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Development of the smartphone and learning inventory: Measuring self-regulated use

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Abstract
Smartphone use in learning environments can be productive or distracting depending upon the type of use. The use is also impacted by the learner's view and understanding of the smartphone and self-regulated learning skills. Measures are needed to specify uses and learner understandings to address the implications for teaching and learning. This study reports on the development of a multi-factor inventory designed to measure multitasking while studying, avoiding distractions while studying, mindful phone use, and phone knowledge. The inventory was completed by 514 undergraduate students enrolled in a first-year seminar. The results indicate good reliability and a three-factor structure with multitasking and avoiding distraction merging into one factor. The resulting measure can support research to improve self-regulation of smartphone use. Suggestions regarding instructional use are provided.

Keywords Smartphones and learning · Self-regulated learning · Mobile learning · Metacognition

1 Introduction

In a recent survey of over 200 first-year seminar college students, 100% of the participants responded 'yes' to the question "Do you own a smartphone?" (Hartley et al. 2020). The mass adoption of a device introduced just over 10 years ago (circa 2007, iPhone introduced) has implications that are only beginning to be understood.

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The distinctly negative consequences for learners are well documented. There is a clear negative correlation between overall smartphone use and achievement (Lepp et al. 2015). The smartphone is easily the most distracting product ever adopted on such a large scale (Alter 2017) and its mere presence can be detrimental to learning (Gazzaley and Rosen 2016). Among many negatives, excessive use can contribute to disconnectedness in the classroom (Soomro et al. 2019) and is the main conduit for cyberbullying (Anderson 2018).

Conversely, the capabilities to support learning provided by such a powerful device seem limited only by human ingenuity. Many students are convinced that the smartphone makes a valuable contribution to their learning (Anshari et al. 2017). And, it appears to be a permanent fixture in the learning environment for students (Anderson and Jiang 2018) and instructors (Ariel and Elishar-Malka 2019).

To better understand the implications for learning, measures are needed to determine how learners are using the smartphone in different contexts. While classroom use has been widely investigated, the use of the smartphone while studying has garnered less attention. The purpose of this study is to report on the development of a survey to measure learners' use of the smartphone while studying, the awareness of the need to manage usage (mindful use), and their knowledge of how to manage relevant phone features such as notification settings. Self-regulated learning theory has proven to be a useful framework for studying learning environments and guided the development of the instrument (Schunk and Greene 2018).

2 Measuring smartphone use

The nature of the smartphone use is an important consideration when studying its implications. The student who, for example, is using the smartphone to better manage their study time can be contrasted with the student who is attempting to simultaneously prepare for an exam and watch gaming videos. A variety of methods are used for measuring smartphone use. Each method presents different opportunities and challenges.

The widely referenced Pew Internet studies use a frequency measure of particular smartphone applications (Anderson and Smith 2018). For example, participants are asked whether or not they use a platform such as Snapchat (yes/no) and then how often they used it (several times a day, once a day, etc). Similarly, The Media and Technology Usage and Attitudes Scale (MTUAS) includes a smartphone use subscale (Terry et al. 2016; Uzun and Kilis 2019). Respondents are asked about the frequency of specific practical uses such as "Browse the web on a mobile phone?" and "Listen to music using a mobile phone?" (Never, once a month, . . . once a day, once each hour . . .). In a study indicating a negative relationship between phone use and academic achievement, Lepp et al. (2015) asked participants to estimate the total time using the phone each day. They asked participants to include all uses except listening to music, thus lumping all uses together. In summary, these popular measures are focused on the general use of the phone and phone applications. The purpose of the use is not measured.

Observing individual and collective use of smartphones is also a common measurement practice. Researchers have used observations to support a better understanding of smartphone use and multitasking. Rosen et al. (2013) observed

15 min study sessions of students and recorded the time spent working on homework. Researchers have also used classroom observations to describe the use and misuse of technology such as school assigned laptops (Donovan et al. 2010). Observations have the advantage of capturing the complex interactions between the learner, teacher, and technology.

A more technical approach to observation utilizes computer software. For example, apps that are installed in the user's phone can directly measure student app usage (e.g., Instant, Space, Moment, and App Usage Tracker). This has the benefit of avoiding errors introduced through self-reports. The challenges inherent in this approach include privacy concerns and a myriad of technical issues. In one example of direct measurement, researchers tracked 43 undergraduate students' smartphone use through the apps Moment (iPhone) or App Usage Tracker (Android). The experiment confirmed earlier findings that more time spent using the phone was negatively related to academic outcomes (Felisoni and Godoi 2018). Given that only 54 out of 250 students agreed to participate in the study, it is worth reviewing expectations placed upon the study subjects. Expectations included technical tasks such as the installation of an app on their personal device, application setup, exporting of the data, and emailing the data to the researchers. In addition, it is reasonable to assume that at least a portion of the non-participants might have security and privacy concerns.

Problematic smartphone use (PSU) and its measurement is a related area of interest in the literature. Numerous measures have been developed to identify usage that has gone beyond typical and has begun to negatively impact family, work, and school (Nayak 2018). Consistent with the purpose, Nayak's measure explicitly moves beyond frequency towards describing more nuanced activities. For example, Nayak asked participants to agree/disagree with statements such as "I am often late for my lectures because I was occupied with my smartphone." Another common measure of PSU is the nomophobia questionnaire (NMP-Q) (Yildirim and Correia 2015), which targets anxiety-inducing characteristics of use. For example, one agree/disagree item states "Running out of battery in my smartphone would scare me."

One PSU study went further by measuring patterns of use (Elhai and Contractor 2018). In this research, participants were classified according to use patterns in areas such as social networking, image/video taking and audio/visual entertainment. In this way, the researchers were able to parse the particular uses that might be associated with PSU. By identifying and utilizing the heterogeneity of use patterns the researchers were also able to specify how the nature of the use impacted the behavior of interest (in this case PSU). While each of these measures serve the intended purpose of identifying PSU, they do not provide information directly related to learning behaviors.

3 The current study

What is missing from each of the aforementioned approaches to measuring smartphone use is the student's intent. From a learning perspective, the student who is using the phone to better manage cognitive resources by utilizing time management features (e.g., scheduling and timers) will likely see some benefit. Unfortunately, less beneficial practices such as media multitasking (e.g., watching videos while studying) appear to be more prevalent. This could be viewed from the perspective of self-regulated learning

(SRL) (Usher and Schunk 2018). The student using the timer to manage study sessions is trying to make efficient use of their limited cognitive resources (Britton and Tesser 1991). The student who fails to see the futility in attempting to watch videos while studying is demonstrating poor cognitive monitoring (Schraw and Dennison 1994). SRL theory also provides guidance regarding the learners' knowledge of their own cognition that may impact the choices they make regarding the use of the smartphone and learning (Schraw and Dennison 1994). What is needed is a measure that translates what is known about effective cognitive behaviors, knowledge, and strategies into specific uses of the smartphone as they relate to or impact learning.

3.1 Study purpose

The purpose of this research is to develop an inventory of smartphone learning practices and understandings that impact learning. The working title of the survey is the Smartphone and Learning Inventory (SALI). This inventory can provide clarity regarding the nature of smartphone use as it relates to self-regulated learning. This research will attempt to determine if phone practices and understandings related to learning can be categorized by common areas of self-regulated learning concepts such as multitasking, avoiding distraction, mindful use, and phone knowledge. The first two concepts, multitasking and avoiding distraction are of particular interest while the learner is studying. The propensity to multitask while gaming for example, is of less concern here. Conversely, mindful phone use and phone knowledge, while likely related to self-regulated learning, can be measured independent of a specific learning context.

3.2 Constructs

Multitasking refers to the common practice of engaging in multiple simultaneous activities (Kirschner and De Bruyckere 2017). In the context of learning, this reflects a belief that while studying, one can engage in secondary activities, without adversely impacting the primary activity. For example, students often report that they watch videos while doing homework. This is not a new activity but its prevalence has increased with the always-present smartphone.

Conversely, avoiding distraction refers to the conscious effort to maintain focus on the object of study. Tactics to avoid distraction while studying include placing the smartphone some distance away from the owner. Avoiding distraction is a self-regulated learning skill that has been classified as cognitive resource management (Pintrich and De Groot 1990). This can also be viewed as a form of conscientiousness (Schneider and Preckel 2017).

Mindful use refers to the conscious management of the smartphone to reduce the negative consequences of its use. A student might, for example, limit the use of the phone during certain times of day. This can be viewed as helpful cognitive resource management as well as knowledge of cognition (Schraw and Dennison 1994). For the purposes of this study, mindful use is a general measure of smartphone awareness that has implications for learning and other aspects of daily life.

A related, albeit less-researched concern, is the learner's *phone knowledge*. In particular, the learner's understanding of how to use notification-related features of the smartphone will impact their capacity to manage interruptions and monitor use. For example, the learner's ability to manage the phone notifications might impact how well they can focus in a study session. Like *mindful use,* this construct is of a more general nature that can be measured without a direct reference to a learning context. In other words, while understanding how the phone works has implications for learning, this knowledge can be measured irrespective of the context.

3.3 Smartphone and learning inventory (SALI)

The current research builds upon a series of survey items used in a previous study to compare student phone use with self-regulated learning skills (Hartley et al. 2020). In that study, undergraduate students enrolled in a first-year seminar course completed an online survey of common phone uses and self-regulatory skills. For that study, nine questions were developed, with three items in each of the areas of a) multitasking while studying, b) avoiding distraction while studying, and c) mindful phone use. The items were reviewed for content validity and clarity by three researchers with expertise in educational technology and learning. Each item used a 5-point fully-labeled Likert response scale: 1) Not at all typical of me 2) Not very typical of me 3) Somewhat typical of me 4) Fairly typical of me 5) Very typical of me.

A subsequent item analysis indicated a high degree of reliability in the areas of avoiding distraction (3 items; $\alpha = .73$) and mindful use (3 items; $\alpha = .72$). The reliability of the multitasking measure was moderate (3 items; $\alpha = .58$). A principal component factor analysis was conducted using varimax rotation and a lower limit eigenvalue of 1. This indicated support for the independence and meaningfulness of the three factors. However, the categories avoiding distraction and multitasking did have three items that cross loaded at −0.200, −0.269, and, −0.211. While these items were retained based upon the loadings being below the recommended 0.3 cut-off, it did raise the possibility that the same construct was being measured (albeit in reverse). Additional evidence was suggested when the two constructs demonstrated similar relationships to the self-regulated learning skills under investigation (Hartley et al. 2020).

Absent from the initial survey items was any measure of the students' knowledge of the related phone capabilities. This may have significant bearing on the assessment of the students' smartphone use as it relates to learning. This may be related to the mindful phone use items. In other words, the learner's mindful use of the phone is in part dependent upon his or her understanding of the features of the phone that may support such use Table 1.

Table 1 Summary scale statistics from initial study (Hartley et al. 2020)

Category	Sample item	No. Items	Mean	S.D.	α
Avoiding distraction while studying	I avoid checking my phone for notifications while studying.	3	8.10	2.61	0.73
Mindful phone use	I pay attention to how much time I spend on different phone applications.	3	7.62	3.22	0.72
Multitasking while studying	I simultaneously watch videos.	3	10.39	2.71	0.58

The initial use of the survey items with a relatively small sample provided promise for the development and evaluation of a fully independent measure of smartphone use as it relates to learning. The current study aimed to complete that development with three significant modifications. First, this study used a much larger sample (514 vs. 227) that will support a more robust analysis of the underlying factors and model testing. Second, this work aimed to provide clarity regarding the independence of measured factors. In particular, the relationship between the behaviors reported while studying, *avoiding distraction* and *multitasking,* were evaluated. Finally, the current study evaluated the efficacy of adding a related smartphone and learning factor to assess the learner's knowledge of relevant smartphone features such as notification management. The outcome is the Smartphone and Learning Inventory (SALI) that can provide researchers and educators with a useful measure of specific behaviors and knowledge that impact learning.

4 Methodology

4.1 Participants

Participants included 514 students (241 female, 273 male) from a research university in the southwest U.S. They were enrolled in a first-year seminar course designed for students exploring their choice of major or students working toward acceptance into their desired major. The ages ranged from 18 to 36 years old with a mean age of 18.39. The study was reviewed and approved by the university's Institutional Review Board.

4.2 Measure

Building upon the items used in the prior research, a substantially revised survey instrument was developed to measure four aspects of smartphone use and knowledge as they relate to self-regulation and learning. The four categories include the previously used three (*avoiding distraction, multitasking*, and *mindful use*) and a new section labeled *phone knowledge*.

As noted above, the categories *avoiding distraction* and *multitasking* are designed to specifically measure behaviors exhibited while studying. The multitasking items were changed slightly to avoid confusion. In the previous study, the multitasking items were presented in a section with the heading "Studying: Rate how typical each of the following activities is for you while studying." However, unlike the *avoiding distraction* items, the *multitasking* items did not specify the studying criteria. For the current study, each multitasking item text was appended with the phrase "while studying."

An additional category, *phone knowledge*, was added to capture the students' understanding of how to operate the phone in a manner that supports focused attention. This category is designed to be distinct from the other behavioral categories although it will inevitably exhibit some overlap. For example, the avoiding distraction (AD1) behavior of ". . . *taking steps to ensure my phone will not interrupt my studying"* will share some variability with the phone knowledge item "*I know how to ensure my phone remains silent."* It is anticipated that the twofold distinction of construct type (behavior vs knowledge) and context (studying vs. general) will result in a suitably distinct parameter as indicated by the factor loadings. Five new items were developed for this category. Given that this category was concerned with knowledge rather than behaviors, a different response scale was needed. For the phone knowledge category, each item used a 5-point fully labeled Likert response agreement scale: 1) Strongly disagree 2) Disagree 3) Neither agree nor disagree 4) Agree 5) Strongly agree.

Also, four new items were added to the inventory (one each in avoiding distraction and multitasking, two in mindful use) in an effort to improve the instrument reliability. All survey items were reviewed by three researchers with expertise in educational technology and learning for content validity and clarity. A complete listing of the items is provided in Table 2.

Table 2 Smartphone and learning inventory (SALI)

Category	*Survey item*	*Item identifier*
Studying: Rate how typical each of the following activities is for you while studying.		
Multitasking while studying	I pay attention to what is happening on social media (e.g., Instagram, Facebook, Snapchat) while studying.	MT1
	I simultaneously watch videos while studying.	MT2
	I respond to direct messages on my phone from friends and family while studying.	MT3
	I check any new phone notifications while studying.	MT4
Avoiding distractions while studying	I take steps to ensure that my phone will not interrupt my studying.	AD1
	I avoid checking my phone for notifications while studying.	AD2
	I occasionally stop studying to look up unrelated information on my phone (reversed).	AD3
	I find the notifications on my phone contribute to my mind wandering while studying (reversed).	AD4
Rate how typical each of the following activities is for you.		
Mindful phone use	I set my phone to silent with no vibration.	MU1
	I set tight restrictions on the apps that are permitted to send me notifications.	MU2
	I pay attention to how much time I spend on different phone applications.	MU3
	I set aside time where I restrict my use of the phone.	MU4
	I use apps that help me monitor my phone usage.	MU5
Rate your level of agreement with the following statements.		
Phone Knowledge (new)	I know how to adjust the notification settings on my phone.	PK1
	I know how to ensure that my phone remains silent.	PK2
	I know how to schedule 'do not disturb' time on my phone.	PK3
	I know how to check how much time I spend on different applications.	PK4
	I know how to restrict an app from sending me a notification.	PK5

4.3 Procedure

Participants completed the inventory as a required activity in class. Enrollees were given the option to not have their responses used for research and publication purposes. Responses from those who chose not to have their data used and/or were under the age of 18 were excluded from the analysis. Participants were asked by the instructor to use an "internet-connected device" such as a smartphone or laptop. The online survey software Qualtrics was used to develop and launch the inventory. Students were directed to a web page that provided an overview of the study and a consent form. Subsequent pages presented the above inventory and several other measures unrelated to the current study. Demographic information was collected from the institutional student information system.

5 Results

5.1 Factor structure

A series of analyses using R with the Jamovi user interface (The Jamovi Project 2019; R Core Team 2018) were conducted to examine the match between identified and proposed factors. An initial review of the survey items revealed substantial kurtosis and negative skewness for the phone knowledge items. Participants expressed near unanimous confidence in their phone knowledge. In some situations, various data transformation techniques to mitigate the violations of normality can be appropriate (Tabachnick and Fidell 2013). However, attempts at applying recommended techniques to this dataset proved unsatisfactory. The phone knowledge items should be interpreted with caution.

An initial exploratory factor analysis using principal axis factoring extraction and varimax rotation was conducted with all 4 item sets. The overall Kaiser-Meyer-Olkin measure of sampling adequacy was .828, well above the recommended .6 (Tabachnick and Fidell 2013). Using an eigenvalue cutoff of one, 3 factors were identified.

The initial analysis revealed high negative correlations between the Avoiding Distraction and Multitasking items. This contrasts with the earlier use of the items and may be a result of rewording of the multitasking items. It was clear that going forward these items should be treated as one factor. The combined factor is labeled 'Focus On Studying'. The multitasking items are reversed in subsequent analyses to ease interpretability (i.e., low multitasking reflects high focus).

A second exploratory analysis using principal axis factor extraction and varimax rotation was completed with the multitasking items reversed (Table 3). The number of factors produced was again based upon eigenvalues greater than 1.

A visual analysis of the resulting scree plot (Fig. 1) provides support for a three factor solution.

The previous analysis revealed that the item "I take steps to ensure that my phone will not interrupt my studying" (AD1) was loading above 0.3 on two factors and was removed from the subsequent analysis. The item "I set my phone to silent with no

Table 3 Factor loadings

	Factor			Uniqueness
	1	2	3	
MT4*	0.823			0.311
MT3*	0.667		0.232	0.499
MT1*	0.665			0.554
AD2	0.550			0.658
AD3*	0.546			0.690
MT2*	0.478			0.766
AD4*	0.441			0.805
AD1	0.436		0.355	0.672
PK5		0.792		0.365
PK1		0.753		0.421
PK4		0.727		0.457
PK2		0.718		0.466
PK3		0.682		0.520
MU3			0.757	0.426
MU4			0.649	0.539
MU5			0.632	0.600
MU2			0.492	0.745
MU1			0.273	0.890
Eigenvalue	3.23	2.19	1.28	
% of Variance	16.1	15.3	11.0	
Cumulative %		29.2	40.8	

Principal axis factoring extraction method was used in combination with a varimax rotation

Loadings are sorted by size. Loadings below .2 are hidden

*Item reversed

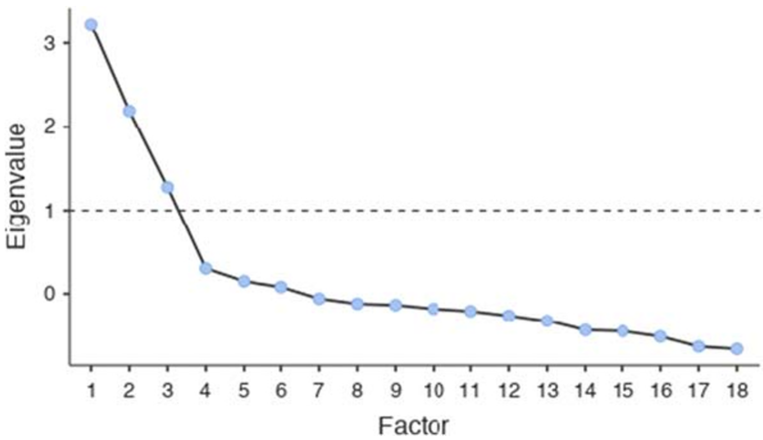

Fig. 1 Scree plot exploratory factor analysis

vibration" (MU1) was also removed as it did not load above .3 on any factor. Otherwise, the three factors and respective indicators from the previous analysis remained the same.

5.2 Model fit

A final confirmatory factor analysis (Table 4) was completed using the Lavaan R: Package with the Jamovi interface (The Jamovi Project 2019; R Core Team 2018; Rosseel and Jorgensen 2018).

The factor covariances indicate a moderate correlation between the focus and mindful use factors (Table 5). The root mean square error of approximation (RMSEA) of .0578 falls below the recommended cut-off of 0.6 and indicative of a good fitting model (Tabachnick and Fidell 2013). However, the comparative fit index (CFI) of .93 falls below the recommended cutoff of .95 (Table 6).

To improve the model fit, a post-hoc analysis of the factor loading modification indices was completed. The largest modification index (MI) value was for the mindful use item #4, "I set aside time where I restrict my use of the phone" (MI = 19.5) loading onto the Focus factor. This item was retained due to the conceptual fit with the mindful use factor and the substantial contribution made to the reliability of the mindfulness factor (.733 with and .671 without). Also, while the item did load with the focus factor on the initial EFA (.198), it was well below the .3 cutoff.

Table 4 Confirmatory factor analysis

Factor	Indicator	Estimate	SE	Z	p	Stand. Estimate
Focus	MT1*	1.000[a]				0.647
	MT2*	0.856	0.0917	9.33	< .001	0.481
	MT3*	1.079	0.0845	12.78	< .001	0.699
	MT4*	1.354	0.0946	14.31	< .001	0.848
	AD2	0.888	0.0854	10.40	< .001	0.544
	AD3*	0.826	0.0796	10.38	< .001	0.543
	AD4*	0.710	0.0807	8.80	< .001	0.450
Mindful	MU2	1.000[a]				0.502
	MU3	1.448	0.1563	9.26	< .001	0.766
	MU4	1.229	0.1385	8.87	< .001	0.645
	MU5	1.243	0.1398	8.89	< .001	0.648
Phone Knowledge	PK1	1.000[a]				0.738
	PK2	0.903	0.0623	14.51	< .001	0.700
	PK3	1.209	0.0853	14.18	< .001	0.684
	PK4	1.394	0.0911	15.30	< .001	0.741
	PK5	1.266	0.0775	16.35	< .001	0.798

*reversed, [a] fixed parameter

Table 5 Factor covariances

		Estimate	SE	Z	p	Stand. Estimate
Focus	Focus	0.53313	0.0711	7.495	< .001	1.0000
	Mindful Use	0.11028	0.0289	3.812	< .001	0.2360
	Phone Knowledge	−0.01525	0.0196	−0.778	0.437	−0.0410
Mindful Use	Mindful Use	0.40950	0.0789	5.189	< .001	1.0000
	Phone Knowledge	−0.00419	0.0181	−0.231	0.817	−0.0129
Phone Knowledge	Phone Knowledge	0.25946	0.0289	8.977	< .001	1.0000

Table 6 Goodness of fit measures

			RMSEA 90% CI	
CFI	TLI	RMSEA	Lower	Upper
0.931	0.918	0.0578	0.0495	0.0662

The next highest MI values were for the phone knowledge items 1 and 2. As indicated earlier, the phone knowledge items suffered from substantial negative skewness. Items one (I know how to adjust the notification settings on my phone) and two (.. . ensure my phone remains silent) were the most negatively skewed items with respondents expressing little doubt that they possess the requisite knowledge. Removing these items has a positive impact on the model fit (CFI improves from .931 to .952). Conceptually, these items add little to the factor given the limited discrimination (i.e., virtually everyone 'strongly agrees'). Removing these items reduces the reliability from .84 to .79. The advantages to removing the items outweigh the negative impact on the reliability.

5.3 Composite scores

The resulting composite scores and properties are presented in Table 7. The 25th and 75th percentile scores can be used to identify high and low scores for each scale. The utility of these scores will be revisited in the discussion. Note that the negative

Table 7 Psychometric properties for SALI scales

	M	*SD*	Range	25th %	75th %	Cronbach's α
Focus	19.9	5.50	7–35	16	23	0.796
Mindful Use	9.7	3.70	4–20	7	12	0.733
Phone Knowledge	13.7	2.25	3–15	13	15	0.792

skewness of the *phone knowledge* items is reflected in the scale score. The 75th percentile is equal to the maximum of the score.

6 Discussion

The purpose of this study was develop a tool to investigate the nature of students' self-regulated use of the smartphone. More specifically, the survey should measure learners' use of the smartphone while studying (focus), their awareness of the need to manage usage (mindful use), and their knowledge of how to manage relevant phone features such as notification settings (phone knowledge).

While contrary to the initial model, the combination of the multitasking and avoiding distraction factors does reflect a compatible conceptual model. Avoiding distraction could be viewed as proactive multitasking avoidance. From a self-regulated learning skills perspective, the learner actions are similar. Mindful use emerges as a robust and independent factor. It does exhibit a modest, and unsurprising correlation with the merged factor focus on studying. Similarly, phone knowledge exhibits strong cohesion and reliability.

6.1 Implications

The resulting three-factor measure has some immediate practical applications. Given that these factors address malleable behaviors (focus and mindful use) and concrete knowledge (phone knowledge), providing customized reports can provide some useful feedback for instructors and students. With a standardized version of the measure, it will be possible to report to students how responses compare to other students. Reports to instructors can provide a context for a discussion regarding the cognitive implications of smartphone use. In particular, the SALI results can encourage reflection on the types of use as opposed to general time using the phone.

Automated reports to students could include targeted interventions. Short-term interventions related to self-regulated learning and have shown promise (Bellhäuser et al. 2016; Bernacki et al. 2019). Responses that fall within the bottom quartile of the *focus* scale could be directed towards a tutorial on the disadvantages of multitasking. A brief mindfulness training has been shown to benefit heavy multitaskers (Gorman and Green 2016). Similar interventions could be designed for those scoring lower on *mindful use*.

The *phone knowledge* factor results can promote an increased understanding of the capabilities of the smartphone. Completing the survey can raise the awareness of the affordances provided to support focused attention.

6.2 Future research

The development of the smartphone and learning inventory has the potential to help address a number of issues regarding learning and smartphones. Preliminary evidence suggests (Hartley et al. 2020) that there are substantive relationships between the factors in this inventory and cognitive constructs such as self-regulatory skills as measured by the Metacognitive Awareness Inventory (Schraw and Dennison 1994) and the Resource Management subscale of the MSLQ (Pintrich et al. 1991). The malleability of these usage patterns, both positive and negative, are important next steps.

Also of future interest is the relationship between the constructs identified here and problematic use measures. The demarcation between typical and problematic use could prove helpful in determining what type of intervention is warranted regarding smartphone use. While SALI is focused on the types of use, it is important to situate that use within a consideration of the overall time on the phone. This is analogous to an individual's overall cholesterol number. While that number is worth knowing, the ratio of *good* to *bad* cholesterol provides more actionable information.

7 Conclusion

The smartphone and learning inventory (SALI) provides a reliable mechanism for ascertaining student smartphone use and understanding as it pertains to learning. The items are grounded in common smartphone uses with suggested links to productive self-regulated learning activities and consequently improved achievement. In other words, the expectation is that higher scores on SALI will have a positive impact on learning outcomes. Further research can now evaluate these associations with a validated instrument at a granular level that was not previously available. It is anticipated that these links will assist with development of evidence-based guidance to learners and educators regarding the productive role of the smartphone as it relates to learning.

The development and validation of SALI represents an important first step in building an understanding of the role of the smartphone in self-regulated learning. The smartphone, or similar yet to-be-developed tools, appear to be permanent fixtures in the learning environment. It is important to determine how these tools are being used while learning.

Availability of data and material All de-identified data and materials are available upon request.

Compliance with ethical standards

Conflict of interest None.

References

Alter, A. L. (2017). *Irresistible: The rise of addictive technology and the business of keeping us hooked* (EBSCOhost, Ed.). New York : Penguin Press.

Anderson, M. (2018). *A Majority of Teens Have Experienced Some Form of Cyberbullying* (Pew Research Center Internet & Technology). https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2018/09/PI_2018.09.27_teens-and-cyberbullying_FINAL.pdf

Anderson, M., & Jiang, J. (2018). *Teens, Social Media & Technology 2018* (may; pp. 1–19). Pew research center. https://www.pewresearch.org

Anderson, M., & Smith, A. (2018). *Social Media Use in 2018*. Pew Research Center. https://www.pewresearch.org, http://assets.pewresearch.org/wp-content/uploads/sites/14/2018/03/01105133/PI_2018.03.01_Social-Media_FINAL.pdf

Anshari, M., Almunawar, M. N., Shahrill, M., Wicaksono, D. K., & Huda, M. (2017). Smartphones usage in the classrooms: Learning aid or interference? *Education and Information Technologies, 22*(6), 3063–3079. https://doi.org/10.1007/s10639-017-9572-7.

Ariel, Y., & Elishar-Malka, V. (2019). Learning in the smartphone era: Viewpoints and perceptions on both sides of the lectern. *Education and Information Technologies, 24*(4), 2329–2340. https://doi.org/10.1007/s10639-019-09871-w.

Bellhäuser, H., Lösch, T., Winter, C., & Schmitz, B. (2016). Applying a web-based training to foster self-regulated learning—Effects of an intervention for large numbers of participants. *The Internet and Higher Education, 31*, 87–100. https://doi.org/10.1016/J.IHEDUC.2016.07.002.

Bernacki, M. L., Vosicka, L., & Utz, J. C. (2019). Can a brief, digital skill training intervention help undergraduates "learn to learn" and improve their STEM achievement? *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000405.

Britton, B. K., & Tesser, A. (1991). Effects of time-management practices on college grades. *Journal of Educational Psychology, 83*(3), 405–410. https://doi.org/10.1037/0022-0663.83.3.405.

Donovan, L., Green, T., & Hartley, K. (2010). An examination of one-to-one computing in the middle school: Does increased access bring about increased student engagement? *Journal of Educational Computing Research, 42*(4), 423-441.

Elhai, J. D., & Contractor, A. A. (2018). Examining latent classes of smartphone users: Relations with psychopathology and problematic smartphone use. *Computers in Human Behavior, 82*, 159–166. https://doi.org/10.1016/J.CHB.2018.01.010.

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.

Gazzaley, A., & Rosen, L. D. (2016). *The distracted mind: Ancient brains in a high-tech world*. MIT Press.

Gorman, T. E., & Green, C. S. (2016). Short-term mindfulness intervention reduces the negative attentional effects associated with heavy media multitasking. *Scientific Reports, 6*(1), 24542. https://doi.org/10.1038/srep24542.

Hartley, K., Bendixen, L. D., Shreve, E., Gianoutsos, D., & Olafson, L (2020, April). Smartphone use and the self-regulated learner: Relationships between type of use and metacognitive factors. Paper accepted (meeting cancelled) for presentation at the annual meeting of the American Educational Research Association, San Francisco, CA.

Kirschner, P. A., & De Bruyckere, P. (2017). The myths of the digital native and the multitasker. *Teaching and Teacher Education, 67*, 135–142. https://doi.org/10.1016/J.TATE.2017.06.001.

Lepp, A., Barkley, J. E., & Karpinski, A. C. (2015). The relationship between cell phone use and academic performance in a sample of U.S. college students. *SAGE Open*, *5*(1). https://doi.org/10.1177/2158244015573169.

Nayak, J. K. (2018). Relationship among smartphone usage, addiction, academic performance and the moderating role of gender: A study of higher education students in India. *Computers & Education, 123*, 164–173. https://doi.org/10.1016/J.COMPEDU.2018.05.007.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33–40.

Pintrich, P. R., Smith, D., Garcia, T., & Mckeachie, W. J. (1991). *Motivated strategies for learning questionnaire manual* (pp. 1–79). https://doi.org/10.13140/RG.2.1.2547.6968

R Core Team. (2018). *R: A Language and environment for statistical computing*. https://cran.r-project.org/

Rosen, L. D., Carrier, L. M., & Cheever, N. A. (2013). Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior, 29*(3), 948–958. https://doi.org/10.1016/J.CHB.2012.12.001.

Rosseel, Y., & Jorgensen, T. D. (2018). *lavaan: Latent Variable Analysis*. https://cran.r-project.org/package=lavaan.

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological Bulletin, 143*(6), 565–600. https://doi.org/10.1037/bul0000098.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*(4), 460–475.

Schunk, D. H., & Greene, J. A. (2018). *Handbook of self-regulation of learning and performance*. Routledge.

Soomro, K. A., Zai, S. A. Y., Nasrullah, & Hina, Q.A. (2019). Investigating the impact of university students' smartphone addiction on their satisfaction with classroom connectedness. Education and Information Technologies, 24(6), 3523–3535. https://doi.org/10.1007/s10639-019-09947-7.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson.
Terry, C. A., Mishra, P., & Roseth, C. J. (2016). Preference for multitasking, technological dependency, student metacognition, & pervasive technology use: An experimental intervention. *Computers in Human Behavior, 65*, 241–251. https://doi.org/10.1016/j.chb.2016.08.009.
The Jamovi Project. (2019). *Jamovi* (Version 1.0) [Computer Software]. jamovi. https://www.jamovi.org/
Usher, E. L., & Schunk, D. H. (2018). Social cognitive theoretical perspective of self-regulation. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 35–51). Routledge. https://doi.org/10.4324/9781315697048.
Uzun, A. M., & Kilis, S. (2019). Does persistent involvement in media and technology lead to lower academic performance? Evaluating media and technology use in relation to multitasking, self-regulation and academic performance. *Computers in Human Behavior, 90*, 196–203. https://doi.org/10.1016/J.CHB.2018.08.045.
Yildirim, C., & Correia, A.-P. (2015). Exploring the dimensions of nomophobia: Development and validation of a self-reported questionnaire. *Computers in Human Behavior, 49*, 130–137. https://doi.org/10.1016/j.chb.2015.02.059.