A ten-step behavioural intervention to reduce screen time and problematic smartphone use*

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Abstract

Problematic smartphone use is rising across the world and has been associated with reductions in concentration and well-being. Few interventions aiming to reduce smartphone use take a multi-faceted approach that balances feasibility and effectiveness. We developed such an intervention with ten simple guidelines that nudge users to reduce their screen time (e.g., disabling non-essential notifications). Two pre-registered studies tested the intervention. Study 1 (N = 51) found reductions in screen time, problematic smartphone use, and depressive symptoms after two weeks. Study 2 (N = 70) found that the intervention caused larger changes in screen time, problematic smartphone use, and sleep quality than a control group of screen time monitoring alone. Our brief intervention reduced screen time by one hour per day and returned problematic smartphone use scores to normal levels for at least six weeks. This intervention provides simple, scalable, and feasible behavioural guidelines to promote healthy technology use.

Nearly half of the global population owns a smartphone[1] and this number continues to rise[2]. In countries such as South Korea, 99.9% of young adults now own a smartphone[3]. Screen time has similarly been increasing: American teenagers now spend over 7.5 hours per day on their phones outside of school work[4]. Accordingly, there have been growing concerns about *problematic smartphone use*[5], in which phones interfere with daily functioning. A recent meta-analysis of 24 countries showed that such problematic smartphone use has been increasing across the world for the past decade[6]. Yet, there are currently few feasible, effective, and scalable interventions that reduce problematic smartphone use and its associated negative effects.

Many of these negative effects involve cognitive impairments caused by phone use[7] across the domains of driving, work, and education. Using a phone while driving

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slows reaction time, increases erratic behaviour, and can cause collisions[8–10]. Similarly, pedestrian smartphone use is associated with unsafe behaviour when crossing the street[11]. In work-related contexts, receiving notifications during an attention task can impair performance as much as writing a text message or talking on the phone[12]. Even the mere presence of one's smartphone can reduce performance on working memory tasks[13,14]. One survey found that the majority of medical residents consider smartphones a serious distraction during clinical rounds and many reported missing important information due to smartphone use[15]. Several studies have also shown that problematic smartphone use, social networking site use, and screen time all negatively correlate with university grades[16–18], though these correlations may be small[19].

Evidence is mixed regarding the relationship between problematic smartphone use and various aspects of well-being. Some studies have found that smartphone use at night is associated with later bedtimes and lower sleep quality[20,21]; others have argued that these correlations are present but weak[22,23]. There is even less agreement about the relationship between phone use and depression. Country-wide smartphone ownership has coincided with increases in depression and anxiety among teenagers and young adults[24]. Cross-sectional surveys show negative correlations between screen time and well-being across the United States and the United Kingdom[25,26], and laboratory studies have found correlations between problematic smartphone use and depression[27]. These links may be strongest when phones are used for passive social media consumption (e.g., scrolling through feeds without interaction) rather than to actively socialise[27,28]. In contrast, other researchers have argued that these correlations may be inflated by flexible definitions of well-being; the actual correlations may be minimal[29,30]. Evidence is also mixed regarding the effectiveness of behavioural interventions targeting problematic smartphone use to reduce depression. One study found that limiting social networking site use to 10 min per platform per day reduced depression[31]; another intervention that also reduced screen time found no such effect[32]. Researchers continue to debate the nature and magnitude of the link between smartphone use and specific aspects of well-being[33].

Perhaps the simplest argument for reducing problematic smartphone use is that many people would rather spend their time on something else[34,35]. According to the displacement hypothesis[36,37], problematic smartphone use may have negative consequences because it replaces other activities that increase well-being, such as sleeping, exercising, or (in-person) socialising. Likely at least in part due to smartphone use, adolescents worldwide are doing less of these healthy activities than in the past[26,38–41].

A common approach to reducing smartphone use relies on technology. Phone manufacturers such as Apple and Google have led campaigns on "digital well-being" and developed features such as screen time monitoring. Phones can now be set up to track daily screen time and give reminders when exceeding user-defined limits. The helpfulness of these reminders may be minimal; they do not seem to reduce screen time or phone checking behaviour over a span of two months[42]. Some researchers have also argued that "fighting tech with tech" may pose a conflict of interest, since phone manufacturers and app designers may be financially motivated to maximise rather than reduce engagement[43]. In addition to the built-in features in phones, over 100 apps claim to help with reducing screen time[44], only a handful of which have been formally tested[45]. Independent of their effectiveness, one survey showed that most people wanting to reduce their screen time are not willing to use additional technology to help them do so; they would rather have more control over the process[46].

Approaches relying on self-control to reduce phone use have their own limitations. Abstinence strategies such as using a basic flip phone may be infeasible for many people whose work or daily life now depends on features enabled by smartphones. Others have suggested disabling social media entirely, but many people are unwilling to do so; several studies have estimated that people would need to be paid an average of over $1,000 to deactivate their Facebook account for one year[47,48]. Further, some amount of digital engagement may be beneficial to well-being[49,50]. Moderate approaches — such as reducing smartphone use for a period — may be more promising[31,51,52]. Relying on self-control, however, may be less feasible given that many smartphone apps are designed to promote habitual use[53,54]. One survey found that although most Americans are trying to reduce their phone use, only half report successfully doing so[34].

Behavioural interventions based on habits[55] or "nudges"[56] present an alternative solution that does not rely on additional technology or much self-control. Making phones less attractive by changing their display to greyscale can reduce screen time[32], dispersing notifications in predictable batches throughout the day can reduce stress[57], and keeping the phone out of the bedroom at night can improve subjective well-being[58]. These strategies demonstrate the potential to reduce problematic smartphone use through simple changes to phone settings or behaviour.

To our knowledge, no studies have attempted to combine these various strategies into an intervention that balances feasibility and effectiveness. For example, letting people choose among several intervention strategies that are adapted to their lifestyle may be more feasible on a broader scale than one-size-fits-all interventions. Further, a recent study estimated that 89% of smartphone interactions are self-generated rather than prompted by notifications[59]. Targeting both self-generated and prompted smartphone use in a combined approach may thus be more effective than an isolated strategy. Accordingly, we sought to develop a personalised and multi-faceted intervention to reduce screen time and problematic smartphone use. The intervention targets habitual and passive phone use, such as scrolling through social media feeds when bored. One survey found that almost all participants considered this type of phone use meaningless and they wanted to reduce it[35]. This passive phone use may also be most associated with reductions in well-being[28].

Our intervention builds on the Fogg Behaviour Model[55], which posits that habitual behaviours result from the combination of prompts, ability, and motivation. Habitual phone use, for example, may result from a prompt such as a social media notification, the ease of picking up the phone and scrolling through a feed, and the motivation to pass time when bored[60]. We therefore developed an intervention targeting this habitual behaviour by reducing prompts (e.g., disabling non-essential notifications), ability (e.g., making the phone harder to unlock), and motivation (e.g., making the phone screen look less attractive). Table 1 shows the ten guidelines of the intervention.

Table 1: Ten-step intervention and the associated components of the Fogg Behaviour Model[55].

Guideline	Target	Rationale
1. Disable non-essential notifications (sounds, banners, and vibration).	Prompts	Notifications disrupt task performance[12] and may increase stress[57,61].
2. Keep your phone on silent (vibrate off), face down, out of sight, and out of reach when not in use throughout the day.	Prompts, ability	The mere presence of a smartphone reduces cognitive task performance[13,14].
3. Disable Touch ID/Face ID (i.e., the fingerprint/face scanner to unlock your phone); use a password instead.	Ability	Making a behaviour more effortful reduces its frequency[55,56].
4. Keep your phone on silent (vibrate off) and out of reach when going to bed (e.g., on the opposite side of the room).	Prompts, ability	Avoiding smartphone use at night may improve sleep[20,21] and quality of life[58].
5. Turn down your phone's brightness, set it to greyscale (black and white), and change the colour warmth to filter out blue light (i.e., turn on the "night shift" feature).	Ability, motivation	Reducing light before bed may improve sleep[62,63] and the greyscale setting may reduce screen time[32].
6. Hide social media and email apps (e.g., Instagram, SnapChat, Facebook, Gmail, Outlook) in a folder off of the home screen (or even delete them).	Ability	Reducing social networking site use may improve well-being[31].
7. If you can do the task on a computer, try to keep it on the computer (e.g. social media, web search, or e-mail).	Ability, motivation	Social networking site use primarily occurs on smartphones[64] and may be more likely to produce habitual use compared to computers[60].
8. Let your family, friends, or colleagues know that you will be replying less often unless they call you directly.	Motivation	Messaging is the most common use of smartphones[65], and social uses of phones may be the most likely to promote habits[66,67].
9. Leave your phone at home when you do not need it (e.g., when getting groceries or going to the gym).	Ability	Not having a phone accessible will prevent it from interfering with other activities[37] such as social interactions[68].

Guideline	Target	Rationale
10. Overall, use your phone as little as possible.	Motivation	A moderate amount of screen time may be beneficial[49,50] and people are able to limit it through will-power[31] with varying degrees of success[34].

We tested this intervention in two studies of university students. Study 1 tested compliance and initial effectiveness using a pre-post design over a span of two weeks. We hypothesised that the intervention would reduce screen time and problematic smartphone use as well as improve cognition and well-being. Study 2 compared our intervention to a control group who simply monitored their screen time, with confirmatory assessments two weeks later and exploratory assessments six weeks later. Combined, these studies demonstrate the feasibility and effectiveness of a multi-faceted behavioural intervention to reduce problematic smartphone use.

Results

Compliance To improve feasibility, participants chose which of the 10 guidelines they wanted to follow in the intervention. In Study 1, participants reported following an average of 7.5 guidelines by week 2 ($SD = 1.49$). In Study 2, with a slightly modified intervention, participants initially agreed to follow 8.8 (1.37) of the guidelines; two weeks later, they reported following 7.28 (1.4) of them. After these two weeks, we told participants that the main study period had ended but to continue to follow the intervention as much as is feasible. At six weeks, participants continued to follow most of the guidelines ($M = 5.55$, $SD = 2.27$). Participants were most likely to comply with reducing notifications and least likely to keep their screen on greyscale (Study 1) or leave their phone at home (Study 2). See Tables S1 and S2 for the differences between the interventions and their compliance rates.

Screen time The intervention reduced daily screen time as measured by the iPhone's monitoring function (Figure 1A). In Study 1, daily usage dropped from 4.67 h to 3.4 h, for a difference of 1.27 h per day at week 2 ($t(49) = -6.18$, $d = -0.87\,[-1.23, -0.50]$, $p < .001$). In Study 2, daily screen time dropped by an average of 0.33 h in the control group and 0.87 h in the intervention group. By week 6, only the control group was slightly above their baseline. The largest proportion of screen time was spent on social networking, consistent with other studies[65]. This amount increased by 0.13 h per day in the control group and decreased by 0.23 h in the intervention group. See Tables S3 and S4 for descriptive statistics and Table 2 for regression models.

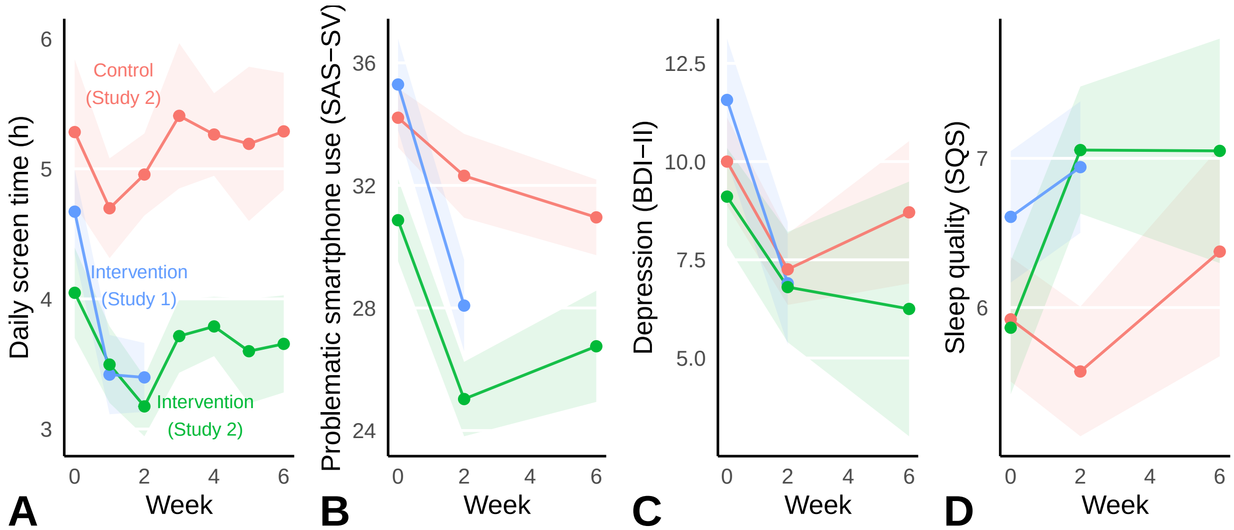

Figure 1: Select dependent measures by condition. Participants followed the intervention until week 2 (Studies 1 and 2) and then were asked to follow it as much as was feasible until week 6 (Study 2). Averages show the previous week; for example, week 0 shows the baseline week up until the participants began the study. The intervention reduced screen time (A) and problematic smartphone use (B). There was little change between the groups in depression (C). Sleep quality improved the most in the intervention group (D). Dots show means and bands show 95% confidence intervals.

Table 2: Regression results for Study 2 comparing weeks 0 and 2. Only the interactions were tested in order to isolate the differences between the groups while reducing experiment-wise Type I error.

Type	Outcome	Predictor	*b*	*CI*	*SE*	*t*	*df*	*p*
Confirmatory	Screen time (h/d)	(Intercept)	0.33	[0.02, 0.63]	0.15			
		Time	-0.04	[-0.33, 0.24]	0.14			
		Intervention	-0.46	[-0.89, -0.02]	0.22			
		Interaction	**-0.40**	**[-0.80, 0.00]**	**0.20**	**-1.98**	**74**	**.026**
	Problematic smartphone use (SAS-SV)	(Intercept)	0.31	[0.00, 0.61]	0.15			
		Time	-0.11	[-0.32, 0.11]	0.11			
		Intervention	-0.28	[-0.70, 0.15]	0.22			
		Interaction	**-0.56**	**[-0.86, -0.26]**	**0.15**	**-3.73**	**75**	**<.001**
	Depression (BDI-II)	(Intercept)	0.12	[-0.21, 0.44]	0.16			
		Time	-0.27	[-0.49, -0.05]	0.11			
		Intervention	-0.00	[-0.46, 0.46]	0.23			
		Interaction	-0.04	[-0.34, 0.27]	0.15	-0.24	75	.407
	Working memory (OSpan)	(Intercept)	-0.25	[-0.62, 0.11]	0.18			
		Time	0.42	[0.08, 0.76]	0.17			
		Intervention	0.09	[-0.44, 0.61]	0.26			
		Interaction	0.09	[-0.40, 0.58]	0.24	0.38	57	.354
Exploratory	Sleep quality (SQS)	(Intercept)	-0.00	[-0.32, 0.32]	0.16			
		Time	-0.26	[-0.54, 0.03]	0.14			
		Intervention	-0.13	[-0.58, 0.33]	0.23			
		Interaction	**0.82**	**[0.42, 1.23]**	**0.20**	**4.05**	**75**	**<.001**
	Positive mood (PANAS)	(Intercept)	0.09	[-0.24, 0.42]	0.17			
		Time	-0.03	[-0.31, 0.25]	0.14			

Type	Outcome	Predictor	*b*	*CI*	*SE*	*t*	*df*	*p*
		Intervention	-0.26	[-0.72, 0.21]	0.23			
		Interaction	0.28	[-0.11, 0.68]	0.20	1.43	76	.078
	Negative mood (PANAS)	(Intercept)	0.38	[0.07, 0.70]	0.16			
		Time	-0.43	[-0.70, -0.16]	0.13			
		Intervention	-0.33	[-0.78, 0.11]	0.22			
		Interaction	-0.10	[-0.48, 0.28]	0.19	-0.53	75	.300

Problematic smartphone use Problematic smartphone use similarly dropped when following the intervention (Figure 1B). In Study 1, participants initially scored 35.29 on the Smartphone Addiction Scale (Short Version), which ranges from 10 to 60. This average was higher than in other studies of the same population[69] likely because we recruited people interested in reducing their phone use. Based on the scale authors' original cut-off of 31 (for men) or 33 (for women)[70], 67% would be considered at a high risk of smartphone addiction. During the intervention, participants dropped to a score of 28.08 ($t(50) = -6.85$, $d = -0.96\,[-1.20, -0.71]$, $p < .001$), putting only 35% above the high-risk threshold and thereby returning them to a more normal range for samples in North America[6]. Study 2 showed similar reductions; the intervention dropped by 5.84 points while the control group dropped by only 1.9. At six weeks, both groups remained lower than their baseline.

Depression There were inconsistent results for depression (Figure 1C). In Study 1, participants began with a depression score of 11.57, with 33% in the range of at least mild depression. During the intervention, their depression scores reduced to 6.9, with only 14% at the clinical cut-off ($t(50) = -4.25$, $d = -0.59\,[-0.92, -0.12]$, $p < .001$). Study 2, however, found no difference in depression between the groups; both appeared to show similar reductions.

Cognition In Study 1, working memory improved ($t(50) = 1.95$, $d = 0.27\,[-0.01, 0.53]$, $p = .029$), but this may have just been a learning effect: both groups showed similar changes in Study 2. We did not see any large changes in sustained attention errors, which we only tested in Study 1 ($t(50) = 1.12$, $d = 0.16\,[-0.11, 0.44]$, $p = .866$).

Sleep quality The rest of the measures were exploratory. Study 1 found little change in sleep quality, which went from 6.61 to 6.94 out of 10 ($t(50) = 1.07$, $d = 0.15\,[-0.14, 0.43]$, $p = .144$). In Study 2, the control group showed no increase (-0.35 points) while the intervention group showed an increase of 1.19 points (Figure 1D). This improvement would be considered clinically significant[71] and persisted for at least six weeks.

Mood There was comparatively little change in mood. Positive affect remained fairly consistent and negative affect seemed to reduce by similar amounts across both studies and groups. Figure 2 summarises the overall effects.

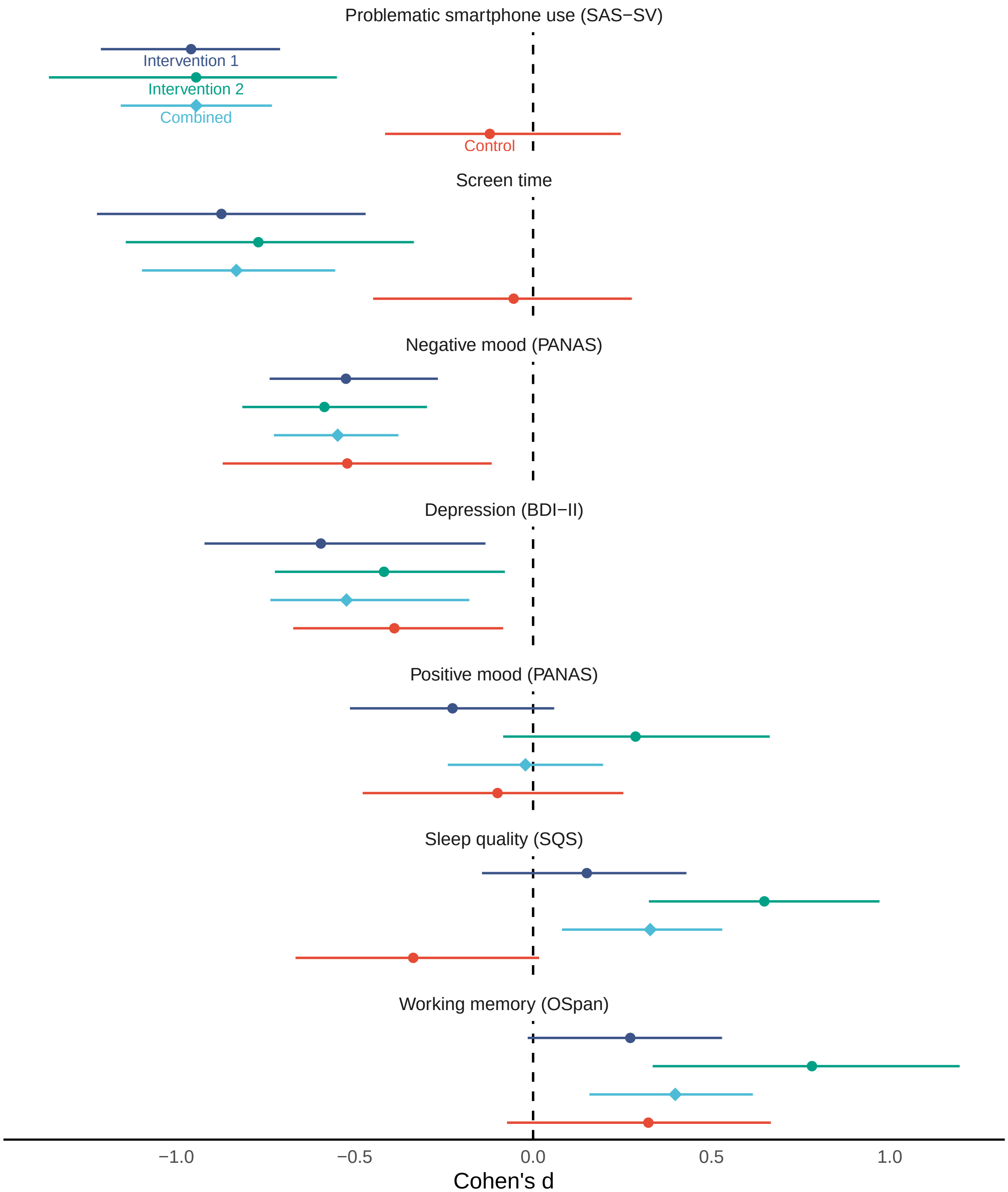

Figure 2: Effect sizes across studies between the baseline and two weeks later (post minus pre). The control group never improved more than the average of the intervention groups. Our behavioural intervention reduced problematic smartphone use and screen time as well as improved sleep quality compared to screen time tracking alone. Participants in both groups showed similar reductions in negative mood and depression. Error bars show bootstrapped 95% confidence intervals.

Individual differences Combining both intervention groups for greater statistical power ($N = 86$), exploratory tests revealed that people who followed more of the intervention guidelines showed greater reductions in both depression and screen time as well as greater improvements in positive mood (Figure 3). All of the sample correlations were in the predicted directions. Beyond compliance, none of the demographic or personality measures, such as the Big Five, strongly predicted intervention effectiveness.

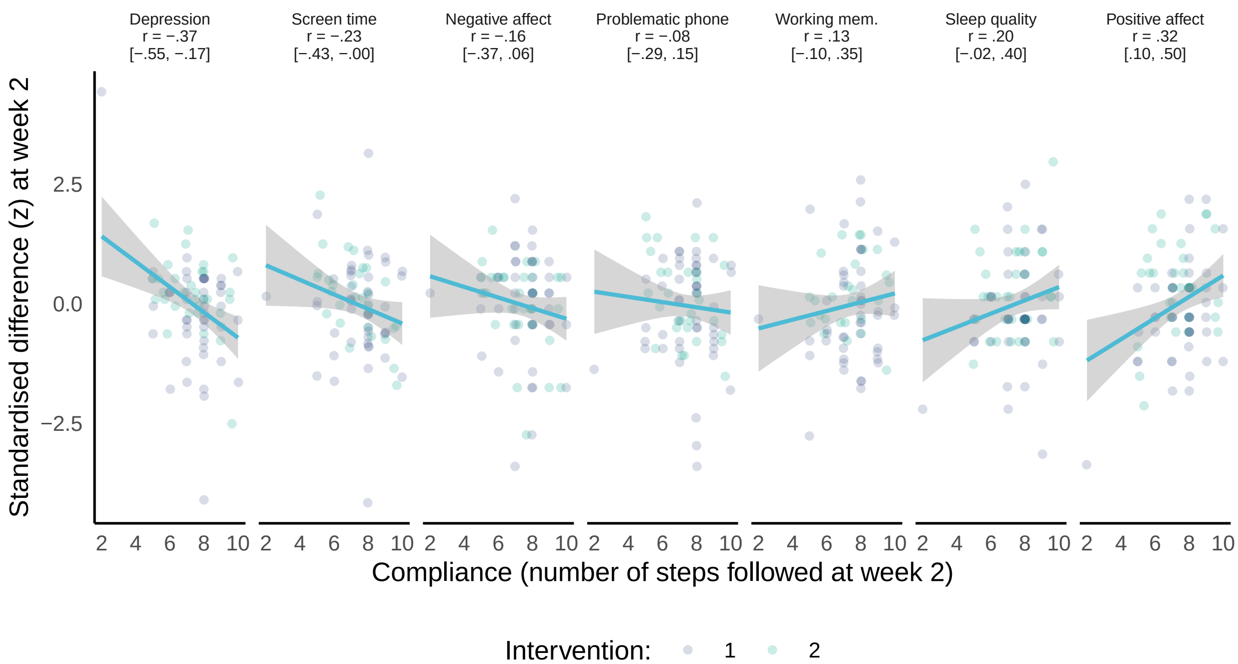

Figure 3: Participant compliance by all common measures across Studies 1 and 2. Participants who followed more guidelines of the intervention by week 2 showed larger reductions in depression and screen time as well as greater improvements in positive affect. The sample correlations were all in the predicted directions. Lines show linear predictions across both interventions and bands show 95% confidence intervals.

At the baseline, across all participants ($N = 121$) we saw several of the expected correlations between the dependent measures and individual difference variables (Figure S1). Screen time, problematic smartphone use, depression, and negative mood all positively correlated with each other, consistent with previous findings[24–26].

Creativity Study 2 also tested creativity as an exploratory predictor. Participants who scored higher on problematic smartphone use generated less divergent ideas. The correlations were similar across weeks 0 ($r = -.35$ $[-.55, -.11]$), 2 ($r = -.29$ $[-.51, -.04]$), and 6 ($r = -.29$ $[-.55, .01]$). We are not aware of any other empirical studies that have tested this link[7] although it has frequently been hypothesised[72]. However, in a follow-up pre-registered study (https://osf.io/ztdbk) with a more diverse sample ($N = 300$), we were unable to replicate this relationship across two measures of smartphone use (screen time and the Smartphone Addiction Scale)[70] and two measures of creativity (the Divergent Association Task and the Creative Achievement Questionnaire)[73,74]. The link between creativity and smartphone use thus remains unclear.

Experience In Study 2 at week 2, we interviewed participants about their experience with the intervention. They reported a variety of positive effects such as more focus and better social interactions (Table 3). The only adverse effect reported was an increase in anxiety, especially during the beginning of the intervention. One participant noted that this increase was due to a fear of missing out on important conversations, consistent with previous findings[31]. The control group reported fewer effects, whether positive or negative.

Table 3: Categories of effects reported during the interview on week 2 of Study 2. The intervention group generally reported more effects.

Reported effect	Control	Intervention	Example intervention quote
More focus	6%	23%	"I was able to concentrate on work for prolonged periods of time."
Less anxiety	0%	21%	"I definitely feel less depressed/stressed/anxious because I do not feel the stress of missing one of the texts from my friends anymore nor the need to respond immediately."
Concerned when using phone	9%	15%	"It leaves a bad taste in my mouth after wasting so much time on my phone."
Improved physical well-being	0%	15%	"It increased my sleeping time — waking up was much more comfortable."
Better social interactions	0%	13%	"I do think I have been able to strengthen my relationships with close friends by meeting up with them in person more as opposed to endless texting."
More self-control	0%	13%	"I guess [the intervention] made me happier — I felt more freedom because I'm not stuck in a vicious cycle of scrolling."
Improved productivity	6%	8%	"I love making music, so I composed music instead."

Reported effect	Control	Intervention	Example intervention quote
More time	6%	8%	"I spent so much more time with schoolwork, going to gym, waking up early — generally I'm pretty positive coming out of this."
More anxiety	3%	5%	"Keeping notifications off was distressing, I felt like I was missing out on social contact."

We also asked participants how they spent any additional free time, in case they simply replaced phone screen time with computer screen time. Participants most commonly reported spending more time on studying or work (51%), enjoyable activities such as hobbies or cooking (26%), or interacting with friends and family (21%). More rarely, participants spent time on household chores (13%), computer use (13%), exercise (5%), or sleep (5%). Importantly, many of these activities can potentially improve well-being. These results support the idea that the link between problematic smartphone use and well-being may be due in part to a reduction in these healthy activities[37].

Discussion

As problematic smartphone use continues to rise across the world[6], there is a need for feasible, effective, and scalable approaches to reduce it. We developed and tested a behavioural intervention that aimed to reduce people's phone use without relying on additional technology or considerable self-control. The intervention, which takes 10 min to explain and implement, reduced screen time by an hour per day for two weeks; some of this reduction persisted an additional four weeks later. The intervention also reduced problematic smartphone use to more normal levels and improved sleep quality, both for a period of at least six weeks. These improvements were larger than those from screen time monitoring alone.

The effects on depression were less clear. Both screen time monitoring and the full intervention reduced depression and negative affect in similar ways (Figure 2). It is thus difficult to tell whether any reductions were caused by the intervention or incidental aspects of the study itself, such as demand characteristics or observation effects. Still, participants who followed the intervention more closely showed larger reductions in depressive symptoms, and these symptoms positively correlated with both screen time and problematic smartphone use (Figure S1). These results are consistent with a growing body of literature suggesting that there may be a link between well-being and problematic smartphone use, but this link may not be as strong as is often believed[75].

Our intervention has several strengths compared to existing approaches. First, the intervention showed high compliance; participants could choose which guidelines to follow in order to adapt the intervention to their lifestyle. This approach likely matches how people would reduce their phone use outside of a study context and thus has high external validity. Indeed, participants in Study 2 continued to follow most of the intervention guidelines for at least four weeks beyond the main study period (Table S2). Second, many of the intervention guidelines are "set and forget" making them sustainable in the longer term rather than relying on consistent self-control. Third, because the intervention is based on general behavioural principles[55], the guidelines can be adapted for future phone operating systems or devices such as wearable technologies.

The main explanatory limitation of our study is that we could not isolate the key components of the intervention. It is possible that a subset of the intervention guidelines provided the majority of the benefits. Given participants' ratings (Tables S1 and S2), reducing notifications, hiding social media apps, and making the phone less accessible may be the strongest candidates. We have previously argued that intervention development could involve an initial "kitchen sink" approach to first determine whether the intervention as a whole is feasible and effective before dismantling the key components in future studies[76]. Still, given that participants choose which guidelines to follow, the intervention may be simple enough that dismantling it may be less necessary.

Our results may be useful for phone manufacturers and app developers interested in improving digital well-being. Screen time tracking — though commonly included in smartphone operating systems — had little effect on phone behaviour six weeks later (Figure 1B), consistent with other studies[42]. To effectively reduce screen time, several of our intervention guidelines could be adapted for future operating systems. For example, smartphones could learn which notifications users tend to engage with and then de-emphasise or batch low-importance alerts[57]. Apple's app store has recently started disclosing privacy ratings of various apps; a similar approach for digital well-being could also be useful. Of course, implementing several of the tested intervention guidelines by default in phones would make them less accessible, less attractive, and harder to use — and perhaps less profitable. Phone manufacturers promoting digital well-being are thus in the tenuous position of being both a potential cause and solution of problematic smartphone use and excessive screen time[43].

Future studies could test similar multi-faceted interventions over a longer period to see whether particular improvements need more time to become apparent. At six weeks, depression was still trending downwards in our intervention group (Figure 1C); a longer time span may have revealed stronger effects. These interventions may become even more important following the COVID-19 pandemic. Remote schooling and telecommuting have increased technology use and some of these trends will likely persist in the longer term[77–79]. Interventions that promote healthy technology use may therefore have even greater benefits in the future.

We agree with researchers and ethicists who argue that reducing problematic smartphone use should ultimately result from re-establishing healthy habits, a broader philosophy of technology use, and cooperation from phone manufacturers[51,59]. Newport, who argues for "digital minimalism", states that:

> What all of us who struggle with these issues need [. . .] is a philosophy of technology use, something that covers from the ground up which digital tools we allow into our life, for what reasons, and under what constraints. In the absence of this introspection, we'll be left struggling in a whirlwind of addictive and appealing cyber-trinkets, vainly hoping that the right mix of ad hoc hacks will save us.[51]

Until our habits are rewired and such a philosophy of technology gains traction, we hope that our particular mix of guidelines can at least serve as a stopgap. With 3.5 billion smartphone users worldwide[1] and millions if not billions trying to reduce their screen time[34], even small changes to phone habits — saving an hour per day — could have large and compounding effects across the world.

Methods

Study 1

We first assessed the feasibility of our intervention and its potential effects over a span of two weeks.

Participants

We recruited 51 participants (36 women) from social media advertisements and from the psychology participant pool at McGill University. Most were students and all were between 18 and 34 years old ($M = 21.7$, $SD = 2.8$). To be eligible, participants needed an iPhone with iOS 12 or later, since this includes built-in objective screen time tracking[80]. We included only participants with normal or corrected-to-normal vision who were not taking any medication and had no history of neurological or psychiatric issues. Participants were compensated $20 or course credit. The protocols for both studies were approved by the McGill University Research Ethics Board II (#451-0518).

We chose our sample size based on a power analysis. We were interested in medium effect sizes, so we kept posting weekly experiment slots until we reached 50 participants with complete data sets. This gave 80% power to detect small-to-medium effects of $d = 0.36$ for our one-tailed confirmatory analyses.

Procedure

Baseline measures After completing an online screening for eligibility, participants were asked if they had screen time tracking enabled on their phone. Those who did scheduled a lab visit; those who did not were asked to enable it and schedule a visit one week later to allow for a week of baseline screen time tracking. At the lab, the experimenter obtained informed consent, and then the participants were asked to silence their phone and place it in the corner of the room to reduce distractions[13]. Participants then completed measures of sustained attention, working memory, depression, problematic smartphone use, sleep, mood, and personality.

Intervention After completing the baseline measures, the experimenter explained that the purpose of the study was to test the feasibility of a ten-step behavioural intervention to reduce smartphone use (see Table S1 for the full intervention). The experimenter led the participants through each guideline, asked them if they would like to follow it, and if so, guided them through the implementation. Participants were asked to make the changes to their phones right then, such as disabling phone notifications; they made all of the changes themselves. Participants chose the extent to which they followed each guideline, such as ranging from disabling only sounds to disabling any visual notifications.

The participants then received a hard copy of the intervention instructions and were asked to follow it for two weeks. To increase compliance, we offered them an additional $20 incentive to follow the guidelines, which we would provide at the end of the study period.

Finally, the participants took a screenshot of the screen time summary on their phone and emailed it to the experimenter. This formed their baseline screen time measurement (i.e., the week prior to the study), and participants completed this procedure each week.

Post measurements Two weeks after the first visit (13 to 15 days later), participants returned to the lab to complete the same measures except for the personality questionnaires. The experimenter also collected the final measurement of screen time. After a post-test interview (described in detail below) the experimenter debriefed the participants and gave the full compensation.

Materials

Participants completed the questionnaires and tasks on a computer running PsychoPy version 3.1[81]. The cognitive tasks used Inquisit Lab 6 (Millisecond Software, Seattle, WA). During all tasks and questionnaires, participants wore ear protection to reduce noise distractions. The computer had a 55 cm ViewSonic monitor (Brea, CA, USA) at 1920×1080 resolution, placed approximately 45 cm away from the participants.

Measures

Sustained Attention to Response Task (SART) Participants first completed the SART, which measures sustained attention and response inhibition[82]. Task performance is impaired when receiving phone notifications[12]. Each trial presented a digit for 250 ms which was then masked by an "X" for 900 ms, during which participants had to press a key if the digit presented was anything but a 3; on the 3 they had to withhold their response. The task had 225 trials and took under 5 min to complete.

Operation Span Task (OSpan) The OSpan measures working memory capacity[83] and is affected by the presence of a smartphone[13]. Participants saw sequences of 3 to 7 letters that they had to remember in order. Each letter appeared for 800 ms. Between each letter, a math problem appeared (e.g., $(8 \times 2) - 8$) followed by a proposed solution on the next screen. Participants then pressed a key to indicate whether the solution was correct. They then clicked on the letters from a matrix in the order that they appeared. Including 22 practice trials (corresponding to different aspects of the task), the task took 20 to 25 min to complete.

Beck Depression Inventory II (BDI-II) The BDI assesses the severity of depressive symptoms over the previous two weeks[84]. The questionnaire has 21 items measuring areas such as sadness, loss of pleasure, and suicidal thoughts. For example, participants responded to items ranging from "I do not feel sad" (0 points) to "I am so sad or unhappy that I can't stand it" (3 points). Summing the points gives a total score from 0 to 63, with 14 being the cut-off for mild depression. Participants who reported suicidal ideation were given mental health resources and were contacted by a psychiatrist. The scale's internal consistency for college students is high ($\alpha = .93$)[84] and was similar in our samples (Study 1: $\alpha = .93$, Study 2: $\alpha = .88$).

Smartphone Addiction Scale — Short Version (SAS-SV) The SAS-SV is the most common measure of problematic smartphone use[6] and asks about disturbances in daily life and withdrawal symptoms related to phones[70]. We used the 10-item version of the scale with minor edits for clarity that we have tested in a previous study[69]. An example item is: "I have a hard time concentrating in class, while doing assignments, or while working, due to smartphone use." Each item uses a Likert scale ranging from 1 (Strongly disagree) to 6 (Strongly agree), for a total score between 10 and 60. The authors of the scale found that a score of 31 for males and 33 for females predicted clinical diagnoses in an adolescent sample in South Korea[70]. The scale usually has high internal consistency ($\alpha = .91$)[70]; it was slightly lower in our samples (Study 1: $\alpha = .82$, Study 2: $\alpha = .78$) but was similar to another sample from the same university (.83)[69]. This and the subsequent non-trait questionnaires asked about the previous two weeks to stay consistent with the BDI.

Sleep Quality Scale (SQS) The SQS measures sleep quality based on a single question: "Rate your sleep quality from 0 to 10, with 0 being the worst possible sleep, and 10 being the best"[85]. The measure correlates well with longer sleep questionnaires[85].

International Positive and Negative Affect Scale — Short Form (PANAS) The PANAS measures positive and negative affect as independent dimensions[86]. Participants rated how much they felt of each dimension based on a total of 10 items (e.g., Interested, Hostile) on 5-point scales ranging from 1 (Never) to 5 (Always). Total scores on positive and negative affect each range from 10 to 50. The scale usually has acceptable reliability (α of .75 for positive affect and .76 for negative), which was similar in our sample for positive (Study 1: $\alpha = .66$, Study 2: $\alpha = .80$) and negative affect (Study 1: $\alpha = .82$, Study 2: $\alpha = .75$).

Big Five Inventory (BFI) The BFI measures five broad personality traits: openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism[87]. Participants rate 44 items (e.g., "I am someone who is talkative") on a scale from 1 (Disagree strongly) to 5 (Agree strongly). In Study 1, reliability was lower than expected: αs for the traits ranged from .41 to .69, with an average of .55. In Study 2, reliability was higher with αs ranging from .69 to .89, with an average of .81. Previous studies have found that traits such as extroversion and neuroticism predict smartphone use[88].

Internal Control Index (ICI) The ICI measures feelings of control over one's life[89]. People with a more internal locus of control feel more control over their life situation; people with an external locus are more likely to believe in the contribution of luck or fate. The scale has 28 items such as "I like jobs where I can make decisions and be responsible for my own work". Participants rate each item on a 5-point scale ranging from 1 (Rarely) to 5 (Usually). The total score ranges from 28 to 140; higher scores represent a more internal locus. The scale typically has good reliability (α = .84)[89]; it was similar in our sample for Study 1 (.83) but lower in Study 2 (.59). Previous studies have suggested that people with higher screen time may have a more external locus of control[16].

Analysis

All aspects of the study were pre-registered online (https://osf.io/wmvje). We conducted one-tailed paired-samples t tests to estimate the potential effects of the intervention. We used a Type I error rate of .05 with no family-wise error control since we were running few tests. The assumption of normality was reasonable. We used an intention-to-treat analysis, keeping all participants regardless of how much of the intervention they followed, in order to promote external generalisability[90].

In total, we conducted 6 confirmatory tests, predicting that during the intervention participants would: (1) use their phone less (as measured by daily screen time), (2) report lower problematic smartphone use (SAS-SV), (3) reduce depression (BDI-II), (4) improve sleep quality (SQS), (5) increase working memory capacity (OSpan), and (6) make fewer attentional errors (SART). One participant missed one week of screen time reporting and so was excluded from the test of screen time. Two of the co-authors independently cleaned and analysed the data based on the pre-registration to ensure consistency of the results.

Study 2

Study 2 added a control group and an additional follow-up four weeks later, making the full study six weeks long.

Participants

Using the same procedure as in Study 1, we recruited 82 participants. Based on the pre-registration, we had to exclude 12 of them: 7 dropped out (4 during the pandemic), 4 did not end up following at least 5 guidelines of the intervention, and 1 updated his phone which lost the screen time monitoring data. The final sample included 70 participants (54 women, aged 18 to 33, $M = 20.7$, $SD = 2.6$).

Participants completed two lab visits over two weeks. The final 11 participants completed their second visit via online questionnaires after the university closed due to the COVID-19 pandemic. This group was able to complete all of the tasks except for the OSpan; we excluded them only from tests of this measure. The last half of the sample ($N = 44$) additionally completed an online questionnaire six weeks after the baseline measurements to monitor any improvements over a longer period.

Procedure

Participants completed the same tasks and questionnaires as in Study 1 except for the SART. Only after completing the baseline measurements, participants were randomly assigned to an experimental condition. The experimenter explained that we were testing the feasibility of a smartphone use reduction intervention and then either explained the control procedure (screen time tracking alone) or the full intervention. Both groups were told that they were in the intervention group, in order to help equalise participant expectations and reduce any differences due to demand characteristics[91].

The intervention was similar to that of Study 1, with three small changes based on new research and technology (see Table S2). We added a mention of disabling unlocking by face recognition (Face ID) in addition to by fingerprint (Touch ID). We also mentioned reducing the brightness of the phone, since more research has shown that the colour warmth feature alone may not be as effective to improve sleep[63]. Finally we suggested that participants leave their phone at home when they do not need it, such as when getting groceries.

We then assessed feedback about the intervention through a questionnaire and semi-structured interview. The questions assessed feasibility, ease of use, and willingness to continue following each of the intervention guidelines. Participants were also asked about any effects they noticed during the intervention. Each question used a Likert scale ranging from 1 (Not at all) to 7 (Very), based on a questionnaire we previously developed[92]. During the interview, we also asked participants how they spent their additional free time given any reduction in screen time. Two raters later coded the responses into common categories; a third rater resolved discrepancies.

The participants were then compensated. We asked them to continue to follow the intervention as much as is feasible but that the intervention period was now complete. Four weeks later, participants completed an online follow-up and were compensated an additional $20.

Measures

Our primary outcomes were all of the measures that showed effects in Study 1: screen time, problematic smartphone use, depression, and working memory. Our secondary outcomes included some of the measures that did not show effects: sleep quality, positive affect, and negative affect. We dropped the sustained attention measure.

Divergent Association Task (DAT) As an exploratory predictor, a subset of the participants ($N = 62$) additionally completed the DAT, a measure of creativity[73]. The task involves writing 10 words that are as different from each other as possible in all meanings and uses of the words. Participants had 4 minutes to complete the task. An algorithm then computed the semantic distance between each of the words; higher average distances indicate greater creativity. The task correlates well with traditional creativity measures[73].

Analysis

As in Study 1, all aspects of the analysis were pre-registered online (https://osf.io/3p7rz). We used mixed-effect linear regression to predict each measure given the condition (control or intervention), time (baseline or two weeks later), and the intervention (control group versus full intervention), with the participant as a random factor. We tested only the interactions, with confirmatory tests of our four primary outcomes and exploratory tests of our secondary outcomes. We used a Type I error rate of .05 and one-tailed tests, predicting that participants in the intervention group would show larger improvements on all of the measures. All assumptions were reasonable. Note that although participants were randomly assigned after completing the baseline measures, there appeared to be some pre-existing differences between the groups (Figures 1A and 1B) which were controlled for by the regression model.

Based on the pre-registration, we excluded two additional participants from only the test of screen time: one had an extreme score ($z < -4$) and one sent the week 2 screen time data too late. For the test of the OSpan, an additional five participants were excluded due to computer errors during the task.

We had one deviation from our pre-registered design. We aimed to run 80 to 120 participants, which would have given 80% power to detect small-to-medium effects of $d = 0.32$ to 0.40 using an independent samples t test as a conservative model. Although we recruited 82 participants, many of them dropped out due to the COVID-19 pandemic and the university closed before we could reach the planned sample size. We considered our final sample of 70 participants sufficient for analysis given the circumstances.

Data availability

All datasets are available on the Open Science Framework (https://osf.io/5mqnp/).

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Author contributions

JO, DS, and SV designed the studies. DS and DC ran participants. JO and DS analysed the data. AR supervised. SV provided funding. All contributed to the manuscript.

Competing interests

The authors declare no competing interests.

Supplementary results

Tables S1 and S2 show the interventions used in the studies along with their compliance rates. Tables S3 and S4 show descriptive statistics for Studies 1 and 2. Figure S1 shows the correlations between the measures.

Table S1: Intervention used in Study 1 with compliance rates.

Recommendation	Followed
1. Disable non-essential notifications (sounds, banners, and vibration).	98%
2. Keep your phone on silent (vibrate off), face down, out of sight, and out of reach when not in use throughout the day.	83%
3. Disable Touch ID (i.e., the fingerprint scanner to unlock your phone); use a password instead.	79%
4. Keep your phone on silent (vibrate off) and out of reach when going to bed (e.g., on the opposite side of the room).	58%
5. Change the colour warmth to filter out blue light (i.e., turn on the "night shift" feature).	94%
6. Hide social media and email apps (e.g., Instagram, SnapChat, Facebook, Gmail, Outlook) in a folder off of the home screen (or even delete them).	90%
7. If you can do the task on a computer, try to keep it on the computer (e.g., social media, web search, or email).	83%
8. Let your family, friends, or colleagues know that you will be replying less often unless they call you directly.	40%
9. Set your phone screen to greyscale (black and white).	38%
10. Overall, use your phone as little as possible.	88%

Table S2: Intervention used in Study 2 with compliance rates as well as means (and SDs) of ease of use and willingness to continue to follow the guidelines in the long term (with responses ranging from 1 to 7). Differences from the first intervention are shown in bold.

Recommendation	Already followed	Planned to follow	Followed at 2 weeks	Followed at 6 weeks	Feasibility	Long term
1. Disable non-essential notifications (sounds, banners, and vibration).	46%	91%	97%	82%	5.71 (1.71)	5.18 (1.77)
2. Keep your phone on silent (vibrate off), face down, out of sight, and out of reach when not in use throughout the day.	33%	94%	82%	88%	5.49 (1.73)	5.69 (1.46)

Recommendation	Already followed	Planned to follow	Followed at 2 weeks	Followed at 6 weeks	Feasibility	Long term
3. Disable Touch ID/**Face ID** (i.e., the fingerprint/**face** scanner to unlock your phone); use a password instead.	11%	83%	76%	48%	5.24 (2.36)	3.85 (2.16)
4. Keep your phone on silent (vibrate off) and out of reach when going to bed (e.g., on the opposite side of the room).	40%	96%	73%	58%	5.42 (2.05)	5.61 (1.95)
5. **Turn down your phone's brightness**, set it to greyscale (black and white), and change the colour warmth to filter out blue light (i.e., turn on the "night shift" feature).	35%	86%	71%	58%	5.09 (2.23)	4.73 (2.47)
6. Hide social media and email apps (e.g., Instagram, SnapChat, Facebook, Gmail, Outlook) in a folder off of the home screen (or even delete them).	14%	60%	56%	70%	4.98 (2.06)	4.45 (2.10)
7. If you can do the task on a computer, try to keep it on the computer (e.g., social media, web search, or email).	17%	100%	84%	67%	5.09 (1.48)	5.26 (1.54)
8. Let your family, friends, or colleagues know that you will be replying less often unless they call you directly.	0%	86%	65%	21%	4.70 (2.20)	3.44 (2.00)

Recommendation	Already followed	Planned to follow	Followed at 2 weeks	Followed at 6 weeks	Feasibility	Long term
9. **Leave your phone at home when you do not need it (e.g., when getting groceries or going to the gym).**	11%	86%	34%	21%	2.88 (2.06)	2.79 (2.07)
10. Overall, use your phone as little as possible.	0%	100%	90%	42%	4.79 (1.55)	5.41 (1.26)

Table S3: Means (and SDs) of measures across weeks in Study 1.

Measure	Intervention week 0	Intervention week 2
Screen time (h/d)	4.67 (2.09)	3.40 (1.99)
Problematic smartphone use (SAS-SV)	35.29 (8.84)	28.08 (9.00)
Depression (BDI-II)	11.57 (9.51)	6.90 (7.04)
Working memory (OSpan)	46.69 (18.28)	50.59 (17.62)
Sustained attention errors (SART)	16.33 (9.83)	17.82 (12.72)
Sleep quality (SQS)	6.61 (1.72)	6.94 (1.59)
Positive mood (PANAS)	17.69 (3.30)	16.96 (3.05)
Negative mood (PANAS)	11.33 (4.30)	9.63 (3.58)

Table S4: Means (and SDs) of measures across conditions and weeks in Study 2.

Measure	Control week 0	Control week 2	Intervention week 0	Intervention week 2
Screen time (h/d)	5.28 (2.19)	5.34 (2.49)	4.05 (1.59)	3.14 (1.46)
Problematic smartphone use (SAS-SV)	34.21 (8.39)	32.61 (7.35)	30.86 (7.80)	25.16 (7.23)
Depression (BDI-II)	10.00 (7.88)	7.47 (5.45)	9.11 (6.94)	6.95 (6.78)
Working memory (OSpan)	44.58 (13.79)	53.32 (14.14)	47.11 (14.73)	54.59 (15.06)
Sleep quality (SQS)	5.92 (2.08)	5.53 (1.98)	5.86 (1.99)	7.00 (1.91)
Positive mood (PANAS)	15.92 (4.33)	16.21 (2.71)	15.57 (3.52)	16.49 (3.07)
Negative mood (PANAS)	12.00 (3.04)	10.42 (2.43)	10.68 (3.70)	8.84 (2.77)

	Screen time	Problematic use	Depression	Working memory	Sleep quality	Positive mood	Negative mood	Creativity	Agreeableness	Conscientiousness	Extroversion	Neuroticism	Openness	Locus of control
Screen time (h/d)														
Problematic smartphone use (SAS−SV)	.26**													
Depression (BDI−II)	.25**	.32***												
Working memory (OSpan)	.05	−.13	−.11											
Sleep quality (SQS)	−.14	−.21	−.33***	.07										
Positive mood (PANAS)	−.03	−.16	−.21	.03	.34***									
Negative mood (PANAS)	.13	.32***	.59***	−.09	−.28**	−.05								
Creativity (DAT)	−.25	−.35**	.13	.19	.10	.18	−.04							
Agreeableness (BFI)	−.06	.03	−.24**	−.12	−.00	−.04	−.16	−.26						
Conscientiousness (BFI)	−.20	−.33***	−.29***	.05	.05	.30***	−.30***	.03	.16					
Extroversion (BFI)	.26**	.14	.03	.11	.06	.12	−.07	−.04	−.03	−.20				
Neuroticism (BFI)	.07	.33***	.36***	.03	−.16	−.19	.39***	−.04	−.23	−.27**	−.17			
Openness to experience (BFI)	−.14	−.06	.09	−.03	.03	−.03	.06	.32	−.05	−.09	.18	.01		
Locus of control (ICI)	.10	−.24**	−.13	−.08	−.04	.06	−.28**	.17	.02	.30***	.08	−.21	.30***	

Figure S1: Exploratory correlations at week 0 across both studies. There were notable positive correlations between screen time, problematic smartphone use, depression, and negative mood. The novel correlation between creativity and problematic smartphone use did not replicate in a follow-up study. $^{**}p < .01$, $^{***}p < .001$.