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**Screen exposure exacerbates impulsivity
indirectly through addiction to internet and sleep disturbance.**

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Abstract

Abundant research has shown that prolonged screen exposure is associated on the one hand to impulsivity and on the other hand to sleep quality. The present study tested individual addiction to internet and sleep disturbance as mediators of the relationship between screen exposure and impulsivity, and this in a general adult population. 482 individuals completed questionnaires measuring their usual exposure of screen devices, as well as their internet addiction, sleep disturbance and impulsivity. The results confirmed the increase in impulsivity with increasing screen time. However, the screen-impulsivity relationship was mediated by the additive effect of sleep disturbance and internet addiction.

Keywords: Screen use; Impulsivity; Sleep disturbance; Internet addiction.

Screen exposure and impulsivity: links through sleep disturbance and addiction to internet.

In 2020, the time dedicated by a typical US adult citizen to watching television or videos exceeded six hours a day (Barwise et al., 2020), constituting around 30% of waking hours. The ever-increasing use of screens raises questions of the consequences on psychological health. Studies have shown that high exposure to screens is associated with a higher level of impulsivity (Gentile et al., 2012; Montagni et al., 2016). Recent reviews have further highlighted a link between internet addiction and impulsivity on the one hand (Lee et al., 2019), and sleep disorders and impulsivity on the other hand (Gillett et al., 2021). The goal of the present paper was to test a serial mediation model in which internet addiction and sleep disturbance explain the relationship between screen time and impulsivity.

Several studies have indicated that prolonged exposure to screens by individuals increases their levels of inattention and impulsivity, regardless of whether the screens in question are televisions (David Acevedo-Polakovich et al., 2007; Christakis et al., 2004; Johnson et al., 2007; Landhuis et al., 2007; Mistry et al., 2007), smartphones (Grant et al., 2019; Kim et al., 2014; Peterka-Bonetta et al., 2019) or video games (Bioulac et al., 2008; Chan & Rabinowitz, 2006; Gentile et al., 2012; Swing & Anderson, 2014; Irless & Gomis, 2016). The considerable increase in the diagnosis of Attention-Deficit Hyperactivity Disorder (ADHD) in recent decades has thus been explained by different authors with reference to excessive screen use (Beyens, Valkenburg & Piotrowski, 2018). This may be due, at least in part to the fast-paced media that forces subjects to repeatedly/constantly shift their attention and renew their orienting responses, meaning they develop a cognitive style of impulsivity (Nikkelen et al., 2014).

Cognitive impulsivity is defined as “the inability to inhibit behavioural impulses and thoughts” (Bakhshani, 2014, p.1). It is usually assessed using self-reported questionnaires such as the Barratt Impulsiveness Scale (BIS) (Patton et al., 1995). In the BIS, impulsiveness results from three different dimensions, named Motor Impulsiveness, Attentional Impulsiveness and Lack of Planning. In the present work, the focus has been placed on the sub-component of Attentional Impulsiveness (problems related to concentrating and paying attention), since it is the dimension which seems to be most affected by screens. Indeed, neuroscience studies have shown that the prolonged use of screens has a direct effect on the brain since it reduces the

number of dopamine D2 receptors (Kim et al., 2011), and that this brain change is directly associated with attentional impulsiveness on the Barratt Impulsiveness Scale (Taylor et al., 2018).

Impulsivity is also a hallmark of addiction (Ersche et al., 2005; Garavan & Stout, 2005, Wilson et al., 2007). Choudhary and his colleagues (2022) recently found that adolescents and children may have aggressive behaviour and screen time was a significant predictor. In the public health field, a screen dependency disorder has been identified that corresponds to screen addictive behaviour which results in a misuse of screens beyond the normal level (Crunelle et al., 2013). Cao and colleagues (2007) reported a direct link between impulsivity scores and scores on the Internet Addiction Test. In this test, the Internet refers to all web-based service activities, therefore including the digital activities that are performed on many kinds of devices (computers, screens, connected devices, smartphones, and other forms of technology) (Young, 2009). Subjects with internet addiction disorder show modulations in the activation of the striatum, prefrontal cortex, and insula in comparison to control individuals, i.e., there are changes to the cerebral structures involved in cognitive and motor impulsivity in people suffering from internet addiction (Dalley et al., 2011; Liu et al., 2017, Tanaka et al., 2016). In summary, an individual's internet addiction scores could be a significant factor mediating the effect of screen time on the individual's impulsivity trait.

There is evidence supporting an association between internet addiction and sleep which in turn can cause or amplify impulsivity. Specifically, research has revealed that various forms of internet addiction are linked to sleep problems (Wong et al., 2020). Moreover, this relationship between internet addiction and sleep problems has been observed in diverse populations (Chang et al., 2022; El Abiddine et al., 2022; Lin et al., 2021; Saffari et al., 2022; Tahir et al., 2021; Wong et al., 2020). Additionally, sleep disturbance has been found to be associated with symptoms of internet addiction (Schierenbeck et al., 2008; Wong et al., 2009). Notably, a recent study discovered a direct positive correlation between social media usage and sleep disturbance (Kwok et al., 2021). On the one hand, it is well established that the light emitted by monitors modulates the healthy production of melatonin (Higuchi et al., 2003; Wood et al., 2013), leading to circadian rhythm disorders and insomnia (Cajochen et al., 2011; Figueiro & Rea., 2010; Green et al., 2017; Münch et al., 2006). This has been shown regardless of the content of the screen activity or the screen type (American Academy of Pediatrics, 2001). On the other hand, higher levels of sleepiness have been found to produce higher personality-related impulsiveness (or higher ADHD symptoms), as well as attentional emotional difficulties

(Lim & Dinges, 2008; Lin et al., 2019). A recent study on a population of children run by Cavalli et al. (2021) demonstrated that screen consumption exacerbates ADHD symptoms, but that this effect was effectively mediated by sleep disturbance.

To the best of our knowledge, no study to date has simultaneously worked on the link between screen consumption, internet addiction, sleep disturbance and impulsivity. The aim of the present study was therefore to bring this gap by proposing a serial mediation model. We expected that (1) longer screen exposure would be related to higher impulsivity scores, but also that (2) this link would be partially or fully mediated by internet addiction and sleep disturbance, and that internet addiction would be associated to an increase sleep disturbance, with the latter amplifying the impulsivity score. The originality of the present study lies in the sample of neuro-typical adult subjects, while the majority of the studies in the literature were carried out on a clinical sample and/or on children with developmental issues. Thus, we can provide a novel examination of the psychological consequence of screen exposure time with cognitive measures which could be generalised to the whole adult population and allow general preventive actions.

Method

Population

The sample consisted of 482 participants, 256 of whom were female (74%). The participants were aged from 18 to 61 years ($M = 24.35$, $SD = 8.67$) and were recruited in the French universities of Clermont-Auvergne, Poitiers and Lyon, in exchange for course credit for their participation. Participants gave their consent via an electronic form presented at the beginning of the experiment. This study was approved by the IRB-UCA research ethical committee [IRB00011540-2021-02].

Material and measurements

The survey was conducted using Qualtrics® electronic survey software, which randomly recorded the participants' responses and delivered the four questionnaires assessing (1) time exposure to screens, (2) impulsivity, (3) internet addiction and (4) sleep quality.

In order to measure screen exposure time, participants were asked to estimate the time they had spent in front of five types of screens: televisions, connected devices (streaming, video game consoles), computers, smartphones and tablets. Each of the participants made estimates in hours and minutes, using the numeric keypad for each of the devices, for a typical weekday

and a typical weekend day. The screen time used in our study was the average of screens over a week ($5 \times \text{estimate}_{\text{weekday}} + 2 \times \text{estimate}_{\text{weekendday}}/7$). An additional paired t-test demonstrated no significant difference between the screen time exposure estimate based on a typical week day and that of a typical week-end day ($p > .05$). This variable was therefore not considered in subsequent analyses.

Impulsivity was measured using the Barratt Impulsiveness Scale 15 (Spinella, 2007; adapted in French by Rousselle & Vigneau, 2016), which is a short version of Barratt's original scale (Patton et al., 1995). This scale is a self-reported questionnaire consisting of 15 items scored from 1 to 4 with 1 = rarely / never, 2 = sometimes, 3 = often and 4 = almost always / always. Scores range from 15 to 60, with higher scores reflecting greater impulsiveness. The internal consistency of this measure in the present study was robust ($\alpha = .80$). The scale also contains three subscales representing *motor impulsivity*, *lack of planning* and *attentional impulsivity*, with satisfying or passable consistency ($\alpha = .71$ (motor impulsivity), $\alpha = .71$ (lack of planning), and $\alpha = .68$ (attentional impulsivity), as the Cronbach's alpha was superior to .60 (Griethuijsen et al., 2014).

For addiction to screens, we used the French version of the Internet Addiction Test (IAT) (Young, 1998; adapted in French by Khazaal et al., 2008). Each statement is weighted in a 5-point Likert-scale (score from 1 "rarely" to 5 "always"). The higher the score, the greater the problems caused by internet usage. This variable was used as a continuous factor. According to Young (1998), scores ranging from 20 to 39 points indicate "no problems" for the user, from 40 to 69 mean "frequent problems", and from 70 to 100 "significant problems". The internal consistency of this scale has been shown to be very satisfactory: $\alpha = .86$.

The sleep quality was assessed using the French version of the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989, adapted in French by Blaise et al., 1997). This is a 19-item self-reported questionnaire composed of seven dimensions: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) sleep efficiency, (5) sleep disturbances, (6) use of sleep medication and (7) impairment of daytime functioning. Each dimension is scored on a scale from 0 to 3, with higher scores indicating more severe problems. The internal consistency of this test was barely acceptable: $\alpha = .64$.

Results

Table 1 shows the descriptive results for screen time and neuropsychological measures and Table 2 indicates their correlations. Table 2 suggests high correlations between the different variables. As we expected, the impulsive dimension found to be most modulated by screen exposure was that of Attentional Impulsivity, $\beta = .21$, $ES = 0.0001$, $t = 4.79$, $p < .001$. The higher the screen exposure, the higher the attentional impulsivity. It should be noted that the other variables were also significantly modulated by screen time exposure (BIS Score: $F(1, 474) = \beta = .19$, $ES = 0.001$, $t = 4.25$, $p < .001$, Non-Planning: $\beta = .10$, $ES = 0.0001$, $t = 2.18$, $p = .03$; Motor Impulsiveness: $\beta = .13$, $ES = 0.0001$, $t = 2.80$, $p = .005$). Therefore, in the subsequent statistical analysis, we decided only to use the Attentional Impulsivity score.

Table 1. Mean, Standard Deviation, Minimum and Maximum of raw scores of screen time and of different neuropsychological measures.

	M	SD	[Min;Max]
Screen time (min)	699.53	336.22	[33;2841]
Screen time week day	708.46	387.51	[40;3570]
Screen time week-end day	677.22	370.26	[4;2400]
BIS	29.95	7.67	[15;51]
BIS – Motor Impulsivity	10.15	3.43	[5;20]
BIS – Lack of Planning	10.44	3.59	[5;20]
BIS – Attentional Impulsivity	9.36	3.26	[5;19]
IAT	42.73	11.41	[20;82]
PSQI	6.44	3.11	[0;18]

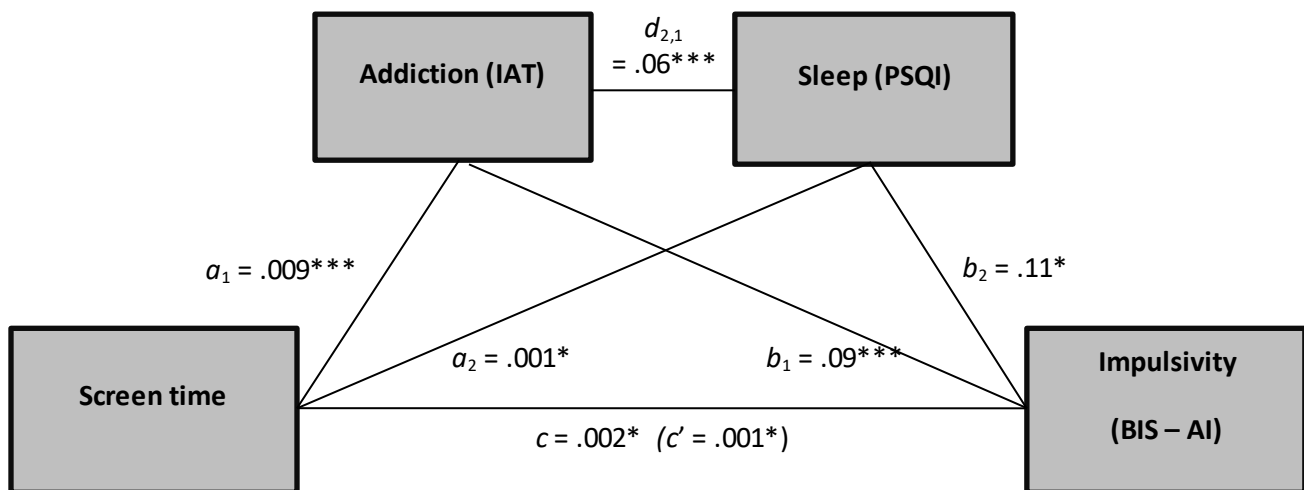
Table 2. Table of correlations of the variables.

Variable	1	2	3	4	5	6	7	8	9
1. Screen Time									
2. Screen time week day	.95***								
3. Screen time week-end day	.67***	.43***							
4. BIS	.19**	.17***	.17***						
5. BIS- Motor Impulsivity	.13**	.10*	.14**	.77***					
6. BIS – Lack of Planning	.10*	.08	.10*	.73***	.33***				
7. BIS – Attentional Impulsivity	.21***	.20***	.15**	.76***	.43***	.31***			
8. IAT	.29***	.22***	.34***	.41***	.28***	.28***	.38***		
9. PSQI	.16***	.13**	.17***	.20***	.14**	.14***	.20***	.24***	

Note. * $p < .05$; ** $p < .01$; *** $p < .001$

The serial mediation model of the roles of internet addiction (IA) and sleep quality (PSQI) on the direct effect of screen time on impulsivity was thus tested using Process SPSS macro model 6, and a bootstrap sample of 5000 (Praicher & Hayes, 2008). The serial mediation diagram is exposed Figure 1. First, there was a significant direct effect of screen time on the Attentional Impulsivity scores, $B = 0.002$, 95%CI [0.0012, 0.0029], $p < .001$. However, screen time was also associated with the IAT scores, $B = 0.01$, 95 CI [0.0063, 0.0122], $p < .001$, and the PSQI scores, $B = 0.001$, 95%CI [0.0063, 0.0122], $p < .04$. In addition, both the IAT and the PSQI scores were significantly linked with the Attentional Impulsivity scores ($B = 0.09$, 95%CI [0.0666, 0.1175], $p < .001$ and $B = 0.11$, 95%CI [0.019, 0.200], $p = .018$, respectively).

The serial mediation model revealed that the significant effect of screen time on Attentional Impulsivity decreased when the two moderators (IA and PSQI) were taken into account, $B = 0.002$, 95%CI [0.0002, 0.0019], $p = .015$, although it remained significant. Preacher and Hayes's bootstrap method confirmed the significance of the indirect effect of IAT ($B = 0.001$, 95%CI [0.0005, 0.0013]) and PSQI ($B = 0.0001$, 95%CI [0.0000, 0.0003]), and both simultaneously ($B = 0.0001$, 95%CI [0.0000, 0.0001]) on the relation between screen time and Attentional Impulsivity.



* $p < .05$; ** $p < .01$; *** $p < .001$

Figure 1. Dual mediation diagram. a , b , c and c' are path coefficients representing unstandardised regression weights. The c path coefficient represents the direct effect of screen time on impulsivity (BIS-IA scores). The c' path coefficient refers to the total effect of screen time on impulsivity through addiction (IAT scores) and sleep scores (PSQI scores).

Discussion

The goal of the present study was to examine the roles of internet addiction and sleep disturbance on the relation between screen exposure time and attentional impulsivity. Our results showed a significant direct relationship between screen exposure time and impulsivity in a typical French adult population: to be more specific, the more time individuals spent in front of a screen, the higher their level of attentional impulsivity. Moreover, when analysing the indirect effect, the relation between screen time and impulsivity was partially mediated by both sleep disturbance and internet addiction. Indeed, screen exposure was linked both to an increase in sleep disturbance (PSQI) and internet addiction (IAT), which in turn were both related to an increase in impulsivity. Researchers have previously found that the relationship between children's media use and ADHD-related behaviours was weak (Beyens, Valkenburg & Piotrowski, 2016). Our results revealed that the effect of screen time on impulsivity was observable even in neuro-typical subjects. Therefore, the weak effect found in clinical participants may be explained by a lack of statistical power. The present study also showed that the majority of participants may be psychologically affected by screen time, because their use in the general population is very high, i.e., more than 11 hours and a half per day, all activities combined.

As we expected, attentional impulsivity was the impulsivity factor which was most modulated by the time of exposure to screens. This result is in line with the hypothesis on the influence of the fast-paced nature of modern media on the relationship between higher exposure to screens and impulsivity (Nikkelen et al., 2014). According to this view, due to a process of habituation, subjects become increasingly accustomed to the over-stimulation they experience via screens, and therefore show greater difficulty concentrating in normal situations where they are less aroused and solicited. Interestingly, arousal-related mechanisms could also be intrinsically involved. Indeed, neuroscience has shown that the striatum and prefrontal cortex are implicated in the functioning/regulation of arousal (Dahl, 1996; Kelley et al., 2005), while they are also shown to be altered in subjects who are addicted to screens (Cai et al., 2016; Kim et al., 2011; Wang et al., 2016; Yuan et al., 2016) as well as in subjects suffering from sleep disturbance (Dahl, 1996). Recent studies have shown that nocturnal cognitive arousal is associated with sleep disturbance and physiologic hyperarousal (Kalmbach, Buysse, Cheng, Roth, Yang & Drake, 2020; Soffer-Dudek, 2017). In our study, the screen time exposure corresponded to the total screen exposure over a day. Therefore, the longer the exposure time,

the more it shortened the sleep time, which could explain why sleep disturbance was the prevalent mediator in our study.

The present findings replicate the significant link between internet addiction and sleep disturbance found in numerous studies (Alimoradi et al., 2019; Hadadvand et al., 2013; Petit et al., 2016; Zhang et al., 2017). Indeed, the prevalence of insomnia and other sleep disturbances such as nightmares was particularly significant among people with internet addiction (Choi et al., 2018). According to Lam (2014), internet gamers playing MMORPG games (Massively Multiplayer Online Role-Playing Games) tend to have the worst quality of sleep. In addition, in their study, Cheung and Wong (2011) highlighted that internet addiction and sleep disturbances are inter-related with depressive symptoms. Therefore, the early identification of excessive screen use could be crucial to the success of a preventive approach to mental health in the general population.

The strengths of the current study are that we have managed to validate a dual-mediator model clearly showing the negative effect of excessive screen time on attentional abilities related to internet addiction and associated sleep disturbance. However, it is important to note that there are also some limitations to the present work. First, as a cross-sectional study, the results cannot provide evidence on causal relationship between screen exposure time and sleep disturbances or addiction. It is possible that subjects with insomnia may be more likely to spend more time in front of screens for instance. Furthermore, the findings of this study should be cautiously generalized, given the presence of an imbalanced gender distribution issue within the current sample (i.e., the majority of the participants were female). Another limitation is that hundreds of activities of a different nature can be hidden behind the catch-all measurement of screen time exposure. For instance, on a computer, subjects could watch short or long videos on a video hosting website, spend some time on social media platforms, play a wide variety of video games, work, or even learn a new language. Theoretically, it is above all the type of activity on the screen that should be analysed as it could have modulated effects on arousal as well as on both of our present mediators of interest. However, from a practical point of view, this is far less easy to control. The time exposure corresponding to the plurality of sub-activities could quickly become fuzzy for the participant, and thus become difficult or even impossible to be temporally represented. Finally, a third limitation is that we did not control for media multi-tasking (i.e., engagement in more than one screen activity at the same time). As was already exposed in Table 1, some participants reported more than 24 hours a day of screen exposure, implying that they use more than one screen at a time. Media multi-tasking has also

been shown to be correlated with impulsivity (Shin et al., 2019), addiction (Lin et al., 2020), and sleep disturbance (van der Schuur et al., 2018). In the future, it would be interesting to analyse the influence on an individual's attention levels of using a single screen compared to multiple screens simultaneously. However, our study clearly showed the connection between time spend on screens and impulsiveness in a general adult population, linked in particular to the sleep disorders that this generates, but also, to a lesser extent, to the addiction associated with the activity.

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