone separation on executive functions. This suggests that the absence of a smartphone, rather than its mere presence, might cause cognitive disruption.

Study 2

In Study 2, considering our findings in Study 1, we aimed to further investigate the effect of smartphone location on performance in a fluid intelligence task among adolescent girls in a high school context. Given the lack of support for a mere presence effect observed in Study 1, we formulated, firstly, a research question to test the effect of phone location on RSPM performance (RQ1). Like Study 1, we hypothesised that smartphone vigilance would moderate any observed impact of smartphone presence on RSPM scores, with higher smartphone vigilance associated with greater susceptibility to smartphone presence (H1).

Additionally, although the difference was not statistically significant, considering our observation that learners performed better in the *Desk* than the *Bag* condition in Study 1, we adapted the study protocol to investigate whether experiences of phone separation anxiety may explain this observation. To this end, we added a third condition (*Envelope*) to the study. In two studies among undergraduate students in Singapore, Hartanto and Yang

(2016) report increased state anxiety among participants that were separated from their phones during the performance of a colour-shape switching task which, in turn, had a negative impact on inhibitory control and working memory performance during the task. While trait anxiety refers to an individual's tendency to be anxious, state anxiety describes the "psychological and physiological transient reactions directly related to adverse situations in a specific moment" (Leal et al., 2017, p. 148). McKay (2021), similar to Hartanto and Yang (2016), reports a negative effect of phone attachment on performance in tasks with high cognitive load among high school learners who were separated from their phones. She also ascribes the observed effect to heightened anxiety resulting from phone separation. Based on these findings, we hypothesised that participants with greater smartphone separation will experience higher state anxiety than those whose phones are close to them (e.g., on their desk or in their schoolbag next to them) during task execution (H2).

Additionally, we developed a research question to examine whether the potential effect of smartphone separation on state anxiety is moderated by smartphone vigilance (RQ2). Finally, we formulated a research question to investigate whether any observed effect of smartphone separation on task performance is mediated by state anxiety (RQ3). These research questions and hypotheses were preregistered after Study 1 and before data collection for Study 2 (https://osf.io/r2ycn). The survey and data analysis scripts are available via the OSF repository (https://osf.io/m9st7) but, due to institutional agreements, the data cannot be publicly shared.

Method

Participants

The study was conducted at a single English-medium, girls-only high school in South Africa. The school's policy on smartphones allows learners to bring their phones to school and have them on their person during the schoolday, but they are only permitted to use their phones in class with the permission or under the instruction of their teacher. Nine tutorial classes participated in the study, with each class including approximately 30 girls across the five high school grades. Three tutorial classes were randomly assigned to each condition, resulting in a potential sample of about 270 girls aged 13 to 18. After obtaining parental and participant consent and excluding those with incomplete data, the final sample comprised 115 girls, with an average of 23 girls per grade (SD = 3.5; gr8: 19.13%; gr9: 18.26%; gr10: 21.73%; gr11: 24.34%; gr12: 16.52%). The *Bag* condition included n = 49 girls, the *Desk* condition included n = 41 girls, and the *Envelope* condition included n = 25 girls.

Procedure

Study 2 was conducted in May 2024 and followed a similar procedure to Study 1 and. The instructions for the *Desk* and *Bag* conditions were identical to those used in Study 1. For the *Envelope* condition, learners were instructed to place their smartphones in an envelope which was provided to them, seal the envelope, write their names on it, and then place it on their teacher's desk for the duration of the study.

Measures

All measures in Study 2 were exactly the same as Study 1 but were provided in English (smartphone vigilance: α = .92). Alongside these aforementioned measures, Study 2 also assessed state anxiety using the state trait anxiety inventory (STAI Y-6; Marteau & Bekker, 1992).

State Anxiety. In a similar manner to Hartanto and Yang (2016), state anxiety was assessed by asking participants to rate six statements included in the State-Trait Anxiety Inventory (STAI Y-6; Marteau & Bekker, 1992). These items were: *I feel calm*, *I am tense*, *I feel upset*, *I am relaxed*, *I feel content*, and *I am worried*. Statements are rated on a Likert-type scale anchored by 1 (*not at all*) to 4 (*very much*). The *calm*, *relaxed*, and *content* items were reverse coded. The scale demonstrated acceptable, though not good internal consistency (α = .67).

Analysis Plan

Like Study 1, we initially planned to address RQ1, H1, and RQ2 using multilevel modelling to account for the clustering of participants within classes. However, the data collection site did not preserve information on the clusters when the data were collected. This means that we were unable to run the pre-registered multilevel models as originally intended. As a result, we shifted to using our pre-registered sensitivity analyses, which involved linear regression analyses (i.e., ANOVA), as the primary analytical approach.

For RQ1, the effect of smartphone location, we conducted a two-way ANCOVA to predict RSPM scores, using condition as the independent variable and grade and academic performance as covariates. Additionally, we performed a univariate ANOVA with condition as the predictor for RSPM scores. To assess the differences between the levels of the condition variable, we conducted post hoc Tukey HSD tests and equivalence tests (with SESOI: $d = 0.1$). In addressing H1, we estimated two versions of a two-way ANCOVA that included the interaction effect of smartphone vigilance with smartphone location: one that included covariates (grade and academic performance) and another without covariates. Pairwise comparisons between the levels of the condition variable were evaluated using post hoc *t*-tests with equivalence tests (SESOI: $d = 0.1$). For RQ2, we fitted a two-way ANCOVA to predict state anxiety with the interaction between smartphone location and smartphone vigilance and followed up with post hoc *t*-tests, applying equivalence tests to compare condition levels (SESOI: $d = 0.1$).

To test H2, we employed a one-way ANOVA with anxiety as the dependent variable and smartphone separation condition as the independent variable. We also conducted post hoc Tukey HSD tests with equivalence for pairwise comparisons between the levels of the condition variable (SESOI: $d = 0.1$). Finally, if H2 is supported and the analysis for RQ1 shows that participants in the smartphone separation conditions perform worse than those in the presence condition, we planned a mediation analysis to determine whether state anxiety induced by smartphone separation mediates the effect of smartphone separation on fluid intelligence. In this mediation analysis, the desk-level condition would serve as the reference level for comparison with the other conditions. Due to imbalanced group sizes, all analyses were estimated using Type III sums of squares.

Results

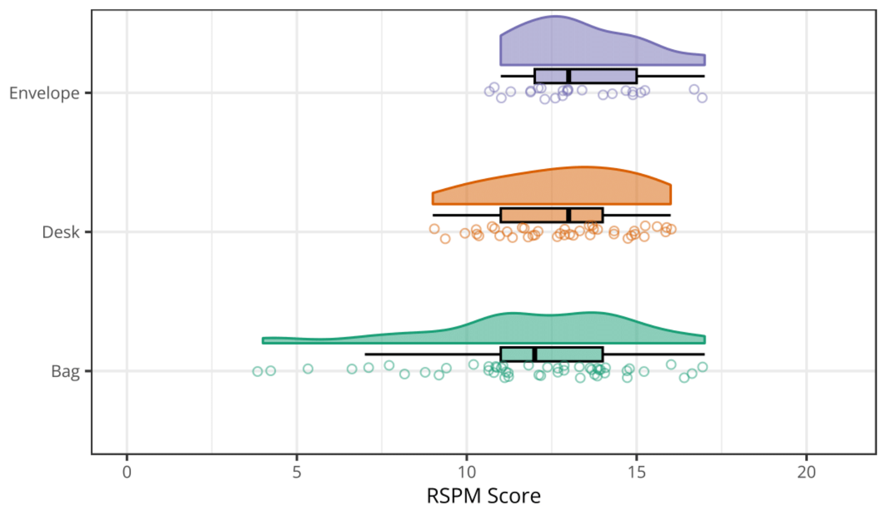
Table 3 presents the descriptive statistics for Study 2, with Figure 2 depicting the RSPM distributions for each condition. Separate one-way ANOVAs show no significant differences between the conditions for academic performance; $F(2, 124) = 0.60$, $p = .550$ or smartphone vigilance; $F(2, 112) = 0.96$, $p = .386$.

Table 3. *Descriptive Statistics for Key Study Variables.*

Variable	*Bag* condition		*Desk* condition		*Envelope* condition	
	N	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*
RSPM Score	49	11.81 (3.09)	41	12.87 (2.00)	25	13.28 (1.75)
Smartphone vigilance	49	2.67 (0.77)	41	2.66 (0.73)	25	2.42 (0.89)
Academic performance	49	68.82 (9.56)	41	68.56 (10.56)	25	71.2 (10.56)
State anxiety	48	2.05 (0.58)	40	1.98 (0.50)	24	2.06 (0.63)

Note. In each condition one participant did not complete the state anxiety scale. These participants are excluded from all analyses involving state anxiety but retained for the rest.

Figure 2. *Distributions of RSPM Scores for Each Experimental Group.*



For the full sample, RSPM scores positively correlated with both academic grade and typical academic performance (see Table 4 for the correlation matrix). In the *Desk* condition, RSPM scores were significantly correlated with academic grade (r = .39, p = .015). In the *Bag* condition, RSPM scores were significantly correlated with academic performance (r = .49, p <.001). In the *Envelope* condition, the only statistically significant correlation was found between state anxiety and smartphone vigilance (r = .54, p = .007).

Table 4. *Correlation Matrix for Key Variables in Study 2.*

Variable	Grade	SV	AP	RSPM	STAI Y-6
Grade	1	—			
Smartphone vigilance (SV)	−.02	1	—		
Academic performance (AP)	−.17	−.12	1	—	
RSPM	.20*	.01	.32***	1	—
State anxiety (STAI Y-6)	−.04	.16	−.03	−.04	1

Note: * p < .05, ** p < .01, *** p < .001.

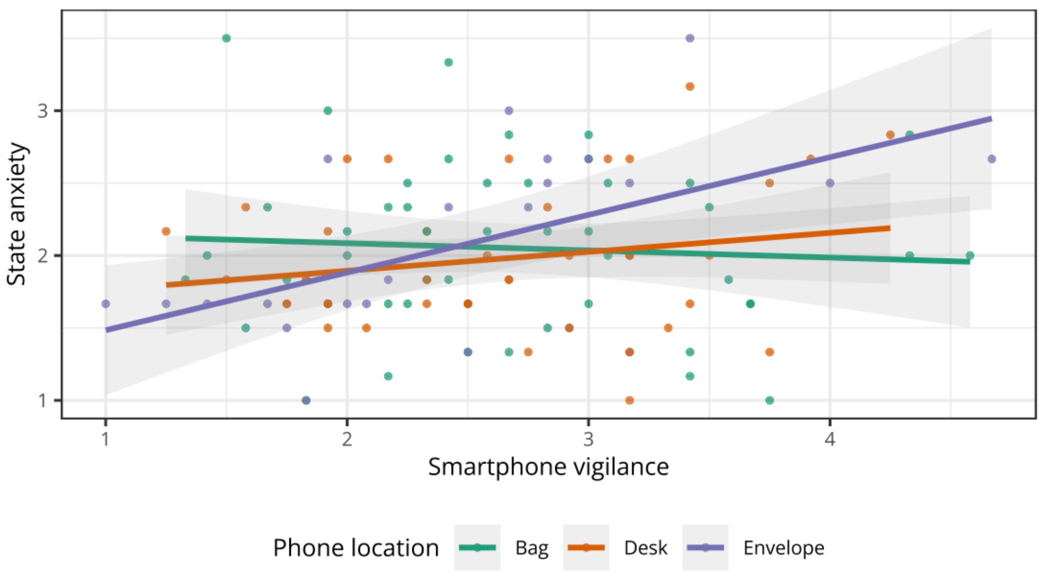
The descriptive statistics reported in Table 3 and the distributions depicted in Figure 2 suggest that there may be an effect of the experimental group on RSPM scores. To examine the impact of smartphone location on performance in the RSPM, we conducted a univariate ANOVA, which found a statistically significant effect of smartphone location on RSPM scores; F(2, 44) = 3.55, p = .032, η_p^2 = 0.06. However, our preregistered sensitivity analysis controlling for grade and academic performance showed a marginal effect, with the p-value close to the conventional threshold for significance; F(2, 30.52) = 2.91, p = .059, η_p^2 = 0.05.

To further investigate the effect of smartphone location on RSPM performance, we conducted Tukey's HSD post-hoc test. The pairwise comparisons did not yield statistically significant results for *Desk-Bag;* t(112) = 2.02, p = .113 and *Desk-Envelope*; t(112) = −0.64, p = .800, but a marginal effect was found for *Bag-Envelope*; t(112) = −2.39, p = .048. Additionally, an equivalence test with bounds of d = 0.1 suggests that we cannot rule out the possibility that the true pairwise effect is larger than the SESOI (*Desk-Bag*: p = .965; *Desk-Envelope*: p = .683; *Bag-Envelope*: p = .986).

Like the findings in Study 1, there was no evidence that smartphone vigilance moderated the effect of phone location on RSPM scores in Study 2. This result remained consistent across various analytic approaches, including a two-way ANCOVA that controlled for grade and academic performance covariates; F(2, 1.89) = 0.18, p = .838, η_p^2 = 0.003, and another two-way ANOVA without covariates; F(2, 7.17) = 0.57, p = .567, η_p^2 = 0.01. Given these outcomes, we did not conduct any post hoc comparisons between the experimental conditions.

In contrast to H2, a one-way ANOVA examining the impact of smartphone location on state anxiety found no significant differences among the locations; F(2, 0.16) = 0.25, p = .772, η_p^2 = 0.01, with participants in the *Desk* (M = 1.98, SD = 0.50), *Bag* (M = 2.05, SD = 0.58), and *Envelope* (M = 2.06, SD = 0.63) conditions all indicating relatively low scores on the STAI Y-6. However, a two-way ANCOVA testing whether smartphone vigilance moderates the effect of phone location on state anxiety (RQ2), revealed a significant interaction effect between phone location and smartphone vigilance; F(2, 2.17) = 3.68, p = .028, η_p^2 = 0.07, as depicted in Figure 3. To further explore this interaction, we conducted an equivalence test on the estimated marginal means (EMMs) from the interaction model, with equivalence bounds set to [−0.1, 0.1]. The results indicated that all pairwise comparisons of EMMs fell within these bounds; *Bag*: t(106) = 26.16, p < .001; *Desk*: t(106) = 22.98, p < .001; *Envelope*: t(106) = 18.92, p < .001. Despite the statistical significance observed in the ANCOVA, as is evident in Figure 3, the equivalence test suggests that the interaction effect between smartphone location and smartphone vigilance on state anxiety is practically negligible.

Figure 3. *Interaction Effect of Smartphone Vigilance and Phone Location on State Anxiety.*



Discussion

Consistent with the findings from Study 1, Study 2 found that learners performed the worst when their phones were placed in their schoolbags next to their desks. Although the difference in performance between the *Bag* and *Desk* conditions did not reach statistical significance (p = .113), the pattern of results suggested slightly poorer performance when phones were in bags. The only statistically reliable difference was between the bag and teacher's desk conditions, with learners performing significantly better when their phones were kept on the teacher's desk.

Taken together, these results suggest that, when compared to the other two phone locations, the mere visual presence of a smartphone on a learner's desk did not negatively impact their cognitive performance during the task, independent of their level of smartphone vigilance. Rather, the pattern hints at a more complex relationship between phone proximity and cognitive availability: moderate separation (such as placing a phone in a nearby bag) may be more disruptive than either full access or complete separation.

Importantly, while the overall analyses indicated some group differences, the post hoc comparisons were inconclusive, and our ability to detect small effects may have been limited by the sample size in each condition.

No clear evidence was found for increased anxiety due to smartphone separation, nor was there consistent moderation by smartphone vigilance. Taken together, the findings remain inconclusive but suggest that the degree of separation between a learner and their phone may matter more than its mere visibility.

General Discussion

The regulation of smartphone use in high school settings has emerged as a contentious issue over the past decade. An important dimension of this debate concerns the physical location of learners' phones during the schoolday, and how this may affect their cognitive availability and performance in class. In the present paper we contribute to this domain by reporting two experimental studies that test the effect of different phone location conditions on learners' performance in a fluid intelligence task while they are in their normal high school class environments.

In accordance with the only other study testing for the mere presence effect among high school learners (McKay, 2021), both our studies failed to support the notion that the visual presence of learners' phones on their desks negatively impacts their cognitive performance when compared to other phone locations, independent of their level of smartphone vigilance. In both studies learners performed marginally worse when their phones were placed in their bags next to their desks and, in Study 2, we observed no significant difference in performance between learners who had their phones on their desks and learners whose phones were placed in envelopes on their teachers' desks. Additionally, learners whose phones were placed on their teachers' desks did not experience raised anxiety. This partly contradicts the findings of Hartanto and Yang (2016) where students whose phones were placed in an adjacent room performed worse and displayed higher levels of anxiety during the task.

While our findings do not support the existence of a mere presence effect, they suggest that phone location may indeed be an important factor to consider when developing in-class policies. Specifically, while a low degree of separation (*Bag* condition) seems to harm performance, more separation (*Envelope* condition) potentially enhances it. In both schools where the studies were conducted, learners typically carry their phones on their person (e.g., in the pocket of their school blazer) and are therefore familiar with always having their phones physically near them. Accordingly, the phone's physical proximity has likely become completely normal to them which may explain the lack of any adverse impact of visual presence on cognition. This aligns with recent findings by Koessmeier and Büttner (2022).

In both studies learners performed worst, though marginally so, when their phones were placed in their schoolbags next to their desks. Considering the distributions of RSPM performance as presented in Figure 1 (Panel A) and Figure 2, the lower mean performance in the *Bag* condition can be attributed, in both studies, to a relatively small collection of very low outliers (i.e., RSPM scores < 8). Interestingly, these outliers are not observable in the other conditions. This pattern in the data aligns with McKay (2021)'s findings and suggests that, for some learners, placing their phone in an unfamiliar location can lead to adverse cognitive effects, potentially due to concern over phone safety. The small sample sizes in Study 2 may have limited our ability to detect any increased anxiety resulting from such concerns. Rather than having a small effect on their overall performance in the task (e.g., RSPM scores 1 SD below the mean), these learners seem to have started the task but, at a certain point, chose to stop trying earnestly to solve the problems (i.e., gave up). It may be the case that, since participation was voluntary and not incentivised in any way, they reasoned that the sooner they finish the task, the sooner they can take their phones from their bags and place it where it "should be" (i.e., in their pockets).

However, this line of reasoning seems to contradict our findings in relation to the *Envelope* condition in Study 2. While this phone location was also unfamiliar to learners, it was associated with the highest performance and no increased anxiety. It may be the case that the *Envelope* condition forced the learners to relinquish their sense access to or control over their phones, while the *Bag* condition presents an "in-between" situation which, while unproblematic for most learners, negatively impacts a small sub-group of learners.

In conclusion, in their totality, our findings align with those of studies which found that the visual presence of a phone does not affect cognitive performance (see Böttger et al., 2023; Hartanto et al., 2024; Parry, 2024 for meta-analyses), while contradicting studies that did find an effect (e.g., Thornton et al., 2014; Ward et al., 2017). However, like McKay (2021), our evidence suggests that, for some high school learners, the location of their phones may indeed impact their cognitive availability. We call for future studies to further investigate which particular aspects of phone location (e.g., familiarity, degree of separation, perception of location safety etc.) explain differences in cognitive outcomes.

Practical Implications

From a high school smartphone policy perspective, it should be emphasised that our findings speak only to physical proximity effects, not to affects that may result from actual instances of off-task phone use (e.g., cognitive switch costs). There may be various positive outcomes associated with policies which impose physical separation which result from other effects. For example, physical separation makes it impossible for learners to use their phones during class, thus curbing off-task use and digital distraction. Additionally, it relieves educators from the burden of constantly policing phone use in their classes, allowing them to focus their energy and attention on teaching and learning. Depending on the nature of the policy (e.g., in-class or central phone locker system), it may still be possible for teachers to distribute smartphones to learners when they want to use them as part of a particular teaching or learning activity. Moreover, our findings also suggest that high school learners do not experience smartphone separation anxiety when their phones are in a secure location in their class.

The finding that learners perform worse when their phones are placed in their schoolbags, may also be of importance from a policy perspective. For example, if teachers, due to fears about cheating, require learners to place their phones in their schoolbags during assessment opportunities, it is possible that some learners may experience cognitive disruption. Our data suggests that, in such scenarios, storing phones in a secure location which is not within the learner's reach may be a better option.

Limitations and Future Research

As noted in our discussion sections, although both studies used samples larger than the average in this domain (see Parry, 2024 for a review), the small sample sizes for the various conditions, particularly in Study 2, may have limited our ability to detect small effects. This applies to effects of phone location on performance, but also on anxiety. Consequently, throughout, our findings are tentative and should be interpreted with care.

While our study design enhanced the ecological validity of our findings by using classroom settings and involving teachers, it has the obvious effect of limiting the degree of control the researchers had over the study conditions. For example, in contrast to a laboratory setting, there may be a broad range of subtle differences across the various classes, or in the ways teachers provided the study instructions to participants. These differences may have impacted learners' task performance in ways that could not be controlled for in the analyses. Furthermore, as would be the case in a lab-setting, the test conditions created when asking participants to complete the RSPM task, may lead to enhanced attention regulation which limits the degree to which our results can be extrapolated to normal lesson settings.

While the results from our two studies are largely congruent, we are mindful that different schools have different norms and values around smartphone use among learners. While the two schools that served as research sites largely aligned in terms of their official (de jure) smartphone policies, these may not accurately reflect how smartphone regulation is enacted at the school (de facto). Accordingly, care should be taken when comparing data across the two studies.

In both Studies 1 and 2, we did not use a control condition in which learners were not given any instructions related to their phones. While this would have meant that learners' phones would have been in their pockets and, therefore, "present", we cannot rule out the possibility that learners in this condition would have performed differently than those whose phones were on their desks, in their schoolbags, or on their teachers' desks. Future studies should address this limitation by including a control condition alongside test conditions.

In Study 1 we did not measure state anxiety among participants and therefore cannot say with certainty that the absence of a smartphone separation effect observed in Study 2, which involved only female participants, will also extend to adolescent boys.

Many earlier studies of the mere presence effect adopted measures of cognition that target particular executive functions (e.g., working memory or sustained attention). Given our aim to perform the studies in normal high school classroom settings, it was not possible for us to implement computer-based tasks that enable targeted executive function measuring. While we believe that RSPM presents a valid and useful measure of cognitive availability and performance, we acknowledge that it limits the conclusions which may be drawn from our findings.

Finally, in line with ethical considerations relating to conducting research among minors, we emphasised the voluntary nature of participation when introducing the study procedures to participants. An unintended consequence of this emphasis may be that some learners exerted little effort during task execution, reflected in RSPM scores below 8 (and even below 5). These scores are unlikely to truly reflect the learners' actual cognitive ability and may have skewed our data as a result. Considering the fairly small size of the various samples, we are mindful of the potential impact of these low scores on our results.

Footnote

[1] Böttger et al. (2023) did not define these categories, specify which tasks belonged to each, nor did they indicate how many effects were included in each category.

Conflict of Interest

The authors do not have any conflicts of interest to report.

Use of AI Services

The authors declare they have not used any AI services to generate or edit any part of the manuscript or data.

Authors' Contribution

Daniel B. le Roux: conceptualization, methodology, investigation, formal analysis, validation, data curation, writing—original draft, writing—review & editing. **Douglas A. Parry:** conceptualization, methodology, formal analysis, validation, data curation, writing—original draft, writing—review & editing. **Jennifer Feldman**: investigation, funding acquisition.

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