Smartphone addiction, fluid intelligence and working memory in Mexican students

Adicción al teléfono inteligente, inteligencia fluida y memoria operativa en estudiantes mexicanos

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Keywords
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ABSTRACT

The purpose of this article was to determine the association of the level of smartphone addiction with working memory in university students and fluid intelligence in high school graduates. For this purpose, initial measurements were made with an adaptation of the smartphone addiction scale to measure the former, with complex scope tasks for working memory and with Raven's progressive matrices for fluid intelligence. For this purpose, a descriptive and cross-sectional study was implemented in three groups of Mexican institutions that receive a public subsidy. The sample consisted of 154 participants in total: 65 high school and 89 university students. The average age of high school students was 15.9 years, while the average age of university students was 20.9 years. Of the participants in general, 23% perceived themselves to be addicted, with the most prevalent symptoms tolerance and withdrawal syndrome, and the least prevalent being disregard for the consequences. The results indicate that there was no association between perceived addiction and working memory capacity or fluid intelligence. These findings lead to the development of new studies to determine other harmful effects on the daily lives of Mexican adolescents and young adults.

Palabras clave
Teléfono inteligente;
uso problemático;
capacidades cognitivas;
jóvenes

RESUMEN

El propósito del presente artículo fue determinar la asociación del nivel de adicción al teléfono inteligente con la memoria operativa en universitarios, y con la inteligencia fluida en bachilleres. Para ese motivo, se realizaron inicialmente mediciones, con una adaptación de la escala de adicción al teléfono inteligente, con tareas de alcance complejo para la memoria operativa y con las matrices progresivas de Raven para la inteligencia fluida. Para ello, se implementó un estudio descriptivo y transversal en tres grupos de instituciones mexicanas que reciben subsidio público. La muestra estuvo conformada por 154 participantes en total: 65 de bachillerato y 89 de universidad. En los estudiantes de bachillerato la edad promedio fue de 15.9, mientras que en los universitarios fue de 20.9 años. Del total de participantes, 23% se percibió con adicción, cuyos síntomas más prevalentes fueron tolerancia y síndrome de abstinencia, y el menos prevalente fue el desprecio de las consecuencias. Los resultados indican que no hubo asociación entre la adicción percibida ni con la capacidad de memoria operativa ni con la inteligencia fluida. Estos hallazgos conducen a desarrollar nuevos trabajos para determinar otros efectos nocivos en la vida cotidiana de adolescentes y jóvenes mexicanos.

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INTRODUCTION

Smartphones have added tools and functions that facilitate using the internet for different activities (Weinstein & Siste, 2022). Smartphone use serves multiple purposes, from checking the weather and exploring romantic interests, to checking bank accounts, making online payments and purchases, checking email, and live streaming experiences in real time (Ward *et al.*, 2017). Due to their functions' versatility, productive, recreational and social connectivity, smartphones have become essential in daily life (Afzali, 2022). However, a worrying aspect is its excessive use, which increases its presence in everyday life (Müller *et al.*, 2021), which could generate addiction and affect different aspects of people's lives (Weinstein & Siste, 2022).

There is growing concern about the negative long-term effects that smartphones can have on thinking, memory, attention, and emotional regulation (Wilmer *et al.*, 2017). Evidence that its use can be harmful has led to intense research and debate, where literature suggests that the simple presence of a smartphone causes distraction and reduces attention span, leading to interruptions in daily routine (Afzali, 2022). According to Hartanto *et al.* (2023), inappropriate use of smartphones can affect personal performance, especially in the short term given their distracting nature.

In the development of daily activities, working memory – associated with tasks such as understanding, processing and maintaining objectives when solving problems – and fluid intelligence – related to the development of critical thinking skills and the pool of crystallized intelligence to its subsequent use in the work field –, take on great importance; therefore, the objective of this study is to determine the association of the perceived level of smartphone addiction with the fluid intelligence capacity in high school students and with the working memory capacity in university students. Next, the object of study is introduced, similar previous works are described, the characteristics of the method used, the results, the discussion and the conclusions are presented.

SMARTPHONE ADDICTION

Smartphone addiction is similar to most addictive disorders, but the size and portability make the risks more insidious and dangerous (Lin *et al.*, 2014). Among the research on the negative effects derived from excessive smartphone use is the systematic review of the literature by Amez and Baert (2020), who found a harmful association between the frequency of use and academic success, in individuals between 18 and 29 years old highly dependent, although they recognize the limitation of not inferring causality from this association. In another report, Buctot *et al.* (2020), when evaluating 1,447 Filipino middle school students, determined a high prevalence of addiction (66.2% in males and 60.2% in females). Furthermore, they indicated that smartphone addiction has a negative impact on health-related life quality, for example on physical and psychological well-being, and school environment.

For their part, Cabré-Riera *et al.* (2019) revealed that phone calls, smartphone dependency, and tablet use are associated with sleep problems in adolescents. Likewise, Herrero *et al.* (2019), in their study with 416 Spaniards, with a balanced distribution between men and women, found a negative impact of smartphone addiction on the level of satisfaction in support needs from close colleagues. Boumosleh and Jaalouk (2017), in their work with 688 Lebanese university students, identified several risk factors for this addiction, such as excessive use, personality type, depression, anxiety, and possible lack of social and family support. In the same vein, Kim *et al.* (2018), in their study with 4,854 Koreans between 19 and 49 years old, detected that this addiction has a stronger link with depression and anxiety than internet addiction.

Fluid intelligence

According to Cattell (1987), fluid intelligence represents the ability to reason and find solutions to new problems without resorting to previously acquired knowledge or skills (crystallized intelligence). This ability plays an essential role in various daily activities, such as problem-solving, fostering creativity, and carrying out critical analysis (Cattell, 1963). In a very particular way, students need this intelligence to carry out demanding tasks related to the process of learning new materials (Schwaiger & Tahir, 2022).

Working memory

According to the multiple component model developed by Baddeley (2012), other than being a temporary storage system, working memory (WM) also performs information manipulation functions. The same author defines WM as a hypothetical system that offers temporary storage and manipulation of data, essential tasks to perform a wide variety of cognitive activities.

This model mainly consists of four subsystems: a) phonological loop, b) visuospatial agenda, c) executive central and d) episodic buffer. The phonological loop is responsible for temporarily storing verbal information for processing, playing an important role in learning tasks (Shearer *et al.*, 2021). In theory, this loop is made up of two elements: a phonological store that saves information and an articulatory system that facilitates learning through repetition (Baddeley *et al.*, 1998). For its part, the visuospatial agenda manages visual and spatial information, carrying out its processing and temporal retention (Gómez-Veiga *et al.*, 2013).

The executive central, another main component of the WM, regulates and controls activity in the cognitive system; likewise, it is responsible for selecting appropriate strategies to perform complex cognitive tasks, supervise the use of resources, and monitor information processing. The functions of the executive central include activating and retrieving data from long-term memory, regulating attention, and changing focus during multitasking (Gómez-Veiga *et al*., 2013). Finally, the episodic buffer, from the perspective of Saeed (2011), is responsible for gathering information to create coherent processes, connecting the three previous components and long-term memory, filtering stimuli according to their nature.

Both fluid intelligence and working memory emphasize the ability to select, store, and manipulate information in a goal-directed manner. Both are limited by the availability of attentional resources (Ward *et al*., 2017).

Previous related work

Of the studies in population samples with ages comparable to those on this work that used the same smartphone addiction scale, those that measured the effect of this addiction on intelligence or working memory were found.

Mohta and Halder (2021) conducted a six-month study with one hundred adolescents between 12 and 17 years old, evaluating cognitive, emotional, and social functioning in two groups of smartphone addicts and one control group, excluding individuals with various disorders or other addictions. In addition, they applied the N-Back tests (1-Back and 2-Back) to evaluate WM and the standard progressive matrices test to evaluate intellectual functioning. The results showed that intelligence did not vary significantly between the groups, but smartphone addiction did. The control group made more mistakes in WM, while the smartphone addicts had faster processing. Their findings indicate that addiction to these devices affects the functioning of adolescents, which impacts their psychological development and adaptation to the digital age.

Ward *et al*. (2017) coordinated two experiments to investigate intellectual exhaustion (brain drain) related to the use of the smartphone, because its presence at the table could harm cognitive performance. They used a span of operations task to measure WM and a ten-question subset of the Raven's Progressive Matrices test. The first experiment, with 548 university students, showed that the proximity of the smartphone affected cognitive ability, while the second confirmed these results and analyzed sustained attention, considering the dependence on the phone and its state (silenced or turned off). Both experiments support the fact that the presence of smartphones has a negative impact, especially on those with high dependence; with which they concluded that these devices can reduce cognitive capacity and negatively affect attention.

The study of Mendoza *et al.* (2021) investigated the impact of social media use on episodic and location memory, considering individual factors related to smartphones. A navigation task was applied, it consisted of physically navigating a route within the campus while receiving a variable number of texts. 116 American college students participated and compared chronic and normal smartphone users, as well as high and low distractions in location and landmark memory. The authors found that chronic smartphone use had no significant impact on memory, possibly due to the simplicity of the task. Distractions affected location memory but not episodic memory, as there were no significant interactions; therefore, a direct relationship between chronic smartphone use and memory performance was not found, but the influence of other possible factors was noted.

Likewise, the research of Hartmann *et al.* (2020) sought to evaluate the impact of the smartphone presence on WM capacity, considering dependence on this device and impulsivity. To do this, they used a short-term memory test and another prospective memory test, of their own authorship. 302 Swiss university students participated, and it was found that the presence of the smartphone did not negatively affect short-term memory, since the memory of elements was the same in its presence as in its absence; however, prospective memory was observed to be better when the smartphone was absent, especially in people with low dependency. Therefore, they suggest that smartphone-induced WM problems may not apply to other aspects of memory.

Yaya (2021) researched if taking photos of works of art with a smartphone affected memory. During a visit to a simulated museum, 54 Italian university students, ages 18 to 35, were asked to observe or take photos of works of art. Participants were randomly assigned to three groups: one without taking photos, another with one photo to take, and a third with eight photos. Results indicated that taking photos negatively affects memory when focusing on details, but there were no significant differences in memory between the groups that took one or more photos. In addition, influences were found on metacognitive aspects of memory, such as confidence and retrieval strategies.

From another approach, Dwiggins (2021) researched if the presence of smartphones affected learning, and data from 194 Americans of various ages (between 18 and 70 years old) was used. Participants learned translations from Lithuanian to English in a memory task. This study found no evidence that having a smartphone in sight decreased the number of remembered translations or the accuracy of memory tracking, which is obtained by associating how well someone knows an item (retrospective confidence judgment) with their actual performance (that is, whether the correct translation was provided). There was also no indication that smartphone addiction and location interacted to affect memory or supervisory performance. In summary, the presence of smartphones in the line of sight did not seem to hinder the learning process.

In another study carried out by Hartanto *et al.* (2023), there were three main objectives: 1) to distinguish between normative use (for example, to obtain knowledge or information) and problematic use (excessive use, loss of control, withdrawal symptoms and disorders in daily life) of smartphones; 2) objectively measure smartphone use, along with routine self-assessments, to better understand problematic use; 3) employ a latent variable approach to address problems of task impurity, where studies have consistently reported low associations between tasks measuring executive functions, due to the involvement of non-executive function processes. They worked with 261 university students from Singapore, using complex WM tasks (operations, rotation and symmetry), plus six other measures of executive functions. The results showed that normative smartphone use was not related to deficits in these functions, suggesting that moderate use does not harm the measured abilities.

Schwaiger and Tahir (2022) evaluated how the presence of smartphones affected the performance of 154 Pakistani university students on non-verbal reasoning and attention tasks. To do this, they used Raven's Progressive Matrices test and the Stroop test of colors and words, respectively. They discovered a weak negative correlation between nomophobia (fear of being left without a phone) and fluid intelligence, as the presence of the smartphone did not affect fluid intelligence in experimental conditions. The authors suggest that smartphone addiction and its personal relevance play a more important role in non-verbal reasoning than the mere physical presence of the phone. However, they point out that although this device did not affect basic attention, it hindered performance on more complex attentional tasks.

In a recent study developed by Tu *et al.* (2023), they carried out research with a sample of 156 university participants with problematic smartphone use, on how the restriction of using them at bedtime impacts the WM of the next day. The study was conducted for six days with daily N-back tests, to measure WM, and the results revealed that limiting its use in bed had a positive effect on WM capacity the next day, supporting their hypothesis. This suggests that reducing smartphone use before bed could be a solution to counteract the negative effects on such ability.

As can be seen, there are findings for and against the negative effect of smartphone abuse on capabilities such as those reviewed here. This work has been developed due to the lack of studies identified with a focus on the Mexican population.

METHOD

From a quantitative approach, a descriptive, cross-sectional and prospective study was carried out. The sample, the instruments used, and the procedure followed are described below.

Sample

The study was carried out through non-probabilistic convenience sampling, in groups already formed from three public Mexican institutions, two of them at the university level and the other at the high school level. The inclusion criterion was regular students enrolled in a school year, and the exclusion criterion was those who did not respond to all the planned instruments.

Participants

154 students completed all the tests, of which 65 were high school graduates and 89 were university students. The proportion of women was 42% and 53%, respectively. In the former, the average age was 15.9 years, and, in the latter, it was 20.9 years.

Instruments

Smartphone addiction

The Kwon *et al.* (2013) Smartphone Addiction Scale in its abbreviated version (SAS-SV) was used, adapted to Spanish and validated by López-Fernández (2017) in Spanish university students. The items were modified based on the validations of this adaptation, carried out in a Mexican population with similar ages (Escalera-Chávez and Rojas-Kramer, 2020; García-Santillán *et al.*, 2022), which obtained results that were misaligned with those of López-Fernández (2017).

The first adjustment was the change of the term *smartphone* to *cell phone* and, the second, was the reduction of the text without losing clarity in most items. The instrument consists of ten items with six possible response options, ranging from strongly disagree (1) to strongly agree (6). Out of a total of 60 points, the potential level of excessive use or addiction is predicted to be 31 and 33 for men and women, respectively. The level of risky use or potential risk ranges from 22 points for both genders. In its adaptation, López-Fernández (2017) considered that the scale covers six addiction symptoms: loss of control, family or school disorder, disregard for consequences, withdrawal syndrome, concern and tolerance.

Of the items, numbers 1 and 8 correspond to the loss of control symptom; 2 and 10 to family disorder; 3 and 7 disregard of the consequences; 4 and 5 to withdrawal syndrome; 6 to concern and 9 to tolerance. The score of the respective symptom is obtained by averaging the corresponding items, and to assess its existence, scores greater than three are taken into account. To respond, a previously assigned personal identifier, gender, age and the various uses they gave to the smartphone were requested. From this point on, this instrument is identified with the acronym SAS-SV and the term *cell phone* is used as a synonym for *smartphone*.

Fluid intelligence

The Raven's General Progressive Matrices test was used in its general scale (Raven *et al*., 1996). This test consists of solving 60 problems arranged in five series of twelve, ordered by level of difficulty. The test was incorporated into a course hosted on a Moodle platform. The participant's objective was to choose the correct option among several alternatives, seeking to adequately complete the series of non-verbal patterns in each case. Each participant's score was the number of correct answers (0-60), resulting in direct scores.

Working memory (WM)

Currently, there are several types of tasks to measure WM, such as complex reach, N-back task, and change detection. According to Ellingsen and Engle (2019), in the first ones, participants alternate between memorizing and processing elements, and then recovering the memorized elements. Due to their effectiveness, these tasks were used with stimuli from both domains (verbal and visuospatial), contained in the online NeuronsWorkOut software, validated in Esquivel *et al*. (2018). The tasks consist of three stages: retention, processing and retrieval; each one has four levels with stimuli from two to five and with three trials per level. Before each one, the number of elements is displayed, and at the end, correct, ordered responses, response time, and processing accuracy are recorded. To obtain the memorization score, an approach similar to that of Conway *et al*. (2005) was used, which involves dividing the sum of the quotients (obtained by dividing the ordered responses by the expected responses for the corresponding level) by the total number of attempts. The first three tasks described below include stimuli from the verbal domain and the other three from the visuospatial domain:

- Reading scope: a sentence is presented, and it must be determined whether it is logical or not, followed by a letter to be memorized.

- Operations scope: an arithmetic operation is shown and must be verified if it is correct, and then memorize a word that will show up.

- Counting scope: three-color geometric figures are shown, and participants are asked to verify if the number of blue circles is an even or odd number and memorize the quantity.

- Navigation Scope: An arrow is memorized in one of 16 layouts, while checking whether a dot falls on an outside or inside corner of a capital letter.

- Rotation scope: A letter is displayed in a normal or rotated position and must be indicated if it is rotated, and then an arrow is memorized in a 16-pattern orientation.

- Symmetry scope: a silhouette is formed in a matrix to indicate if it is symmetrical on its vertical axis, and then a red cell is displayed, and its position must be remembered.

Of the instruments described, the cell phone addiction scale was administered to all, the Raven's Progressive Matrices test to high school students, and working memory tasks to university students. To answer, they used their mobile phone and a computer, respectively, according to their academic degree.

PROCEDURE

Sensitization

Participants were informed about the purpose, products, mechanics and duration of the activities. They then signed a letter of informed consent and their access to testing was verified with the data provided.

General application

The sessions were held in computer rooms for university students and in classrooms for high school students. Clear instructions were provided, time allocated, and doubts were answered before beginning each application.

Estimation of cell phone addiction

The SAS-SV scale was applied in a single session, before which they were asked to read each item carefully and respond honestly.

Measurement of fluid intelligence

Before starting, the types of items were explained, an example of an item was solved and any doubts raised were clarified. They were told that they had 40 minutes to solve it and that when they finished, they should remain seated in order to avoid affecting the performance of those participants who continued in the test.

WM measurement

Before the application, students reviewed demonstration videos in a survey that asked, in addition to the perceived level of difficulty, for an explanation of how each test worked. After it was confirmed that everyone had understood it, the tasks were applied interspersed by type of stimulus in two 50-minute sessions.

RESULTS

The data collected from the measurement tasks were processed using SPSS software version 25. Initially, the Kolmogorov-Smirnov statistical test was applied to determine the normality of the data. The findings for each instrument are described below.

Working memory and fluid intelligence

Table 1 shows the descriptive and associative values of the scores per test. Spearman's Rho statistical test was applied due to the non-normal distribution of the data. In addition, the descriptive values are shown by type of domain (VERBAL-WM and VISO-WM), in general (WM) and those related to fluid intelligence (RAVEN). Between the memorization scores of verbal and visuospatial stimuli (VERBAL-WM and VISO-WM), a moderate and highly significant level of association was obtained (rho = 0.430, p < .000). Additionally, age had a significant inverse association with VERBAL-WM and VISO-WM (rho = -.258, p = 0.015 and rho = -.222, p = .038).

As for cell phone addiction, the frequency was determined according to the level of cell phone use from the perspective of educational level and gender (see table 2). Of the participants, 23% were in the potential “excessive use of cell phones” level, of which 42% were women and 58% were men. When comparing averages between participants from both levels of study, a significant difference was found (high school students A = 19.91, SD = 9.619; university students A = 27.20, SD = 9.662; t (152) = -4.63, p < .001). However, in general no difference was found in the averages by gender.

As in López-Fernández (2017), the frequency and incidence percentage per symptom were calculated for the 36 potentially excessive users (see table 3). In general, the most prevalent symptoms were “tolerance” (83.3%) and “withdrawal syndrome” (77.8%), with “disregard of consequences” (33.3%) being the least prevalent.

Table 1. Descriptive and associative values

Measurement	Media	SD	1	2	3	4	5	6
Age	20.87	1.773	$-.241^{*}$	$-.246^{*}$	-0.16	-0.16	$-.282^{**}$	-0.13
1) Counting	0.86	0.116		$.366^{**}$	$.411^{**}$	$.313^{**}$	$.260^{*}$	$.350^{**}$
2) Reading	0.92	0.077			$.579^{**}$	$.455^{**}$	0.15	$.265^{*}$
3) Operations	0.89	0.095				$.431^{**}$	$.295^{**}$	$.276^{**}$
4) Navigation	0.72	0.147					$.461^{**}$	$.405^{**}$
5) Rotation	0.71	0.128						$.555^{**}$
6) Symmetry	0.80	0.118						
VERBAL-WM	0.89	0.074						
VISO-WM	0.74	0.105						
WM	0.82	0.078						
RAVEN	38.85	6.496						

Note: SD = standard deviation.

* p < .05, ** p < .01

Table 2. Distribution of participants by level and gender

	High School students				University students				Total			
	Female		Male		Female		Male		Female		Male	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
No risk	20	(31)	25	(38)	9	(10)	20	(22)	29	(39)	45	(61)
At risk	3	(5)	8	(12)	10	(11)	23	(26)	13	(30)	31	(70)
Excessive	4	(6)	5	(8)	11	(12)	16	(18)	15	(42)	21	(58)
Total	27	(42)	38	(58)	30	(34)	59	(66)	57	(37)	97	(63)

Table 3. Frequency of incidence by symptom and educational level (excessive users)

Symptom	High School students		University students		Total	
	n = 9		n = 27		n = 36	
	n	(%)	n	(%)	n	(%)
1) Loss of control	5	(55.6)	17	(63.0)	22	(61.1)
2) Family or school disorder	4	(44.4)	13	(48.1)	17	(47.2)

3) Disregard of consequences	3	(33.3)	9	(33.3)	12	(33.3)
4) Withdrawal syndrome	7	(77.8)	21	(77.8)	28	(77.8)
5) Concern	6	(66.7)	14	(51.9)	20	(55.6)
6) Tolerance	4	(44.4)	26	(96.3)	30	(83.3)

The same participants indicated various cell phone uses in a proportion ordered from highest to lowest, as mentioned below: social media (24.1%), communication (22.6%), entertainment (19.5%), productivity (18.8%) and internet (15%).

To verify the instrument’s internal consistency level, Cronbach's Alpha test was applied, finding a global value of .871. Table 4 shows the average values for each of the items, the standard deviation and the corrected item-total association. Likewise, because the instrument is a Likert-type scale, and in the absence of normality, it was decided to perform the exploratory factor analysis (EFA) with a polychoric correlation matrix, as in García-Santillan *et al.* (2022). For processing, Factor software version 12 and initially a static Chi Square value was found (Chi2 = 919.8, $p < .000$) with 45 degrees of freedom and a significant determinant value (.002) which indicated that the variables were appropriate to perform an EFA.

Table 4. Item analysis, internal consistency and factor loading.

Item	Average	Standard Dev.	Corrected item-total association	Load	Communality
1) Due to cell phone use, I have stopped doing tasks/activities/works/etc. that I had planned.	2.59	1.444	0.518	0.597	0.356
2) Due to cell phone use, I have had concentration problems while studying or working	2.69	1.518	0.464	0.579	0.335
3) Due to using the cell phone I have felt pain in one of my wrists or neck	2.08	1.482	0.468	0.549	0.302
4) I can't be without my cell phone	2.61	1.754	0.709	0.875	0.766
5) I feel impatient or restless when I don't have my cell phone	2.40	1.611	0.723	0.862	0.743
6) I keep my cell phone in mind even when I'm not using it	2.02	1.416	0.712	0.871	0.759

7) I will never stop using my cell phone, even if it affects my daily life	2.07	1.299	0.57	0.713	0.509
8) I am continually checking my cell phone, so I won't miss conversations on social media	2.49	1.505	0.654	0.759	0.575
9) I use my cell phone more than I had initially anticipated.	2.86	1.526	0.626	0.728	0.53
10) Family or friends tell me that I use my cell phone too much	2.29	1.486	0.460	0.552	0.305

All values of the measure of sampling adequacy (MSA) were greater than .50 (Lorenzo-Seva and Ferrando, 2021) and the Kaiser-Meyer-Olkin test statistic was .88. When reviewing the polychoric correlations, they were all found to be different from zero, and from the EFA a single factor was identified that explained 54.84% of the total variance.

Association between instruments

To find the levels of association between the SAS-SV scale scores and those corresponding to the tests, Spearman's Rho statistic was run due to the distribution of the data. In the case of working memory, no association was found with the score related to cell phone addiction. From this, the average value was obtained (me = 26) to divide the values into two addiction groups (low and high) and verify, using the Mann-Whitney U test, differences between averages of the task scores of WM. Regarding fluid intelligence, no significant association was found with the level of addiction either. Similarly, the average value of this score (me = 17) allowed us to obtain two groups and compare the fluid intelligence averages, with the Mann-Whitney U statistics. At none of the educational levels there was a significant difference found between the average scores of the groups.

DISCUSSION

Smartphone addiction

Regarding the instrument used, the reliability analysis showed a Cronbach's Alpha value close to the one obtained by López-Fernández (2017) in Spanish students (Alpha = .88), and an almost equal range of corrected item-total correlations (.46 to .72). As in their case, the construct validity showed a factor (excessive cell phone use) with a similar total explained variance. Compared to the Spanish sample, this study found some differences; for example, participants identified themselves when responding, the average age was younger, and the sample size was larger. In turn, no significant association was detected between age and the SAS-

SV scale score; the overall average of the scale was higher (24.17 vs. 21.10) and the proportion of participants with excessive use was almost double.

Gender scores did not show significant differences, and the most common symptoms were similar (tolerance, withdrawal syndrome and loss of control), except for the order of appearance of the last two. The university students showed more prevalent symptoms, such as tolerance and withdrawal syndrome, similar to Lin *et al.* (2014). The above, and according to Kwon *et al.* (2013), implies that these participants cannot stop using their cell phone no matter how hard they try, in addition to perceiving themselves as impatient and intolerable when they do not have it and when they use it, and even get upset if someone interrupts them. The latter also applied to high school students in the first place, and secondly the concern about constantly thinking about the cell phone, even when it is not used, according to the same author.

As in López-Fernández (2017), at both levels of study the least supported symptom was "disregard for physical or psychological consequences", which implies that alterations in daily life, such as lack of concentration in class, were little considered, such as lack of concentration during class and ailments resulting from abuse of the device (Kwon *et al.*, 2013). Likewise, perhaps due to the greater availability of internet access that university students had, they reported an addiction higher than high school students, who also thought more about their cell phone, possibly due to the novelty that its use represents.

Fluid intelligence

The average obtained was similar to the study by Guerrero and Esquivel (2023), applying the same instrument to university students from rural communities (38.85 versus 42.13), although they had a sample size of half (33) and using a computer.

Working memory

This work follows the recommendation of Conway *et al.* (2005) of applying multiple WM measurements, since the shared variance between them is a better representation of their capacity. With the use of the same tasks, the results show memorization averages similar to previous studies, including Guerrero and Esquivel (2023) and Esquivel-Gámez *et al.* (2020). As in this last study, a highly significant positive correlation was observed ($r = 0.430$, $p < .000$) and, as in both, in this work a significant positive correlation was found between the stimulus domains, in addition to verbal tests having higher scores, which may be because these tasks involve stimuli related to more advanced skills.

Better performance was also observed at a younger age, although with reservations due to the magnitude of the statistic ($rho < 0.25$). The results may reinforce the idea that problematic smartphone use does not affect attention, in contrast to Ward *et al.* (2017), who used fewer tasks to measure WM and fluid intelligence.

Association between measurements

For high school students, although the average fluid intelligence was lower than in the case of Mohta and Halder (2021), there was also no significant difference in the averages between users who are self-perceived as addicts and as normal. For their part, Schwaiger and Tahir (2022) obtained a small negative correlation between the Raven matrix test score, but with the perception of nomophobia, measured with the NMP-Q scale. Although the average of the test was similar to the one in this study (39.22 versus 38.85), they worked with students from university instead of high school.

As in our research, Hartmann *et al.* (2020), Mendoza (2021), Dwiggins (2021) and in the pretest of Olson *et al.* (2023), no significant association was found between memorization and cell phone addiction scores, using the same SAS-SV scale. Furthermore, Mohta and Halder (2021), with the 2-Back test to measure WM, found more errors in adolescents without addiction, the processing speed was greater in adolescents with addiction and the number of correct answers was similar between both groups.

Hartanto *et al.* (2023), following three measures of WM similar to those in this study, found that perceived normative smartphone use significantly predicted greater WM capacity; instead of the SAS-SV scale, they used the Mobile Technology Engagement Scale (Wilmer & Chein, 2016). Based on those findings, Hartanto *et al.* (2023) point out that it is plausible that the use of social media is positively associated with the level of performance in WM, due to their adaptive functions.

Yaya (2021) found that those who took several photos recognized fewer pieces of art than those who took one or none, but it is necessary to note that a not validated test was used. Finally, it is important to highlight that the participants may have felt watched since they identified themselves when answering the survey on cell phone use, which could have influenced their responses.

Future work

Ward *et al.* (2017) found that the presence of cell phones affects fluid intelligence and working memory; however, Dwiggins (2021) and Hartmann *et al.* (2020) have contradictory findings. Therefore, a similar study is proposed with Mexican students and strategies based on Tu *et al.* (2023) and Olson *et al.* (2023) to reduce the negative effects of cell phone addiction. In addition to using objective measurements on cell phone use, following the approach of Mohta and Halder (2021), it is desirable to evaluate social and emotional functioning. On the other hand, it is necessary to determine the association between the level of cell phone addiction and the level of procrastination to verify its effect on the cognitive abilities reviewed.

CONCLUSION

The adaptation of the SAS-SV instrument for a Mexican sample of students provided adequate results of reliability and validity, which allowed us to continue the search for associations between the measurements carried out. The concern of tutors and teachers about the time that young people use their cell phones is natural, since they fear the harmful effects on various facets of their lives. However, according to some reviewed works, in this study the evidence indicates that there is no association between perceived cell phone use and performance in cognitive abilities. Unlike other analyses, the presence of a cell phone was not manipulated when applying the instruments, since in some cases it was the device used to respond to them.

In this sense, it is considered pertinent to make a proposal. In the scope of this study, after the confinement due to the covid-19 pandemic, some teachers, when trying to continue their practice supported using personal computers by students, found that there was no availability of these resources in their schools. Given this situation, teachers migrated some of the activities carried out on cell phones. This initiative can help train young people to perceive smartphones as their allies in increasing productivity and effectiveness, apart from their entertainment.

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