



“Instant Happiness”: Smartphones as tools for everyday emotion regulation

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ABSTRACT

Smartphone use has become an indispensable aspect of daily life for billions of people. Increasingly, researchers are examining the impact of smartphone use upon psychological well-being. However, little research has investigated how people deliberately use their smartphones to shape affective states; in other words, how smartphones are used as tools to support everyday emotion regulation. In this paper, we report a study that uses quantitative (experience sampling) and qualitative (semi-structured interview) methods to examine when and how people use smartphones to regulate emotions in everyday life, and the associated psychological consequences. Participants report spending a significant amount of time using their smartphones for emotion regulation, in particular to cope with unpleasant feelings such as boredom and stress. They report that smartphone-mediated emotion regulation is effective for attaining desired affective states. However, the perceived emotional benefits of smartphone emotion regulation do not emerge in lagged analyses predicting changes in momentary mood across a few hours, suggesting that emotional benefits may be transient or may reflect self-report biases. Participants discuss their perceptions of smartphone-supported emotion regulation in relation to smartphone addiction. This study provides evidence on how people use their smartphones for emotion regulation, and contributes to better understanding the complex relationship between smartphone use and emotional wellbeing.

1. Introduction

Digital technologies – particularly the most pervasive of digital devices: the smartphone – have deeply permeated everyday life, providing people with access to rich sources of information as well as multiple forms of entertainment and social connection. The ubiquitous availability of smartphones has allowed their use to become deeply embedded within people’s everyday lives (e.g., Alter, 2017; Lepp et al., 2015). In recent years, researchers have increasingly explored how smartphone use influences people’s emotional well-being, with studies demonstrating both beneficial and harmful effects. For example, smartphone use (e.g., via social media) helps individuals to increase social capital and reduce social isolation (Cho, 2015; Ellison et al., 2007; Gil de Zúñiga et al., 2012). However, smartphone use can also be detrimental for psychological well-being (Lee et al., 2014; Twenge et al., 2018; Kim and Koh, 2018; Noë et al., 2019).

While research has focused on the influence of smartphone use upon psychological well-being, few studies have investigated how people use smartphones to deliberately *regulate* their emotions, and the corresponding psychological consequences. A broad body of research has

shown that users’ experience of technology often includes emotional responses (e.g., McCarthy and Wright 2004; Hassenzahl et al., 2000). Researchers recognize that positive emotion can arise from the successful use of technology to achieve a goal (Forlizzi and Battarbee, 2004). However, recent work suggests that digital technology, especially smartphones, may also be used with the specific goal of modifying emotions (Wadley et al., 2020; Eschler et al., 2020). Here, emotion-change is the goal. Put otherwise, we contend that after more than a decade of increasingly widespread smartphone ownership, people may have learned that smartphones have utility as strategic tools for emotion regulation. In this study, we contribute to the nascent literature on the use of smartphones as emotion regulation tools by investigating this behaviour in daily life using a mixed-methods study design. Specifically, we use experience sampling, a naturalistic method for studying moment-to-moment psychological experience and behaviour in daily life (Csikszentmihalyi and Larson, 2014), to capture when and how people use their smartphones to regulate emotions in everyday life, and to investigate the emotional outcomes of this behaviour. Complementing this quantitative approach, we also conduct face-to-face interviews to qualitatively investigate people’s insights into their digital emotion

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regulation behaviour. We ask participants to reflect on their emotional and social contexts, the specific smartphone applications they use, how their emotions change when using smartphones for emotion regulation, and how they perceive smartphones as everyday emotion regulation tools.

We find that participants do indeed make significant use of smartphones for emotion regulation; in fact, half of smartphone use may have this goal. The smartphone affordances most often used for emotion regulation are browsing social media, contacting other people, and consuming audio-visual content. Negative states such as boredom and stress are the emotional contexts most likely to lead to smartphone emotion regulation. Participants perceive using smartphone for emotion regulation as effective; however, the effects seem to be largely transitory. Participants have concerns about overuse of smartphones but perceive emotion regulation to be largely a normal and helpful use of smartphones.

This study contributes to HCI by providing evidence on how people use smartphones for emotion regulation, leading to better understanding the complex relationship between smartphone use and emotional wellbeing.

2. Related work

2.1. Smartphone use and its psychological consequences

The ever-growing ubiquity of smartphones is fuelling concern about whether overuse of these devices impacts user wellbeing (Monge Roffarello and De Russis, 2019). A large body of research has documented the psychological consequences of smartphone use, revealing a mixture of salutary and detrimental effects. For instance, communication features in smartphones can help enhance interpersonal relationships (Rettie, 2008; Erickson, 2011), and the social support gained through digital connections can have beneficial consequences for subjective well-being (Chan, 2015). Studies have shown that social media can enhance positive affect (Krasnova et al., 2013), help people to form meaningful connections, and increase well-being (Clark et al., 2018). Digital music applications can improve mood and reduce tension (Chen et al., 2011), providing energy and motivation for work (Bauer and Kratschmar, 2015; Wadley et al., 2019). Playing games on smartphones can relieve boredom (Hjorth and Richardson, 2011; Leung, 2020) and help people to cope with life stressors (Collins and Cox, 2014).

Yet, researchers have also found that smartphone use can be detrimental to psychological well-being. One study found that non-communicative use of smartphones reduced positive affect (Chan, 2015). Similarly, Verduyn et al. (2015, 2022) found that passive social media use (e.g., reading Facebook posts without directly interacting with other people) can undermine people's affective well-being if it involves social comparisons that threaten their self-concept. Furthermore, excessive use of social networking sites is linked with phone addiction (Salehan and Negahban, 2013), and habitual checking of phone messages may develop into compulsive usage (Noë et al., 2019; Bianchi and Phillips, 2005), potentially leading to sleep disturbance and depression (Lemola et al., 2015).

Although the above studies reveal the affective consequences of using smartphones, less is known about when the change in affect might be *intended* by users as a goal of phone use. In other words, few studies have investigated when smartphone use may represent a form of effortful emotion regulation. We now turn to this relatively embryonic literature on smartphones as emotion-regulation tools.

2.2. Smartphone use for emotion regulation

Emotion regulation is defined as attempts to influence the trajectory of emotions and other affective processes (Gross, 2015). While emotions arise in many contexts, and many behaviours may give rise to a (change in) emotion, the defining feature of emotion regulation is "activation of

a goal to influence the emotion trajectory" (Gross, 2015); that is, a behaviour represents emotion regulation when its direct, proximal goal is to change affective state. The *ultimate* goal of an emotion-regulatory behaviour might be instrumental rather than hedonic - for example, to perform better at work, or to be better accepted in a social setting (Tamir, 2016). Nonetheless, the proximate goal in such examples is emotion-change.

Emotion regulation is routine and essential to wellbeing and is deployed dynamically across everyday contexts (Brans et al., 2013; English et al., 2017; Heiy and Cheavens, 2014; Nezlek and Kuppens, 2008; Troy et al., 2019). Previous studies have investigated the use and consequences of various emotion regulation strategies in daily life (e.g., Brans et al., 2013; English et al., 2017; Heiy and Cheavens, 2014).

With the rise of smartphone use and the broad array of informational, entertainment, and social resources that phones make available in an "always on" fashion, researchers have begun to ask whether people have begun to appropriate these devices as emotion regulation tools. *Prima facie*, several emotion regulation strategies including distraction, rumination, reappraisal, and social sharing and support might be well-suited to implementation via smartphones (Wadley et al., 2020). Furthermore, because people take into account the costs and benefits of different emotion regulation strategies when choosing amongst them (Tamir et al., 2020; Sheppes et al., 2014), the ready access to diverse emotion regulation resources that smartphones provide may dispose people to preferentially choose smartphones to support emotion regulation. Once smartphones are adopted for emotion regulation, the ability they afford to easily switch between resources might allow users to fine-tune their choice of emotion regulation strategies to align with their current goals and circumstances.

Until recently, few studies directly investigated how people use smartphones for emotion regulation and with what consequences. Research by Elhai et al. (2016, 2017, 2018) has linked self-reported habitual use of two normatively maladaptive emotion regulation strategies, namely expressive suppression (hiding emotions from others) and rumination (over-engagement with emotions) with more frequent and problematic smartphone use. This provides indirect evidence that smartphones may be used as emotion regulation tools. Similarly, a recent survey study found that young people's problematic smartphone use was related to their own and their parents' emotional dysregulation (Giordano et al., 2021). Further indirect evidence for the possible use of smartphones for emotion regulation comes from studies exploring the correlates of smartphone addiction. Although smartphone addiction is obviously maladaptive, it may be reinforced by the potentially beneficial emotional outcomes of using smartphones. For example, if smartphone use is effective in relieving stress, this could lead to more frequent use and ultimately to phone addiction (Rozgonjuk and Elhai, 2019). Consistent with this, Gokçearslan et al. (2016) found that an inability to self-regulate (which presumably includes emotion regulation) predicted smartphone addiction in university students. Also, both functional and dysfunctional emotion regulation strategies were somewhat predictive of Internet and smartphone addiction amongst adolescents (Yıldız, 2017). Similar observations have been made regarding the use of other digital technologies to support emotion regulation, including social media (Brailovskaia et al., 2020), video streaming platforms (Myrick, 2015) and videogames (Gaetan et al., 2016; Snodgrass et al., 2014; Kaye et al., 2018; Fairclough et al., 2020; Williams et al., 2011).

Some studies provide direct evidence for the use of smartphones as emotion regulation tools. Using a combination of experience sampling, usage logging and interviews, Lukoff et al. (2018) found that participants used phones for temporary relief from undesirable emotions and situations and differed in the degree to which they felt such escapism was useful. Other evidence is emerging that smartphones are used for coping with stress, a behaviour related to emotion regulation. Wang et al. (2015) surveyed college students and found that some reported using smartphones for entertainment and escapism when stressed, although with poor affective outcomes. In a similar survey study,

Wolfers et al. (2020) found that older people reported using Facebook more intensively when feeling stressed. Duvenage et al. (2020) used focus groups and experience sampling to find that school students often use smartphones to cope with stress despite the strategy being ineffective in the long term. In an interview study, Eschler et al. (2020) found that some people with depression use digital technologies such as social media and streaming media for managing moods and negative thought patterns. In a diary study, Smith et al. (2022) found that office workers used a wide range of digital technologies to support everyday digital emotion regulation. In a survey study, Diefenbach and Borrmann (2019) found that young people prone to negative emotions use smartphones as “pacifiers” which help them to regulate negative emotions. In another survey study, Tag et al. (2022) found that students engaged in digital emotion regulation more intensely during pandemic lockdowns.

2.3. Motivation for our study

While some research has explored links between smartphone use and emotion regulation, much remains to be discovered about when, why, and how people use their smartphones to regulate emotions, and its psychological consequences. Most prior work has employed cross-sectional designs and used retrospective or global self-reports to measure the use of smartphones for emotion regulation. Such methods capture people’s memories or beliefs rather than their momentary attempts to regulate their emotions using smartphones in daily life (Conner and Barrett, 2012; Schwarz, 2012), suggesting the need to employ methods with higher ecological validity that measure smartphone-based emotion regulation as it occurs in the moment across a range of daily contexts. Furthermore, most research to date has focused on maladaptive behaviours and negative consequences such as phone addiction. Yet, given that emotion regulation is a frequent and largely adaptive behaviour in daily life (Gross, 2015), it seems plausible that some smartphone-based emotion regulation has useful outcomes.

Studying the emotional experiences that arise in smartphone use is challenging, requiring non-invasive gathering of emotion data in unpredictable contexts (Isomursu et al., 2007). Studying smartphone emotion regulation is even more challenging as it requires determination not only of affective states but of whether the user has activated a goal to influence these states, along with tracking of interactions between goals, behaviours and emotion that play out over time (Wadley et al., 2020). In response to these challenges, we chose to combine quantitative methods used in psychology to study emotion regulation in daily life (Brans et al., 2013) with qualitative methods used in HCI to understand complex user experiences (Blandford et al., 2016).

Thus, in the current study we used experience sampling, which allowed us to measure participants’ momentary emotional experience and smartphone usage in everyday life with higher ecological validity than traditional survey measures. Recognising that emotion regulation is inherently dynamic and context-dependant, researchers are increasingly adopting experience sampling methods to study emotion regulation in daily life (Colombo et al., 2020; Koval et al., 2022). We also conducted follow-up interviews to investigate participants’ reflections on smartphone-based emotion regulation in daily life. In the experience sampling surveys, we sought to measure how much phone use has the goal of regulating emotion, and which smartphone features are used for this purpose. We measured the perceived emotional impact of phone-based emotion regulation and compared this with the modelled effect of smartphone emotion regulation on changes in momentary affect over time. Finally, in qualitative interviews, we explored the relationship between smartphone emotion regulation and addiction, and the perceived advantages and disadvantages of using smartphones as emotion regulation tools. We aimed to address the following four research questions:

1 Do people use smartphones as tools for everyday emotion regulation?

2 How do people use smartphones to regulate emotion?

3 What are the emotional antecedents and consequences of smartphone emotion regulation?

4 What is the relationship between smartphone emotion regulation and smartphone addiction?

3. Method

In the current study we first used experience sampling to assess people’s intentional use of smartphones for emotion regulation in daily life, and the emotional consequences of such behaviour. Using experience sampling allowed us to obtain ecologically valid reports of smartphone-based emotion regulation in natural settings, thereby reducing reliance on retrospective memory and beliefs. At five pseudo-random times each day for seven consecutive days, participants were prompted to complete an experience sampling survey assessing their momentary affect as well as their general and emotion-regulation directed smartphone usage.

Further, to gain a deeper understanding of participants’ motivations for and reflections on using smartphones to regulate their emotions, we supplemented the experience sampling method with semi-structured interviews conducted at the end of our study (Fig. 1).

3.1. Participants

We recruited 40 participants ($M_{age} = 25.4$, $SD_{age} = 6.02$; 24 females; 25% South Asian, 42.5% other Asian, 15% European, 17.5% other) via advertisement on an online university notice board. To be eligible for the study, participants were required to be daily smartphone users. Participants were compensated with \$10 for their participation in the experience sampling study.

Twenty-one of the 40 participants ($M_{age} = 24.5$, $SD_{age} = 5.81$; 13 females; 42.9% South Asian, 28.6% East Asian, 14.3% European, 14.3% other; 85.7% of them were international students) agreed to complete a follow-up qualitative interview after the experience sampling study, for which they received an additional \$10 reimbursement. The university’s ethics committee approved this study.

3.2. Procedure and measures

3.2.1. Phase 1

In phase 1, participants individually met with a researcher in person to set up the experience sampling survey and complete baseline questionnaires including demographics. Participants downloaded and installed SEMA3, a freely available experience sampling smartphone app (Koval et al., 2019), on their own smartphones. SEMA3 was programmed to send participants notifications to complete experience sampling surveys at five pseudo-random times each day over the following week.

To prepare participants to understand and appropriately respond to experience sampling surveys, the researcher explained to them what was meant by smartphone-based emotion regulation by describing it as “using your smartphone to shape your emotional state.” We used the word “shape” rather than “regulate” as pilot-testing indicated it was easier to understand. The researcher explained that we were interested in any situations where “you are feeling an unwanted emotion, such as stress, upset or boredom, and you use your smartphone with the purpose of changing this state”. When the researcher confirmed that each participant understood the concept, participants completed a “demo” survey on their own smartphone. The researcher explained the survey items and addressed their questions. Finally, participants were asked to pay particular attention to their goals when they used their smartphones and how much time they spent on their smartphones over the following week, to make this easier for them to recall when answering the surveys.

emotion regulation behaviour and perhaps to change their phone usage.

3.3. Data analysis methods

3.3.1. Quantitative analysis of the experience sampling data

To provide an overall picture of smartphone-based emotion regulation, we first investigated *whether* and *how* people used smartphones for emotion regulation. We calculated the percentage of time people spent on their smartphones for emotion regulation and the total amount of time they spent on their phones, based on the number of minutes participants reported in the experience sampling surveys. We also calculated the mean intensity of use (see Table 1, question 7) of each smartphone feature that participants used for emotion regulation.

We then examined *when* people engage in smartphone-based emotion regulation, and how it influences their affective experience. To account for the nested structure of the experience sampling data (i.e., experience sampling surveys nested within participants), we used multilevel regression models. To examine how momentary affect influences people's phone usage for emotion regulation and how smartphone-based emotion regulation predicts affective change over time, we conducted lagged analyses.

Specifically, as illustrated in Fig. 2, we examined how participants' affect at occasion T_1 influences their phone usage (i.e., duration and intensity) for emotion regulation between occasions T_1 and T_2 (path a); and how the smartphone usage for emotion regulation occurring between occasions T_1 and T_2 predicts momentary affect at T_2 (path b) and the perceived emotional change (path c).

We excluded periods in which participants did not answer the previous survey (missing T_1 affect data), and we also excluded between-day lags (e.g., Koval et al., 2012), resulting in 753 observations for the lagged analysis. In the multilevel regression analysis discussed above, all level-1 predictors were person-mean centred, and both the intercepts and slopes were estimated as random effects that were allowed to vary across participants. We validated all the results both with and without control variables (e.g., participants' age, gender, T_1 affect, offline interactions between T_1 and T_2).

3.3.2. Qualitative data analysis

We transcribed the audio recordings of the interviews and conducted thematic analysis (Braun and Clarke, 2006) using NVivo 12 software. Because we had clear ideas on the topics that we would like participants to reflect on during the interviews, and participants were asked the same questions, we created first-level codes based on these interview questions. These first-level codes include "reasons for choosing phone for emotion regulation", "the contexts of using smartphones for emotion regulation", "the applications used for emotion regulation", "the emotional outcomes", "smartphone addiction", "advantages of using phones for emotion regulation" and "disadvantages of using phones for emotion regulation", and we used these codes as a coding scheme to code all the interview transcripts.

The first author carefully read through each interview transcript, and coded participants answers to each question into the first-level codes. Then based on participants' responses to each topic, second-level codes were developed. For example, under the first-level code "reasons for choosing phone for emotion regulation", we extracted in total 12 second-level codes from participants' responses to this topic, these codes include "convenient", "always accessible", "alone and do not have other people around", "effective", "low energy cost" etc., with some of them mentioned by more than half of participants, and others mentioned by fewer participants. The list of second-level codes emerged from the interview data for each first-level code and the number of participants associated with each code are presented in Table 3. To maximize the consistency of the coding, each transcript was read through and coded again after the coding scheme was developed based on the first-round coding.

Below we present the qualitative results together with the

quantitative findings to answer each research question. We use the qualitative data to supplement the quantitative data, thus they provide a richer picture of participants' smartphone emotion regulation behaviour that was unable to be captured by the experience sampling surveys.

4. Results

Because the use of smartphones to regulate one's emotion is a recently hypothesised phenomenon, there is a very broad range of questions that needs to be investigated. In this study we focus on the fundamental aspects of this behaviour. Specifically, we investigate whether people indeed use their phones to regulate their emotions, and if so, the circumstances in which this behaviour occurs, how people use their phones to serve this purpose, and its consequences over time. Finally, we consider people's perceptions regarding this behaviour, and its perceived advantages and drawbacks. We organize the results based on these questions, and present quantitative and qualitative findings for each question below.

4.1. Do people use smartphones as emotion regulation tools in daily life?

4.1.1. Experience sampling data

We first examined *whether* people used their smartphones to regulate emotion in their daily lives, and *how much time* they spent on phones for emotion regulation purposes. We found that participants reported smartphone usage (in general) since the previous survey on 80.32% of all completed experience sampling surveys. Further, on more than half (56.83%) of these responses, participants reported smartphone usage for emotion regulation. Based on the number of minutes participants reported, we found that 42.94% of the time participants spent on their phones had the goal of regulating emotion. These results suggest that people frequently use their smartphones with the goal of modifying or regulating their emotions in everyday life.

We calculated the percentage of time (during the sampling period from 10am to 9:30pm) people reported using their smartphones in general and specifically for emotion regulation, as well as time spent in offline interactions, as a proportion of the total time between consecutive experience sampling surveys (T_{1-2} , range: 41 min - 294 min).¹ We found that, on average, participants spent 23.58% of their time in offline interactions, 19.06% on overall phone usage, and 10.73% on using a phone for emotion regulation (see Fig. 3).

4.1.2. Interview data

In interviews, *all* participants reported that they used their smartphones to shape their emotions.

"[participating in this study] made me realize I use my phone a lot to shape my emotions." (Female, 19)

"I realized like I'm always using it (smartphone) to get rid of boredom [and] to make me feel more positive." (Male, 36)

"I really use my phone to shape my mood. [...] music and music videos really helped me to feel better in the mornings." (Female, 20)

Thus, the interview results supported the experience sampling results: participants reported frequently using their smartphones to shape affective states during daily life. Furthermore, some participants reported that they had been unaware that they were engaged in "digital emotion regulation" before participating the study. Once their attention was drawn to this behaviour, they realized that it was something they engaged in frequently.

¹ This analysis was based only on intervals between consecutive surveys within the same day, excluding missed surveys.

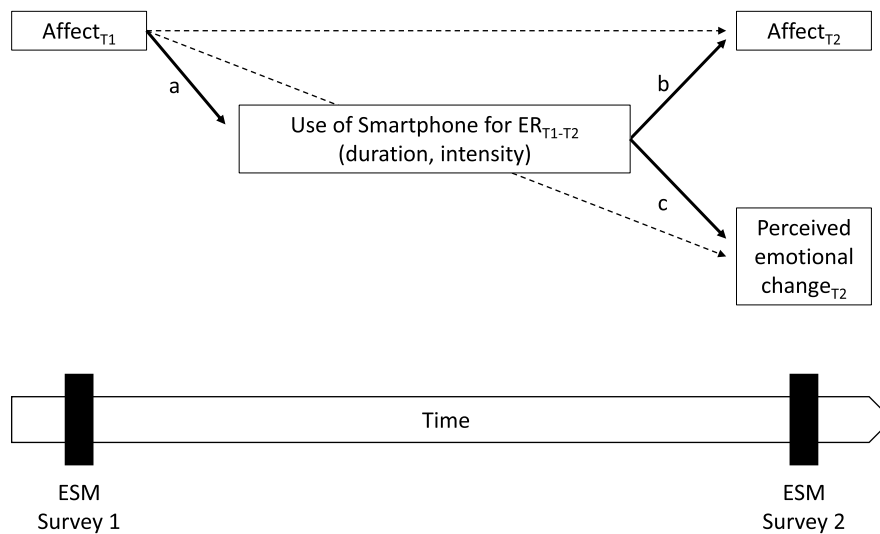


Fig. 2. Framework of the experience sampling data analysis.

Note: The two dashed paths indicate that we controlled participants' affect at occasion T1 when examining how the smartphone usage for emotion regulation occurring between occasions T1 and T2 predicts momentary affect at T2 and perceived emotional change at T2.

Table 3

First-level and second-level codes from the interview data.

First-level code	Second-level code
Reasons for choosing phone for emotion regulation	convenient (11), always accessible (9), alone and do not have other people around (8), effective (5), low energy cost (5), flexible (5), do not want to talk to others when feel negative (3), save time (3), other people also use phones (2)
The contexts of using smartphones for emotion regulation	Affective context: bored (14); stressed (8), lonely (3), tired (3), sad (2), moody (1), positive (1), worried (1) Situational context: alone (15), short break (8), at home (3), outside (3), nothing to do (3), commute (3), walking (3), at work (1)
The applications used for emotion regulation	social media (11), videos (9), contact others (7), games (7), music (6), shopping (1)
The emotional outcomes	satisfied (10), positive (5), relaxed (4), negative (2), guilty (1)
Smartphone addiction	not addicted (13), a little addicted (2), addicted (3)
Advantages of using phones for emotion regulation	convenient (10), accessible (6), overcome physical distance with other people (5), flexible (3), save time (2), many options to choose (1), low cost (1)
Disadvantages of using phones for emotion regulation	antisocial (9), addiction (9), bad for sleep (8), waste time (5), harm eyes (4), distraction (3), may have negative emotion outcomes (3), less physical exercise (1)

Note: The numeric numbers in the parentheses refer to the number of participants who mentioned the second-level code.

4.2. How do people use smartphones to regulate emotions?

4.2.1. Experience sampling data

Amongst all responses where participants indicated that they had used smartphones to regulate their emotions during T₁₋₂, we examined how different smartphone features were used for emotion regulation. The average intensity (rated on a scale from 0: not at all to 10: a lot) of each feature usage was calculated across all participants, and the mean scores are plotted in Fig. 4. Participants reported browsing social media to be the smartphone feature most intensively used for emotion regulation, with direct personal contact, and consumption of audio and visual media also intensively used.

We also calculated the within-person and between-person

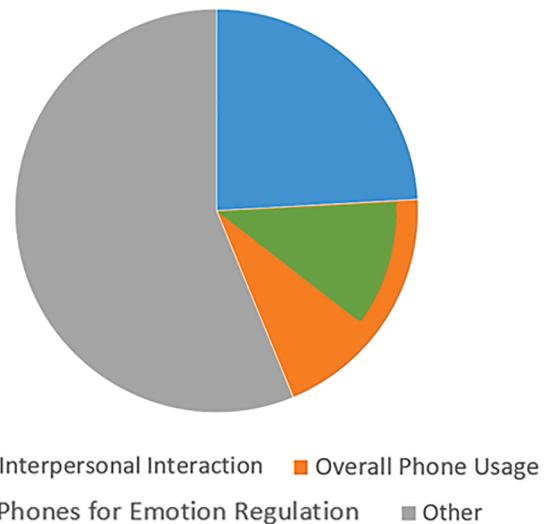


Fig. 3. Percentage of Time Spent on Offline Interactions and Smartphones During 10am-9:30pm.

Note. There may be small overlaps between phone usage, offline interpersonal interaction, and other activities, since people could do those activities together at the same time. Unfortunately, we were not able to capture the overlap in the experience sampling surveys.

correlations amongst the intensities of different smartphone features used for emotion regulation (see Table 4). Between-person correlations indicate that contacting others to regulate emotion is negatively associated with listening to music, playing games, browsing social media or watching videos for emotion regulation, while browsing social media is positively related to playing games and watching videos for emotion regulation. In contrast, within-person correlations amongst the smartphone features were generally negative or close to zero, suggesting that people did not use multiple smartphone features simultaneously to regulate their emotions.

4.3. Affective antecedents of using smartphones for emotion regulation

4.3.1. Experience sampling data

To explore in what affective contexts people use their smartphones for

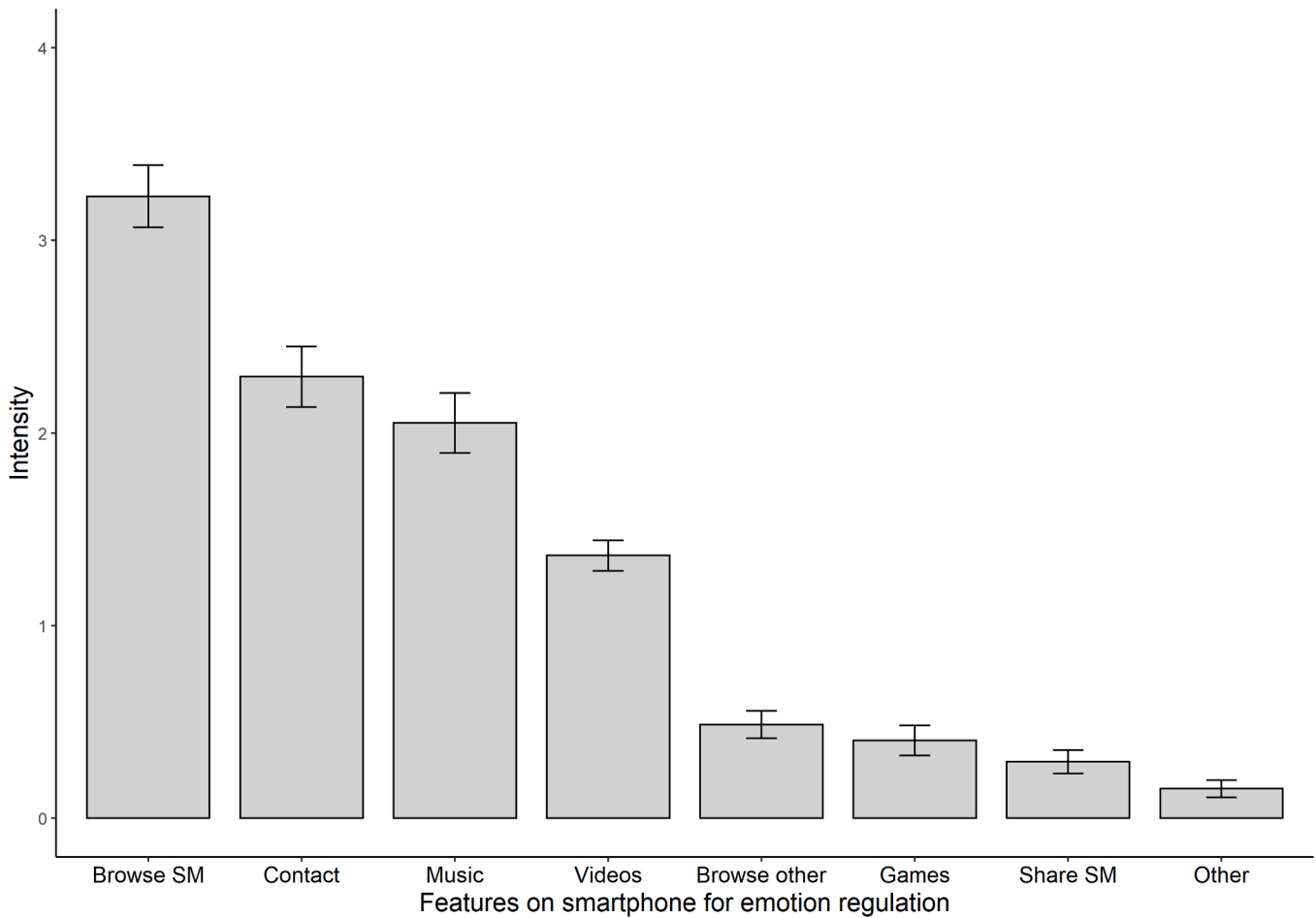


Fig. 4. The Average Intensity of Use of Smartphone Features for Emotion Regulation.

Note: The original scale ranges from 0 to 10. Error bars represent +/- one standard error. *Contact* refers to direct personal contact, *Share SM* refers to sharing content on social media, *Browse SM* refers to browsing social media, *Browse Other* refers to browsing information sources other than social media, while *Other* includes online shopping, online reading, searching etc.

Table 4
Correlations between phone features used for emotion regulation.

Variable	1	2	3	4	5	6	7
1. Direct personal contact	–	–0.19	–0.30	–0.20	0.10	–0.23	0.04
2. Listen to music	–0.21	–	0.02	0.13	–0.11	0.01	–0.16
3. Play games	–0.05	–0.03	–	0.11	–0.18	0.24	–0.12
4. Watch videos	–0.17	–0.16	0.02	–	–0.09	0.10	0.17
5. Share on social media	–0.09	–0.04	–0.01	0.07	–	–0.04	0.14
6. Browse social media	–0.11	–0.22	–0.17	0.06	0.05	–	0.13
7. Browse other information	–0.06	–0.05	–0.05	0.17	0.01	0.13	–

Note: Between-person correlations are displayed above the diagonal, and within-person correlations are displayed beneath the diagonal.

emotion regulation, we investigated how participants' affect at one measurement occasion predicted their use (and duration) of smartphone-based emotion regulation reported at the next measurement occasion.

Because the variable that indicates *whether* people used their smartphones for emotion regulation was binary (yes/no), we used multilevel logistic regression to examine this question. We found that T_1 affect negatively predicted people's likelihood of using phones for emotion regulation ($B = -0.17, SE = 0.05, z = -3.25, p = .001, 95\%CI = [-0.28, -0.07]$). Given that affect was measured on a bipolar scale with negative scores reflecting more unpleasant feelings, this means that people were more likely to use their phones for emotion regulation when they experienced more negative affect at T_1 . In contrast, and consistent

with a motivational account of smartphone-based emotion regulation, T_1 affect did not predict people's likelihood of general phone usage ($B = -0.05, SE = 0.60, z = -0.096, p = .924, 95\%CI = [-1.46, 0.87]$).

To examine how T_1 affect influenced the *amount of time* participants reported spending on their smartphones for emotion regulation, we performed a linear multilevel regression analysis, with T_1 affect as the predictor and minutes spent on smartphones for emotion regulation as the continuous outcome variable. We found that lower (i.e., more negative) T_1 affect predicted greater duration of smartphone use for emotion regulation between T_1 and T_2 ($B = -1.48, SE = 0.60, t(36) = -2.46, p = .02, 95\%CI = [-2.67, -0.30]$), which indicates that when participants were feeling more negative, they tended to spend more time using their smartphones for emotion regulation. Once again, consistent

with the view that using smartphones to regulate emotions serves a prohedonic function, overall time spent using phones was not significantly predicted by T_1 affect ($B = -0.20$, $SE = 0.61$, $t(36) = -0.33$, $p = .74$, $95\%CI = [-1.41, 1.00]$). Controlling for number of minutes between surveys (T_{1-2}), participants' gender, and age did not substantially change these results.

4.3.2. Interview data

We asked participants to reflect on their feeling at the moments when they picked up their phones for emotion regulation, and two major themes emerged from their answers: feeling bored (14 of 21 participants) and feeling stressed (8 of 21 participants). Other emotional states were also cited by participants such as loneliness (3 of 21 participants), tiredness (3 of 21 participants) and sadness (2 of 21 participants). We found that, in most cases, people used smartphones to regulate emotion when they were in relatively low arousal and negative emotional states, which are very common in everyday life.

Participants also mentioned common situational contexts where they used smartphones for emotion regulation, for example, when they were alone (15 of 21 participants), at short break between study or work (8 of 21 participants), during commute (3 of 21 participants).

4.3.2.1. Feeling bored. The most common affective context for smartphone emotion regulation reported by participants was boredom. Boredom, a state of low arousal and dissatisfaction, is commonly experienced and leads people to seek stimulation (Vodanovich and Mikulas, 1993). In the interviews, participants mentioned that they felt bored during their daily commute to the university or during breaks between classes, and that their smartphones served as ideal tools to attenuate boredom because they provide varied and easily accessible entertainment options. In terms of the specific features they used, participants reported that they used smartphones to listen to music, watch videos, play games or browse social media to down-regulate boredom.

"I think it's mostly about boredom. We're all studying and trying to finish up assignments, when you're seated at the same place for very long time, you get bored very fast, especially when reading the academic journal articles. [...] I took out my smartphone, it surely got me out of my boredom state." (Male, 36)

"When I get bored, I tend to play games on my phone [or] watch a movie or stay by myself listening to music [which] takes the boredom away from me." (Male, 22)

4.3.2.2. Feeling stressed. Another common emotional context of smartphone emotion regulation was feeling stressed. Participants reported that when they felt stressed during their studies or work, they used smartphones to listen to music or watch videos to attain a more relaxed state. Some participants mentioned that they used smartphones before going to bed in order to relieve stress and help them to fall asleep. We also found that when people were stressed, they may not have been willing to interact with others, or had the energy to perform other activities (e.g., go out for a walk) for relief: in such cases, smartphones provide easier options.

"I'm stressed out in the university and you know, essays and assignments and stuff. I take a few minutes out of it and [...] watch the videos on YouTube or something." (Female, 23)

"When I went to sleep, I used my phone to watch YouTube videos to calm me down and get me ready to sleep. During the day I get very tense doing assignments, doing projects, the phone helps me to relax." (Male, 30)

It is notable that when discussing their attempts to regulate boredom and stress, these busy students indicated that they were attempting not just to down-regulate unpleasant feelings, but to attain mental states

that were conducive to getting work done. This is in line with earlier research showing that emotion regulation can have instrumental as well as hedonic goals (Tamir, 2016).

4.3.2.3. Other emotional contexts. During the interviews, participants also mentioned other emotional contexts in which they used smartphones for emotion regulation.

For example, 3 out of 21 participants mentioned that they used their phones to regulate loneliness. They explained that they lived alone, or without their families or close friends nearby, and they used their phones to connect with others when felt lonely. Communication and social media applications such as WhatsApp and Facebook were mentioned that could provide convenient ways for them to connect with friends or families to reduce feelings of loneliness.

Participants also reported that they used smartphones to regulate tiredness and sadness. For example, when they were tired after a day's study or work, they turned to the entertainment applications on their phones to relax themselves. And when they felt sad, they chatted with others via phones to seek comfort and express emotions.

"At night, I feel lonely, because my friends are in another country, and I know chatting with friends and my family is a good way to shape my emotion." (Female, 39)

"If I'm tired or annoyed, I go to Facebook, or Twitter to read some jokes, or chat with friends." (Male, 21)

4.4. Affective consequences of using smartphones for emotion regulation

4.4.1. Experience sampling data

We explored whether using smartphones for emotion regulation influences people's affect over time, first by conducting lagged analysis with data collected from experience sampling surveys. We examined whether the amount of time participants spent on smartphones for emotion regulation between two surveys (T_{1-2}) predicted the momentary affect at T_2 . We found that neither the minutes of overall phone usage ($B = -0.001$, $SE = 0.004$, $t(21) = -0.24$, $p = .81$, $95\%CI = [-0.008, 0.006]$) nor the time people spent on smartphones to regulate emotion ($B = -0.002$, $SE = 0.005$, $t(18) = -0.34$, $p = .74$, $95\%CI = [-0.01, 0.009]$) between T_1 and T_2 predicted affect at T_2 , suggesting that neither using smartphones nor using smartphones for emotion regulation resulted in changes in people's affective experience over a few hours. Controlling for T_1 affect, offline social interactions, age and gender did not substantially change these results. Unsurprisingly and consistent with previous research, duration of offline interaction between T_1 and T_2 significantly predicted more positive affect at T_2 ($B = 0.009$, $SE = 0.002$, $t(22) = 4.04$, $p < .001$, $95\%CI = [0.005, 0.014]$), indicating that people felt more pleasant after spending more time in offline (face-to-face) interpersonal interaction during the preceding period.

We also analysed participants' recall of how their usage of smartphones for emotion regulation changed their emotional states, in order to test the *perceived short-term* effects of using smartphones for emotion regulation. First, we entered ratings of the perceived emotion change item (see Item 9 in Table 1), which ranged from -5 (unwanted emotion) to +5 (desired emotion), as the dependent variable in a multilevel random-intercept model. The fixed intercept was estimated as 1.61 ($SE = 0.21$, $t(35) = 7.56$, $p < .001$, $95\%CI = [1.19, 2.03]$), indicating that people perceived their use of smartphones for emotion regulation as generally helpful to experience desired emotions. We also examined whether the amount of time spent using smartphones for emotion regulation predicted perceived emotion change and found that people reported reaching a more desirable emotional state when they spent a longer time using their smartphone for emotion regulation ($B = 0.01$, $SE = 0.003$, $t(95) = 3.37$, $p < .01$, $95\%CI = [0.005, 0.018]$). The results did not change substantially when we controlled for participants' age,

gender and T_1 affect. These results are inconsistent with our previous analysis modelling change in momentary affect as a function of smartphone emotion regulation use, but they are in line with the interview data reported below.

To further examine how the use of *different phone features* for emotion regulation changed perceived emotion change, we entered the intensities of using different features in the regression model and found that using phones for interpersonal contact ($B = 0.14$, $SE = 0.04$, $t(24) = 3.44$, $p < .001$, $95\%CI = [0.07, 0.21]$), listening to music ($B = 0.18$, $SE = 0.03$, $t(58) = 5.46$, $p < .001$, $95\%CI = [0.10, 0.23]$), playing games ($B = 0.18$, $SE = 0.07$, $t(4) = 2.52$, $p = .012$, $95\%CI = [0.03, 0.29]$), and sharing on social media ($B = 0.14$, $SE = 0.08$, $t(44) = 1.80$, $p = .07$, $95\%CI = [0.00, 0.29]$) all predicted more desired emotional outcomes. These results indicate that when people use their smartphones for emotion regulation, the more they use for interpersonal contact, listening to music, playing games, and sharing on social media, the more they report subsequently reaching a desired emotional state.

4.4.2. Interview data

4.4.2.4. Using smartphones for emotion regulation is perceived as effective. In the interviews, participants reported that smartphone-based emotion regulation was usually effective in helping them to down-regulate unwanted emotional states and attain desired ones. Participants also mentioned that using smartphones could quickly and effectively take their minds off their situations, helping them achieve better emotional states.

“For most of the time, I wanted to use my phone to shape my emotion, it did the job.” (Female, 27)

“Yeah it helps. It helps to relieve me, especially when I’m stressed. See, we have so much stress in our lives and everything, the phone is probably something that helps to calm me down.” (Female, 23)

4.4.2.5. The effect of phone-based emotion regulation is usually short-term. Although participants reported that they were mostly satisfied with the outcome of using smartphones to shape their emotions, they also mentioned that the effects usually did not last long. In most cases, smartphones only provided a brief relief, so that participants might use phones repeatedly to help them maintain desired emotional states.

“Smartphone provides instant happiness.” (Male, 30)

“You don’t get any concrete thing, it’s just something for entertainment to make you feel like are ‘Haha’ at that moment, that’s all.” (Female, 22)

“Usually when I use the phone to shape the mood, it’s not last longer than one hour. So if I use my phone to shape my mood, I will use it again shortly.” (Female, 27)

4.4.2.6. Varying efficacy of smartphone features for emotion regulation. Most participants mentioned that, of the different affordances that smartphones offer, connecting with other people via phone was the most effective for shaping emotions, and the effects of reaching desired emotional states lasted for a relatively longer time.

“I like to use direct person contact a lot because I’m an international student and my family is away. So I think that’s the most case when the smartphone changes my emotion to desired one, because I always feel good whenever I talk to my parents and my family.” (Male, 20)

“I love talking to people, talking to someone or interacting with someone always helps me take my mind off things and rejuvenates me. That makes me feel good.” (Male, 25)

Despite this, participants mentioned that they preferred to interact

with other people face-to-face (offline) when possible, as it led to better emotional outcomes than interacting with people online. They turned to their phones for emotion regulation usually when they were in situations that did not allow for face-to-face interaction.

“I usually like talk to someone, [...] maybe my friend is busy studying and I can’t disturb her maybe because when you study in a library, you can’t really talk. So I feel it’s more entertaining and comfortable to use your phone.” (Female, 23)

Participants also said that listening to music reliably made them feel better, provided them with energy, helped them to get rid of boredom during a commute, reduced tiredness after study or work, and helped them feel relaxed.

Again, there were indications that some instances of smartphone-based emotion regulation had instrumental motives, allowing participants to maintain energy and focus in order to work more effectively.

“Music always pumps me. [...] if I am tired of working, if I’m working for too long, I’m excited because I can listen to music. It is like a factor that keeps me going.” (Female, 27)

“Music is a huge part in my life [...]. It just helps me stay calm. Stay focused and feel better.” (Male, 25)

However, participants reported that engaging in social media browsing for emotion regulation sometimes led to negative emotions. They felt happy when scrolling novel social news, but felt sad if they saw other users showing off, or saw bad news such as disasters or violence.

“I feel both happy and depressed when use [social media]. For example, if you’re looking for a job, and then on social media you see other people celebrating getting a job and stuff, it made you feel inadequate, I was unhappy.” (Male, 25)

“Facebook does create negative reactions. [...] It could be some posts or somebody’s friends’ posts doesn’t align with what I feel or it could be news about violence, that could be negative, or just spending too much time on it.” (Female, 26)

4.5. Smartphone addiction and using smartphones for emotion regulation

4.5.1. Interview data

In interviews, more than half of the participants (13 of 21 participants) said that they did not think that using their phone for emotion regulation represented phone addiction. They believed that they could control the amount of time they spent using their phone for emotion regulation and could regulate emotions in ways other than using their phones.

“Not really addicted, like I said if I do have people around me and I am very happy to keep my phone away and talk to them. I do know other means of dealing with my emotions apart from my phone.” (Female, 25)

On the other hand, some participants were worried that using smartphones to regulate emotion too much would make them addicted. Some participants were especially concerned about social media because they thought it was designed to be addictive and that users may lose control while scrolling newsfeeds.

“On Facebook, it’s like one video after one, [...] once one stops, the next one starts, so it’s just a continuous cycle. I would say it’s so easy to get addicted.” (Female, 23)

4.6. Perceived advantages and disadvantages of using smartphones to regulate emotion

4.6.1. Interview data

The most frequently mentioned *advantages* of using smartphones to

regulate emotion were that phones were very convenient to use in many contexts and always accessible. Compared to other emotion regulation strategies such as going for a walk, going shopping and chatting with people offline, using smartphones was felt to be more convenient, and unaffected by constraints such as the weather or the availability of friends. Participants mentioned that smartphones offered a wide range of resources for emotion regulation and allowed people to flexibly switch from one resource to another.

“I can control my emotion by sleeping or by eating or doing shopping or something. But when you’re working, you cannot go out or shop, the easiest thing that I can do is to take out my phone and look at something. So, it’s convenient.” (Male, 25)

When asked about the *disadvantages* of using smartphones for emotion regulation, some participants (9 of 21 participants) were worried about becoming addicted to the positive emotional rewards derived from playing games and using social media, which could lead to problems such as depression and anxiety in the long run, as discussed earlier. Some participants (9 of 21 participants) were concerned that using smartphones to regulate emotions could make people more anti-social. Due to the convenience and flexibility of using smartphones for emotion regulation, people may use their smartphones as the first choice for regulating emotions rather than engage in face-to-face interactions with other people. Additionally, some participants (8 of 21 participants) were concerned about the downside of using smartphones to regulate emotions late at night, because spending too much time on phones could cause eye discomfort and decrease sleep quality. Finally, participants commented that using smartphones sometimes led to more negative emotions since outcomes were not always under control.

“Some people are just addicted. [...] people consume all time playing games.” (Female, 22)

“It makes you antisocial, and you don’t spend as much time with other people as you could.” (Female, 22)

“I rarely see two people having a conversation on the train, reading the newspaper or whatever, enjoying the scenery. I think, in the long run you lose your social interactions, face to face contact with other people.” (Female, 20)

“If I’m [using smartphone to regulate emotion] at night, then I may not sleep very well because of the light coming from the smartphone.” (Male, 29)

5. Discussion

This study aimed to explore the everyday use of smartphones for emotion regulation. We used experience sampling, combined with in-depth interviews, to investigate whether, when and how people use smartphones as emotion regulation tools in daily life, how this behaviour influences momentary affect, and how people perceive the value and impact of smartphone use as an emotion regulation strategy.

Using both quantitative and qualitative data, we found evidence that people indeed spend a significant amount of time using phones to regulate their emotional states; in fact, almost half (42.94%) of the total time participants spent using smartphones was to regulate their emotions. They used smartphones in particular to cope with unpleasant feelings such as boredom and stress. Our results also suggest, however, that the emotional effects of smartphone-based emotion regulation may often be short-lived.

5.1. Widespread engagement in phone-based emotion regulation

Several recent publications have suggested that smartphone-based emotion regulation is a widespread phenomenon with an important role in daily life for many people (Smith et al., 2022; Wadley et al., 2020;

Colasante et al., 2020; Rozgonjuk and Elhai, 2019). The study reported in this paper provides new empirical evidence in support of this claim.

A series of papers from Elhai et al. (2016, 2017, 2018), Rozgonjuk and Elhai (2019) has focused attention on emotion regulation as possible motivator of phone overuse. The results reported here support this suggestion, but also suggest that the use of phones as tools for emotion regulation does not always lead to problematic use, or at least it is not always perceived by users as doing so. Rather, it seems that phone-based emotion regulation is useful, or at least not harmful, for many people. This finding resonates with the recent report by Eschler et al. (2020) that digital emotion regulation can be helpful for people with depression. Likewise, Colasante et al. (2020) recently reported that a particular form of phone-based emotion regulation, involving social support, is felt by young “digital natives” to be as effective as in-person support. We speculate that smartphones, like other tools used in emotion regulation, are likely to be used moderately by most people, with problematic use occurring in a minority of people for whom the need to regulate emotion occurs relatively frequently or intensely.

It has long been known that emotion is part of the user experience of technology use. The results reported in this paper suggest that, in many cases, emotion change is not merely a side-effect but rather a deliberate goal of smartphone use, and that smartphones are adopted in part because they afford emotion regulation in many daily contexts. Perhaps more than any other digital technologies, the smartphone appears to provide access to a wide variety of resources for regulating emotion, and to do so at virtually all times and places (Wadley et al., 2020). While digital emotion regulation probably adds to the overall amount of phone use, the evidence reported here suggests that this is not always problematic and may be useful for many people.

5.2. Use of different phone-based resources for emotion regulation

We compared the effects of different phone features used for emotion regulation, finding that directly connecting with other people via phone and sharing on social media predicted more desired emotional states. This is in line with previous research findings that active social media usage is linked with positive well-being, via its effect on increasing social support (Kim and Lee, 2010; Kim et al., 2014). Playing games and listening to music also predicted desirable emotional states, and this is also consistent with prior studies (Katz, 2013; Liang and Yeh, 2011; Skånland, 2011). In the interviews, participants commented that browsing social media sometimes led to negative emotional states despite the goal to feel more positive; this too aligns with previous studies showing that passive social media usage reduces affective well-being (Verduyn et al., 2015; Lukoff et al., 2018; Duvenage et al., 2020).

Prior research has reported the use of videogames for relaxing, coping with stress, and distracting from negative feelings (Villani et al., 2018). Yet in this study we were surprised to find that these mostly-young people used social media and music intensively for emotion regulation, but rarely used games. This may be because our sample mostly comprised students who were busy with study and preferred social media over games as it wasted less time, as well as international participants who reported feeling lonely and homesick, leading them to use phones often to contact friends and family in their home country.

5.3. Short-term utility of smartphone-based emotion regulation

Lagged analysis of the experience sampling data showed that the use of smartphones for emotion regulation did not predict any change in momentary affective well-being over time. In contrast, our analyses of perceived emotion change ratings showed that participants retrospectively reported their smartphone-based emotion regulation efforts as effective in moving them towards desired emotional states.

In interviews, participants claimed that smartphone-based emotion

regulation is effective, though the effect is transient. This may explain the inconsistent findings from the two different experience sampling measures. Because there was a relatively long time (approx. 2.75 h) between surveys, assessing how momentary affect changed from one survey to the next may not have captured the short-term emotional consequences of smartphone emotion regulation, since other factors may have influenced people's affect during this interval. In contrast, self-reports of the perceived emotional efficacy of smartphone-based emotion regulation may reflect the immediate or short-term effects of using smartphones to regulate emotions.

Another possible explanation for the inconsistency between these two measures, however, is that people perceived their use of smartphones for emotion regulation as being effective in achieving desired emotions in order to rationalize this behaviour. Perceiving a voluntary behaviour as harmful to one's well-being is likely to evoke cognitive dissonance (Aronson, 1969), which participants would have been motivated to reduce by perceiving their use of smartphones for emotion regulation as helpful. Future research could use more nuanced measures such as emotion detection to capture the immediate emotional consequences of smartphone emotion regulation.

5.4. Long-term utility of smartphone-based emotion regulation

Previous research has found that attempts at emotion regulation can lead to excessive smartphone use and psychopathological symptoms such as depression and anxiety (Elhai et al., 2017). Our results suggest a nuanced interpretation of smartphone-based emotion regulation, in which smartphones provide convenient tools for routine emotion regulation in daily life, but may also create the risk of overly relying on phones for emotion regulation. In particular, the finding that some instances of smartphone-based emotion regulation probably have instrumental motives (Tamir, 2016), such as enhancing productivity while working, suggests that people may be able to incorporate this form of emotion regulation in non-harmful and indeed life-enhancing ways.

The finding that people value the flexibility of smartphones for supporting different forms of emotion regulation is interesting in the light of psychology research on the value of regulatory flexibility (Aldao et al., 2015; Bonanno and Burton, 2013), and echoes the findings of Wolfers et al. (2020) regarding the flexibility of media devices as coping tools. As Bonanno and Burton (2013) pointed out, people face ever-shifting contextual demands. Perhaps the key advantage of smartphones as emotion-regulatory tools is the wide range of resources that phones make available and the ease with which users can switch amongst them, allowing users to cope with a range of situations and to fine-tune their regulation efforts over time. This may facilitate context-appropriate use of emotion regulation strategies, which has been shown to be associated with greater well-being (e.g., Haines et al., 2016).

Finally, most participants reported that they did not think they were addicted to their smartphones when using them for emotion regulation, because they could control their phone usage and find alternative strategies for emotion regulation. In most cases they chose to regulate their emotions using smartphones simply for convenience. On the other hand, some participants were concerned that using smartphones for emotion regulation could lead to negative outcomes, including addiction. Future research should continue to investigate the consequences of using smartphones as emotion regulation tools, especially over a longer term, and should examine in more detail the conditions that lead to negative impacts upon social life, mental health and life satisfaction.

6. Limitations

Our study method was limited in ways that may impact the validity and generalisability of our findings. Our participants were drawn from a young student population at one Australian university; therefore, the data they provided may not generalise to a broader population, such as

people who are not young, not students, or who live in other places. On the other hand, students are a relevant cohort to study digital emotion regulation. Students and young people tend to be enthusiastic technology adopters and have been the focus of concerns about overuse and addiction. Students often have high workloads with regular deadlines, making them vulnerable to stress and in need of emotion regulation (Wadley et al., 2019). Many students live far from home and are prone to homesickness and loneliness (Kelly et al., 2021). Combined, these factors make it likely that students would be early adopters of smartphones as resources for emotion regulation. While our sample was restricted in terms of participant age and occupation, it was diverse in terms of gender and ethnicity.

The data in this study were gathered via self-report rather than objective sensing, making them prone to self-report bias. Furthermore, some of the survey questions required participants to remember behaviours performed up to 2–3 h prior, making some of the data prone to memory error. We mitigated these potential biases by collecting the participants' longitudinal affect as a check on their perceptions of emotion-regulation success, and triangulating experience-sampling data with interview data. Furthermore, despite these limitations, self-report remains the most reliable means of assessing the experience and deliberate regulation of emotion, which are inherently subjective and covert psychological processes (Barrett et al., 2007).

We anticipated that the idea of using smartphones to shape emotion might be difficult for study participants to grasp, and that they may not be able to identify using their smartphones for emotion regulation purposes in everyday life. However, after we explained emotion regulation in the introductory sessions, all participants responded that they understood the concept and believed smartphone-based emotion regulation to be a very common phenomenon. Participants reported that it was not always straightforward to answer the survey question "Did you use your smartphone in order to shape your emotional state during this time period?", because sometimes it was difficult to identify whether their goal was to regulate emotion. For example, one participant wondered whether using his smartphone to search for information should be considered emotion regulation, because if he didn't do it, he would feel worried. These ambiguous cases were unusual and did not influence our main findings, but they show that emotion regulation may sometimes be difficult to self-report.

7. Conclusion

This study suggests that people may spend a significant amount of time using smartphones for emotion regulation, especially when experiencing negative emotions such as boredom and stress. People perceive their smartphone-based emotion regulation efforts as being effective for reaching desired emotional states; however, these effects are likely short-lasting and may sometimes lead to negative outcomes.

Our findings suggest that the motives and strategies already discovered in studies of non-digital emotion regulation (Gross, 2015; Tamir, 2016) appear to occur in the digital realm. However, smartphones appear to offer a set of regulatory resources that is unprecedented in its variety and availability.

CRedit authorship contribution statement

Yaoxi Shi: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **Peter Koval:** Conceptualization, Methodology, Formal analysis, Resources, Writing – original draft, Supervision. **Vassilis Kostakos:** Conceptualization, Methodology, Writing – review & editing. **Jorge Goncalves:** Conceptualization, Methodology, Writing – review & editing. **Greg Wadley:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Supervision.

Declaration of Competing Interest

The authors declare no conflict of interest.

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