Computers in Human Behavior 110 (2020) 106378

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: http://www.elsevier.com/locate/comphumbeh

Full length article

Investigating the attentional bias and information processing mechanism of mobile phone addicts towards emotional information

Yixin Hu[a,1], Jiahui Guo[b,1], Min Jou[c,*,1], Shengqi Zhou[a,1], Dawei Wang[a,1,**], Phil Maguire[d], Jing Wei[a], Fangzheng Qu[a]

[a] School of Psychology, Shandong Normal University, Ji'nan, Shandong, China
[b] School of Social Development and Public Policy, Fudan University, School of Psychology, Shandong, China
[c] Department of Industrial Education, National Taiwan Normal University, Taipei, Taiwan
[d] Department of Computer Science, National University of Ireland, Ireland

ARTICLE INFO

Keywords:
Mobile phone addiction
Emotional information
Attentional bias
Behavioral experiments
Eye movement technology

ABSTRACT

Mobile phone addiction is a behavioral addiction that leads to physical and psychological maladaptation. Researchers have focused on the attentional bias of cognitive cues while neglecting the role of emotional information. The main debate concerning emotional information has been on whether its associated attentional bias is caused by different types of emotional information or only by negative emotional information. We investigated the specific information processing mechanism that lies behind mobile phone addicts' attentional bias towards emotional information.

In this study, behavioral experiments were performed using the dot-probe paradigm. The results showed that high-level mobile phone addicts (MPAs) have attentional bias towards negative emotional information. In order to understand the mechanism of attentional bias more precisely, a follow up study was carried out using eye movement techniques. The results of this follow up study found that, compared with the normal use group, high-level MPAs' eyes tended to fixate first on negative faces, and significantly more on negative faces than on positive faces. When high-level MPAs demonstrated attentional bias towards negative faces, their first fixation duration was significantly longer than those for positive faces. However, there was no overall attention maintenance of negative emotional information. We conclude that mobile phone addicts have attentional bias towards negative emotional information, manifested as an alert-maintenance model, meaning that attention orientation and difficult disengagement function together. The results of this study could be used to guide interventions geared towards attentional bias training for mobile phone addicts, as well as providing theoretical support for treatment and intervention.

1. Introduction

Smart phones have opened up people's horizons and brought great convenience to everyday life, work and study. However, with this increasing popularity, mobile phone addicted behavior caused by excessive use of smart phones has also heralded increasing psychological problems. For example, excessive use of smart phones can lead to negative physiological consequences, such as decreased vision, sleep disorders, and headaches (Sahin, Ozdemir, Unsal, & Temiz, 2013; Subba et al., 2013). It can also lead to many psychological problems such as trouble concentrating (Lepp, Barkley & Karpinski, 2014), passive emotional experience (Zheng & Lee, 2016), anxiety, depression, stress (Hawi & Samaha, 2017), reduced mindfulness (Liu, Zhou, Niu, & Fan, 2017), reduced empathy (Lachmann et al., 2018), and interpersonal alienation (Roberts & David, 2016). Accordingly, mobile phone addiction has grown to become a serious issue dominating the physical and mental health of many people. Research in this area not only provides theoretical support for the treatment and intervention of mobile phone

* Corresponding author.
** Corresponding author.
E-mail addresses: huyixin2005@163.com (Y. Hu), 2931379091@qq.com (J. Guo), joum@ntnu.edu.tw (M. Jou), 1113496967@qq.com (S. Zhou), wangdw@sdnu.edu.cn (D. Wang), pmaguire@cs.nuim.ie (P. Maguire), 841511308@qq.com (J. Wei), 1290636061@qq.com (F. Qu).
[1] Yixin Hu, Min Jou, Jiahui Guo, Shengqi Zhou, Dawei Wang, are co-first authors, all owning the first authorship.

https://doi.org/10.1016/j.chb.2020.106378
Received 27 August 2019; Received in revised form 4 April 2020; Accepted 8 April 2020
Available online 13 April 2020
0747-5632/

addicts, but can also directly contribute to improving people's quality of life.

The definition of mobile phone addiction is not yet unified. Ehrenberg, Juckes, White, and Walsh (2008) proposed a definition that includes three indexes: compulsive behavior, withdrawal symptoms and thoughts dominated by behavior, as adapted from the definition criteria of substance addiction. Focusing on symptoms, Ezoe et al. (2009) defined mobile phone addiction as a phenomenon that involves the "desire to use mobile phones excessively and intermittently". Zhou (2010) proposed three aspects for defining mobile addiction: the abuse of mobile phones, the excessive influence of mobile phones on work, study and life, and the physical and psychological discomfort caused by the absence of mobile phones or prohibition of the use of mobile phones. Synthesizing all of these perspectives together, this study defines mobile phone addiction as a behavioral addiction that leads to physical and psychological maladaptation because of the excessive use of mobile phones.

How can the negative impact of mobile phone addiction be addressed in order to improve people's physical and mental health? Research on drug and behavioral addiction has shown that addicts tend to have a processing bias towards negative materials (Wiers & Stacy, 2006; Decker & Gay, 2011; van Holst et al., 2012; Wang, Jiang, & Zhang, 2008; Hua, Wu & Fang, 2016). This bias may further deepen addictive behavior (Cheetham, Allen, Yücel, & Lubman, 2010; Baker, Piper, McCarthy, Majeskie, & Fiore, 2004; Bai; Jia & Wang, 2013). Attention bias training can improve people's physical and mental health by altering their attention patterns, and effectively reduce dependence (Attwood, O'Sullivan, Leonards, Mackintosh, & Munaf, 2010; Schoenmakers et al., 2010; Den, Gladwin, Johannes, & Wiers, 2018; Xing & Yang, 2013; Tang, Zhao, & Wang, 2015).

2. Theoretical background

Attention bias is a phenomenon whereby individuals have higher sensitivity, and pay selective attention to specific stimuli (Gao et al., 2011). Some scholars have argued that attention bias is an unconscious process that leads individuals to focus on substance-related cues in their naturalistic environment and, having done so, experience a corresponding difficulty in disengaging from such cues. This automatic process increases the salience of substance-related cues and could potentially draw abusers towards substances (Field & Cox, 2008).

Research on addicts' attention bias has focused on two areas, namely the attention bias of addiction clues, and the attention bias of emotions. Addiction clues might involve words or pictures associated with the area of addiction. Compared to neutral (or unrelated) cues, addicts show an attention bias towards these stimuli (Franken, 2003; Robbins & Ehrman, 2004; Rooke, Hine & Thorsteinnsson, 2008). This phenomenon can be explained by self-schema theory or inducement-sensitization theory. A schema is a stable structural representation of knowledge stored in memory. According to the self-schema theory, once a stimulus is consistent with a schema or knowledge structure, it is processed more easily. For addicts, information consistent with a schema will be more readily processed, thus activation of a schema or knowledge structure can lead to attention bias. The inducement-sensitization theory proposes that repeated actions provoke a dopaminergic response. The physiological basis of this effect is that the cortical striatal circuit is activated to release dopamine after performing a large number of similar behaviors. Since addiction-related stimuli bring pleasure to addicts, these are given priority. The craving for addictive behavior thus increases, as well as attention bias towards the relevant stimulus. This process is repeated until an addict eventually develops the addictive behavior (Robinson & Berridge, 2000).

Mobile phone addiction is different from drug and behavioral addiction, insofar as the availability of mobile phones is so high. We take them with us every day; mobile phones are so ubiquitous as a gateway to information and communications that, in many cases, it is not feasible to quit using them. The content that mobile phones present is colorful and designed to attract attention (for example, mobile games, short videos, social forums, etc.) (Parasuraman, Sam, Yee, Chuon, & Ren, 2017). The study of mobile phone addiction is thus unique and informative. In addition, there has been relatively little research carried out on mobile phone addicts' attention bias towards emotional information. In general, addicts mainly demonstrate an attention bias towards negative emotions (Aguilar de Arcos et al., 2008; Bai, Jia, & Wang, 2013; Lei, He, Niu, Zhou, & Tian, 2017; Marques-Teixeira & Barbosa, 2005; Wang, Yuan, Luo, Li, & Sui, 2017; Yang, Ma, Zhao, & Zhang, 2015; Zhou et al., 2014). Zu (2017) found that mobile phone addicted college students also demonstrated a negative emotional processing bias. However, the emotional facial materials used in this study were stick figures, which differ greatly from real life contexts, thus having low ecological validity. In contrast, the emotional materials used in this study were selected from the Chinese Facial Affective Picture System (CFAPS) produced in 2005 by Wang and Luo at the Institute of Psychology, Chinese Academy of Science.

Research has shown that mobile phone addiction is closely related to negative emotions, with mobile phone addicts regularly experiencing negative emotions such as depression and loneliness(Ha, Chin, Park, Ryu, & Yu, 2008; Liu & Wang, 2011). People often process facial expressions to obtain social cues for interaction, reading the emotions and intentions of others. For example, happy faces usually mean "like and approve", while angry faces often represent "hostility and aggression", and reflect potential social threat (Schupp et al., 2004). Emotion is an important factor in interpersonal communication. However, if individuals focus their attention resources excessively on emotional information, and fail to inhibit it appropriately, emotional disorders can result (Bai et al., 2013). This in turn can further affect the quality of people's social interactions. Studies have shown that individuals with higher levels of mobile phone addiction tend to have more interpersonal problems (Wang, 2012; Roberts & David, 2016). According to the mood-congruent hypothesis, when individuals are in a state of positive or negative emotion they pay more attention to faces with the same expression as their own mood, meaning that a person's temporary emotions can affect their perception of facial expressions (Becker & Leinenger, 2011). Since mobile phone addicts regularly experience negative emotions, they may be more sensitive and more aware of the negative emotional stimuli that are consistent with their moods. Thus, we hypothesized that mobile phone addicts have an attention bias towards negative emotions.

Research on emotional attention bias is centered on two aspects. One concerns performance patterns, which examines questions such as: what kind of person, in what kind of mood, in what kind of environment, exhibits attention bias, after what kind of events? The other concerns the mechanism behind attention bias (Williams, Watts, MacLeod, & Mathews, 2001). Two prominent models have been proposed, namely alertness and inhibition. Alertness means that during the initial attention-orientation phase, attention is drawn to the location of negative stimuli, leading to attention bias (Brosch et al., 2008); inhibition means that negative stimuli create an effect on the ability to release attention, so that the attention of individuals who are trait-congruent with negative emotions will rest longer on negative stimuli. Attention is harder to release, thus leading to attention bias (Cisler & Olatunji, 2010). Calvo and Nummenmaa (2007) proposed the attention-biased alert-avoidance model, which suggests that attention is initially directed towards a threat stimulus, following which individuals demonstrate avoidance towards the threat stimulus. Studies have shown that attention fast orientation occurs in the early automatic processing stage, and attention disengagement is completed in the late advanced processing stage (Bishop, 2009). Only when a stimulus is presented for more than 3000 ms does it follow an alert-maintenance model (Gamble & Rapee, 2010). There remains no consensus as to whether attention bias occurs in the orientation stage or in the dissolution stage, or in both stages. In other words, it is unclear whether the internal mechanism of attention bias is manifested as attention alertness or attention maintenance, or both.

In recent years, many researchers have used eye movement tracking technology to study individuals' attention bias. They have used eye trackers to record eye movement trajectory, and extracted relevant eye movement data, including fixation duration, fixation times and so on. Eye movement indexes measured by eye trackers have high accuracy, which can provide precise information for the research of attention bias mechanisms (Caseras, Garner, Bradley, & Mogg, 2007). As well as observing individuals' visual attention distribution and comparing it with the results of behavioral experiments, eye movement studies can also shed light on individuals' attention directed towards emotional stimuli. In the field of attention bias, first eye-movement direction (position) can be used as a measure of alertness to examine the alertness bias of attention. In addition, first fixation duration and overall gaze duration can be used to examine the maintenance bias of attention (Garner, Mogg, & Bradley, 2006). Calvo, Avero and Lundqvist's (2006) eye movement studies of high-trait anxiety individuals found that they demonstrated a significantly shorter reaction time for angry faces than for happy faces, thus demonstrating attention bias towards negative threat stimuli. Liang, Tsai, and Hsu (2017), using a free-viewing task with an eye tracker, found that high anxiety individuals were more alert to social threat stimuli at the early processing stage compared with non-anxious individuals; when they noticed threat stimuli, they had greater difficulty disengaging their attention. Jackson, Su, and Wang (2018) examined the effects of higher versus lower threat contexts on attention biases in more and less pain-fearful chronic pain subgroups using an eye-tracking methodology. They found that persons with chronic pain more often oriented towards, gazed longer at, and made more unique fixations upon pain images, and had difficulty disengaging from moderately threatening visual pain cues.

In conclusion, we hypothesized that mobile phone addicts also have attention bias towards negative emotions, manifested initially as attention alertness. Our study investigates the question as to what follows next: attention maintenance (difficult disengagement) or attention avoidance (abnormal orientation towards a threat). We speculate that when a threat is significant, attention may be directed towards avoidance (seeing, for example, a picture of a snake), but if a person's face is not overly threatening, then difficulty with disengagement may arise.

In addition to behavioral research, we also used eye movement technology to further investigate the information processing mechanism behind behavior, and directly observe the attention distribution of individuals. Most previous studies have relied on clinical diagnosis and self-report inventories to identify and confirm individuals with mobile phone addiction; these may have been biased as regards subjectivity and experience, lacking objective indicators. In contrast, our study used eye movement technology to study the emotional attention bias of mobile phone addicts, thus developing a novel paradigm for the future collection of objective diagnostic indicators of mobile phone addiction.

3. Experiment 1:Evidence from behavioral experiments

3.1. Participants

At present, among Chinese mobile phone users, the proportion of students is as high as 25%, making this group the largest mobile phone user group in China (China Internet Network Information Center, 2017). Mobile phone usage is becoming an integral part of students' social lives with regards to managing critical situations and maintaining relationships (Roberts, Yaya; Manolis, 2014). In particular, more and more students show a tendency towards mobile phone addiction. This addiction may reduce thinking capabilities, affect cognitive functions, and induce dependency. Accordingly, our research focuses on college students, with ages ranging from 19 to 23.

300 students were selected by the convenience sampling method and tested using the College Students' Mobile Addiction Tendency Scale (MPATS) compiled by Xiong, Zhou, and Chen (2012). If the score of a participant was above 48 points, this participant was classified as "mobile phone addicted". Eight invalid datasets were removed, leaving 292 valid datasets. We identified 96 individuals (32.88%) as having high-level mobile addiction, and the other 184 individuals (63.01%) as having normal levels of mobile phone interest. In the end, 120 participants consented to participating in the experiment. Among them, 60 were in the high-level MPAs group and 60 were in the normal group. All participants' vision or corrected vision was normal, and they had no color blindness or disability. The participants ranged in age from 19 to 23 years, with an average age of 20.18 years ($SD = 1.18$). An independent samples t-test was used to investigate the levels of mobile phone addiction in the two groups. This revealed that the difference of their mobile phone addiction level was significant, $t\ (2,118) = 29.08$, $p < 0.01$. In both groups, 30 participants were randomly selected as participants for Experiment 1, and the remaining 30 participants participated in Experiment 2. The study was carried out in accordance with the ethical standards of the research committee of an East China University. This institutional academic committee is responsible for ethical review in the university. All individuals were informed about the experimental process, and participated voluntarily.

3.2. Mobile addiction measuring scale

The experiment used the College Students' Mobile Addiction Tendency Scale (MPATS) compiled by Xiong in 2012. This scale includes four dimensions: withdrawal symptoms, salient behavior, social comfort, and mood change. There are 16 items in total, such as, "If I don't have my phone with me for a while, I'll check to see if there's a missed call", and "I'd rather chat on my cell phone than communicate face to face". All items in the scale are scored on a five-point Likert-scale. The Cronbach's α coefficient of the total scale is 0.83, while the Cronbach's α coefficient of the four dimensions varies from 0.55 to 0.80. The retest reliability of the total scale is 0.91, while the test-retest reliability of the four dimensions varies from 0.75 to 0.85. Confirmatory factor analysis shows that the four-factor model fits well. Referring to Young's Internet addiction scoring rules, a score of more than 48 points can be considered as a tendency towards addiction to mobile phones. Most of the studies on mobile phone addiction in China have used this scale (Liu, 2012). The studies available showed that the scale had good reliability and validity. In this study, this scale was verified again and the result showed that the Cronbach's α coefficient was 0.81.

3.3. Emotional materials

Emotional materials were selected from the Chinese Facial Affective Picture System (CFAPS) produced by the Institute of Psychology, Chinese Academy of Sciences (Wang & Luo, 2005). Researchers have found that facial expression recognition exhibits a racial bias, that is, facial expressions of one's native race are easier to recognize (Wang & Markham, 1999). The Chinese Facial Affective Picture System (CFAPS) is similar to the Pictures of Facial Affect, (POFA) which was compiled by Ekman in 1976. CFAPS, produced by researchers of the Institute of Psychology of the Chinese Academy of Sciences (Wang & Luo, 2005), is a localized picture collection of emotional facial expressions in China. Twelve images from the sad and glad faces respectively were selected as the emotional stimuli; meanwhile, 24 neutral images were chosen to accompany them. Thus, there were 24 pairs, 12 of which were positive—neutral and the remaining pairs being negative—neutral (see Fig. 1). At the same time, 6 pictures of happiness, 6 pictures of sadness and 12 neutral pictures were also selected to be paired up (one happy/sad picture - one neutral picture) as an exercise for participants. Each picture has been assessed by 200 Chinese college students and has its own scores of emotional intensity. CFAPS is a reliable picture system and its facial expression pictures are representative materials for emotion research. We selected facial pictures according to their scores for

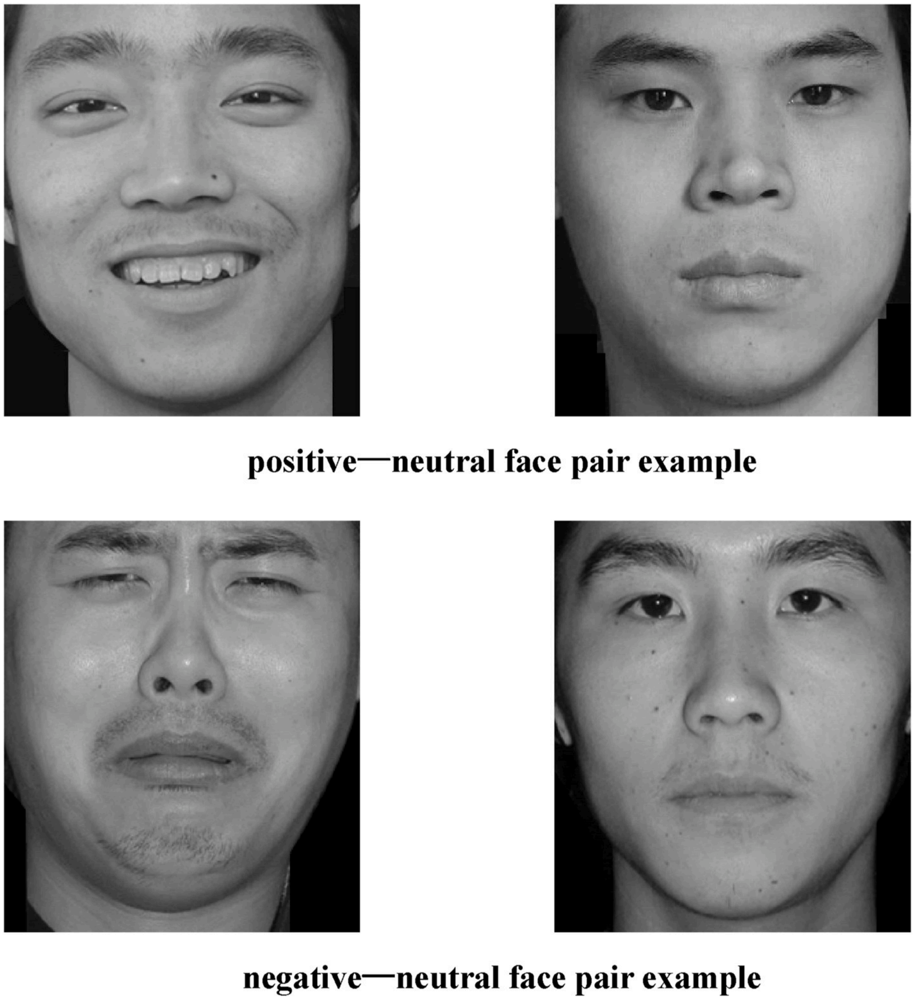

Fig. 1. Positive—neutral face pair example. Negative—neutral face pair example.

'pleasure'. The result of a one-way ANOVA showed that emotional materials have a significant difference in pleasure, $F(2,45) = 257.49$, $p < 0.001$, $\eta^2 = 39.56$. To be specific, positive facial pictures had the highest level of pleasure ($MD = 6.27$), while negative facial pictures had the lowest level of pleasure ($MD = 2.64$). The average score of neutral facial pictures was 4.32. The picture size was 6 cm × 7 cm. The two pictures were symmetrical about the center of the screen. The center of each picture was kept at a distance of 5 cm from the center of the screen.

3.4. Experimental design

The experiment used 2 (group: high-level MPAs group, the normal group) × 2 (face: positive faces, negative faces) mixed design. Group was the between-subject variable, and face type was the within-subject variable. The dependent variable was attention bias score. Attention bias score (ABS) is defined as the difference between the reaction time when probes and emotional faces are in a different location (RTD) and the reaction time when probes and emotional stimuli are in the same location (RTS) (ABS = RTD - RTS). This equation results in a value of zero if a participant has no attention bias to emotional faces. If participants have an attention bias to emotional faces, the equation yields a correspondingly large positive value; if participants move their attention away from emotional faces, the equation yields an appropriately large negative value (MacLeod & Mathews, 1988). The scores that we were interested in were the attention bias scores for positive faces and negative faces.

3.5. Procedure

The structure of Experiment 1 is based on a dot-probe task adopted by Jongen, Smulders, Ranson, Arts, and Krabbendam (2007). The dot-probe paradigm is used to assess selective attention to threatening stimuli (MacLeod, Mathews, & Tata, 1986). There are two stimuli in the research, one of which is neutral-face picture and one of which is negative-face picture, displayed randomly on either side of the screen. The pair of face pictures are presented for a fixed period of time, before the presentation of a dot in the location of one former stimulus. Participants are instructed to indicate the location of this dot as quickly as possible via keyboard.

Before the experiment started, participants were asked to sit in front of the laptop and put their left and right index fingers on the F and J keys respectively. After finishing reading the instructions, they could press the space bar to enter the practice session.

In the practice session 12 emotional face pairs (6 positive—neutral face pairs and 6 negative—neutral face pairs) which were irrelevant to the formal experiment were presented randomly on the screen, with the probe equally likely to occur in the left or the right position. Participants were instructed to respond to every probe quickly and accurately by pressing the F or J key with their index fingers. They pressed F if the probe occurred in the left position and J if it occurred on the right. A 1500 ms-long feedback prompt was given after participants pressed a key in order to inform them as to whether or not their response was correct. When participants completed the practice, they had the option of either pressing the space bar to enter the formal experimental session, or else pressing the Q key to re-enter the practice session if they wanted to practice once more.

In the formal session the experimental procedure was the same as the practice session, except that there was no feedback prompt, and a 500 ms blank screen was used instead. The formal experiment consisted of 48 trails (12 negative-neutral and 12 active-neutral pairs, the probe was equally likely to occur in the left or right position), which were divided into two blocks. There were 24 trials in each block, and participants were able to have a rest between the two blocks. Two images exchanged positions and consequently this pair appeared twice. All face pairs were presented randomly.

At the beginning of each trial, a black fixation point (+) lasting 1000 ms was presented at the center of the screen, and participants were asked to fixate on it. After the fixation point disappeared, the screen presented a face pair for 500 ms. Immediately after the face pair disappeared, the probe point (*) appeared at the position where one face of the pair appeared (the probability of the probe point appearing in the position of the neutral face or the emotional face was equal). The participants were asked to decide the location of the probe point. If the probe point appeared on the left side, the F key was pressed, otherwise, if it appeared on the right side, the J key was pressed. The probe point persisted for a maximum of 5 s.

4. Results

A 2 (group: high-level MAPTS group, the normal group) × 2 (face: positive faces, negative faces) ANOVA was conducted to further compare the attention bias of different types of emotional faces between the high-level MPAs and the normal group (see Table 1). The main effect of group and face was edge significant, F (1, 43) = 3.23, $p = 0.08$, $\eta_p^2 = 0.02$, F (1, 43) = 3.03, $p = 0.09$,$\eta_p^2 = 0.07$, showing that the scores of high-level MPAs was higher than those for the normal group, and that the attention bias scores for negative faces was higher than those for positive faces. There was an interaction effect between group and face, F (1, 43) = 6.22, $p < 0.05$, $\eta_p^2 = 0.13$. Furthermore, the simple effect analysis showed that there was a significant difference in attention bias scores on negative faces between the high-level MPAs group and the normal group, F (1,43) = 9.23, $p < 0.05$. Specifically, the high-level MPAs group had higher attention bias scores for negative faces compared to those of the normal group (see Fig. 2).

The attention bias scores of the two groups were substituted into a single-sample t-test respectively to make a comparison with 0. The results showed that both groups had no attention bias to positive emotional faces, t (22) = −0.44, $p > 0.05$; t (21) = −0.14, $p > 0.05$. The attention bias scores of the high-level MPAs group were significantly higher than 0, t (22) = 3.46, $p < 0.01$. The normal use group had no attention bias to negative emotional faces, t (21) = −0.83, $p > 0.05$.

5. Discussion

The results of Experiment 1 essentially support our hypothesis. Compared with the normal group, the high-level MPAs group paid more attention to negative faces and showed attention bias to negative emotional materials. The attention bias towards negative emotional materials exhibited by high-level MPAs may be related to a lack of interpersonal contacts. Research has shown that mobile phone addicts

Table 1
Summary of ANOVA results for attention bias scores.

	Effect	*SS*	*df*	*MS*	*F*	*Sig.*	η^2
attention bias scores	Group	2996.26	1	2996.26	3.23	0.08	0.20
	Face	2200.05	1	2200.05	3.03	0.09	0.07
	group * face	4511.40	1	4511.40	6.22	0.02*	0.13

Note. * significance level: $p < 0.05$. ** significance level: $p < 0.001$.

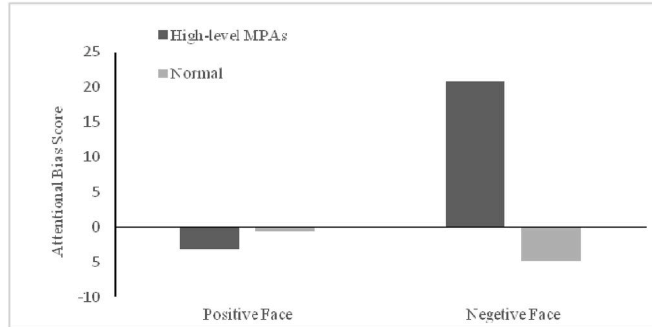

Fig. 2. Interaction effect between group type and face types on attention bias.

have problems with interpersonal communication (Wang, 2012). Being addicted to mobile phones for an extended period can reduce addicts' interpersonal interactions and result in alienation, leading to a decline in individual life satisfaction and personal well-being (Roberts & David, 2016). In the long run, mobile addicted behavior may lead to an increase in negative emotions.

The mood consistency hypothesis proposes that people invest more attention in stimuli that are consistent with their own mood. The high-level MPAs may have experienced negative emotions such as depression and loneliness. Sadness is a representative expression of negative emotions such as loneliness, so high-level MPAs may have demonstrated an attention bias towards such faces.

Experiment 1 confirmed that individuals with mobile addiction show an attention bias towards negative emotional materials. In order to explore the precise mechanism of this attention-biased information processing, we made use of an eye tracker for Experiment 2.

6. Experiment 2: evidence from eye movements

6.1. Apparatus

An Eye Link II tracker was used, including an experimenter machine and a participant machine. The two machines were linked together by an internal network. The experimenter machine was operated by the experimenter, and the images or stimuli were displayed on the participant machine. The Eye Link II tracker has a sampling rate of 1000Hz and a spatial resolution of 0.1, with a monitor display resolution of 1024 × 768 pixels. There was a chin bracket in front of the participant machine used for fixing each participant's head position. The height of participants' eyes and the screen center were kept horizontal, with eyes fixed 70 cm from the screen.

6.2. Experimental design

The emotional materials were the same as for Experiment 1. The experiment used a 2 (group: high-level MPAs group, the normal group) × 2 (face: positive faces, negative faces) mixed design. Group was the between-subject variable, while face type was the within-subject variable. The dependent variables were the indexes of eye movement (eye-movement direction scores, first fixation duration scores and overall gaze duration bias scores).

Following previous studies (Castellanos et al., 2009; Gao et al., 2011; Garner et al., 2006), we took the following three eye movement indexes as dependent variables:

(1) Eye-movement direction scores. These scores were calculated by computing the proportion of trials in which participants' first eye movement was directed towards the emotional faces from all trials in which the first eye movement was made to a face (eye-movement direction scores more than 0.5 reflected an initial orientating bias towards emotional faces; 0.5 meant no bias; less

than 0.5 reflected an initial avoidance bias away from emotional faces).

(2) First fixation duration scores. These scores were calculated by subtracting the first fixation duration for neutral faces from the first fixation duration for emotional faces (first fixation duration scores more than 0 reflected an initial attention maintenance towards emotional faces; 0 reflected no bias; less than 0 reflected an initial attention movement away from emotional faces).

(3) Overall gaze duration bias scores. These scores were calculated by computing the average time spent gazing at emotional faces as a percentage of the total amount of time gazing at both faces in each pair (overall gaze duration bias scores more than 0.5 reflected a maintenance bias towards emotional faces; 0.5 meant no bias; less than 0.5 reflected an avoidance bias away from emotional faces).

6.3. Procedure

Deferring to the experimental procedures of Li (2012), we asked the participants to sit in a chair in front of the participant PC, with eyes 70 cm away from the screen. The experiment was conducted in an eye movement lab, which featured both an ideal lighting environment and a sound insulation system. Before the formal experiment, the 9-point calibration method was adopted. The experiment was started only after participants had successfully completed the calibration process. In the formal experiment, participants were told that there would be 24 pairs of faces on the screen (6 negative - neutral pairs, 6 positive - neutral faces pairs). Each picture was shown for 5 s, and the participants were required to watch carefully.

6.4. Results

6.4.1. Eye-movement direction scores

Taking the eye-movement direction scores as the dependent variable and group and face type as independent variables, we conducted a 2 (group: high-level MPAs group, the normal group) × 2 (face: positive faces, negative faces) ANOVA (see Table 2). The main effect of face was significant, F (1, 44) = 4.41, $p < 0.005$, $\eta_p^2 = 0.09$. The main effect of group was highly significant, F (1, 44) = 22.82, $p < 0.001$, $\eta_p^2 = 0.34$. Moreover, there was an interaction effect between group and face, F (1, 44) = 0.04, $p < 0.005$, $\eta_p^2 = 0.11$. Analyses of simple effects showed that, compared with the normal group, the high-level MPAs group's eye-movement direction scores for negative faces were significantly higher than those for positive faces, F (1, 44) = 9.64, $p < 0.05$ (see Fig. 3). The eye-movement direction scores across the four levels of independent variables were substituted into a one sample t-test respectively to make a comparison against 0.5. The results showed that the high-level MPAs had an initial orienting bias towards negative faces, t (22) = 3.21, $p < 0.05$, but had no bias towards positive faces, t (22) = 1.59, $p > 0.05$; participants from the normal group had an initial avoidance bias away from both negative faces and positive faces, t (22) = −5.12, $p < 0.01$, t (22) = −4.41, $p < 0.01$.

6.4.2. First fixation duration scores

Taking the first fixation duration scores as the dependent variable and group and face type as independent variables, we conducted a 2 (group: high-level MPAs group, the normal group) × 2 (face: positive faces, negative faces) ANOVA (see Table 3). The main effect of face was significant, F (1, 44) = 6.57, $p < 0.005$, $\eta_p^2 = 0.130$. The main effect of group was significant, F (1, 44) = 6.14, $p < 0.005$, $\eta_p^2 = 0.12$. Moreover, there was an interaction effect between group and face, F (1, 44) = 4.36, $p < 0.005$, $\eta_p^2 = 0.09$. Analyses of simple effects showed that, compared with the normal group, the high-level MPAs group's first fixation duration scores for negative faces were significantly higher than those for positive faces, F (1, 44) = 10.84, $p < 0.05$ (see Fig. 4). The first fixation duration scores across the four levels of independent variables were substituted into a one sample t-test respectively to make a comparison against 0. The results showed that the high-level MPAs had an initial attention maintenance towards negative faces and positive faces, t (22) = 3.08, $p < 0.05$, t (22) = 6.39, $p < 0.01$; participants from the normal group had no bias towards negative faces or positive faces, t (22) = 1.52, $p > 0.05$, t (22) = 1.04, $p > 0.05$.

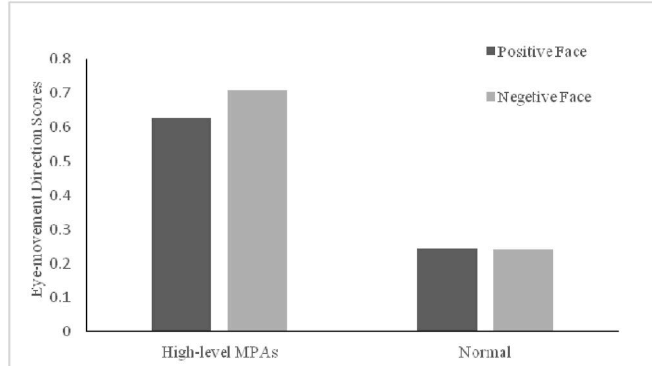

Fig. 3. Interaction effect between group type and face types on eye-movement direction scores.

6.4.3. Overall gaze duration bias scores

Taking the overall gaze duration bias scores as the dependent variable and group and face type as independent variables, we conducted a 2 (group: high-level MPAs group, the normal group) × 2 (face: positive faces, negative faces) ANOVA (see Table 4). The 2 × 2 ANOVA revealed a null effect for face and group, F (1,44) = 1.60, $p > 0.05$, $\eta_p^2 = 0.04$, F (1,44) = 1.12, $p > 0.05$, $\eta_p^2 = 0.03$. The interaction effect between group and face was not significant, F (1,44) = 0.00, $p < 0.05$, $\eta_p^2 = 0.00$. The overall gaze duration bias scores across the four levels of independent variables were substituted into a one sample t-test respectively to make a comparison against 0.5. The results showed no significant effect, t (22) = −0.937, $p > 0.05$, t (22) = 0.277, $p > 0.05$, t (22) = 0.157, $p > 0.05$, t (22) = 1.457, $p > 0.05$.

7. Discussion

According to our results from the eye-movement direction scores, the high-level MPAs had an initial orienting bias towards negative faces, but no bias towards positive faces. This indicates that, consistent with our hypothesis, high-level MPAs experienced an attention alertness effect towards negative emotional materials. The high-level MPAs' attention

Table 2
Summary of ANOVA results for eye-movement direction scores.

	Effect	*SS*	*df*	*MS*	*F*	*Sig.*	η^2
eye-movement direction scores	group	4.14	1	4.14	22.82	0.00**	0.34
	face	0.04	1	0.04	4.41	0.04*	0.09
	group * face	0.04	1	0.04	5.25	0.03*	0.11

Note. * significance level: $p < 0.05$. ** significance level: $p < 0.01$.

Table 3
Summary of ANOVA results for first fixation duration scores.

	Effect	*SS*	*df*	*MS*	*F*	*Sig.*	η^2
first fixation duration scores	group	82380.53	1	82380.53	6.14	0.02*	0.12
	face	0.04	1	0.04	6.57	0.01*	0.13
	group * face	0.04	1	0.04	4.36	0.04*	0.09

Note. * significance level: $p < 0.05$. ** significance level: $p < 0.001$.

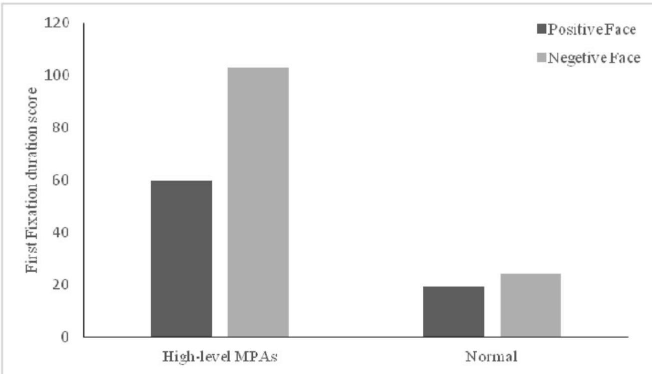

Fig. 4. Interaction effect between group type and face types on first fixation duration scores.

Table 4
Summary of ANOVA results for overall gaze duration bias scores.

	Effect	*SS*	*df*	*MS*	*F*	*Sig.*	η^2
overall gaze duration bias scores	group	0.01	1	0.01	1.11	0.30*	0.03
	face	0.01	1	0.01	1.60	0.21	0.04
	group * face	3.61	1	3.61	0.00	0.98	0.00

Note. * significance level: $p < 0.05$. ** significance level: $p < 0.001$.

bias towards negative faces can be explained by the negative reinforcement model. This model posits that the avoidance of negative emotions leads to problem behaviors such as overeating, impulsive buying, internet addiction and mobile phone addiction (Baker, Piper & Mccarthy et al., 2004). Thus, a processing bias towards negative emotions can incur and maintain mobile phone addiction behavior. The high-level MPAs' avoidance of negative emotions may increase their alertness towards negative emotions, and render them more sensitive to negative emotional stimuli. Accordingly, the high-level MPAs have a tendency to demonstrate attention alertness towards negative faces.

The one sample t - test results of eye-movement direction scores for the normal group showed that these participants demonstrated attention avoidance towards positive faces and negative faces, a finding which was not consistent with our hypothesis. A possible explanation here is that, according to self-schema theory, self-schema-relevant information has a lower activation threshold than irrelevant information, and enters the information processing system more easily (Derry & Kuiper, 1981). If participants in the normal group experience a lower daily load of emotional experiences than those in the high-level MPAs group, then they may be less likely to form a self-schema for emotional faces. Instead, they may identify more closely with neutral faces, leading them to show attention avoidance towards emotional stimuli.

As for the first fixation duration scores, although the high-level MPAs had initial attention maintenance towards both positive and negative faces, their first fixation duration scores for negative faces were higher than those for positive faces. That is to say, although high-level MPAs had initial attention relieving difficulties towards both positive and negative emotional stimuli, it was harder for them to move their attention away from the negative emotional stimuli. According to the *t*-test, compared with neutral emotions, mobile phone addicts demonstrated greater initial attention to maintaining negative and positive emotional information; on the whole they were more inclined to pay attention to negative emotions. The normal use group did not have any maintenance bias towards either positive or negative emotions. Furthermore, mobile phone addicts did not demonstrate attention orientation towards either negative or positive emotional information. As shown in Fig. 3, mobile phone addicts did not demonstrate attention bias towards positive faces; the *t*-test, taking 0.5 as test standard (see the relevant explanation in the experimental design section), did not show a significant difference. However, it is clear that mobile phone addicts do display attention orientation bias to positive emotions.

We posit that these observations are related to the characteristics of mobile phone addiction. As previously discussed, mobile phone addicts can be satisfied almost anytime and anywhere. It is well known that the stimuli associated with addiction provide temporary pleasure to addicts. However, in the long run, mobile phone addicts will also experience greater negative emotions (Zheng & Lee, 2016), resulting in anxiety, depression and other negative mental states (Hawi & Samaha, 2017). In other words, when using mobile phones, addicts experience a state of both pain and pleasure. According to the mood-congruent hypothesis, when individuals are in a state of positive or negative emotions, they pay more attention to faces with the same expression as their own mood (Becker & Leinenger, 2011). Accordingly, both positive and negative emotions are more likely to result in the formation of schema (stable structural representations of knowledge stored in memory) in the brains of mobile phone addicts. According to self-schema theory, once a set of stimuli is consistent with an internal schema or knowledge structure, such information is processed more easily. For addicts, information consistent with a schema will be more easily processed, and may lead to attention bias. If mobile phone addicts have more emotional experiences than normal individuals, they are more likely to form relevant schemas. Therefore, they may be more inclined to show a tendency of attention bias to positive emotional information than normal individuals. Although mobile phone addicts tend to have attention bias to positive emotions, our data suggest that, overall, they still pay more attention to negative emotions.

For overall gaze duration bias scores, the high-level MPAs had no attention bias towards positive or negative face stimuli. There were no significant differences for overall gaze duration bias scores between the high-level MPAs group and the normal group. These results were not consistent with our hypothesis. Emotion regulation includes strategies that people use to increase, maintain, or decrease one or more components of an emotional response (Gross & James, 2001). There are five stages in its occurrence and development, including situation selection, situation modification, attention deployment, cognitive change/reappraisal and response modulation. When emotional cues are observed, but emotions have not yet been generated, strategies can be used to regulate emotional responses. For example, in the situation selection stage, individuals can actively choose a situation to reduce negative emotions. As for this study, in order to alleviate negative emotions incurred by negative face stimuli, the high-level MPAs adopted an emotion regulation strategy initiative aimed at avoiding negative face images following the initial onset of attention maintenance. Such behavior might have reduced the gap of overall gaze duration time between the high-level MPAs group and the normal group.

8. General discussion

This study investigated mobile phone addicts' attention bias towards differently valenced emotional materials, and the associated information processing mechanism behind it. The results from Experiment 1 show that high-level MPAs have attention bias to negative materials, but not to positive materials. The dot-probe task we used suffers from several limitations, insofar as it can only explore attention bias generated by cognitive resource competition taking place within participants' space range, and cannot distinguish between separate components of attention bias or account for late processing. Eye tracking techniques, which we used in Experiment 2, can address this deficiency. The results showed that the high-level MPAs had an initial orienting bias and initial attention maintenance towards negative materials, but no overall attention maintenance towards negative materials. The results of both experiments support the conclusion that mobile phone addicts have an attention bias towards negative emotional materials in the early stage of cognitive processing. This is consistent with Zu's (2017) finding that, compared with peers, mobile phone-dependent college students demonstrate a negative emotional processing bias, manifested as a faster recognition of negative emotional information. Another possible explanation for this attention bias towards negative emotional materials might lie with the trait congruence effect (Rusting, 1998). Mobile phone addicts tend to have serious depression, anxiety and other problems (Demirci, Akgönül, & Akpinar, 2015; Chen et al., 2015), which promote a self-schema involving negative emotions. Information which is perceived by observers to be congruent with their own traits has a lower activation threshold and is easier to process than irrelevant information (Markus, 1977). Thus, when the MPAs looked at pictures of sad faces, their cognitive networks may have been more activated, making them more likely to notice negative emotional stimuli than normal mobile phone users.

Through the eye movement task, we found that the attention bias mechanism of mobile addicts to negative emotional materials was best explained in terms of an alert-maintenance model, a finding which is inconsistent with the idea of an attention-biased alert-avoidance model, as proposed by Calvo and Nummenmaa (2007). They, in contrast, suggested that attention is initially directed towards threat stimuli, and then subsequently towards stimuli associated with threat avoidance. Studies have shown that attention fast orientation occurs in the early automatic processing stage, and attention disengagement is completed in the late advanced processing stage (Bishop, 2009). Only when a stimulus is presented for more than 3000 ms does it show an alert-maintenance model (Gamble & Rapee, 2010). In our experiment, the stimuli presentation time of the eye movement task was 5000 ms, thus satisfying the condition of attention-biased warning-avoidance mode. Nevertheless, we found that after the attention alert, participants demonstrated attention maintenance, but not attention avoidance. This is an interesting discovery which might potentially be explained from the perspective of dopamine. Studies have shown that level of addiction is positively correlated with the release of an individuals' dopamine (Wiers and Stacy, 2006), implying that individuals with high levels of addiction probably experience higher levels of dopamine release than non-addicted individuals. The inducement-sensitization theory proposes that repeated actions carried out by the human body provoke a dopaminergic response. The physiological basis of this effect is that the cortical striatal circuit is activated to release dopamine after performing a large number of similar behaviors. Since addiction-related stimuli bring pleasure to addicts, these are given priority. The craving for addictive behavior thus increases, as well as attention bias towards the relevant stimulus. This process is repeated until an addict eventually develops the addictive behavior (Robinson & Berridge, 2000). In particular, the release of dopamine attenuates individuals' inhibitory ability (Salgado et al., 2000), which prevents individuals from inhibiting the inappropriate behavior. Individuals in the high-level MPAs group presumably experienced a greater release of dopamine from mobile phone use, and a reduced level of inhibitory ability. When such addicts are attracted by negative stimuli yielding an initial attention orientation, their weaker inhibitory ability renders them less able to shift their attention to other stimuli. As a result, an effect of attention maintenance is observed. Another finding from our study is that, overall, no attention maintenance towards the negative emotional materials was found. It may be the case that individuals with high levels of mobile phone addiction actively adopt avoidance strategies to regulate and alleviate the negative emotions caused by negative face stimuli (Southam-Gerow & Kendall, 2002). This mood-adjusting strategy may reduce the difference in overall gaze time between emotional and neutral faces, resulting in no overall attention maintenance towards emotional faces.

To conclude, we found that mobile phone addicts had attention bias towards negative emotional materials in the early stage of cognitive processing, but had no attention bias towards positive emotional materials. This effect may be related to a lack of interpersonal contacts, as modeled by the negative reinforcement model and trait congruence effect. We also found that the attention bias mechanism of mobile addicts on negative emotional materials was manifested as an alert-maintenance effect, which can be explained from the perspective of dopamine and inhibitory ability. Individuals showed no overall attention maintenance, suggesting that they may use avoidance strategies to adjust their emotions.

Prior studies on the attention bias of mobile addicted individuals have relied on traditional research paradigms such as the dot-probe paradigm (Hua, Wu, & Wan, 2016; Philip, Stefan, & Richard, 2014), the emotional stroop paradigm (Veronika, Akos, & Adam, 2017), or the visual search paradigm (Zu, 2017). These approaches, however, examine only a certain component of attention, and neglect the late processing of attention bias, making it difficult to comprehensively address the information processing mechanism behind it. Compared with traditional behavioral experiments, eye movement tasks are not as easily affected by factors such as distraction and inhibition of behavioral responses. Moreover, eye movement techniques have good immediacy, revealing more effectively the change of attention bias over time. This study has offered a deeper insight into the cognitive characteristics of individuals with a mobile phone addiction tendency. Individuals with this addiction tend to have a bias towards negative emotional materials and behave according to the predictions of the alert-maintenance model.

Based on these results, it is possible to make recommendations for correcting the behavior of mobile addicted individuals. For example, changing the emotional processing bias of such addicts might increase their positive emotional experience, decrease their negative emotional experience, reduce their desire to use mobile phones, and thus reduce the frequency with which they use mobile phones (Zu, 2017). In addition, positive attention-biased training can be used to guide mobile addicts to increase their attention and sensitivity towards positive information, an active choice which can play a role in improving their emotional state and mental health (Wadlinger & Isaacowitz, 2008).

9. Limitations and future directions

As the participants of this study were mainly college students, future studies should aim to generalize the results to other populations by using alternative participant samples. Furthermore, while this study used facial pictures as materials, future studies could enlist virtual reality technology or use photographs of emotional scenes to give the research greater ecological validity. Another aspect worth exploring is the possibility that different emotional arousal levels might have different effects. For example, fear at the highest arousal levels may no longer manifest as attention maintenance, but rather as attention avoidance, a strategy for avoiding the negative emotions brought on by fear. On a final note, current studies on the physiological basis of cognitive processes have found that attention bias is related to the activation of the amygdala and prefrontal lobe. The amygdala may be responsible for alertness and orientation of threatening information, while the prefrontal lobe is associated with difficulty in disengaging from threatening information. The activation of information in the amygdala and prefrontal lobe have not yet been studied in the mobile phone addict population. In future studies, ERP (event-related potential), fMRI (functional magnetic resonance imaging) and other brain imaging methods might be introduced to investigate the phenomenon of mobile phone attention bias from a physiological perspective.

10. Conclusions

Combining the results of the two studies, we found that mobile phone addicts display attention bias towards negative materials in the early stage of cognitive processing, presenting as an attention orientation bias and a difficulty with disengagement. Our results from the eye tracking study indicate that, although mobile phone addicts tend to show attention bias to positive emotions, overall, they still pay more attention to negative emotions. Normal individuals, by contrast, display no attention bias towards either type of emotion.

CRediT authorship contribution statement

Yixin Hu: Conceptualization, Writing - original draft. **Jiahui Guo:** Investigation, Data curation, Formal analysis. **Min Jou:** Conceptualization, Investigation, Writing - review & editing. **Shengqi Zhou:** Visualization, Methodology, Data curation, Investigation. **Dawei Wang:** Conceptualization, Formal analysis, Investigation, Methodology. **Phil Maguire:** Visualization, Investigation. **Jing Wei:** Validation, Formal analysis, Software. **Fangzheng Qu:** Resources, Investigation, Data curation.

Acknowledgements

This study was supported by National Natural Science Fund of China (grant no. 31471002), "Dongyue Scholar" Fund of Shandong Normal University and Key R & D program in Shandong Province of China (grant no. 2015GSF120015), as well as partial support offered by MOST 106-2511-S-003 -036 -MY3. Yixin Hu, Jiahui Guo, Min Jou, Shengqi Zhou, Dawei Wang, are co-first authors, making the same amount of contribution.

References

Aguilar de Arcos, F., Verdejo-García, A., Ceverino, A., Montañez-Pareja, M., López-Juárez, E., Sánchez-Barrera, M., et al. (2008). Dysregulation of emotional response in current and abstinent heroin users: Negative heightening and positive blunting. *Psychopharmacology, 198*(2), 159–166. https://doi.org/10.1007/s00213-008-1110-2.

Attwood, A. S., O'Sullivan, H., Leonards, U., Mackintosh, B., & Munaf, M. R. (2010). Attention bias training and cue reactivity in cigarette smokers. *Addiction, 103*(11), 1875–1882. https://doi.org/10.1111/j.1360-0443.2008.02335.x.

Bai, X. J., Jia, L. P., & Wang, J. X. (2013). Emotional attention bias under inhibition paradigm. *Advances in Psychological Science, 21*(5), 785–791. https://doi.org/10.3724/SP.J.1042.2013.00785.

Baker, T. B., Piper, M. E., McCarthy, D. E., Majeskie, M. R., & Fiore, M. C. (2004). Addiction motivation reformulated: An affective processing model of negative reinforcement. *Psychological Review, 111*(1), 33–51. https://doi.org/10.1037/0033-295X.111.1.33.

Becker, M. W., & Leinenger, M. (2011). Attention selection is biased toward mood-congruent stimuli. *Emotion, 11*(5), 1248–1254. https://doi.org/10.1037/a0023524.

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1), 92–98. https://doi.org/10.1038/n.2242.

Brosch, T., Sander, D., Pourtois, G., & Scherer, K. R. (2008). Beyond fear rapid spatial orienting toward positive emotional stimuli. *Psychological Science, 19*(4), 362–370. https://doi.org/10.1111/j.1467-9280.2008.02094.x.

Calvo, M. G., Avero, P., & Lundqvist, D. (2006). Facilitated detection of angry faces: Initial orienting and processing efficiency. *Cognition & Emotion, 20*(6), 785–811. https://doi.org/10.1080/02699930500465224.

Calvo, M. G., & Nummenmaa, L. (2007). Processing of unattended emotional visual scenes. *Journal of Experimental Psychology: General, 136*(3), 347–369. https://doi.org/10.1037/0096-3445.136.3.347.

Caseras, X., Garner, M., Bradley, B. P., & Mogg, K. (2007). Biases in visual orienting to negative and positive scenes in dysphoria: An eye movement study. *Journal of Abnormal Psychology, 116*(3), 491–497. https://doi.org/10.1037/0021-843x.116.3.491.

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., et al. (2009). Obese adults have visual attention bias for food cue images: Evidence for altered reward system function. *International Journal of Obesity, 33*(9), 1063. https://doi.org/10.1038/ijo.2009.138.

Cheetham, A., Allen, N. B., Yücel, M., & Lubman, D. I. (2010). The role of affective dysregulation in drug addiction. *Clinical Psychology Review, 30*(6), 621. https://doi.org/10.1016/j.cpr.2010.04.005.

China Internet Network Information Center. (2017). *China statistical report on internet develpment.* http://49.140.187.1/cache/8/03/cnnic.cn/5e3c9654a7d9a35535d47314210f46ce/P020170123364672657408.pdf.

Cisler, J. M., & Olatunji, B. O. (2010). Components of attention biases in contamination fear: Evidence for difficulty in disengagement. *Behaviour Research and Therapy, 48*(1), 74–78. https://doi.org/10.1016/j.brat.2009.09.003.

Decker, S. A., & Gay, J. N. (2011). Cognitive-bias toward gaming-related words and disinhibition in world of warcraft gamers. *Computers in Human Behavior, 27*(2), 798–810. https://doi.org/10.1016/j.chb.2010.11.005.

Demirci, K., Akgönül, M., & Akpinar, A. (2015). Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. *Journal of Behavioral Addictions, 4*(2), 85–92. https://doi.org/10.1556/2006.4.2015.010.

Den, U. T. E., Gladwin, T. E., Johannes, L., & Wiers, R. W. (2018). A clinical trial with combined transcranial direct current stimulation and attention bias modification in alcohol dependent patients. *Alcoholism: Clinical and Experimental Research, 42*(10), 1961–1969. https://doi.org/10.1111/acer.13841.

Derry, P. A., & Kuiper, N. A. (1981). Schematic processing and self-reference in clinical depression. *Joumal of Abnormal Psychology, 90*(4), 286–297. https://doi.org/10.1037/0021-843X.90.4.286.

Ehrenberg, A., Juckes, S., White, K. M., & Walsh, S. P. (2008). Personality and self-esteem as predictors of young people's technology use. *CyberPsychology and Behavior, 11*(6), 739–741. https://doi.org/10.1089/cpb.2008.0030.

Ezoe, S., Toda, M., Yoshimura, K., Naritomi, A., Den, R., & Morimoto, K. (2009). Relationships of personality and lifestyle with mobile phone dependence among female nursing students. *Social Behavior and Personality: An International Journal, 37*(2), 231–238. https://doi.org/10.2224/sbp.2009.37.2.231.

Field, M., & Cox, W. M. (2008). Attention bias in addictive behaviors: A review of its development, causes, and consequences. *Drug and Alcohol Dependence, 97*(1–2), 1–20. https://doi.org/10.2196/resprot.9740.

Franken, I. H. A. (2003). Drug craving and addiction: Integrating psychological and neuropsychopharmacological approaches. *Progress in Neuropsychopharmacology & Biological Psychiatry, 27*(4), 563–579. https://doi.org/10.1016/S0278-5846(03)00081-2.

Gamble, A. L., & Rapee, R. M. (2010). The time-course of attention to emotional faces in social phobia. *Journal of Behavior Therapy and Experimental Psychiatry, 41*(1), 39–44. https://doi.org/10.1016/j.jbtep.2009.08.008.

Gao, X., Wang, Q. C., Jackson, T., Zhao, G., Liang, Y., & Chen, H. (2011). Biases in orienting and maintenance of attention among weight dissatisfied women: An eye-movement study. *Behaviour Research and Therapy, 49*(4), 252–259. https://doi.org/10.1016/j.brat.2011.01.009.

Garner, M., Mogg, K., & Bradley, B. P. (2006). Orienting and maintenance of gaze to facial expressions in social anxiety. *Journal of Abnormal Psychology, 115*(4), 760–770. https://doi.org/10.1037/0021-843x.115.4.760.

Gross, & James, J. (2001). Emotion regulation in adulthood: Timing is everything. *Current Directions in Psychological Science, 10*(6), 214–219. https://doi.org/10.1111/1467-8721.00152.

Ha, J. H., Chin, B., Park, D. H., Ryu, S. H., & Yu, J. (2008). Characteristics of excessive cellular phone use in Korean adolescents. *CyberPsychology and Behavior, 11*(6), 783–784. https://doi.org/10.1089/cpb.2008.0096.

Hawi, N. S., & Samaha, M. (2017). Validation of the Arabic version of the internet gaming disorder-20 test. *Cyberpsychology, Behavior, and Social Networking, 20*(4), 268–272. https://doi.org/10.1089/2016.0493.

van Holst, R. J., Lemmens, J. S., Valkenburg, P. M., Peter, J., Veltman, D. J., & Goudriaan, A. E. (2012). Attention bias and disinhibition toward gaming cues are related to problem gaming in male adolescents. *Journal of Adolescent Health, 50*(6), 541–547. https://doi.org/10.1016/j.jadoHealth.2011.07.006.

Hua, R., Wu, X. R., & Wan, F. (2016). Attention bias in mobile phone addicted college students and its mechanism research. *Psychological Exploration, 36*(5), 446–450. https://doi.org/10.3969/j.issn.1003-5184.2016.05.011.

Jackson, T., Su, L., & Wang, Y. (2018). Effects of higher versus lower threat contexts on pain-related visual attention biases: An eye-tracking study of chronic pain. *The Journal of Pain, 19*(6), 649–659. https://doi.org/10.1016/j.jpain.2018.01.011.

Jongen, E. M., Smulders, F. T., Ranson, S. M., Arts, B. M., & Krabbendam, L. (2007). Attention bias and general orienting processes in bipolar disorder. *Journal of Behavior Therapy and Experimental Psychiatry, 38*(2), 168–183. https://doi.org/10.1016/j.jbtep.2006.10.007.

Lachmann, B., Sindermann, C., Sariyska, R. Y., Luo, R., Melchers, M. C., Becker, B., et al. (2018). The role of empathy and life satisfaction in internet and smartphone use disorder. *Frontiers in Psychology, 9*, 398–408. https://doi.org/10.3389/fpicg.2018.00398.

Lei, Y. J., He, J. B., Niu, G. F., Zhou, Z. K., & Tian, Y. (2017). Impaired disengagement from negative emotional faces in youth with internet addiction. *Psychological Development and Education, 33*(6), 691–699. https://doi.org/CNKI:SUN:XLFZ.0.2017-06-007.

Lepp, A., Barkley, J. E., & Karpinski, A. C. (2014). The relationship between cell phone use, academic performance, anxiety, and satisfaction with life in college students. *Computers in Human Behavior, 31*(1), 343–350. https://doi.org/10.1016/j.chb.2013.10.049.

Li, H. L. (2012). *Experimental study of attention bias in college athletes with different level of implicit aggression.* M.A. Thesis. Beijing. Beijing Sport University http://cdmd.cnki.com.cn/Article/CDMD-10043-1012400587.htm.

Liang, C., Tsai, J., & Hsu, W. (2017). Sustained visual attention for competing emotional stimuli in social anxiety: An eye-tracking study. *Journal of Behavior Therapy and Experimental Psychiatry, 54*(3), 178–185. https://doi.org/10.1016/j.jbtep.2016.08.009.

Liu, H., & Wang, H. L. (2011). Research on the relationship between college students' interpersonal relationship, self regulated learning and mobile phone dependence. *Advances in Psychology, 34*(6), 1453–1457. https://doi.org/10.16719/j.cnki.1671-6981.2011.06.017.

Liu, Q., Zhou, Z., Niu, G., & Fan, C. (2017). Mobile phone addiction and sleep quality in adolescents: Mediation and moderation analyses. *Acta Psychology Sinica, 72*, 108–114. https://doi.org/10.1016/j.chb.2017.02.042.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 40*(4), 653–670. https://doi.org/10.1080/14640748808402292.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attention bias in emotional disorders. *Journal of Abnormal Psychology, 95*, 15–20. https://doi.org/10.1037/0021-843X.95.1.15.

Markus, H. (1977). Self-schemata and processing information about the self. *Journal of Personality and Social Psychology, 35*(2), 63–78. https://doi.org/10.1037/0022-3514.35.2.63.

Marques-Teixeira, J. E., & Barbosa, M. F. S. (2005). Emotional states and informational brain processing in drug addicts free of drugs: An erps study. *International Journal of Psychiatry in Clinical Practice, 9*(3), 213–220. https://doi.org/10.1080/13651500510029101.

Parasuraman, S., Sam, A. T., Yee, S. W., Chuon, B. L., & Ren, L. Y. (2017). Smartphone usage and increased risk of mobile phone addiction: A concurrent study. *International Journal of Pharmaceutical Investigation, 7*(3), 125–131. https://doi.org/10.4103/jphi.JPHI_56_17:10.4103/jphi.JPHI_56_17.

Philip, M. E., Stefan, G. H., & Richard, J. M. (2014). Attention bias modification training via smartphone to reduce social anxiety: A randomized, controlled multi-session experiment. *Cognitive Therapy and Research, 38*(2), 200–216. https://doi.org/10.1007/s10608-014-9606-z.

Robbins, S. J., & Ehrman, R. N. (2004). The role of attention bias in substance abuse. *Behavioral and Cognitive Neuroscience Reviews, 3*(4), 243–260. https://doi.org/10.1177/15345.82305275423.

Roberts, J. A., & David, M. E. (2016). My life has become a major distraction from my cell phone: Partner phubbing and relationship satisfaction among romantic partners. *Computers in Human Behavior, 54*, 134–141. https://doi.org/10.1016/j.chb.2015.07.058.

Roberts, J. A., Yaya, L. H., & Manolis, C. (2014). The invisible addiction: Cell-phone activities and addiction among male and female college students. *Journal of behavioral addictions, 3*(4), 254–265. https://doi.org/10.1556/JBA.3.2014.015.

Robinson, T. E., & Berridge, K. C. (2000). The psychology and neurobiology of addiction: An incentive-sensitization view. *Addiction, 95*, 91–117. https://doi.org/10.1046/j.1360-0443.95.8s2.19.x.

Rooke, S. E., Hine, D. W., & Thorsteinsson, E. B. (2008). Implicit cognition and substance use: A meta-analysis. *Addictive Behaviors, 33*(10), 1–1328. https://doi.org/10.1016/j.addbeh.2008.06.009.

Rusting, C. L. (1998). Personality,mood,and cognitive processing of emotional information:Three conceptual frameworks. *Psychological Bulletin, 124*(2), 165–196. https://doi.org/10.1037//0033-2909.124.2.165.

Sahin, S., Ozdemir, K., Unsal, A., & Temiz, N. (2013). Evaluation of mobile phone addiction level and sleep quality in university students. *Pakistan journal of medical sciences, 29*(4), 913–918. https://doi.org/10.12669/pjms.294.3686.

Salgado, J. V., Hetem, L. A., Vidal, M., Graeff, F. G., Danion, J. M., & Sandner, G. (2000). Reduction of latent inhibition by d-amphetamine in a conditioned suppression paradigm in humans. *Behavioural Brain Research, 117*(1), 61–67. https://doi.org/10.1016/S0166-4328(00)00279-5.

Schoenmakers, T. M., de Bruin, M., Lux, I. F. M., Goertz, A. G., van Kerkhof, D. H. A. T., & Wiers, R. W. (2010). Clinical effectiveness of attention bias modification training in abstinent alcoholic patients. *Drug and Alcohol Dependence, 109*, 30–36. https://doi.org/10.1016/j.drgalcdep.2009.11.022.

Schupp, H. T., Ohman, A., Junghöfer, M., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: An ERP analysis. *Emotion, 4*(2), 189–200. https://doi.org/10.1037/1528-3542.4.2.189.

Southam-Gerow, M. A., & Kendall, P. C. (2002). Emotion regulation and understanding: Implications for child psychopathology and therapy. *Clinical Psychology Review, 22*(2), 189–222. https://doi.org/10.1016/S0272-7358(01)00087-3.

Subba, S. H., Mandelia, C., Pathak, V., Reddy, D., Goel, A., Tayal, A., et al. (2013). Ringxiety and the mobile phone usage pattern among the students of a medical college in South India. *Journal of Clinical and Diagnostic Research, 7*(2), 205–209. https://doi.org/10.7860/JCDR/2013/4652.2729.

Tang, H., Zhao, H. W., & Wang, W. (2015). Application of attention bias and attention bias training in addiction behavior of drug addicts. *Chinese Journal of Drug Dependence, 24*(3), 174–179. https://doi.org/10.13936/j.cnki.cjdd1992.2015.03.004.

Veronika, K., Akos, P., & Adam, M. (2017). Mobile attachment: Separation from the mobile phone induces physiological and behavioural stress and attention bias to separation-related stimuli. *Computers in Human Behavior, 71*, 228–239. https://doi.org/10.1016/j.chb.2017.02.002.

Wadlinger, H. A., & Isaacowitz, D. M. (2008). Looking happy: The experimental manipulation of a positive visual attention bias. *Emotion, 8*(1), 121–126. https://doi.org/10.1037/1528-3542.8.1.121.

Wang, W. (2012). *Inter-personal problems in mobile-addicted college students: An exploration based on emotion expression and emotion recognition*. M.A. Thesis. Jinhua. Zhejiang Normal University. https://doi.org/10.7666/d.y2194301.

Wang, Z., Jiang, Q., & Zhang, D. J. (2008). A study on coding and recognition of internet addicts. *Psychological Development and Education, 1*, 106–112. https://doi.org/10.16187/j.cnki.issn1001-4918.2008.01.008.

Wang, Y., & Luo, Y. J. (2005). Standardization and assessment of college students' facial expression of emotion. *Chinese Journal of Clinical Psychology*, (4), 21–23. https://doi.org/10.16128/j.cnki.1005-3611.2005.04.006.

Wang, L., & Markham, R. (1999). The development of a series of photographs of Chinese facial expressions of emotion. *Journal of Cross-Cultural Psychology, 30*(4), 397–410. https://doi.org/10.1177/0022022199030004001.

Wang, C. G., Yuan, M., Luo, G. L., Li, Y. H., & Sui, N. (2017). The progress in identifying of the behavioral and neurobiological characteristics of emotional dysfunction and its integrated clinic intervention strategies in methamphetamine addicts. *Progress in Biochemistry and Biophysics, 44*(6), 455–465. https://doi.org/CNKI:SUN:ZYLF.0.2019-01-004.

Wiers, R. W., & Stacy, A. W. (2006). Implicit cognition and addiction. *Current Directions in Psychological Science, 15*(6), 292–296. https://doi.org/10.1111/j.1467-8721.2006.00455.x.

Williams, J. M. G., Watts, F., MacLeod, C., & Mathews, A. (2001). *Cognitive psychology and emotional disorders* (2nd ed., pp. 106–133). Chichester: John Wiley & Sons. https://doi.org/10.1016/S0005-7916(97)00035-9.

Xing, C., & Yang, M. M. (2013). Regulating emotion through attention training: Paradigms and evidences. *Advances in Psychological Science, 21*(10), 1780–1793. https://doi.org/10.3724/SP.J.1042.2013.01780.

Xiong, J., Zhou, Z. K., & Chen, W. (2012). Development of the mobile phone addicted tendency scale for college students. *Chinese Mental Health Journal, 26*(3), 222–223. https://doi.org/10.3969/j.issn.1000-6729.2012.03.013.

Yang, L., Ma, L., Zhao, X., & Zhang, G. S. (2015). Characteristics of drug addicts in emotional processing and coping style: Based on negative emotions. *Journal of Psychological Science*, (2), 482–489. https://doi.org/10.16719/j.cnki.1671-6981.2015.02.021.

Zheng, X., & Lee, M. K. O. (2016). Excessive use of mobile social networking sites: Negative consequences on individuals. *Computers in Human Behavior, 65*, 65–76. https://doi.org/10.1016/j.chb.2016.08.011.

Zhou, X. H. (2010). The exploration of the addiction by using mobile phone among university students. *Education and Teaching Research, 24*(4), 16–18. https://doi.org/10.13627/j.cnki.cdjy.2010.04.013.

Zhou, P. Y., Zhou, R. L., Hui, Y., Fan, W. Y., Sun, B. L., & Xiao, J. (2014). Different healing phases of heroin abstainers' processing to emotional stimuli: The evidence from ERP research. *Psychological Exploration, 34*(2), 172–178. https://doi.org/10.3969/j.issn.1003-5184.2014.02.013.

Zu, J. (2017). *A study of the characteristics of the inhibitory control and emotion processing of college students dependent on mobile phone and the interventions*. Doctoral dissertation. Northeast Normal University http://cdmd.cnki.com.cn/Article/CDMD-10200-1017143326.htm.