



Do persuasive designs make smartphones more addictive? - A mixed-methods study on Chinese university students

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ABSTRACT

Persuasive designs have become prevalent for smartphones, and an increasing number of users report problematic smartphone use behaviours. Persuasive designs in smartphones might be accountable for the development and reinforcement of such problematic use. This paper uses a mixed-methods approach to study the relationship between persuasive designs and problematic smartphone use: (1) questionnaires (N=183) to investigate the proportion of participants with multiple problematic smartphone use behaviours and smartphone designs and applications (apps) that they perceived affecting their attitudes and behaviours, and (2) interviews (N=10) to deepen our understanding of users' observations and evaluations of persuasive designs. 25% of the participants self-reported having multiple problematic smartphone use behaviours, with short video, social networking, game and learning apps perceived as the most attitude- and behaviour-affecting. Interviewees identified multiple persuasive designs in most of these apps and stated that persuasive designs prolonged their screen time, reinforced phone-checking habits, and caused distractions. Overall, this study provides evidence to argue that persuasive designs contribute to problematic smartphone use, potentially making smartphones more addictive. We end our study by discussing the ethical implications of persuasive designs that became salient in our study.

1. Introduction

Fogg was one of the first scholars to research computers as persuasive technologies (Fogg, 1998). In the early days of persuasive technology, designers focused on promoting positive attitudes and behaviour changes in the health, economics and education fields (Hamari et al., 2014). Later, persuasive designs became ubiquitous online, with attitude and behaviour change design methods being increasingly integrated into social networking, retail, news and entertainment sites. Billions of users are exposed to such persuasive designs each day by internet giants such as Facebook, TikTok, Amazon, Netflix, Alibaba, YouTube and others.

Persuasive designs might negatively affect users' attitudes and behaviours (Borgefalk & Leon, 2019). On the one hand, for products designed to serve their customers better, it is possible that unintended impacts on users might arise despite firms' good intentions. One prominent case is the introduction of the Facebook "like" button, which was intended to enable users to share affirmation and positivity easily

(eCorner, 2013). However, studies have shown that the "like" button negatively affects users' mental health, resulting in social comparisons and increased envy and depression (Blease, 2015). On the other hand, in the context of the attention economy, persuasive designs (for example, recommendation algorithms on video and e-commerce platforms) insatiably seek users' attention and consume their leisure time (Williams, 2018). Companies adopt persuasive designs to prolong users' time on their digital services and seek to make their products more engaging and habit-forming than those of their competitors (Eyal, 2014). Experts fear that the precipitous rise in smartphone and social media usage (Rosenquist et al., 2021) is leading to mental (Lei et al., 2020) and physical harm (Kim et al., 2015), especially among children and adolescents (Lewis, 2017).

Screen time and mental/physical problems associated with smartphone use are increasing worldwide (Busch & McCarthy, 2021; Olson, Sandra, Colucci, et al., 2022; Rozgonjuk et al., 2018). Studies have found that some mobile applications (apps) predominantly occupy users' screen time, i.e., lifestyle, social networking (Noë et al., 2019) and

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instant messaging apps (Ding et al., 2016). Furthermore, Noë et al. found some features of Snapchat that make users prolong their usage, for example, making friends compete against each other for the top position (competition) and incentivising users not to break their “Snapstreaks” with close friends (reward) (Noë et al., 2019). It seems legitimate to consider Snapchat’s success in light of its integration of these persuasion strategies.

The majority of studies on applications of persuasive technology are in the health, wellness, and education domains (Devincenzi et al., 2017; Orji & Moffatt, 2018); recently, scholars have paid growing attention to its adverse effects on volunteerism, privacy, transparency, and users’ awareness (Nyström & Stibe, 2020). However, the relationship between persuasive designs and problematic smartphone use (PSU) is less studied. This study makes two main contributions.

- (1) Our findings extend existing knowledge on how users perceive the influence of persuasive design features.
- (2) We identify potential relationships between persuasive designs and problematic smartphone use behaviours, and links to addiction-like behaviours.

Our study makes empirical contributions relevant for researchers and designers in Human-computer Interaction (HCI), as well as psychologists, by providing qualitative insights into the longitudinal effects of persuasive designs on technology users. This study is among the first to use a mixed-methods approach to investigate the relationship between problematic smartphone use and the design features of smartphones in China, one of the countries with the most problematic smartphone use (Busch & McCarthy, 2021; Olson, Sandra, Colucci, et al., 2022). This is timely in an era in which many cutting-edge technologies are applied to exert influence on users across the world.

The remainder of this paper is organised as follows. In section 2, the definitions, applications and ethical concerns of persuasive technology and studies about PSU are examined; subsequently, research questions are formulated. In section 3, the study methods and data analysis process are described in detail. We then present our results in section 4 and discuss the results in section 5. In section 6, we present our conclusions.

2. Related work

Definitions and applications of persuasive technology: Fogg (2002) defined persuasive technology as “interactive computing systems designed to change people’s attitudes and/or behaviours, without using coercion or deception” (p.15) (PT1). He excluded unethical applications from the definition. However, when Kampik et al. (2018) studied the persuasive properties of several popular apps, including Duolingo, Facebook, Slack, and YouTube, they found prevalent use of deception and coercion and suggested redefining persuasive technology as “any information system that proactively affects human behaviour, in or against the interests of its users” (PT2). Kampik et al. (2018) listed four core indicators of persuasive technology, i.e., intentionally persuasive, behaviour-affecting, technology-enabled, and proactive (“some extent of autonomy or a high degree of automation”). This study adopts the PT2 definition and applies the four core indicators in identifying persuasive designs.

Over the past two decades, multiple frameworks and psychological theories have been introduced to the persuasive technology design process as persuasion strategies. Oinas-Kukkonen and Harjuma (2009) developed Fogg’s taxonomy of persuasive design principles and proposed a framework for the design and evaluation of persuasive systems—the Persuasive System Design (PSD) model (see Fig. 1). The PSD model divides persuasion strategies into four categories: primary task support, dialogue support, system credibility support, and social support. Orji and Moffatt (2018) analysed 85 articles on persuasive technologies for health and wellness. They found that the most frequently employed strategies in this field were “tracking”, “monitoring”,

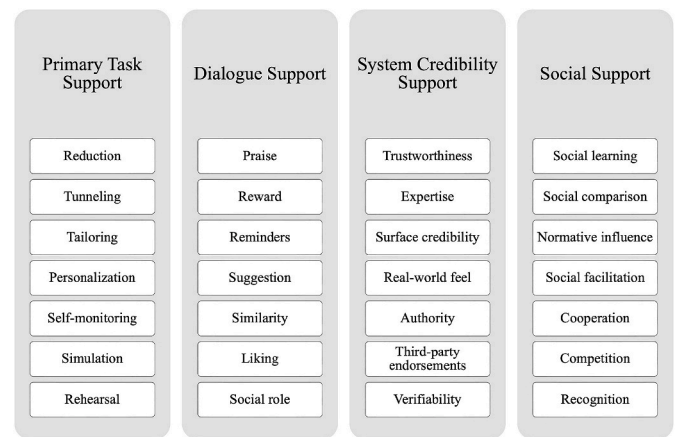


Fig. 1. The PSD model (Oinas-Kukkonen & Harjuma, 2009).

“feedback”, “social support, sharing and comparison”, “reminders”, “alert, reward, points, credits”, “objectives”, and “personalisation”. Kaptein et al. (2015) presented persuasion profiling as a method of personalising messages, which represent different persuasion principles, to influence users. Oyibo and Vassileva (2019) studied how participants with different personality traits exhibit different levels of susceptibility to social influencing strategies (i.e., social learning, social proof and social comparison). All of these studies advance our knowledge of how different persuasion strategies could be deployed in designing persuasive applications.

Ethical concerns regarding persuasive technology: Berdichevsky and Neuenschwander (1999) discussed the potential negative impacts of persuasive technology on its users and proposed a guideline for designers. They formulated a golden rule: interaction designers should never seek to persuade users of “something they themselves would not consent to be persuaded to do” (Berdichevsky & Neuenschwander, 1999). Fogg (2002) was concerned that ethical issues regarding persuasive technology could be the same as those for persuasion in general and recommended that designers perform stakeholder analysis in complicated situations. In addition, Fogg predicted that persuasive technology might encounter increasing scrutiny from policymakers because of its potential impact on the public, prompting regulatory efforts to guard against certain coercive tactics and protect specific audiences. Smids (2012) found that persuasive technologies often influence users beyond the point of self-control. Smids (2012) recommended that persuasive technology designers perform voluntariness assessments, specifically reviewing whether there is manipulation (“influence users in ways of which they are not aware and cannot control”) and coercion (“apply direct force or credible threat to control users”) in their persuasive designs and whether users act intentionally during persuasion. Timmer et al. (2015) analysed new challenges brought on by the integration of persuasive technology and ambient intelligence. They emphasized transparency about the interests of different stakeholders and proposed that users and providers should have open discussions and reach agreements on the goals, methods and interests of persuasive technology to achieve trustworthiness. Borgefalk and Leon (2019) observed the rise and proliferation of digital platforms that use persuasive designs in business operations, proposing interdisciplinary research approaches, combining persuasive technology, governance, and management studies to address associated ethical challenges.

PSU and smartphone addiction: There is a divide in academia on the most precise term to describe users’ prolonged screen time and the mental/physical problems associated with smartphone use (Billieux, Maurage, et al., 2015). Based on the internet addiction scale, Kwon, Lee, et al. (2013) validated a self-diagnostic scale for smartphone addiction. More than 3300 articles have cited the scale and its short version (Kwon, Kim, et al., 2013) as of April 2023. By contrast, some scholars use the

term PSU to study the “*craving to use a smartphone in a way that is difficult to control and leads to impaired daily functioning*” (Busch & McCarthy, 2021). Lanette et al. (2018) noted that the expression “smartphone addiction” was overused in academia and the media. They questioned the objectiveness of self-reported scales and stressed the situated and complex nature of phone use. They suggested looking deep into smartphone functionalities and users’ self-reflective behaviour. Likewise, Billieux, Schimmenti, et al. (2015) advised caution in overpathologizing everyday behaviour as behavioural addictions. They highlighted the multi-faceted nature and heterogeneity of daily life disorders. Therefore, this study does not aim to examine which terms describe current smartphone use problems most precisely; it instead seeks to study factors that contribute to the problematic situation, and studies using both terms (“smartphone addiction” and “PSU”) will be referred to.

Almourad et al. (2020) reviewed different definitions of digital addiction in 47 studies, including internet, gaming and smartphone addiction. Several features were identified and classified into categories that provide an image of digital addiction with respect to four aspects, i. e., device usage, social interaction, psychological states, and clinical symptoms (see Fig. 2). In addition to providing a holistic view of the digital addiction research field, they observed a set of shared features across terms, including impulsivity, compulsion, lack of control, negative emotional outcomes, and impairment in work and study (Almourad et al., 2020). This integrated approach considers the diversity of smartphone functionalities, given that smartphones have become synthetic devices for communication, connectivity, and gaming.

For the purposes of this article, we will use the term Problematic Smartphone Use (PSU) to refer to users overusing smartphones to a degree that causes a perceived negative impact on their productivity, mental/physical health, and other aspects of life.

Scholars have striven to identify the factors that contribute to PSU. Some researchers investigated users’ susceptibility to PSU. They found that user characteristics, such as antagonism and negative affect, serve as positive predictors for latent PSU behaviours (Marciano et al., 2021). Further, researchers found that fear of missing out (FOMO)/lower well-being/distress were correlated with PSU (Della Vedova et al., 2022; Elhai et al., 2016; Horwood & Anglim, 2019). Higher levels of FOMO were found to be associated with greater impact of social media on one’s daily activities and productivity (Rozgonjuk, Sindermann, Elhai, & Montag, 2020). Meanwhile, scholars studied users’ interactions with smartphones to explore why smartphones are disruptive. Frequent phone-checking habits make up a substantial amount of users’ smartphone use (Oulasvirta et al., 2012). Heitmayer and Lahlou (2021) found

that 89% of smartphone interactions are initiated by users, not by notifications. Importantly, they suggested investigating the routines and habitualised behaviours users develop over time in interacting with smartphones. One possible explanation is that persuasive designs in smartphone operating systems and apps cultivate and reinforce users’ habitual behaviours. Studies have identified persuasive designs in popular apps such as YouTube, Facebook, Snapchat, Flipkart and AliExpress (Adib & Orji, 2021; Kampik et al., 2018; Noë et al., 2019), while persuasive technology is effective in motivating users to change behaviours (empirical studies) (Cellina et al., 2021; Khalil & Abdallah, 2013) and in sustaining behaviours (theoretical framework) (Kaptein et al., 2010).

Teenagers spend prolonged time online with social media and games, which might be linked to persuasive designs (Daniel, 2018). Cemiloglu et al. (2021) compared theories explaining digital addiction behaviours with the PSD model, suggesting that certain PSD strategies, such as reduction (simplifying tasks), rewards (rewarding target behaviours), social comparison (comparing oneself with others), liking (being visually attractive to users) and personalisation (offering personalised content or services), may trigger and expedite digital addiction in specific contexts. To the best of our knowledge, there is no empirical study on the relationship between persuasive technology and PSU; as a result, we formulate the following research questions (RQs) to fill this research gap:

RQ1. What proportion of study participants self-report having multiple problematic smartphone use behaviours?

RQ2. Which smartphone designs and apps do participants report influence their attitude or behaviour?

RQ3. How do participants perceive persuasive designs and their influences on smartphone use?

3. Research methods

3.1. Overview

We used a mixed-methods approach to answer our research questions. We administered a questionnaire to answer RQ1 and RQ2 (section 3.2) and interviewed ten study participants to provide additional answers to RQ1 and answer RQ3 (section 3.3).

3.2. Questionnaire

3.2.1. Participants

Participants were recruited through multiple channels. We published the link to the questionnaire on the university intranet forum (Beijing Institute of Graphic Communication), student group chats (Energy and Sustainability program at Zhejiang University), and Tencent questionnaire service¹ (Survey distribution set to college students aged 18 to 26). 248 users completed the survey. With Tencent’s automatic spam screen² and manual age-grade consistency check (i.e., Chinese students, in general, start their freshman year between age 17-19 years old; This age-grade consistency check filtered out participants who deviated more than two years from the average number), 183 questionnaires were verified as valid.

The participants of our study are Chinese university students. There were 90 male and 93 female participants, ranging from 18 to 26 years old (mean=21.7, SD=1.8). 83% (n=152) of the participants use Android

¹ **Tencent questionnaire service:** a free and professional questionnaire design and distribution platform operated by Tencent company, the largest social networking company in China.

² **Tencent automatic spam screen:** the Tencent machine learning algorithm studied respondents’ answering behaviour, number of answers, question types, and other factors to filter spams.

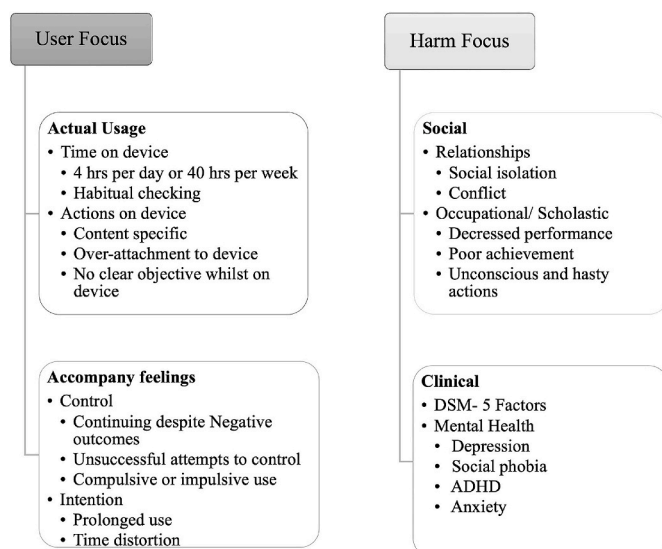


Fig. 2. Digital Addiction features (Almourad et al., 2020).

smartphones, while 17% (n=31) use iPhones (see Fig. 3 for the histograms by age, gender, and operating system). The most common study programs in the survey sample were engineering (n=27%), economics & management (n=25%), computer science (n=23%), and e-commerce & marketing (n=14%).

3.2.2. Procedure

We pre-tested the questionnaire with four university students. The first two students were from a Swedish university and complete the pilot questionnaire in English. They provided valuable feedback for constructing the smartphone usage and open-ended questions. Then, the pretests were held with two Chinese university students using a Chinese translation of the questionnaire. All pretest sessions were conducted via Zoom. We collected the data using the Chinese version of the questionnaire.

The questionnaire was published on April 3, 2021, and data collection remained open until April 25, 2021. During this period, no lockdown measures were implemented in the cities in which our participants resided. However participants needed to use smartphones to track their contacts and install e-learning apps. Questionnaires could be answered through web pages, QQ, and WeChat. On average, users took 3 minutes to complete the survey. Each valid survey participant received ¥3 (US \$0.5) as compensation.

3.2.3. Materials

The questionnaire included multiple-choice questions and open-ended questions in three sections:

Demographics Q1-Q5: Participants' age, gender, smartphone operating system (OS), study program, and year in university (i.e., Bachelor [freshman, sophomore, junior, senior] or graduate program [master's student, PhD student]).

Smartphone usage Q6-Q7: We asked the participants to report their average daily screen time and gaming time. Q8-Q11: We adapted questions from published studies and chose loss of control, perceived negativeness and overuse as key PSU indicators (Huang et al., 2021), including:

- Q8. Do you feel that the use of smartphones takes up too much time? a) Yes. b) No. c) Hard to tell. d) Occasionally.
- Q9. Have you tried to control your smartphone usage time? a) Yes, I reduced my usage time. b) Yes, but I failed to reduce my usage time. c) No, I do not intend to reduce my usage time. d) No, but I plan to reduce my usage time in the future.
- Q10. Do you inadvertently use your smartphone for longer times than you planned?

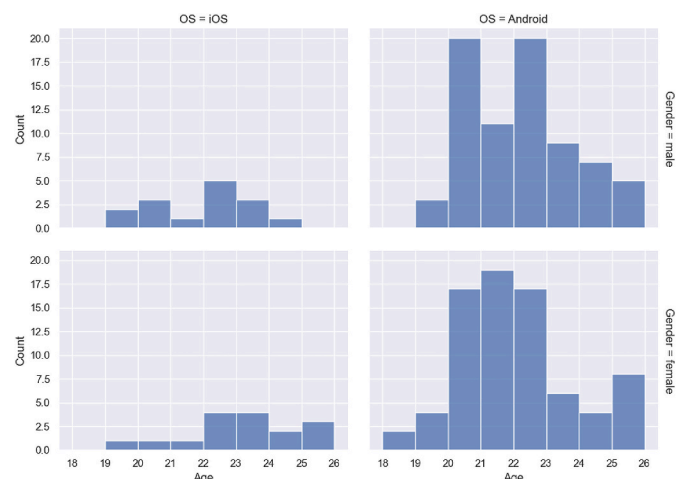


Fig. 3. Age, gender, operating system count.

- a) No. b) Very rarely. c) Rarely. d) Occasionally. e) Frequently.
- Q11. Does the smartphone negatively affect your studies or professional life? a) No. b) Very rarely. c) Rarely. d) Occasionally. e) Frequently.

Perception of persuasive applications Q12-Q13 investigate participants' perceptions of persuasive applications on their smartphones. Specifically, the participants contribute to identifying intentionally persuasive and behaviour-affecting features, and we examine whether the mentioned apps/OS features are technology-enabled and proactive. The questionnaire ends with Q14, about whether the participants would be willing to participate in an interview:

- Q12. Are there any apps that have changed your attitude or behaviour? (If yes, please elaborate briefly.)
- Q13. Are there any functions, apps, or designs of your smartphone that led you to develop new habits? (If yes, please elaborate briefly.)
- Q14. Would you like to participate in a 30-minute interview about your smartphone usage habits? (If yes, please leave your contact details.)

3.3. Interview

3.3.1. Participants

Ten interviewees were sampled on April 6, 2021, from the survey participants who had submitted contact information; 172 valid answers had been collected by then. Participant gender and screen time were taken into account to match the survey sample distribution. We sampled five females and five males. The sampled interviewees reported spending on average 6.0 h/d on their smartphones, while the survey participants reported 5.6 h/d. Interviewees came from various study programs, including energy and sustainability, computer science, media and civil engineering (see Table 1).

3.3.2. Procedure

We designed and pre-tested interview questions using the same procedure as described above for the questionnaire. The in-depth interviews started with a self-evaluation of their problematic smartphone use. Then, we asked interviewees questions related to smartphone usage and screen time. Next, the interviewees were asked to identify persuasive designs that they could observe in their smartphone usage; if the interviewees weren't familiar with the concept of persuasive technology before the interview, the definitions, applications and examples of persuasive technology were explained to them. The interviews ended with a self-evaluation of how the persuasive designs observed by interviewees affect their screen time and smartphone usage habits.

The interviews lasted between 18 and 45 minutes and were conducted remotely via WeChat voice call. The interviews were recorded with permission. Each interviewee was compensated ¥50 (US\$7.3) for participation.

3.3.3. Materials

A Chinese translation of Fig. 2 was presented to the interviewees, and we provided the definitions of the DSM- 5 Factors and ADHD as footnotes to the interviewees. We referred to the recommendation and red dots notification designs of WeChat as examples of persuasive technology in question 5, because all participants used WeChat and were familiar with these features. We prepared the following seven questions for the interviews:

1. Would you mind going through the Digital Addiction Features (Fig. 2) and telling me which features match your experience?
2. Please indicate the occasions when you have to use your smartphone daily.

Table 1
Summary of interviewee information.

Participants	Ages	Gender	OS	Study Program	Grade	Screen Time (h/d)
P1	19	Female	Android	Media	Freshman	6.0
P2	22	Male	Android	Civil Engineering	Senior	7.0
P3	22	Male	Android	Computer Science	Master Student	4.0
P4	22	Female	iOS	Mathematics	Senior	6.0
P5	22	Female	Android	Language	Senior	7.0
P6	23	Female	Android	Medicine	Junior	8.0
P7	23	Male	iOS	Computer Science	Senior	6.0
P8	23	Male	Android	Energy and Sustainability	PhD Student	5.0
P9	24	Male	Android	Energy and Sustainability	Master Student	5.0
P10	24	Female	iOS	Media	Master Student	6.0

3. Please evaluate the hours needed for these essential occasions. What are the factors that caused you to spend more time on your smartphone?
4. Have you heard about Persuasive Technology before? (If yes, can you elaborate a bit.)
5. Discuss Persuasive Technology definitions by [Fogg \(2002\)](#) and [Kampik et al. \(2018\)](#) and applications.
6. Can you recognise some persuasive applications/features/designs on your smartphone?
7. Would you mind evaluating the impact of the above-mentioned persuasive applications on your smartphone use?

3.4. Data analysis

The questionnaires were collected in Chinese, and then the raw data were translated from Chinese to English. For screen time and gaming time, means were computed by gender and operating system. Quantitative analyses were performed using Microsoft Excel and SPSS. For open-ended questions, sentiment analysis was performed using Excel Azure Machine Learning. The results were also manually checked for errors. Data were visualised using Python Seaborn Library ([Waskom, 2021](#)).

We used thematic analysis ([Clarke et al., 2015](#)) to analyse the qualitative data collected from the interviews. The audio recordings were transcribed to text via the iFlytek³ automatic transcription service, then manually checked and extracted by author 1. The interviewee transcripts were translated into English by author 1. Authors 1 and 2 discussed together how to choose matched codes in the coding process and search for the relevant themes. The themes were reviewed and discussed between the authors in the process of structuring and composing the results section.

3.5. Privacy and ethical considerations

The study was conducted at a Swedish University which does not, under normal circumstances, require ethical review board approval for HCI studies. Participants who were younger than 18 years old were automatically deleted from the survey results to protect the privacy of minors. The quantitative and qualitative data collected in the study were analysed anonymously, and participants' identity was protected. The collected data were stored in an encrypted hard drive. We informed all study participants of the purpose of the study and their right to withdraw at any time. We obtained verbal consent from all interviewees prior to the interviews.

³ **iFlytek**: a Chinese information technology company specialising in voice recognition and communication technology. We employed automatic transcription, and the audio and transcripts were deleted from the researchers' iFlytek account after downloading them.

4. Results

4.1. Questionnaire

4.1.1. Problematic smartphone usage (RQ1)

In this section, we describe what proportion of users self-reported having multiple PSU behaviours.

The participants reported spending on average 5.6 h/d using their smartphones. 15% (n=28) of them spent less than 4 h/d using their smartphone, while 85% (n=155) spent 4 h or more. On average, female participants used their phones 5.9 h/d, while male participants used theirs for 5.4 h. We would like to point out that the screen times in this study are self-reported, with the exception of [Table 3](#) and interviewees' transcripts, which were documented based on screenshots. We will discuss this further in the study limitations.

67% (n=122) of participants indicated that they spent too much time on their smartphones. 83% (n=152) of participants had tried to control their smartphone usage time; among them, 58 (mean=5.3 h) participants were able to reduce their screen time, while 94 (mean=5.8 h) participants failed to do so. 122 (67%) participants (frequently and occasionally) used their smartphones for longer times than planned, while 81 (44%) participants (frequently and occasionally) thought smartphones negatively affected their studies or professional life.

To sum up, 25% (n=46) of participants reported multiple PSU behaviours at the same time, including smartphone overuse (Q8: a or d and Q10: d or e), had failed to control or planned to control their phone use in future (Q9: b or d), and felt that they had been negatively affected by phones (Q11: d or e). They reported spending 6.3 h daily on their phones.

4.1.2. Reported persuasive features (RQ2)

In this section, we describe the perceived persuasive applications reported by survey participants.

145 (79%) participants answered the open-ended question: *Are there any apps that have changed your attitude or behaviour?* Among participants who filled in answers, 38 participants only mentioned app names, with no specification of how these apps influenced them. Consequently, 107 valid answers were analysed by Azure to identify sentiments. The most mentioned apps were TikTok⁴, WeChat (social networking), Honor of Kings (a popular game), Kuaishou (short video platform), Little Red Book (social networking), Weibo (Chinese Twitter) and Taobao (e-commerce) (see [Table 2](#), the most mentioned apps that changed users' attitude or behaviour with sentiment analysis, count, and coded comments). These are all popular apps among young Chinese. Surprisingly, TikTok, WeChat, Honor of Kings, and Taobao were also the most frequently mentioned as having negative influences on participants.

"Time" was the most frequently mentioned keyword, which was recorded in 23 answers. Positive sentiments were associated with

⁴ **TikTok**: TikTok in this study refers to Douyin which is the Chinese version of TikTok international version.

Table 2
The most mentioned apps that have changed participants' attitudes or behaviours.

Apps	Sentiment Analysis				Count	Comment
	Pos.	Neu.	Neg.	N. D.		
TikTok	11	2	10	5	28	Learn skills/Broad horizon/Inspirational/Kill boredom/New Knowledge/Lose control/Can't stop/Too much time/You can find everything on it
WeChat	5	2	8	4	19	Help me with social/Inspiring tweets/Convenient to make payment/Without notice, half of my screen time was on social media/FOMO/Constantly check my phone/Distracted
Honor of Kings			3	7	10	Angry/stay up late/Decreased self-control and study time
Kuaishou short video	4		3	2	9	Life tips/Diverse/You can watch everything/Vulgar/Don't want to put down your phone/not so optimistic
Little Red Book	7			2	9	Learn new knowledge/Different people and diverse world/Help me with dress code
Learning apps (2); XueXiaoyi (1); Xuexi Tong (1); Zhihu (4)	6			2	8	Learn a lot in extracurricular/TED videos/Help me with my studies/Learn knowledge and ideas about life and science
Forest (4); Toma Todo (3)	6			1	7	Focus/Reduce time playing on my phone/Concentrate more on studying/Schedule my study time
Weibo	4	1	2		7	Diverse world/Meet new people/Check phone too frequently
Taobao		2	3	1	6	Addiction/No longer enjoy shopping malls/Spent too much money on it

Notes: Pos. for Positive; Neu. for Neutral; Neg. for Negative; N.D. for No Detail.
'(n)' in Apps means count of the specific app.

Countdown (a timer app with schedule features), Forest (time management), Douban (an online community of book, music and movie lovers), e-learning, Screen Time (iOS and Android digital health functions), and Toma Todo (a timer app with screen locker function). In contrast, negative sentiments were linked to Honor of Kings (decreased self-control), TikTok (spent too much time on TikTok, "cannot stop"), WeChat (half of the screen time goes by without noticing it).

More than ten users positively commented on a set of lifestyle, hobby and learning apps: Keep (fitness), Mint (healthy diet), National Karaoke (hobby), Kuwo Music, Duolingo (language learning), and Fluently Speaking (English learning). Words such as "fun", "inspiring", "helpful", "time well-spent", and "productive" were found in these positive comments.

125 (68%) participants answered the question: *Are there any functions, apps, or designs on your smartphone that led you to develop new habits?* Among participants with filled-in answers, 26 participants did not elaborate on their answers. Azure marked 4 of the answers as negative, 25 as neutral, and 70 as positive. 31 (17%) participants mentioned the functions of their smartphone operating system with positive sentiments, such as: "AI assistant is so smart, I get used to operating my phone using voice", "the Digital Health function gives me a clear idea about how much time I spend on my phone", "I use phone memos to write lab notes, it is so convenient", and "Turning on NFC by double-clicking makes the payment process easier, saving commute time". It was observed that these participants were satisfied with the utilisation and application of forefront technologies, and they accepted and appreciated the convenience brought by smartphones. Many identified useful operating system functions that had nothing to do with persuasive technology.

The apps most mentioned as leading to new habits were WeChat (11 times, about changing ways of socialising and making payments, refreshing the app to check updates, walking 10000 steps daily, etc.); Toma Todo (6 times, about concentrating on learning); Alipay (4 times, about digital payment and feeding pets on virtual farms); Baidu (3 times, about the benefits of maps and search engine). All these comments were either positive or neutral, except one participant mentioned that "WeChat has negative influences on my sleep time". Survey participants mentioned a set of apps that led them to adopt daily check-in habits: QQ (instant messaging), Taobao (e-commerce), Banking (finance), Alipay (finance), Forest (time management), vocabulary apps and Xuexi Tong (e-learning).

Overall, short video, social networking, gaming, e-learning and time management apps were the most persuasive apps reported by participants. Habit changes brought about by built-in features of smartphones were almost entirely described as positive, while the impact of apps on

users was both positive and negative; social networking, time management, and digital payment apps were the most mentioned apps leading to new habits; additionally, some of these apps lead users to adopt daily check-in habits.

4.2. Interviews

4.2.1. Self-evaluation of smartphone use (RQ1)

In this section, we document interviewees' self-evaluations of smartphone use and their reflections.

After going through the features of digital addiction (Fig. 2), interviewees indicated which experiences matched their own. The most frequently mentioned were using smartphones "over 4 h per day", "habitual checking/unconsciously unlocking phone", "checking specific content on smartphones", "time distortion/forget about time", and "prolonged usage".

P2, P8 and P9 self-reported that they felt addicted to their phones. They reported spending 5.7 h/d on average on their phones. They mentioned the following symptoms: Time distortion (P2, P8), mild depression (P9), low productivity in studies (P8, P9), blurring eyesight and sore fingers (P2), and habits that could cause physical harm (P8 and P9 share a common habit of scrolling through their phones while walking). For participants who did not consider themselves addicted, some symptoms were nevertheless reported: bad sleep quality associated with phone usage (P10), sometimes feeling anxious when scrolling through one's phone (P1), cannot stop scrolling (P4, P6) and habitually unlocking one's phone (all participants except P7).

P8 and P10 expressed being worried about spending over 2 h daily on WeChat to socialise with peers because of FOMO. P2, P3 and P5 expressed that their performance in their studies/internship had been less productive recently due to excessive use of smartphones:

"I know that I spend too much time on my smartphone, it negatively affects me. I cannot focus on studying and often drift away. Tried a few times to reduce screen time; however, I never succeeded." (P2)

"Playing with my smartphone causes me to delay the hand-in of assignments. When stress is high, it is more difficult to put aside my phone. This leads to a cycle of inefficiency and self-indulgence." (P3)

"I was troubled by the notifications. I fear that I will miss something important if I do not read them. Some make me emotionally disturbed, which affect my study and productivity." (P5)

In order to gain a deeper understanding of the roles of smartphones in interviewees' daily lives, the interviewer asked in which situations

Table 3
Screen time and App usage of interviewees.

Participants	Screen Time (h/d)	Necessary (h/d)	PD	Comments	Most used apps (h/d)
P1	7.8	3.0	-30%	No intention to reduce smartphone usage. Smartphone is a useful tool.	Weibo (2.0); WeChat (1.2); TikTok (1.1); QQ (0.7)
P2	10.0	2.5	-50%	I blocked all notifications and try to reduce the frequency of checking my phone.	WeChat (2.4); Videos (1.4); TikTok (1.4); Gaming (1.1)
P3	4.0	2.0	-50%	I blocked notifications, recommendations, and deleted video apps to reduce my screen time.	WeChat (1.6); Browser (0.7); Music (0.5); Stock app (0.3)
P4	5.7	1.0	-50%	\	Douban (1.6); WeChat (1.2); YouTube (0.8); Tiktok (0.6)
P5	7.0	3.0	-20%	I traveled to another city with friends and do not have much time to play with smartphone.	Gaming (1.7); WeChat (1.5); Meituan (1.4); Weibo (0.4)
P6	9.1	6.0	-25%	Smartphone is my only digital device for assignments, lectures and entertainment.	Videos (1.2); Pinduoduo (1.1); Kuaishou (1.0); WeChat (0.8)
P7	6.1	5.0	-25%	I used iOS Screen Time to control the usage of certain apps.	WeChat (2.4); Bilibili (1.5); QQ Music (0.3); Taobao (0.3)
P8	8.0	5.0	-65%	I used multiple devices to reduce my frequency of checking my phone. All work-related tasks have been moved to laptop and iPad.	WeChat (2.8); Bilibili (1.1); Ciwei reading (0.5)
P9	7.0	2.5	-10%	I deleted TikTok.	Xianyu (0.4)
P10	6.0	5.0	-40%	Smartphone has been integrated into my daily life, makes tasks easier. Smartphone reduced my time using laptops.	Reading (2.6); WeChat (2.5); Bilibili (0.8); QQ (0.7)
Mean	7.1	3.5	-37%	-	WeChat (1.4); Gaming (1.2); TikTok (1.0); Weibo (0.7)

Notes: screen times and most used apps in this table were logged from screenshots provided by the interviewees.

PD: Persuasive Designs. This column is the user's self-evaluation; if they could turn off all persuasive features, their screen time might change n%. '\': No record. '-': not applicable.

interviewees must use their smartphones and with what functions. According to these functionalities, a list of apps could then be identified and divided into six categories:

Social networking QQ, WeChat, Weibo, Douban, Little Red Book;
Shopping Taobao, Pinduoduo, JD, Alipay, Xianyu, Meituan
takeaway;

Study/work DingTalk, university apps, Email, NFC commuting card;

Tools Vocabulary apps, maps, Forest, stocks and funds, banks, Toma Todo, Calendar;

Reading Zhihu, WeChat news subscription, Qidian online;

Leisure Music apps, games, short video apps, streaming services.

When the interviewees were asked to evaluate the time needed for these essential use, this ranged from 1 h to 5 h. The mean time was 3.5 h, which is 58% of their self-reported total screen time (mean=6 h). The interviewees mentioned some of the factors that caused them to spend prolonged hours on their smartphones:

"I feel bored when commuting, so I play with my smartphone like others; When I encounter difficulty in writing my bachelor's thesis and my internship tasks, I check social media and escape from all the stress during the break to relax." (P5)

"My roommate and I compete on the Alipay virtual farm. It is a silly game; however, it is fun to have a routine game with a friend. Additionally, I play TikTok videos when I have meals; then, time flies without noticing it." (P6)

"I know that using a smartphone for 6 hours daily is a bit too much. The entertainment provided by the smartphone is very convenient. Since I am so happy when playing on the device, and making changes will be painful, why do I need to control my usage? If the purpose of life is to pursue happiness, smartphones can indeed fulfil my needs." (P7)

"When I hang out with my friends during the weekends, I have less screen time. However, when I spend weekends by myself, I feel isolated if I don't refresh my social media feeds. Also, commuting between two campuses of the university takes 3 to 4 hours each week. I play with my phone on public transportation." (P9)

Participants used phrases associated with emotions in their own reflections on overusing smartphones: "bored", "stress", "relax", "fun", "happy", "isolated".

In summary, three out of ten interviewees self-reported that they were addicted to their smartphones. Physical harm, depression, FOMO and low productivity were reported to be associated with smartphone overuse. Interviewees reported apps that were essential to them, covering many aspects of their life. Interviewees used emotion-related expressions to reflect on their smartphone overuse.

4.2.2. Perception of persuasive designs (RQ3)

In this section, we describe how interviewees perceived persuasive designs and which persuasive designs interviewees identified on their smartphones.

Interviewees were divided in terms of knowledge of persuasive technology. On the one hand, two interviewees who were studying computer science (P3 and P7) and one interviewee with a media major (P10) had learnt about persuasive technology in their previous studies. They defined persuasive technology as "using automatic algorithms and notifications to persuade users" (P3), "applying psychological methods in ICT products design" (P7), and "studying users' preference to cultivate and reinforce habits" (P10). On the other hand, the other seven interviewees had no prior knowledge of persuasive technology before the interviews. To investigate their perceptions of persuasive technology, definitions, applications and examples of persuasive technology were discussed with the interviewees to ensure that the interviewees understood what persuasive technologies were and how they worked. After the discussion, the interviewer invited the interviewees to identify persuasive applications and features in the apps they use daily. The persuasive apps, designs and features that the interviewees identified can be classified into the following categories:

Social networking Little Red Book integrates purchase links into its online community, making it easier to place orders from influencers' posts. WeChat has subscriptions; QQ pushes notifications; while Weibo and Douban recommend articles and ads based on the users' viewing history and profiles. WeChat uses tags, such as "N friend(s) favourited" and "N friend(s) read this article" to persuade users to click on the recommended articles (see Appendix Fig. 4). All these social networking

companies incorporated “like” buttons in their apps.

Shopping Taobao, Pinduoduo, Xianyu, and JD recommend new purchases based on users’ searching, browsing and typing history. Meituan takeaway suggests menus to users based on their location, profile, and local weather forecast. Pinduoduo uses *gambling-like designs*⁵ to deceive users and gamification to attract users to spend more time on it (see Appendix Fig. 4). Alipay’s virtual farm uses incentives (virtual coins) and competition (rankings) to foster users’ daily check-in habits. Additionally, all these apps send coupons to stimulate new purchases.

Tools Time management apps such as Toma Todo and Forest have persuasive reminders to help users manage their schedules. Keep and Mint have persuasive notifications to encourage users to exercise and eat healthy diets. Vocabulary apps use personalised notifications and goals to remind users to check in daily. The Baidu map highlights restaurants and shops that have paid promotion fees to make their locations more visible.

Reading Top Buzz news and Zhihu recommend articles based on users’ reading history. Ads are personalised according to users’ unique profiles, making the ads more attractive and relevant to users. Top Buzz, WeChat subscription channel and Weibo trending news use emotionally triggering titles to lure users. “Smart” algorithms are applied to provide personalised suggestions.

Leisure Short videos, user-generated content, and streaming platforms recommend new videos/playlists based on users’ viewing history (i.e., WeChat video, TikTok, Kuaishou, iQIYI, Youku, Bilibili, YouTube). TikTok and Kuaishou integrate buying links with video content, encouraging users to place orders with only one click.

OS The red dots on app and system icons draw users’ attention and keep persuading users to click on them (iOS and Android). Xiaomi and Huawei phones show recommendations of readings and app promotions after system updates. Participants were annoyed by those solicitations, which were difficult/impossible to turn off.

Proactive persuasive designs were identified in most essential apps by interviewees, with the exception of a few tools (stocks & investments, calendar) and study/work apps (DingTalk, university, email and NFC commute apps). Interviewees used negative expressions to describe their experience with intrusive persuasions that relied on personal information and distracting notifications. On the other hand, interviewees used positive expressions to discuss persuasive features of time management apps, Keep, Mint, and vocabulary apps. The interviewees used neutral expressions to describe their experience with persuasive designs, but they were annoyed that they could not turn off some persuasive features that were imposed on them without their consent.

All interviewees expressed positive sentiments towards their phones. This matches the analysis of the questionnaire’s open-ended answers. However, users complained about the red dots on the operating system icons, which made users click reflexively, and intrusive AI recommendations (for example, the AI assistant page of Harmony OS), which were described as “harassing” and “manipulative” by participants. E-

⁵ **Gambling-like designs:** Pinduoduo persuades users to invite their friends to download or register with Pinduoduo to endorse them to get “free cash” or “free products”. Pinduoduo’s algorithm calculates how much the invited friends would endorse a user. In many cases, even if the user spends days inviting all his friends to sign up and log in to Pinduoduo, the promised money is never transferred to the user. This persuasion strategy applies deception and matches the definition of gambling, i.e., “the practice of risking money or other stakes in a game or bet” ([merriam-webster.com](https://www.merriam-webster.com/dictionary/gambling)). In these gambling-like designs, users lost their valuable time and their friends’ personal data; and most users gained nothing at the end of the games. Lawyer Liu Yuhang sued Pinduoduo for allegedly violating the principle of good faith, using false data, and concealing rules, which constituted fraud, on March 31, 2021, in Shanghai, China. Even though Pinduoduo is listed on Nasdaq, there is not much international coverage of this lawsuit, which was trending on Chinese social media sites for weeks in April 2021.

commerce apps recommend too many products to users based on their purchase history and browser history. P3, P7, and P10 identified more persuasive designs than other interviewees. Concerns about user privacy and data ownership were also raised by P7 and P10.

In summary, interviewees identified multiple persuasive designs in most of their essential daily apps, and they expressed quite positive sentiments towards the functionalities of these apps; however, they complained about the distraction, lack of consent, user privacy and blurring data ownership related to persuasive designs. Besides the common persuasion strategies, some ethically controversial ones were also reported by interviewees, that is, using emotional triggers and gambling-like designs to persuade users.

4.2.3. Evaluation of persuasive designs (RQ3)

In this section, we record how the interviewees evaluate the influence of persuasive designs on them.

Interviewees indicated that persuasive designs prolonged their screen time, caused distractions, and affected their behaviours; specifically, P5, P7 and P10 mentioned disruptiveness, exploiting human weakness and reinforcing habits:

“Without these subtle persuasive designs, I would spend less time checking my phone. When I was reading a paper or working on assignments, the reminders that a drama I followed had just updated would prompt me to watch the drama first.” (P5)

“All popular apps have persuasive designs integrated. Interaction designers took advantage of human weaknesses and created these apps. It seems that only users are being blamed for their lack of self-control.” (P7)

“Persuasive designs feed users according to their preferences, which could make users stuck in their own habits knowing how it works does not make me immune to the algorithms.” (P10)

At the end of the interviews, interviewees were asked to spend 2 minutes reflecting on their smartphone usage and evaluating the influence of persuasive apps on them. All interviewees indicated that persuasive applications increased their smartphone usage time. The interviewees estimated that if they could turn off all persuasive features on their smartphones, they might reduce their screen time by 10%–65%, with a mean value of 37% (see Table 3).

All interviewees shared their screen time screenshots with the interviewer during the interviews. The most frequently used apps by interviewees were social networking apps (WeChat, Weibo, QQ), video platforms (Tencent, Youku, Bilibili), short video apps (TikTok, Kuaishou), shopping apps (Taobao, Pinduoduo, Xianyu, Meituan), reading apps (Ciwei, Qidian) and games. These apps accounted for more than half of the interviewees’ screen time. As we recorded in Section 4.2.2, nearly all these apps integrate multiple persuasive designs into their services. We collected comments from the interviewees three weeks after the interviews regarding their participation in the study. Five interviewees had reduced their screen time after the interviews, and they mentioned blocking notifications, deleting addictive apps, traveling with friends, setting time limits on addictive apps, and using alternative devices to reduce the frequency of unlocking their smartphones. For interviewees who did not seem to worry about their screen time, their screen times remained nearly the same, and they mentioned that their smartphone was “useful”, “integrated with everyday life” and one participant’s “only digital device”.

Overall, the interviewees evaluated that persuasive designs prolonged their screen time, reinforced habits and caused distractions. Interviewees had different evaluations of the impact of persuasive designs on their screen time, but all reported that persuasive designs increase their screen times.

5. Discussion

In this section, we reflect on the three research questions of this

paper. First, we discuss our results regarding problematic smartphone usage (RQ1). Second, we discuss the results concerning perceptions, identification and evaluation of persuasive designs (RQ2 and RQ3). Next, we discuss our findings regarding interaction design ethics. We also discuss the limitations of the present work and suggest directions for future research.

5.1. Problematic smartphone use: proportions, screen times and reflections

Throughout our study, similar proportions of participants reported multiple PSU behaviours (25% in the survey, 3 out of 10 in the interviews). Many previous studies have used SAS-SV to measure the PSU of Chinese students, with varying results, ranging from 30% (Chen et al., 2017) to 72% (Yang et al., 2019). Different sample methods and participant demographics might contribute to the differences in results. The interviewees' reported symptoms, such as time distortion, mild depression, low productivity, blurred eyesight, and wrist pains, were also recorded by other PSU studies (Busch & McCarthy, 2021; Rozgonjuk, Sindermann, Elhai, Christensen, & Montag, 2020).

There are multiple reasons why survey participants reported spending 5.6 h/d on average on their phones. Previous studies found that correlation points between FOMO and PSU are much higher for Chinese students compared to Western countries (Elhai, Yang, Fang, et al., 2020). The anxiety of the COVID-19 pandemic has been found to be associated with PSU severity (Elhai, Yang, McKay, & Asmundson, 2020). Besides these reasons reported in earlier work, we found that the less developed IT infrastructure of Chinese universities (intranet and emails), which resulted in the adoption of instant messaging apps (QQ and WeChat) as primary communication tools among students, administrators and educators, make students spend prolonged hours on their phones.

Social network and short video apps were the most mentioned apps in the questionnaire, occupying much of the interviewees' screen time. Users tend to conflate smartphone usage and application usage when self-reporting PSU (Rozgonjuk, Sindermann, Elhai, Christensen, & Montag, 2020). When investigating PSU, researchers should be aware of this problem and consider gathering information on both general smartphone usage and application-specific usage to better understand the relationship between the two. Additionally, different social network applications display varying degrees of addictive potential and impact on users (Rozgonjuk, Sindermann, Elhai, Christensen, & Montag, 2020), underscoring the need to analyse the platforms users choose and their potential contribution to problematic behaviours (Rozgonjuk et al., 2021).

Interviewees' reflections on necessary usage and overuse revealed that smartphones have become indispensable for study/work, social, leisure and finance. Societies globally are undergoing large-scale digital transformations, moving both public service and private business online. It is almost impossible to live everyday life without a smartphone. People would face social, study, mobility, and work difficulties without apps (see Section 4.2.1). The categories of necessary apps reported by interviewees can explain why 85% of survey participants spent at least 4 h daily on their smartphones. People often cannot refuse to use smartphones when living in digital societies. In addition, we found that participants regard their phones as interactive narrative relays between them and others (online strangers/peers/friends/family members). Smartphone users project their mental life through smartphones and receive the projections of others. These internal and external mental projections interact with each other and have impacts on the user's daily life. A kind of companionship is formed between people and their phones, as evidenced by the fact that many users use emotional words to describe their overuse of smartphones.

5.2. Persuasive designs are making smartphones more addictive

We found persuasive designs to be more prevalent than we had expected. Persuasive designs were identified by interviewees in most daily apps, except for a few essential apps (see Section 4.2.2). Reviewing the apps that changed attitudes or behaviours from the questionnaire results (Table 2), we found that all but a few learning apps integrated with multiple persuasive designs. We can deduce from these findings that study participants live their everyday life with ambient persuasions.

Persuasive designs are often designed to exploit users for indirect monetisation by manipulating them to spend as much time as possible interacting with apps and services. For shopping apps, the most identified persuasive designs were personalisation, reduction, suggestion and rewards; for social networking apps, they were recognition, personalisation, social comparison, and reminders; for leisure and reading, the most identified were liking, suggestion, tracking, reduction, and monitoring. These most identified strategies overlapped with Orji and Moffatt's analysis (Orji & Moffatt, 2018). However, they identified the most employed designs when analysing persuasive technologies for health and wellness. In this study, these designs were found in social networking, shopping, leisure and reading apps, which seek more clicks and monetisation from users. The persuasive designs in these apps do not contribute to user well-being and are misaligned with user interests.

Persuasive triggers and reminders play crucial roles in cultivating users' habitual phone-checking behaviours. Both Fogg's Persuasive Design behaviour model (Fogg, 2009) and the PSD model emphasize the role of triggers/reminders in increasing users' performance of target behaviours. In surveys and interviews, participants reported that a set of apps fostered their daily check-in habits. This habitual behaviour was triggered by phone vibrations, rings, reminders and flashing, which eventually led to users unlocking their phones unconsciously every 15–30 min, even without such triggers. Habitual checking is one of the symptoms of digital addiction and takes up a considerable amount of users' screen time daily (Almourad et al., 2020; Heitmayer & Lahlou, 2021).

Some most frequently used PSD strategies, such as personalisation, reduction and rewards, might deprive users of the opportunity to make independent decisions in long-term use. Before video platforms and shopping apps introduced algorithmic recommendations, users had more time to autonomously explore different topics and products. Algorithmic recommendations have come to increasingly influence users' decision-making, in many cases under the banner of convenience for users, but many interviewees in our study indicated that some smartphone apps powered by such algorithms "know" users to an uncomfortable degree. Ten survey participants complained that the videos recommended by TikTok were so addictive that they wasted "too much time" and "lost control" (see Table 2).

Besides popular persuasive design strategies, we found that some companies use manipulative and deceptive strategies to "persuade" users. One example is the WeChat display of FOMO tags on top of recommended articles to persuade users to spend more time on its services. On the one hand, Li et al. (2022) found that FOMO is positively associated with smartphone addiction. This repeated occurrence of the FOMO tag might increase users' level of FOMO, while higher levels of FOMO are associated with a greater impact of social media on one's daily activities and productivity, and particularly messenger and social network use disorders (Przybylski et al., 2013; Rozgonjuk, Sindermann, Elhai, & Montag, 2020). On the other hand, people who use their smartphones frequently for social purposes form smartphone habits more quickly, which might lead to PSU (Van Deursen et al., 2015). Another example is Pinduoduo, which applies gambling-like designs to exploit users' time and social contacts. Gambling disorder has been recognised as a behavioural addiction in DSM-5 (Edition, 2013). Deceiving users with nontransparent rules, decoy rewards, and interactive algorithms can lead to distress and self-blame among users, accustom them to gambling-like behaviours, and possibly lead them to

become addicted to Pinduoduo.

Based on the above empirical evidence, we believe that persuasive designs influence the occurrence of PSU. When analysing PSU behaviours, it is crucial to consider persuasive designs. Interaction designers relying on such technologies need to consider the long-term impact of their products in terms of time spent, habit cultivation, oversimplification of decision-making, behavioural addiction and human-computer relationships.

5.3. Ethical implications for interaction designers

Persuasion in interactive computing systems is becoming increasingly intelligent, subtle and influential. As Fogg pointed out, with interactive technologies, users receive information and respond immediately. Such interactive behaviour is different from traditional media (for example, TV and newspapers), which do not sustain interactive looping behaviours. Persuasive technology has amplified such interactive looping behaviours radically (Fogg, 2009). Persuasive technologies track and produce personalised reminders and suggestions on smartphones autonomously, instantly and persistently, and they are getting better at it every day.

We put more emphasis on investigating the relationship between persuasive designs and PSU in our study; however, we documented that nearly all participants also expressed positive sentiments towards the built-in features of smartphones, learning, hobby and time management apps. Participants believed these apps improved their quality of life and well-being, which were the initial goals of persuasive technology pioneers. According to the user screen time data we collected, users spend far less time using these persuasive technologies designed for user well-being, while most of their time is occupied by persuasive designs, such as those for monetisation, that compromise their well-being.

There are no governmental or industry regulations on persuasive technologies to block deception and manipulation. We have observed some apps applying persuasive designs to exploit users: first, the abusive applications of tailoring and suggestions; for example, some trending articles on Zhihu and Weibo were actually paid promotions targeting specific groups of users. Second, the overuse of reminders to seek users' attention and exploit users' time, for example, the broad adoption of red dots and notifications on app icons. Third, some algorithms take advantage of users' weaknesses; for example, the addictive algorithm of TikTok troubled many study participants. Despite being troubled by these persuasive features, users cannot turn off these persuasive functions.

There are studies on how to design persuasive technologies ethically, and approaches such as stakeholder analysis (Fogg, 2002), moral principles (Berdichevsky & Neuenschwander, 1999), voluntariness assessment (Smids, 2012) and interdisciplinary research methods (Borgefalk & Leon, 2019) have been proposed by academia. Seven out of ten interviewees in our study had not heard of persuasive technology before the interviews, which might point toward a general lack of awareness of persuasive technology. Persuasive designs are often the default setting in operating systems and app installations, as far as we could observe in this study. We argue that one urgent ethical challenge interaction designers face is that most users are persuaded without their consent. Our users found themselves being persuaded not with explicit arguments or reasons, but through the constant harvesting of their private data and exploitation of their emotions. We see no other way to describe such means but manipulative - in other words, as the kind of means Fogg warned against in his inceptional and seminal work on persuasive technology. Constant exposure to persuasive designs might lead to an exhaustion of self-control, which might be addressed in future work.

5.4. Limitations and future work

Our study has some limitations, and open questions for future work remain. First, we used the convenience sampling method, and the

participants we reached were relatively small in number. The survey collected 183 valid results from Chinese university students; it is a small sample compared with the target group population size of 32.86 million (Textor, 2022). More questionnaires with improved sampling methods need to be distributed to study the group in more detail. Second, the self-reported screen time of the participants in this study differed from their actual screen time, as evidenced by the actual screen times (mean=7.1, source: screenshots of their phones) of ten interviewees, which are longer than their self-reported screen times (mean=6.0, source: questionnaires). Future studies need to examine the validity of self-reported measures of smartphone use and develop improved tools for quantifying media use (Parry et al., 2021). Screen time tracking apps could improve the accuracy of capturing usage, but would entail potential invasions of user privacy. We only used three indicators, i.e., loss of control, perceived negativity and overuse, to identify potential PSU. Therefore, our study's findings should be interpreted with caution and further research is needed to validate the items used in our questionnaire. Third, our follow-up study to assess whether knowledge of persuasive technologies would change users' screen time is limited by participants having varying levels of knowledge on how to manage their screen time, since we did not standardise the information provided to them if they asked questions at the end of the interviews. We are also unable to make statements about the reasons why participants changed their screen time. Contextual factors might have played a role, for instance, sickness, family visits or holidays. Further research is needed to identify effective interventions for reducing PSU and improving digital well-being (Loid et al., 2020; Olson, Sandra, Chmoulevitch, et al., 2022). Fourth, we observed that the interviewees who had heard about persuasive technology before the interviews identified more persuasive designs than others. Even after the discussion of the definitions and examples, interviewees might need more time to understand and observe persuasive designs on their smartphones.

We recommend that future research investigate the impact of persuasive designs longitudinally. Currently, there is relatively little research on the abusive application of persuasive technology in commonly used apps and operating systems that consume much of young adults' screen time; there might also be other negative effects besides the ones we discussed.

6. Conclusion

We found that persuasive designs were perceived to prolong the screen time of the participants in our study and contributed to PSU. Participants reported that short video, social networking, gaming and learning apps most affected their attitude and behaviour, and these apps were found to employ multiple persuasive designs and occupy much of participants' screen time. The most frequently identified persuasive design strategies were reminders, personalisation, reduction, rewards, recommendations and emotional motivators. These could have negative long-term impacts on users by prolonging their screen time, reinforcing phone-checking habits and oversimplifying decision-making. Some ethically controversial strategies (persuasion without consent, abusively applying emotional triggers and using gambling-like designs) have also been documented in our study. To answer the question we set out to answer - do persuasive designs make smartphones more addictive - we find indications that persuasive designs might contribute to problematic and addiction-related behaviours. We recommend HCI researchers and designers, as well as psychologists, examine the long-term impact of persuasive designs and other similar designs on their users.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

A. Survey results

The survey results (English translation) can be downloaded at the following link: <http://doi.org/10.5281/zenodo.4934731>.

B. Examples of persuasive designs



(a) Gambling-like-design of Pinduoduo V6.57.0



(b) FOMO tags of WeChat V8.0.35

Fig. 4. Screenshots of persuasive designs

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