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Reducing smartphone overuse for adolescents with attention-deficit hyperactive disorder: study protocol for a randomized controlled trial

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Abstract

Background Smartphone overuse (SO) is pervasive and is detrimental to individuals' quality of life, physical and mental health, and academic/career achievements. Attention-deficit hyperactivity disorder (ADHD) diagnosis and traits are consistently identified as risk factors of SO. Studies revealed that SO interventions can bring about large positive effects on SO, yet there is no published SO intervention for clinically-diagnosed ADHD individuals using a randomized controlled trial (RCT) design. Moreover, very few studies investigated ADHD symptoms and neural correlates of SO as outcome measures of SO interventions. The overall aim of the proposed study is to develop and evaluate a smartphone-based behavioral and individualized intervention for adolescents with ADHD and SO in Hong Kong.

Method We will implement a behavioral smartphone-based RCT intervention with two parallel groups of clinically diagnosed ADHD adolescents with SO in Hong Kong. A total of 120 adolescents with ADHD will be recruited. The intervention group will receive a 12-week individualized behavioral intervention with weekly reminders, implementing specific strategies that counter the potentially addictive qualities of smartphones using built-in smartphone functions. The control group participants will self-monitor their smartphone usage. During the intervention phase, participants will be contacted once a week to collect the objective smartphone use patterns. Both groups will be measured on smartphone dependence and ADHD symptoms, and resting-state electroencephalogram (EEG) signals under the smartphone salient vs. smartphone non-salient conditions will be recorded. Parents need to report children's ADHD symptoms. These outcomes will be measured three times: [1] one week before the intervention [2], one week after the intervention, and [3] nine months after the intervention. Greater sustained reduction in self-reported smartphone dependence and objective smartphone usage, self and parent-rated ADHD symptoms, and spectral power differences in resting-state EEG in the two conditions will index intervention effects among adolescents with ADHD.

Discussion The study results will contribute to the evidence-based practice of SO intervention, providing an intuitive and cost-effective solution. Establishing a causal relationship between the reduction of SO and ADHD symptoms is

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important for informing the nosology of SO. Furthermore, the findings will contribute not only to the local evidence base but the global discussions around the issue of SO.

Trial registration ClinicalTrials.gov (NCT07092787). Registered July 21, 2025.

Background

Updates on smartphone overuse

In the three decades since the first smartphones in 1992, smartphones have become an inseparable tool for many. Globally, people spend 44% of their waking hours (6.5 h) on average looking at screens, with a sizable portion through mobile devices [1]. In Hong Kong, due to the contact tracing efforts during the COVID-19 pandemic, smartphone ownership has become a necessity for all residents. Statistics in 2023 showed that smartphone penetration in Hong Kong is among the highest in the world, with 93.1% of residents owning smartphones, relative to 64.4% worldwide [1]. The Office of Communication Authority in Hong Kong reported an average of 3.14 mobile phones per resident in 2023 [2]. In tandem with the growing importance of smartphones in our lives, smartphone overuse (SO) has become a pressing issue.

SO is also referred to as excessive/problematic smartphone use, smartphone dependence, and smartphone addiction. It is characterized by dependence, tolerance, withdrawal, and disruption to daily life [3], parallel to behavioral addictions like compulsive gambling. In 2019–2021, SO affected 29.3% of a representative sample of 3,033 adolescents in Hong Kong [4]. Ample evidence has shown associations between SO and physical health issues, such as eye and wrist strain, musculoskeletal discomfort, lowered sleep quality, daytime sleepiness, and a sedentary lifestyle [5–8]. Both in Chinese and international contexts, SO is linked to depression, anxiety, and psychological distress [4, 9–11]. SO is also implicated in diverse behavioral difficulties, e.g., social withdrawal, dangerous phone use while driving, financial problems, family conflicts, and academic failure [11–16].

Studies on SO is an extension of the older literature on mobile or cell phone dependence, which identified excessive calls, compulsive text messaging, and obsessive thinking about phone use as three main factors [17]. However, technology has evolved. We now use smartphones to post on social media, watch short videos, chat with AI, play games, count our steps, among many other purposes. The field has not reached an agreement on whether the smartphone itself or activities pursued on the smartphone constitute the key problem. We argue here that smartphones should be studied for their addictive nature. Smartphones are designed to be portable and multi-functional, with push notifications alerting users to real-time happenings and some apps using reward schedules to reinforce regular use. These features grab users' attention and increase the risk of SO as users become unable to disengage. The duration and frequency of smartphone usage and SO increased with the number of push notifications [18]. This hints at certain smartphone designs that may lead to SO and thus changing these designs is a potential avenue for SO intervention [19].

Smartphone overuse in ADHD adolescents

Studies in different regions have reported an increased prevalence of SO, especially among young people [20]. Longitudinal studies have shown that SO tends to increase during adolescence from 10 to 18 years old and stabilize in early adulthood [10, 21]. Compared to young children, adolescents tend to have more flexibility in their smartphone usage because parents exert less screen time control. However, adolescents' executive control is still developing, so they often develop unhealthy smartphone usage habits [8, 10]. SO risk is higher when adolescents encounter environmental and social stressors [12, 21], which were heightened during the COVID-19 pandemic [22]. In a survey conducted in 2020 with a sample of 3,136 Chinese adolescents in Hong Kong, 53.5% reported excessive social media use and 43.6% reported excessive internet gaming [22]. Critically, these poor screentime habits had continued even though the period of social distancing and online learning has ended [23].

To address this problem proactively, the proposed study targets adolescents with attention-deficit hyperactivity disorder (ADHD) who are prone to SO [24]. Various ecological risks on the family, school, and personal levels may lead to SO among students [12], and ADHD diagnosis and traits are consistently identified as risk factors [9, 25]. For instance, in a cross-sectional study, 4,512 Korean adolescents were divided into four groups (ADHD vs. non-ADHD and SO vs. non-SO) based on self-reported ADHD symptoms and scores on the Smartphone Addiction Scale; results showed that the odds ratio of the ADHD group having SO was 6.43 relative to the non-ADHD group, the highest among all tested variables [9].

ADHD is a common neurodevelopmental disorder with a prevalence of 6.4% in Hong Kong [26]. Various characteristics in adolescents with ADHD have been linked to addictive media use and SO risk, including impulsivity, proneness to boredom, social needs, and rapid habituation to positive reinforcement [27]. Importantly, addictive media use and ADHD symptoms may have a transactional relationship, since bidirectional associations over time were seen in longitudinal studies among adolescents [27, 28]. This implies that untreated

SO will exacerbate ADHD symptoms and vice versa. There is a need to develop and test specific interventions for adolescents with ADHD and SO, a current gap in the literature.

Interventions for smartphone overuse

There is suggestive evidence that various interventions are helpful in reducing SO symptoms [29]. The proposed intervention follows a recent study using a "nudge-based" intervention with ten strategies which successfully helped university students with SO change their smartphone usage habits [19]. The intervention takes the Fogg Behavioral Model as a theoretical foundation, which posited that habitual behaviors are formed by slight changes that affect motivation, ease, and prompts [30]. For example, strategies lowered smartphone use by dimming the screen (motivation), putting smartphone out of reach at night (ease), and turning off notifications (prompts). Several small-scale studies examined individual components of this approach and reported positive effects, but they mainly targeted university students with only SO and no comorbid condition. These studies provided short intervention periods between 6 days to 6 weeks, relied on self-reported measures, and lacked long-term follow-ups. In the short term, social desirability or active self-monitoring may lead to reduced smartphone usage. However, relapse is a classic symptom of addictive behaviors, so a longer trial window and follow-up period is important to establish intervention effectiveness.

Researchers have highlighted the ways in which individuals with ADHD may be unusually sensitive to smartphones [24]. Five dimensions are proposed, including screen characteristics, media multitasking, digital disruptions, availability and addiction, and media content. Based on this framework, we adapted corresponding strategies to reduce SO among ADHD adolescents [19]. Since smartphones are frequently used in daily life, including in functional behaviors such as learning support and health tracking [24], the goal of the present intervention is not to eliminate smartphone use. Instead, we aim to increase adolescents' control over smartphone usage according to their needs with the help of smartphone settings and self-awareness. This approach may help adolescents to continue to follow these strategies without active reminders once a healthier usage habit has formed.

The neural basis of smartphone overuse

Establishing the neural and physiological bases of SO will inform intervention design and is a crucial step to understand the condition. A recent review of the neurofunctional regional activations associated with SO revealed regions critical for attentional control, emotional processing, reward processing, decision-making, and language and sensory processing [31]. These findings underscore the neurobiological bases of SO and open up investigation avenues for similarities and differences among addictive behaviors. The proposed study will use scalp-recorded electroencephalogram (EEG) as an outcome measure, which is a well-established, non-invasive, and low-cost neuroscience technique to study human brain activation. Resting-state EEGs are the spontaneous neural activities recorded in a task-free state. A recent systematic review of resting-state EEG studies of gaming disorder and internet addiction showed that individuals with these conditions showed distinct atypical brain activations at rest [32]. Those with gaming disorder have raised delta and theta activity and reduced beta activity, while those with internet addiction showed raised gamma and reduced beta and delta activity. Similar studies for SO are rare and comparisons with related conditions have not been reported. One study found different symptoms of SO to be associated with resting EEG microstates [33]. Another reported that indices from the alpha and delta frequency bands of resting EEG signals were correlated with SO, and these relations were mediated by negative emotions [34]. These initial findings aligned with previous reports and highlighted the roles of depression and anxiety in SO [10, 35].

The field has called for further studies to establish the potential neural signatures for SO [31]. Moreover, adolescence is marked by high neural plasticity wherein the brain circuitries for attention and executive control are maturing. The proposed study will enhance the evidence base of the neural correlates of SO within the design of an RCT. A smartphone-based behavioral intervention will be evaluated among ADHD adolescents in Hong Kong using self- and parent- reports, objective smartphone use pattern, and EEG neural activations in a multidimensional approach.

Aims and hypotheses

The aim of the proposed study is to develop and evaluate a smartphone-based behavioral intervention for adolescents with ADHD and SO in Hong Kong, with three hypotheses:

1. The intervention group will have a greater sustained reduction in self-reported smartphone dependence and objective smartphone usage, relative to the control group.
2. The intervention group will show a greater sustained reduction of self and parent-rated ADHD symptoms compared to the control group.
3. Spectral power differences in resting-state electroencephalogram (EEG) in the smartphone salient vs. smartphone non-salient conditions will index SO intervention effects among adolescents with ADHD.

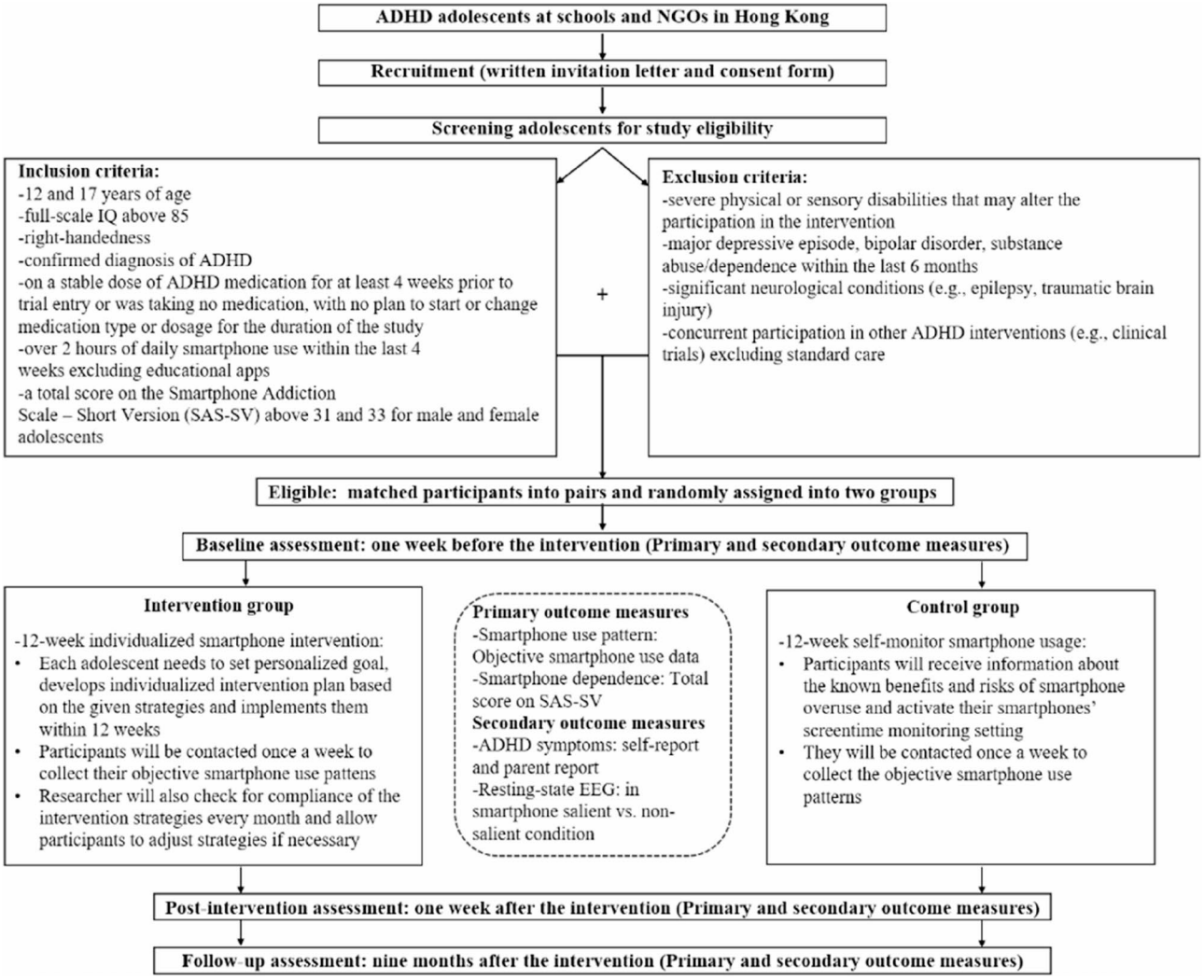

Fig. 1 Participants recruitment and study procedure

Method/design

Study design

The proposed study will be a randomized controlled trial with two parallel groups with 1-to-1 allocation. Study participants will be screened for eligibility, then matched into pairs according to their ages and genders by a research assistant. Another research assistant will use a random number generator to assign the participants in each pair to either the experimental group receiving a 12-week smartphone-based behavioral intervention or the control group who will self-monitor their smartphone usage for 12 weeks. Outcome assessment will be done three times [1], one week before the intervention [2], one week after the intervention, and [3] nine months after the intervention.

Group assignments will not be disclosed to adolescent participants or their parents during the study. All participants will be instructed to engage in a 12-week program designed to promote healthy smartphone use. The research assistants who perform matching and randomization of the participants will not be involved in data collection or outcome assessments. Data collection will proceed until the target sample size is reached and analysis will be conducted by researchers blinded to the group allocation and data values.

Figure 1 shows an overview of the selection of participants and the study design. If any protocol modifications become necessary, the amendments will be communicated to research personnel, experimenters, participants and their parents, the trial registry, the journal that published the study protocol, and the funding body.

Participants

We aim to recruit 120 secondary school students who were born in Hong Kong via referrals from partner schools, assessment services, and community centers, especially those with special education programs. We will conduct talks for parents and teachers to raise interest in SO issues and trends among adolescents. Moreover, to ensure an adequate number of valid participants, we will use social media channels to share targeted ads or posts in ADHD-related groups and forums.

Permission for consent will be obtained prior to formal assessment. Individuals, schools and institutions who wish to participate will be provided with written information about the study by our research assistants and asked to sign an online consent form. All participants will be explicitly informed that their involvement is entirely voluntary, and that they retain the right to decline participation or withdraw from the study at any stage, without the need to provide a reason or justification.

Inclusion and exclusion criteria

The inclusion criteria for adolescent participants are (a) between 12 and 17 years of age, (b) full-scale IQ above 85; (c) right-handedness to control for hemispheric dominance; (d) a confirmed diagnosis of ADHD with parent ratings of current symptoms of ADHD on the Strengths and Weaknesses of Attention Deficit Hyperactivity Disorder Symptoms and Normal Behaviour Scale [36]; (e) on a stable dose of ADHD medication for at least 4 weeks prior to trial entry or was taking no medication, with no plan to start or change medication type or dosage for the duration of the study; (f) over 2 h of daily smartphone use within the last 4 weeks excluding educational apps [4]; and (g) a total score on the Smartphone Addiction Scale–Short Version (SAS-SV) above 31 and 33 for male and female adolescents, respectively [3].

Exclusion criteria include (a) severe physical or sensory disabilities that may alter the participation in the intervention; (b) major depressive episode, bipolar disorder, substance abuse/dependence within the last 6 months; (c) significant neurological conditions (e.g., epilepsy, traumatic brain injury) that could affect cognitive and behavioral functioning; and (d) concurrent participation in other ADHD interventions (e.g., clinical trials) excluding standard care. We do not exclude participants with comorbid neurodevelopmental disorders (e.g., autism spectrum disorder) since comorbidity is highly common and there is value in studying the natural spectrum of conditions. Both parent and adolescent participants will receive store coupons to compensate for their time.

Sample size calculation

According to recent reviews, many pooled behavioral intervention effects for smartphone dependence or screen time had standardized mean differences over 1.0 at immediate post-test [29]. Since we target a clinical group, we calculated the sample size based on the predicted effect size of 0.80 in a two-group comparison. A minimal sample size of 52 participants is estimated ($\alpha = 0.05$, statistical power = 0.8) using G*Power (version 3.1.9.7) [37]. It is expected that recruiting a total of 120 participants will yield statistically meaningful immediate and sustained effects between the two groups even with 25% attrition rate.

Screening

A screening questionnaire will be given to one parent of each adolescent participant to screen for participant eligibility. It includes questions on age, gender, and the inclusion and exclusion criteria. After initial screening, parents will provide the adolescents' clinical diagnostic reports for verification and eligible participants will be invited to join the study.

Assessment sessions

Baseline assessment measures will be collected on the adolescent's status immediately before the intervention. Data collection will take place in a laboratory at the Education University of Hong Kong. Three types of data will be gathered: (a) self-reported and parent-rated survey data on the adolescents' smartphone usage and ADHD symptoms, (b) objective weekly smartphone usage based on app screencap, and (c) resting-state EEG recordings.

After the baseline assessment, the participants will follow the smartphone-based intervention or use their smartphones as usual for 12 weeks. Both groups will submit weekly records of smartphone usage patterns. It is estimated that about 20 study participants in each group will be served every four months, so the whole study will need three rounds of intervention (20 participants x 2 groups x 3 rounds of intervention = 120 participants).

An immediate post-test and a follow-up test will be conducted one week and nine months after the interventions on the outcome measures for all participants with the same procedures as in the pre-test.

A stepwise compensation payment scheme will be implemented to promote participant retention and complete follow-up sessions, with higher payments awarded for completing additional stages of the study. To increase compliance, we will offer participants a bonus to follow the intervention strategies at the end of the study period.

Interventions

Treatment group intervention

The treatment group will receive a 12-week individualized smartphone-based behavioral intervention based on the following strategies. They will be contacted once

a week to collect the objective smartphone use patterns and check for compliance of the intervention strategies.

1. *Personalized goal setting.* At the baseline session, participants will be prompted to view their past week's smartphone usage activities. They will be guided to reflect on their purposes for using their smartphones and set a target for each category of use. During intervention, participants will review their targets and receive simple encouragements.
2. *Screen characteristics.* Participants will change their device settings to limit bright and blue light at subset each day by using f.lux or Apple's Night Shift. During the day, they will turn down the brightness of the display.
3. *Media multitasking.* Participants will be reminded to do as many tasks as possible on the computer and reduce multitasking on the smartphone.
4. *Digital disruptions.* Participants will reduce device notifications including sound, banner, and vibration, initiated by various apps by changing the setting and filtering low-priority messages. They will also use the "do not disturb" function (silent and no vibration) during the school day and put the smartphone out of sight and out of reach.
5. *Media content.* Participants will hide high usage but non-essential apps (e.g., social networking sites) in a folder off the main screen. Participants will gradually limit their exposure to these contents (e.g., online games), with a weekly goal of reducing 15 min of usage per day compared to the previous week.
6. *Availability and addiction.* Participants will disable Touch ID and Face ID (using fingerprint or face to unlock the smartphone) and use a password instead to decrease ease of access. Participants will schedule downtime that sets a lock on all apps 30 min before their regular sleep time. During the 30 min, participants will be suggested to replace smartphone use with non-digital activities that they enjoy, e.g., reading, journaling, stretching, talking to family members. Participants will be encouraged to limit messaging and social interactions via smartphone, reduce the frequency of taking their smartphone outside unless necessary, and decrease overall smartphone usage.

Control group intervention

The control group will receive information about the known benefits and risks of SO and activate their smartphones' screentime monitoring setting. They will be contacted once a week to collect the objective smartphone use patterns, but they will self-monitor their smartphone usage.

Schedule and setting

The intervention will last for 12 weeks. During this period, ADHD adolescents in the treatment group and control group are required to either implement specific smartphone use strategies or self-monitor their smartphone usage in daily routine. The location will be at adolescents' home and school. The intervention will continue unless participants explicitly request to withdraw.

Implementation timeline and intervention fidelity

The proposed recruitment will be completed within one and a half years. The data collection will be conducted over a two-year period. To ensure intervention fidelity, we will prepare a manual with a detailed protocol from participant intake to final debriefing. Two research assistants will monitor the intervention progress of each participant and collect the data.

Outcome measures

Primary outcomes

a. *Smartphone use pattern.* Objective smartphone use data will be collected via smartphone apps (e.g., "ScreenTime" on Apple or "Digital Wellbeing" on Android) to trace the pattern of smartphone use of each participant [19]. Participants will send screenshots of the smartphone usage data on their phones: (a) minutes of use over the previous 7 days, (b) distribution of minutes spent according to categories of use (social networking, games, entertainment, productivity, etc.), (c) number of screen unlocks or "pickups," and (d) number of notifications received.
b. *Smartphone dependence.* To allow for comparisons with existing studies, we will use the SAS-SV [3] validated in Hong Kong, which was designed for the assessment of smartphone dependence and showed good reliability and validity [38]. The scale has ten items, such as "Missing planned work due to smartphone use" and "I will never give up using my smartphone even when my daily life is already greatly affected by it". Each item was measured by 6-point scales, from 1= "strongly disagree" to 6 = "strongly agree". Total score on the scale will be used to assess the degree of each participant's smartphone dependence, with suggested cut-off values of smartphone overuse for male and female was 31 and 33, respectively [3].

Secondary outcomes

(a) *ADHD symptoms.* Adolescents' ADHD symptoms will be assessed via self-report and parent report. The Strengths and Weaknesses of Attention Deficit Hyperactivity Disorder Symptoms and Normal Behaviour Scale [36] will be adopted, which used a 7-point scale and rephrased the 18 ADHD items of the DSM into neutral or positive statements. Scores of each statement range from − 3 (far above average) to + 3 (far below average), anchoring on normative behavior in age-matched adolescents. Two subscales on inattention and hyperactivity–impulsivity symptoms can be derived. We will use a Chinese translation that has been used in Hong Kong [39].

(b) *Resting-state EEG.* During the EEG recording process, adolescent participants will be asked to relax and avoid swallowing and movements that may cause artifacts. For 5 min of recording, participants will look at a blank piece of paper on the table. For another 5 min of recording, they will look at their own smartphone, face-down with notifications turned off, on the table. The order will be counterbalanced across participants. EEG data will be recorded from 32 channels according to the international 10–20 system. Horizontal and vertical eye movements will be recorded from the outer canthi of the eyes and from below the right eye, respectively.

Data analysis

No interim analyses are planned; data collection will proceed until the target sample size is achieved. Upon completion, the final trial dataset will be fully accessible to both investigators and research assistants. All collected data will be organized in time and double checked by research assistants. Missing data will be retained and addressed using appropriate statistical methods based on the type of missingness.

The collected ratings, smartphone usage data, and neural data will form a multi-dimensional dataset, which will be trimmed for outliers based on the Mahalanobis distance. An index of objective smartphone use will be calculated based on a principal component analysis.

EEG signals will be processed and decomposed into different frequency bands to test for differences in spectral power before and after intervention. For statistical tests, we used mixed-effects linear regression [40] to test the effects of condition (intervention vs. control), time (baseline, post-test, follow-up), and the interaction, with pre-intervention age and status as covariates. We will examine the intervention effects for each primary and secondary outcome separately and include a random intercept for each participant. Analyses will be done using EEGLAB [41] and the R platform [42], following the intention-to-treat principle to account for potential bias in drop-outs between intervention and control groups.

Discussion

Overall, despite psychotherapy, exercise intervention, and multicomponent interventions reporting large positive effects on SO [29], it was noted that the existing evidence on SO interventions is still limited and generally of low quality [29]. Specifically, many studies lacked long-term follow-up, and thus could not determine whether intervention effects could be sustained. The studies also mainly relied on self-reported smartphone usage, which are susceptible to social desirability and recall biases [43]. To date, there is no published SO intervention for clinically-diagnosed ADHD individuals using a randomized controlled trial (RCT) design. In addition, although significant associations between ADHD symptomology and SO have been reported, very few studies investigated ADHD symptoms as an outcome measure of SO intervention. Another relatively neglected area of research is the neural correlates of SO. While emerging literature has found SO to be associated with attenuation of the neural responses to reward processing and atypical functional activations in various brain areas [31], few have ascertained how the brain rewires after SO interventions. Finally, the patterns of smartphone use and its effects on individual outcomes may differ in different countries [44], thus SO intervention should be conducted in the local context to account for the societal and educational environments.

The proposed study is designed to develop and evaluate a smartphone-based behavioral intervention for adolescents with ADHD and SO in Hong Kong. Guided by a conceptual framework on SO in ADHD [24], the intervention allows participants to implement specific strategies that counter the potentially addictive qualities of smartphones using built-in smartphone functions that have been previously shown to be effective [19] in an individualized way. Evaluating the proposed behavioral intervention in ADHD adolescents with SO has clear clinical value in managing both ADHD and SO, and for preventing downstream difficulties associated with these conditions. The study results will contribute to the evidence-based practice of SO intervention, providing an intuitive and cost-effective solution. Establishing a causal relationship between the reduction of SO and ADHD symptoms is important for informing the nosology of SO, which is still a matter of debate. We also add to the existing literature by adopting objective measures of smartphone usage obtained via smartphone apps, which can better reveal the impacts and changes resulting from SO interventions [19, 45].

Extant research has shown considerable negative health consequences of SO, and the current application fills an identified gap in the literature for interventions among adolescents. The current study will reveal ways to mitigate the negative consequences of SO for the public. The proposed study's focus on ADHD adolescents, a vulnerable group for SO, also supports the timely prevention and identification of high-risk cases. The research findings can enhance the capacity of healthcare professionals to address SO-related problems in ADHD adolescents. The intervention procedures of the current study are simple to incorporate into training programs to enhance the care for ADHD. This may enhance their quality of life, physical and mental health, and academic/career achievements. The proposed intervention program in the current study not only benefits the local ADHD population but also has the potential for international implementation.

Evidence from the proposed SO intervention will provide a robust scientific foundation for more systematic research to develop public health policies and guidelines for this mounting social problem. For example, recommendations for healthy smartphone use may include the number of hours of use per day over the developmental trajectory. The Australian government recommends no more than two hours of sedentary recreational screen time per day for children and young people aged 5–17 years (excluding schoolwork) [46]. In Hong Kong, an analogous guideline stated that adolescents "should be trained to develop good time management skill and self-discipline to work independently and prepare themselves to be responsible adults" [47]. The study can inform policymakers of the need to limit smartphone use for children at different developmental stages.

The study findings will be disseminated through presentations at scientific conferences, meetings with local special education practitioners, and public knowledge exchange seminars targeting families and individuals affected by ADHD and SO. Research outcomes will also be reported in manuscripts submitted to relevant academic journals. Upon completion of the study and publication of the final report, the full protocol, anonymized participant-level data, and statistical analysis codes will be made publicly accessible within the published article and its supplementary files.

With the evidence collected from the proposed study, evidence-based strategies may be promoted to the public to enhance their digital health and well-being. While this study focuses on the clinical population of ADHD adolescents, the low cost and individualization of the intervention strategies can encourage self-monitoring, preventative intervention, and help-seeking behaviors in the community. Research findings can help to promote healthy usage habits in different contexts, for instance, in schools for children at the start of smartphone ownership, for adults to set usage boundaries, and for parents/teachers to spot signs of smartphone dependence.

Although the research findings of the current study will have fruitful implications to mitigate the negative consequences of smartphone overuse, the technology has rapidly developed and may change in the future. The impact of SO may be moderated by different factors such as new features, social norms, and context, so it is necessary to keep the research field updated to the viability and potentials of smartphone-delivered interventions, including for smartphone dependence itself. Future studies can also test the effectiveness of the intervention procedure in ADHD populations with different characteristics and other neurodivergent features, e.g., autistic traits, to confirm whether the intervention procedure is suitable for a wide range of populations.

Abbreviations

SO	Smartphone overuse
ADHD	Attention-deficit hyperactive disorder
RCT	Randomized controlled trial
EEG	electroencephalogram
SAS-SV	Smartphone Addiction Scale–Short Version

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12888-025-07493-w.

Supplementary Material 1.

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Authors' contributions
YNY, KYP and CHL conceived the study. All authors made significant contributions to the planning of the study. YNY developed the study design and drafted the manuscript. XFL assisted with literature summary, experimental design and drafting the manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All the study procedures have been examined and approved by the Human Research Ethics Committee of the Education University of Hong Kong according to the Helsinki declaration (Reference number: 2023-2024-0412). The research team will brief eligible adolescents and parents thoroughly about the study procedures and the nature of recording smartphone usage patterns and EEG data collection. All participants and parents will give written informed consent before they voluntarily provide data, with no negative consequence for not participating or withdrawing during any part of the

study. Research personnel will keep all data anonymous and confidential. All information related to participants will be identifiable by codes known only to the researcher. All data will be stored on a password-protected online account which can only be accessed by the Principal Investigator and Research Assistants for this project, until 5 years past completion of the study, then the data will be destroyed. Individual feedback on adolescents' performance will not be given to their schools or other parties. The control group will receive instructions for smartphone-based strategies to reduce smartphone use after the study period. After the study period, participants with maintained SO behavioral patterns will be referred for further clinical services.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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