Imagining Consequences of Excessive Smartphone Use via a Character-Based Mobile Application

Abstract:

Excessive use of smartphones or other electronic screen products and the associated symptoms of addiction among youngsters have sparked concerns. This study explores possibilities of preventing adolescents or young adults from excessive smartphone use via a character-based mobile application stimulating their imagination and reflection. The character responds contingently to a user's act of switching on or off the screen, causing one to associate the effects on the character with excessive use. This approach, grounded in the embodied cognition thesis, combines behavior with imaginative consequences for one to experience, which combat the rewarding neural pathways activated in addictive behaviors. The application was deployed in a field trial. Each participant's usage was tracked via automated logging and cognitive responses were probed through in-depth interviews. Interview data were analyzed, followed by comparison with logged data. Overall, about half of the participants attributed imaginative consequences to their ways of using phones. One third of the participants showed evidence of positive change in using phones. These two groups substantially overlapped. The results suggest that experientially grounded association of virtual consequences with physical acts could correlate with behavior change. Using figurative representation as feedback could be promising in supporting individuals for healthy habits.

Introduction

With the advent of the World Wide Web and availability of personal computers at the turn of the last century, the issue of some people's problematic or uncontrollable use

of the Internet, or so-called "Internet addiction" (Block, 2008; Young, 1998), started to raise concerns. Many studies particularly looked into the potential adverse effects on vulnerable groups such as children or adolescents in different regions (Frangos, Frangos, & Sotiropoulos, 2011; Fu, Chan, Wong, & Yip, 2010; Johansson & Götestam, 2004; Kim et al., 2010; Seo, Kang, & Yom, 2009; Shek & Yu, 2016; Yu & Shek, 2013). The problem context meanwhile evolved quickly after the introduction of affordable smartphones and tablet computers, which are mobile devices allowing myriad applications (i.e., apps) to run for various purposes. This technology gave people a pervasive experience of information delivery, business transaction, social communication, multimedia entertainment, and other daily activities. Many people changed to use mobile devices and apps more often. According to reports (Khalaf, 2015; Khalaf & Kesiraju, 2017) issued by Flurry (a Yahoo!-owned company), for instance, Americans' average daily time spent on mobile apps overtook that on web browsing (both computers or mobile devices) in 2011, overshadowed that on television in the third quartile of 2014, and continued to grow every year, reaching a record of five hours in the fourth quartile of 2016. Yet, direct negative impact of spending excessive amounts of time online remains controversial. A few recent large-scale studies done in the U.S. (Ferguson, 2017) and the U.K. (Przybylski & Weinstein, 2017) tend to argue that there are no obvious links between digital-screen time (including television, computers, and smartphones) and mental wellbeing among adolescents or children. Conversely, a survey (*Report of Advisory Group on Health Effects of Use of Internet and Electronic Screen Products*, 2014) done in Hong Kong (by the Department of Health) among 4,300 children and adolescents as well as their parents and teachers between 2013 and 2014 has revealed a worrying situation. It shows that over half of the primary school students (aged from 6 to 12) and over 90%

of the secondary school students (aged from 12 to 18) possessed smartphones. Around 50% of parents considered their children had spent excessive amounts of time on the Internet and affected their daily lives, and 64% of parents regularly or occasionally quarreled with their children on this subject. Students' verbal reports show that 37% of them regularly or occasionally giving up outdoor activities, 49% regularly or occasionally depleting sleep time, 45% regularly or occasionally seeing academic performance being affected, and 19% regularly or occasionally deceiving others of going online. These figures seem to suggest symptoms or signs of addiction, including excessive use (interference with daily routine or neglect of basic needs) and negative repercussions (arguments, lying, poor achievement, etc.). The Department of Health recommends that prolonged screen time should be avoided for children and adolescents.

In fact, exposure of youngsters to potential objects of addiction has consequences in their developments. According to the Addiction Syndrome Model (Shaffer et al., 2004), as supported by neuroscience research results, repeated interactions with an object of addiction result in neurobiological consequences, such as activation of reward circuitry in the brain, that are common to other objects of addiction as well. These consequences accumulate to form the underlying addiction syndrome, which can manifest as multiple possible addictive behaviors along one's lifetime. The pervasive availability and engaging interactivity of mobile devices and apps activate highly rewarding neural pathways in their users, which easily become antecedents constituting the addiction syndrome. Hence, preventing children, adolescents, and even young adults from excessive use of mobile devices and apps is urgent. This article presents a project using a character-based app, Time Off, which prevents excessive use of smartphones through stimulating users' imagination of the

behavioral consequences and reflection on the behavior. The character responds contingently to a user's act of switching on or off the screen, causing one to associate its varied unpleasant states with excessive use. This approach, grounded in the embodied cognition thesis, cognitively connects an act or behavior with augmented feedback, allowing one to perceive their co-occurrence and imagine their cause-effect relationship. The user's attention is directed toward the motivation for switching off the phone, with fewer chances of having the rewarding neural pathways being activated by the mobile contents once the screen is on.

Using technology to track behavior and return feedback as interventions is not new. Studies, usually mixing quantitative with qualitative methods in small scales of trials, have been flourishing in human-computer interaction (HCI) and design on varied topics including energy conservation (Dillahunt & Mankoff, 2014), physical activity (Consolvo et al., 2008; Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006; Maitland et al., 2006), and use of digital devices (Rooksby, Asadzadeh, Rost, Morrison, & Chalmers, 2016). Insights from some studies inform advantages of using figurative, stylized representations that map behavioral data to images as feedback, which are more perceivable at a glance (Consolvo, Klasnja, McDonald, & Landay, 2014) and readily elicit emotions in users (Lin et al., 2006). Drawing on embodied cognition, we argue that to draw users' attention in their daily lives, feedback of a behavioral act should be rendered like an inherent, natural consequence. Their co-occurrence allows imagining the cause-effect relationship. And this imaginative consequence in the representation should be "lively", which means contingently changing to prompt users' reanalysis of the cause-effect relationship. The Time Off app employs what the first author calls the liveliness framework (Chow, 2017) in designing feedback representation of users' mobile screen time (time spent on mobile

devices) in order to stimulate imagination and reflection. The following sections present the theoretical framework of the design approach in Time Off, followed by description of the field trial with participants using Time Off. Findings are then discussed, leading to implications.

Theoretical Framework

The design strategy of feedback representation in Time Off has two parts: (1) to enable imagining the character's feedback to be natural consequences of using the phone, which directs attention toward the motivation for switching off the screen; (2) to map contingent changes of the character with different degrees of excessive use, which continue to prompt reanalysis of the cause-effect relationship and reflection on potential excessive use. The theoretical framework is built on theories in social psychology and embodied cognition, including feedback interventions, conceptual metaphor and blending, the concept of animacy and liveliness.

Feedback Intervention Theory

Feedback Intervention Theory (Kluger & DeNisi, 1996) holds that feedback to a performed task directs attention across three levels of processes and their consequences, starting typically at the mid level, the task motivation, going down to the task components, or moving up to the performing individual self. Perceiving co-occurrence between an act and its distance or indirect consequences enables one to intuitively see the discrepancy between the consequences and initial goals, which directs attention towards the task motivation. Users of Time Off should be able to perceive the effects on the character while using phones. One might not have explicit goals about the character, yet changes of the character would provoke one into

thinking what states of the character are preferred and how they can be achieved. Users are assumed to prefer positive effects on the character. The crux is how one can learn the way of achieving them. Insight from embodied cognition informs the efficient, unconscious learning processes.

The Neural Basis of Metaphor and Blending

The embodied cognition thesis states that many abstract concepts in our minds are built on our physical, bodily experiences (Lakoff & Johnson, 1999). Initial evidence arises from our everyday languages, which show instances (e.g., we say something good as "high quality") of conceptual metaphors (e.g., Good Is Up) mapping schemas (i.e., spatial structures, motion patterns, or sensory scales, e.g., VERTICALITY/UP-DOWN) of bodily experiences (e.g., we lie down when feeling unwell) to abstract ideas (e.g., Good vs. Bad). Mappings in conceptual metaphors are also supported by neuroscience research findings, which refer to physical links in the brain (Lakoff, 2012). Bodily experiences that regularly co-occur (e.g., children are held affectionately by parents and feel warm) activate neurons in corresponding brain regions and strengthen the synaptic connections, resulting in least-energy pathways (e.g., activation of being affectionate becomes easily followed by that of feeling warm). These neural pathways are the mappings of conceptual metaphors (e.g., Affection Is Warmth), which also explain the neural binding phenomena wherein independent groups of neurons activated together in particular contexts.

Primary metaphors are conceptual metaphors that built on regular bodily experiences, resulting in persistent bindings. They combine with less regular experiences (e.g., no work at night), forming complex metaphors (e.g., Rest Is Lights Off), via cognitive operations of conceptual blending. Blending starts with mapping

between two concepts, followed by partial projection onto a new concept (Fauconnier & Turner, 2002). For particular scenarios as perceived, remembered, or imagined, the concepts are called mental spaces, which are mental simulation of the scenarios containing elements like actors, actions, and objects, and their relations structured by frames (conceptual structures formed in long-term memory, which are partly built on schemas). Mental simulation, in neuroscience terms, is neural simulation, which is activation of much the same circuitry in imagining as in perceiving or acting, and the former is guided by the least-energy pathways of the latter. Blending is thus dynamic binding of independent neuron groups in particular contexts (Lakoff, 2012). In short, primary metaphors are more universal and fixed, while blends can be particular and dynamic. Time Off presents the character's feedback co-occurring with the act of switching on the screen, which enable imagining the cause-effect relationship like disturbing or exploiting someone in particular context, forming a blended concept of disturbing or exploiting the character by using the phone. This blend, as embodied in dynamic neural binding with least energy, can take place with minimal cognitive effort, which means one can learn the logic efficiently and unconsciously.

The Concept of Animacy and Liveliness

Animacy refers to people's concept separating the animate from the inanimate built on perceptual experience. Jean M. Mandler (Mandler, 1992) and Mark Turner (Turner, 1996, pp. 20-22) point out that animacy is a complex image schema of observed movements, including (1) self-motion, which can be completely independent; (2) caused motion, which is obviously dependent; and (3) contingent motion, whose link to others may be indirect, thus arousing curiosity. People experience and interpret similar animated phenomena via blends. For example, we

understand the reaction of a cat by blending it with our own response to certain cause (Turner, 1996, p. 21). One might see a slowly, repeatedly glowing and dimming light (that found in some versions of Apple MacBook) as a living thing sleeping with a steady breathing rate and understand that the machine is in standby mode with power on yet not actually functioning. The first author calls this kind of animated phenomenon enabled by technology "liveliness" (Chow, 2013). Lively phenomena often include contingent changes, causing observers to reanalyze the cause-effect relationship of a situation by invoking different frames, what Coulson calls "frame-shifting" (Coulson, pp. 35-36), and elaborating successive blends. The character in Time Off changes contingently and continuingly. Some states may look more curious, for instance sudden disappearing from the screen, prompting one to invoke different frames, like the abuse frame or the tolerance frame, and interpret that the character could not tolerate and left.

The Time Off System

Time Off consists of a mobile app, which polls the screen status (i.e., on or off) of the user's smartphone every five minutes, which is a heuristic measure of time spent on the phone. An animated character with different states mapped with the polls is displayed on the screen. The character has five "incarnations" (i.e., Cute, Anime-styled, Superhero, Wacky, and Typical) for individual user selection. A tailor-made phone jacket is also provided to enhance the multimodal experience. Following the liveliness framework (Chow, 2017), the use of Time Off has at least two stages of cognitive processes (each having four sub-processes).

1.1 Knowing action possibilities – When consecutive polls are positive (i.e., the screen is on), the character starts to be incrementally ill in five states in terms of

different short animations, phone vibrations in different patterns, and notification alerts with different messages. The user can continue to use the phone or switch off the screen.

1.2 Perceiving feedback – If the screen is switched off for a time longer than one polling interval, the consecutive positive polls break, and the character recovers; otherwise, the character becomes more ill, and the phone will vibrate again at the next polling time.

1.3 Triggering immediate blend – Keeping the screen on makes the character sick. It is like disturbing or exploiting someone. An immediate blend takes place, yielding an imaginative act of switching off the screen to give the character time to rest.

1.4 Becoming second nature – The user has unconsciously learned the way to keep the character well.

2.1 Noticing contingent changes – If the user continues to use the phone, the consecutive positive polls grow accordingly. The character suddenly disappears from the screen and only leaves messages (i.e., notifications) to the user in every polling time. The user becomes curious.

2.2 Invoking interpretive frames – The user invokes the tolerance frame structuring a scenario that someone feels unbearable and leaves.

2.3 Elaborating successive blends – The scenario of someone leaving is mapped with the character's disappearing, and the unbearable is mapped with the act of switching on the screen from the blend in (1.3). The output of the new blend is an imaginative narrative that the character cannot bear the user's behavior and leaves.

2.4 Reflecting on the situation – The user no longer assumes that the character always stay in the phone. Instead, the character can leave. The user may take this new perspective on his or her mobile use.

The following (Table 1) lists the subsequent states of the character with the corresponding sample notification messages and the approximate length of the vibrations.

States	Animations	Sample notification messages	Vibrations (in sec.)
0	Relieved	-	-
1	Shivering Uncomforting	-	3-4
2	Chilly Tired	"It's chilly"	8-10
3	Freezing	"It's freezing"	12-15
4	Sneezing Running nose	"Achoo!"	20-30
5	Coughing	"Cough…"	30-40
6	Leaving for cure (no animation)	"I go to the drugstore" "I go to the doctor"	No vibration
7	Leaving for other activities (no animation)	"I take a shower" "I go to bed" "I go to the bookstore" "I go hiking" "I go to the cinema" "I go get something to eat"	No vibration

Table 1. Subsequent states of the character corresponding to incremental length of consecutive polls as a measure of a continuous session of use

Field Trial

This study involves a field trial of Time Off mixing quantitative with qualitative methods. Participants are first asked to complete a questionnaire aiming to know one's usage of smartphones, which informs the personalization of the Time Off app

for the intended experience of the character's feedback. During the trial period, the app logs one's time and frequency of switching the screen on or off. After using the app for at least three weeks, in-depth interviews are conducted with the participant for the cognitive responses during use, based on the liveliness framework. The quantitative data collected via the automated logging are visualized in graphs for detecting changes in the use pattern, while the qualitative data from the interviews are coded according to the liveliness framework for clustering. By comparing the two sides, correlation between usage of smartphones and experiences of the app is to be sought. Initial findings of the trial were presented elsewhere (Chow, 2018), yet more data analyses and more elaborate discussion are delivered in this article.

Participants

The trial period from July 2016 to April 2018 involved 21 participants (14 male, 7 female). Selection criteria included regular users of smartphones whose self-reported daily total time spent on the phone was at least three hours. Thirteen participants were recruited through a local NGO and the others were recruited in the campus of a university in Hong Kong. Seven of them aged from 12 to17, eleven from 18 to 25, and three from 26 to 35. Each of them selected one favorite "incarnation" of the character. Ten of them selected Cute, four Anime-styled, four Superhero, two Wacky, and one Typical. All participants voluntarily used Time Off from three weeks to six weeks, yet five of them only provided 2 weeks of data.

Surveys for Personalization

The questionnaire surveyed the general usage of smartphones, including one's self-estimated daily total time spent on the phone, and usual continuous time of use without breaks, which informed the customization of the app for each participant. The usual continuous time set the time scale for the character's various states (i.e., how

many minutes for each state) that allowed one to experience most states in a day. The daily total time suggested a daily quota of mobile use for the participant, which was measured by the "running difference" between positive and negative polls on a day. The number of days exceeding the quota indirectly indicated one's overall achievement in controlling the behavior. The questionnaire also asked about one's suspended or latent interests, which would be used to personalize the character's notification messages.

Logs

According to Doherty, Coyle, and Matthews (2010), data visibility and privacy is an important guideline to build trust with the clients and the counselors in designing for mental heath. Hence, the screen status data was logged and stored in the participant's smartphone, and the participant was asked to send us the daily log file by email.

Interviews

We conducted interviews with participants, after at least three weeks of use. The interview outline followed the protocol of cognitive processes from the liveliness framework. The first-level questions were crafted thoughtfully to avoid directing the participant:

1.1 How do you feel about the character? Have you tried anything with it? How about the jacket?

1.2 Did you notice any changes of it?

1.3 When it shivered the first time, what did you think?

1.4 How often did it shiver? How did you usually deal with this?

2.1 What did you see then? Did you notice that it disappeared?

2.2 Did you think why it disappeared? What do you think now?

2.3 Have you thought of how to make it back? Have you tried? Did you make it?

2.4 How did you think about the character's behavior?

Data Analyses and Findings

Logged Data

The raw data in the logs consisted of one's screen status in every five minutes and the character's corresponding state mapped with the continuous positive polls. The highest state appearing at the end of a rise indicated the length of a session. The count of each state appearing at the end of a session (corresponding to certain session length) was summarized weekly, which showed the frequency distribution of one's short and long sessions. Meanwhile, the number of days every week with the running difference between positive and negative polls exceeding the quota was also counted to indicate one's overall usage. For each participant, we visualized the above two counts. We found varied patterns that could be regarded as positive change: (a) drop in weekly counts of most states and the number of days exceeding the quota, as in P2 and P20 (see Figure 1 and Figure 2); (b) drop in the number of days exceeding the quota with slight increase in weekly counts of short sessions, which suggests long sessions are broken into short sessions, as in P9, P14, and P16 (see Figure 3, Figure 4, and Figure 5); and (c) drop in weekly counts of most states with the number of days exceeding the quota being steady, as in P4 and P17 (see Figure 6 and Figure 7). Apart from the above seven participants showing positive change, the other fourteen participants' data were either steady or too fluctuating for patterns to be detected (see Figure 8 for example). In other words, one-third of the participants did show positive change. In the graphs, the vertical distribution (session length increasing from top to bottom) and horizontal progression (time moving from left to right) of the red bars show changes of the participant's usage patterns across the weeks of using Time Off.

Figure 1. Visualization of P2's logged data in six weeks

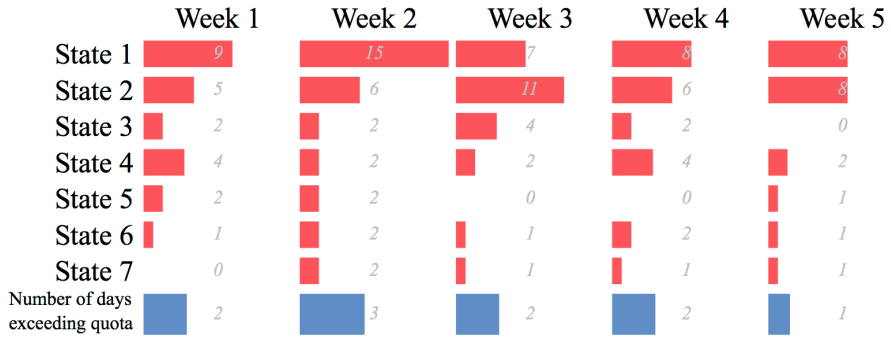

Figure 2. Visualization of P20's logged data in five weeks

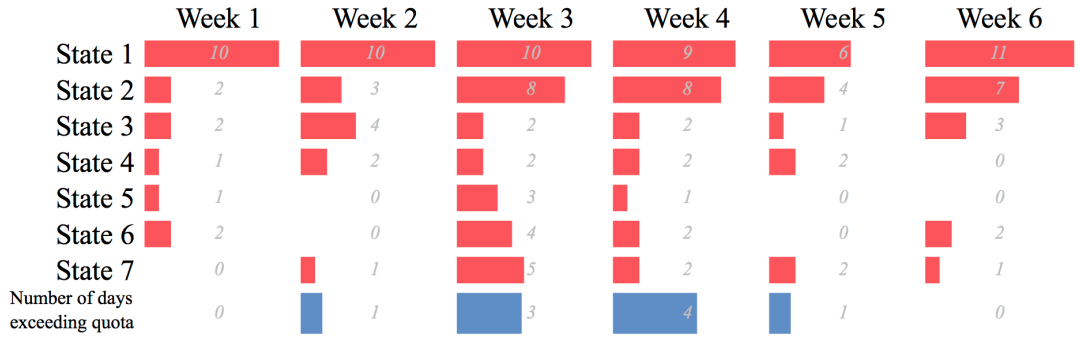

Figure 3. Visualization of P9's logged data in six weeks wherein the latter half shows the drop in number of days exceeding quota

Figure 4. Visualization of P14's logged data in three weeks

Figure 5. Visualization of P16's logged data in three weeks

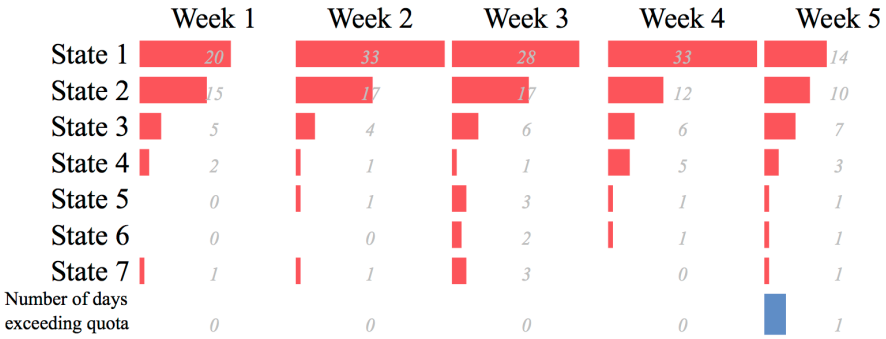

Figure 6. Visualization of P4's logged data in five weeks

Figure 7. Visualization of P17's logged data in four weeks

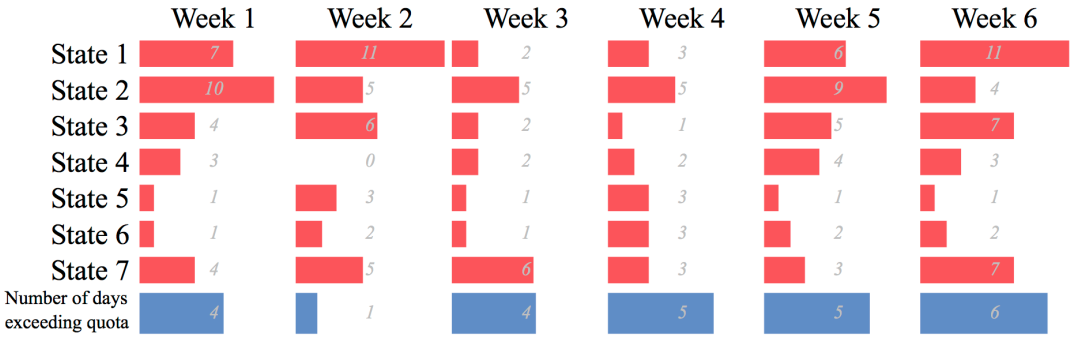

Figure 8. Visualization of P6's logged data in six weeks

Interview Data

All interviews were transcribed and coded according to a scheme informed by the liveliness protocol. The keywords in the protocol, including "motor action" for Stage 1.1, "sensory feedback" for Stage 1.2, scenarios from "another domain" for Stage 1.3, scenarios with "similar changes" for Stage 2.1 and 2.2, "imagined scenarios" with "causes" for Stage 2.3, and "different perspectives" for Stage 2.4, were used as codes to mark in the transcripts. Each set of coded data, for instance those of "similar changes", was then clustered into different groups, which imply different frames invoked among the participants. The clustering of coded interview data, mainly the codes "another domain", "similar changes", and "different perspectives", is summarized as follows, with sample quotes (informative words in italics) from the participants.

Another domain. When participants spoke about the initial changes of the character, their wordings revealed that most of them unconsciously drew on concepts from different domains to describe it, which implied immediate blends in their minds. These domains were clustered into two main themes, namely someone in need of rest (P2, P4, P8, P12, P14, P15, P19, and P20) and someone giving verbal reminders (P5, P6, P10, P12, P16, P19, and P21).

<u>In need of rest</u>

P2: "Switching off the screen, *leaving it alone* for a while"

P4: "Just switched off the phone and let it *rest* a bit."

P12: "It wants to *take a rest*."

P14: "The genie *couldn't rest* because I kept using the phone, just like giving it too much work."

P15: “Let both of us *take rest*.”

Verbal reminders

P5: “It is similar to humans … like *somebody being with* you, *reminding* you.”

P6: “It *asked me* to stop.”

P10: “It was *asking me to turn off* the screen but I just ignored it.”

P12: “To teens, the genie will act like their mother, *asking* them to take a rest.”

Similar changes. Most participants noticed the character’s disappearing. They tried to figure out this curious change in various ways, which showed different interpretive frames invoked among them, namely return after departure (P2, P4, P5, P9, P13, P14, P16, P17, P18, P19, P20, and P21), rebirth after death (P1 and P8), and system issues (P6 and P10).

Gone and back

P2: “Saw that it had already *come back*.”

P4: “A bit shocked and worried whether it would *come back*.”

P5: “It was doing something elsewhere, because it labored for too long … I tried to *call it back* by poking.”

P9: “It will *come back* the next day.”

P13: “Maybe too boring, *gone* for something else as it said.”

P14: “It was *gone* and turned its back on me.”

Dead and reborn

P1: “Reborn anyway; if not, give it a funeral, like how we treat our pets.”

P8: “Spending too much time on the phone caused it to *become sick* … it is dead and reborn.”

System issues

P6: “It disappeared because the app was *closed by overheating*.”

P10: “I thought it was a *bug of the app*.”

Different perspectives. For those invoked the departure frame, eight participants took the character’s perspective, relating its response to their behavior together with the tolerance frame. A few of them self-questioned.

Unbearable

P2: “It *could not take me anymore* because I played games for too long … like a *girlfriend* could not take anymore and leave.”

P4: “It felt *disappointed*.”

P5: “It may be *angry* and leave.” “It has a character. If *I ignore* its messages, it will leave; if I stop using the phone, it will come back. I’m interacting with it.”

P14: “It was *angry at me* because I didn’t give it the jacket, I didn’t take care of it.”

P16: “It’s gone because of *being mad*.”

P19: “It asked me for help, yet I couldn’t and it’s gone.”

P21: “It’s gone; it *doesn’t care* and *doesn’t wanna see* any more.”

Self-evaluation

P2: “I’m *wasting my time*.”

P8: “*Should I* need to stop a while?”

P14: “*I did reflect* on my own usage, asking myself is it necessary to spend so much time on the phone?”

P19: “It made me associated that I used the phone too long.”

The clustering of the code “another domain” implies different immediate blends taking place in the participants. The code “similar changes” informs main interpretive

frames invoked by them when noticing the contingent changes. The code "different perspectives" shows the reflection elicited in them.

Discussion

Time Off is designed to (1) stimulate imagining the character's responses to be natural consequences of using the phone; and (2) prompt reanalysis of the cause-effect relationship through changes contingent on excessive use. For the first design goal, this study's qualitative findings showed that more than two-third of the participants (16 out of 21) saw the character's initial state changes as a direct consequence of using the phone. Nine of them particularly believed that the character asked for rest because using the phone caused it to become tired and ill. This imaginative interpretation matched best with the first design goal. It seemed that the majority of participants perceived the co-occurrence of phone use and the character's changes, performing blends of the situation with certain past experiences (e.g., snubbing, disturbing, or exploiting others), and interpreting the character's changes as a result of using the phone. This interpretation was largely unconscious, as it was found to be an assumption underpinning those participants' responses. Conversely, the other few participants assumed that the character is simply a computer program and did not imagine any relationship at the character level. They did not suspend the disbelief in virtual characters, likely because their conceptual categorization of animacy is much entrenched. This suggested that the figurative representation approach would not work well for those cases.

The character's later disappearing from the screen successfully prompted most participants to reimagine the possible causes, achieving the second design goal. Eleven participants thought that the character left the phone, and two thought that it

died. The crux was that nine of them explicitly related the character's departure (leaving or dying) to themselves. Eight participants believed that their behavior of excessive use drove the character away, and one participant mentioned that overuse caused the death of the character.

Amongst the seven participants who were found to have positive change based on quantitative analyses of the logged data, six of them did see the character's responses as a natural consequence of using the phone. Five out of these six thought that overuse caused the character's departure too. On the other hand, these five participants demonstrated evidence of positive change came out of the aforementioned nine participants who claimed responsibility for the character's departure. In other words, the group of extended imagination (9) overlapped with the group of positive change (7) in 5 participants. This suggested that the phenomena of imaginative blending have obvious correlation with changes in behavior. People who are able to imagine the character from the app would likely believe in the cause-effect relationship and take the character's perspective, probably performing changes for the benefit of both the character and themselves. Meanwhile, the gap between motivation and action still exists. One might consider whether a change is necessary or preferred, and when to change even if it is needed. We believe that Time Off is to indirectly and enduringly highlight the motivation for one to perform change.

Limitations and Implications

This study aimed to explore and investigate the potentials of using the character-based app, Time Off, in intervention for healthy use of smartphones. It included designing and deploying Time Off in a field trial in which quantitative data of mobile screen time were collected via automated logging and users' cognitive responses were

probed through interviews. The study accommodated certain limitations. The app polled the screen status every five minutes, which had energy cost, though insignificant. Polling was a heuristic measure of time spent on the phone, as the user might just turn on and off many times between two consecutive polls. As Time Off aimed to break long continuous sessions of use into short ones, missing out very short sessions in the polling counts seemed acceptable. Apart from the app implementation, deployment in the field was also challenging. The trial has lasted for two years involving different participants at different periods. The duration of use also varied from three weeks to six weeks due to different personal schedules, interests, and degrees of commitment among participants. Some participants' logs were incomplete and could not be counted too. Although the samples collected in two years had many variables that could not be isolated, our analyses focused on detecting patterns of change and examining cognitive responses in individual case scenarios, rather than directly comparing data between individuals.

All in all, this study has both theoretical and practical contribution. Theoretically, it draws on insight from the embodied cognition thesis and connects with social psychology ideas to offer a novel approach to behavioral intervention. The approach is to employ figurative representation as feedback to stimulate imagination of behavioral consequences that motivate changes in habitual or addictive behaviors. Practically, this study has shown that the approach is viable in the field with qualitative data of imaginative experiences collected and quantitative behavioral data tracked. Results of the data analyses suggest that imagination of virtual feedback in combination with physical acts could correlate with actual behavior change. This is promising in future services supporting individuals for healthy habits, such as

physical exercise or moderate consumption, as long as one's suspension of disbelief in virtuality can be achieved.

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