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Cognitive mechanism of intimate interpersonal relationships and loneliness in internet-addicts: An ERP study

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ABSTRACT

Interpersonal relationship and loneliness are important factors affecting internet addictive behavior of individuals. In the present study, we investigated intimate interpersonal relationships and loneliness in internet-addicts. We recorded event-related potentials (ERPs) of 32 internet addicts and 32 non internet-addicts. Participants viewed intimate-/conflict-relationship, happy/lonely, and neutral images. Results concerning attention probes showed that the accuracy rate of attention probes of internet-addicts was significantly lower than that of non internet-addicts; whereas, there was no significant difference in the reaction time of attention probes. Moreover, the differences in the mean amplitude and latency of P1, N1, N2P3, and LPP between internet-addicts and non internet-addicts were insignificant. Then, we found that the P1 amplitude of *conflict* images was significantly higher than that of *intimate* images among non internet-addicts; whereas internet-addicts indicated an insignificant difference between the two types of images. The P1 amplitude of *lonely* images was significantly higher than that of *happy* images among internet-addicts, but non internet-addicts were insignificant. The questionnaire data also obtained similar conclusions based on the EEG data. Finally, internet-addicts reported significantly higher loneliness scores than those of non internet-addicts. These results suggested that the social cognitive function of internet-addicts was probably impaired, especially in the cognition of interpersonal conflict. Furthermore, internet-addicts are likely to keep poor interpersonal relationships, which may induce more loneliness.

1. Introduction

The Internet plays an essential role in our lives due to its convenience and entertainment. The adolescent netizens take a high proportion of the total population of adolescents both at home and worldwide (Shek & Yu, 2016). In China, adolescent netizens (6–24 years old) accounted for 85.3% of the total population of adolescents, and in which nearly half of them were college students (CNNIC, 2016). Young people may be considered as a high-risk group for internet addiction (IA) (Chakraborty, Basu, & Vijaya Kumar, 2010), and the prevalence rate of IA among adolescents was 10.4% in China (Wu et al., 2016). Moreover, IA has been found to be detrimental to adolescents in terms of academic performance, cognitive function, social function, etc. (Ji & Tao, 2014; Wang et al., 2013), affecting their mental health and long-term development (Christakis, Moreno, Jelenchick, Myaing, & Zhou, 2011; He, Guo, Ke, & Zhao, 2008; Spada, 2014).

1.1. Internet addiction (IA)

Internet addiction (IA) refers to an impulsively behavioral disorder under the action of no addictive substance (Young, 1996; Young & Rodgers, 1998). IA was also defined as a mental and behavioral disorder that caused social dysfunction due to the repeated use of the Internet (Tao et al., 2007, 2008), characterizing tolerance and withdrawal (Griffiths, 1998). There were many factors related to IA, such as the time spending on and purposes of using internet (Wang et al., 2011; Ngai, 2007; Cao, Sun, Wan, Hao, & Tao, 2011), gender (Cao et al., 2011; Lam, Peng, Mai, & Jing, 2009; Yen, Yen, Chen, Chen, & Ko, 2007), temperament types (Montag, Jurkiewicz, & Reuter, 2010; Liu & Hu, 2008), sensation seeking and disinhibited personality (Jie, Chen, Yang, & Gao, 2013), and psychiatric variables (Li, Garland, & Howard, 2014; Yen et al., 2007). Among these factors, poor interpersonal relationships - such as parental relationship, parent-child relationship (Kuss, Griffiths, Karila, & Billieux, 2014; Li et al., 2014; Yen et al.,

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2007), and peer relationship (Huang & Leung, 2009) - are particularly important factors affecting internet addictive behavior of adolescents (Ding, Wei, Zhang, & Zhou, 2016; Wang et al., 2011; Milani, Osualdella, & Di, 2009).

1.2. Interpersonal relationship and loneliness in internet-addicts

Families and peers are two essential sources of the development of individuals (Hu et al., 2009; Kobus, 2003; Wei & Jiang, 2007). Compared to non internet-addicts, internet-addicts have poor family functions, emotional communication with family members (parents, parent-child), mutual care, and encouragement (Kuss et al., 2014; Li et al., 2014), and more family conflicts (Yen, Ko, Yen, Chang, & Cheng, 2009). In turn, frequent and intense parental conflicts and parent-child conflicts would also increase the possibility of IA (Deng, Fang, & Yan, 2013; Zhang & Deng, 2015), while parental relationship would affect the development of adolescents through parent-child relationship (Hao & Matsueda, 2006). However, the current study is more focused on family negative factors such as parental conflict and parent-child conflict, and less on the positive factors such as parental intimacy and parent-child intimacy. However, previous studies were from the perspective of either parental relationship or parent-child relationship separately, without integrating the two aspects (Deng et al., 2013). In the meantime, internet-addicts have worse peer relationship and communication than non internet-addicts (Liu et al., 2015; Xiao, Su, Gao, Fan, & Cao, 2007; Yang, Zhu, Chen, Song, & Wang, 2016). Poor peer relationship can predict internet addictive behavior of adolescents, as they may prefer seeking network to socialize (Lei, 2012; Liu & Kuo, 2007; Ye & Li, 2015), having less time and opportunities to interact with peers, resulting in worse companions in real life (Liu, Xu, & Hu, 2009).

Due to poor interpersonal relationship, internet-addicts seem to be more likely to be lonely, and thus need to escape from reality and seek acceptance through Internet (Wang, Yuan, et al., 2011; Song, Kong, Liu, & Yuan, 2010). Some researchers have pointed out that loneliness is another core factor, which may be potential outcomes of poor interpersonal relationship (Bozoglan, Demirer, & Sahin, 2013; Yalçın Özdemir, Kuzucu, & Ak, 2014). Loneliness can effectively predict the tendency of Internet addictive behavior about adolescents (Wang, 2006). There is a worrying vicious circle between IA and loneliness. Loneliness leads to the emergence of IA; in turn, individuals are obsessed with the Internet and reduce the chance of communication with the outside world, which leads to the increasingly alienated interpersonal emotion and experience of loneliness (Yao & Zhong, 2014).

1.3. The facilitation and passivation of sensory function in internet-addicts

Based on the above, an interesting question arises: do individuals who have experienced worse relationships and more loneliness react more sensitively in physiological measures? In the recent years, ERP technology are mainly used in researches about sensitivity/facilitation (Kuss & Griffiths, 2012; Luck & Kappenman, 2011), which is a particular brain evoked potential that can measure the relationship between brain and behavior (Kuss & Griffiths, 2012; Luck & Kappenman, 2011) with its high time resolution to explore individuals' minor changes to the relevant stimulus. Some studies about early sensory aspects first confirmed that the internet-addicts have the phenomenon about sensory perception facilitation. He et al. (2008) found that the amplitude of N1 about the hearing was significantly higher than that of non internet-addicts and the latency of N1 of the internet-addicted group was early, indicating that the addicts might have the facilitation of sensory function. In the early stage of face perception among internet-addicts, researchers also found similar findings (N170) to He et al. (2008) in the occipital (O1, O2) and occipital-temporal regions (P7, P8). That is, internet-addicts appeared the facilitation of early visual perception.

Cue-induced has always been the focus of researches on IA. Brand, Young, and Laier (2014) and Nie, Zhang, Chen, and Li (2016) suggested that internet-addicts were unable to suppress responses to addiction-related or internet-related stimuli. The study found that internet-addicts showed significant attention bias toward internet-related cues (Dai, Ma, & Wang, 2011; Ma & Dai, 2011; Zhang, 2008). Compared with the neutral words, internet-related words induced higher amplitude of P200 and P300 among internet-addicts (Dai et al., 2011). Moreover, compared with non internet-addicts, internet-addicts have lower P2 amplitude for internet-related images because of the increased scope of attention due to attention bias (Zhang, 2008). The study of memory ability about internet-addicts also found that internet-addicts had higher levels of memory for internet-related words than internet-unrelated words (Nie et al., 2016). Both in the coding and extraction stage, internet-addicts have superiority of memory on internet-related words and images (Luo, 2016). Internet-addicts may be exposed to the Internet for a long time so that they are more sensitive to internet-related cues and have the facilitation of memory function. Similarly, we speculated that since internet-addicts have experienced more interpersonal conflict and loneliness in their growth, they may be more sensitive to such feelings and scenes.

However, according to the habituation theory, repeated presentation of similar stimuli or tasks can lead to a reduction in individual responses (Thompson, 2009). So, the internet-addicts may also be accustomed to the scenes of interpersonal conflict and loneliness and will become more adaptable, resulting in weakened response and passivation. Some researchers found that passivation in the cognitive domain (i.e., inhibition and memory) concerning internet-addicts in response to internet-related cues. Also, Liu et al. (2014) found in a Go/NoGo task that the response inhibition of internet-addicted group was impaired due to the interference of internet-related cues and that it was challenging for them to activate the corresponding brain regions and maintain cognitive control and attention distribution (Liu et al., 2014). In the no-go case, the N2 amplitude of internet-addicted group was significantly lower than control group, and the peak latency of P3 was also significantly prolonged, indicating that the ability of addicted group to monitor and suppress the irrelevant information was impaired, and the efficiency of cognitive processing was lower than that of the control group (Dong & Zhou, 2010).

Therefore, will internet-addicts show the facilitation or passivation when facing more interpersonal relationship cues? The previous conclusions focused on the basic cognitive field were different. So, based on the controversy, we tended to use ERP technology to explore this problem further. We tested the following hypotheses: H1 - Different group (internet-addicts versus non internet-addicts) would affect one's recognition processing in response to the stimuli, and the accuracy rate of internet-addicts for probe stimuli would be significantly lower than that of non internet-addicts; whereas the reaction time of Internet-addicts would be significantly higher than that of non internet-addicts. H2 - The cognitive function of interpersonal relationships would be impaired in Internet-addicts, and the amplitude of P1, N1, N2, P3, LPP would be lower, and their latency would be longer than non internet-addicts. H3 - internet-addicts would have a higher amplitude and a shorter latency for conflict images than intimate images, compared to non internet-addicts. H4 - Internet-addicts would have a higher amplitude and a shorter latency for lonely images than happy images while there would be no significant differences in non internet-addicts, which would be supported by the questionnaire data.

2. Materials and methods

2.1. Participants

Participants were recruited by putting up a poster at campus and advertising on the Internet. One hundred and five male undergraduates at Anhui University in China were volunteered to participate in this study. According to the method of Wu (2013) and Ko (2014), participants who met Young's Internet Addiction Test for Chinese (YIAT-

Table 1
Differences in Internet use and demographic information between non-addicted group and internet-addicted group.

	Non-addicts (M ± SD)	Internet-addicts (M ± SD)	*t*	Cohen's d
Age	20.45 ± 1.34	20.34 ± 1.47	0.257	0.08
Internet Addiction Test for Chinese (YIAT-C)	37.38 ± 7.14	65.87 ± 9.78	−13.243***	3.33
DSM-5	2.06 ± 1.29	6.78 ± 1.18	−15.22***	3.82
Network age	4.22 ± 0.91	4.53 ± 0.67	−1.567	0.39
Top 3 purposes of Internet use	Television, communication, game	Game, television, web surfing		

*** $p < .001$.

C) ≥ 50 were defined as internet-addicts, while YIAT-C < 50 were defined as non internet-addicts. Finally, 31 invalid data were discarded because of the scores of YIAT-C failed to meet screening criteria. Data of eight participants were discarded because of artifact rejection from EEG and data of the other two participants was rejected for not reacting to the attention probes (smiling face). Data of 64 participants remained for further analysis (32 addicts and 32 non-addicts). The remaining 64 male participants (mean age = 20.39, *SD* = 1.44, range = 18–24 years old) were healthy, with normal or corrected-to-normal vision, no history of neurological or psychiatric disorder. All 64 participants were right-handed. In the internet-addicts group, 84.38% participants spend > 3 h a day on Internet, while only 53.13% in the non internet-addicts group. Five of the addicts spend > 10 h a day on Internet, compared with just two of the non-addicts. Other internet uses and demographic information of the two groups were shown in Table 1.

This study was approved by the Human Research Ethics Committee of the Anhui University of China according to the principles expressed in the Declaration of Helsinki. Each participant to the study signed a written informed consent after receiving an explanation of the study's purpose and procedure. All the participants were above 18 years old, and they were given 50 RMB (approximately US $ 7.356) as an incentive to participate in the study.

2.2. Measures

2.2.1. Internet Addiction Test for Chinese (YIAT-C)

This scale was developed by Young (1996) and revised by Wu in 2013. It includes 20 items, and each item was rated on a 5-point Likert scale (rating from *1 = never* to *5 = always*). All participants completed YIAT-C. According to Wu (2013), the criteria (i.e., scores) of addiction in YIAT-C was > 50. Higher scores indicate higher levels of internet addiction. The Cronbach's alpha for the scale was 0.940.

2.2.2. DSM-5

In order to further test internet addiction, we used the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), released in May 2013. This scale consists of 9 items, including preoccupation, withdrawal, tolerance, unsuccessful attempts to control, loss of other interests, continued excessive use despite psychosocial problems, deceiving regarding online gaming, escape, and functional impairment (American Psychiatric Association, 2013). Participants were asked to choose “yes” or “no” according to each item and the cut-off point of this scale is fulfilling 5 or more criteria (Ko, 2014). The Cronbach's alpha for the scale was 0.938. The higher the score indicates the higher level of internet addiction.

2.2.3. Children's perception of interparental conflict scale (CPIC)

This scale was translated and revised by Xin and Chi (2003) to survey parental conflict. The 10-item questionnaire includes five items measuring the frequency of the conflict between parents, and the other five items measuring the intensity of parental conflicts. Each item is rated on a 5-point Likert scale (rating from *1 = not same at all* to *5 = entirely same*). Higher scores indicate higher levels of interparental conflict. The Cronbach's alphas for the scale were 0.920 and 0.897.

2.2.4. Parents intimacy scale

This scale was developed by Zou (1998) to survey the parental intimacy. The 5-item questionnaire measures the intimacy of parents. Each item is rated on 5-point Likert scale (rating from *1 = not same at all* to *5 = entirely same*). Higher scores indicate higher levels of parents' intimacy. The Cronbach's alphas for the scale were 0.879.

2.2.5. Parent-child conflict scale

This scale was developed by Fang in 1998 to survey the parent-child conflict. The 16-item questionnaires include eight items measuring the frequency of the conflict of parents and child, and the other eight items measuring the intensity of parent-child conflicts. Each item is rated on 5-point Likert scale (rating from 1 = *not same at all* to 5 = *entirely same*). Higher score indicates higher levels of parental-child conflict. The Cronbach's alphas for the scale were 0.897 and 0. 926.

2.2.6. Parent-child intimacy scale

The scale was developed by Zhang in 2011 to survey the parent-child intimacy. The 9-item questionnaire consists of the father-child and mother-child relationship, which is rated on 5-point Likert scale (rating from 1 = *not same at all* to 5 = *entirely same*). Higher score indicates higher levels of parent-child intimacy. The Cronbach's alphas for the scale were 0.868 and 0.887.

2.2.7. Friendship quality scale

This scale was developed by Parker and Asher (1993) and revised by Zou in 1998 to measure peer relationship. The scale is divided into five dimensions: a) trust and support, b) company and entertainment, c) a positive attitude toward value, d) intimate barely and communication, e) conflict and betrayal. Each item of the scale is rated on a 5-point Likert scale (rating from 1 = *not same at all* to 5 = *entirely same*). The Cronbach's alpha for the scale was 0.916. Higher score indicates higher levels of friendship.

2.2.8. UCLA Loneliness Scale

Participants completed the Chinese version of UCLA Loneliness Scale (Rating scales for mental health, 1999). This questionnaire included 20 items. Each item was rated on a 4-point Likert scale (rating from 1 = *never* to 4 = *all the time*). Higher score indicates higher levels of loneliness. The Cronbach's alpha for the scale was 0.862.

2.3. Materials

Materials for the present experiment included visual images. In order to compare two groups' responses to the stimuli, we divided the original visual images into five categories. (1) There were 60 images about intimate interpersonal relationships, including 15 images about parent intimacy, 15 images about father-child intimacy, 15 images about mother-child intimacy, and 15 images about peer intimate relationship. (2) There were 60 images about conflict interpersonal relationships, including 15 images about parental conflict, 15 images about father-child conflict, 15 images about mother-child conflict, and 15 images about peer conflict relationship. (3) There were 15 images about one person reflecting happiness, (4) and 15 images about one person reflecting loneliness. (5) Also, 30 neutral images (beautiful

scenery like forest, mountains, and rivers) were selected. Images from the five categories were mostly screenshots selected from the television series about Chinese family or friendship. Others were pictures from the internet or taken by ourselves. Each image depicted people's behavior only, and all the persons in the images were of Asian origin. The first two categories contain two persons and the images about peer relationship, including two male persons. All images were standardized for brightness, saturation, and size (683 pixels × 385 pixels) with Photoshop CS4.

Before the experiment, 15 males, not participating in the final study, independently adopted a 7-point rating scale to assess the 180 selected images concerning the levels of intimacy and conflict. We chose the pictures with scores of clarities above 4 and arousal over 3. The scores of intimate pictures were higher than 5 in the dimension of intimacy and lower than 3 in conflict, while the conflict pictures' cut-off was the opposite. The standard of pictures of happiness and loneliness was the same as that of intimate ones. As for the neutral pictures, we chose the ones whose mean scores of four dimensions, including intimacy, conflict, happiness, and loneliness were all above 4. Finally, 88 images were selected for the formal experiment, and the examples of the pictures were presented in Fig. 1. The materials also contained a drawing of a yellow smiling face, which served as an attention probe and was presented 66 times throughout the session according to the Key's proportion of the yellow smiling faces and the images of five categories (brain responses to this stimulus were not included in the analysis) (Key & Corbett, 2014). When the drawing of a yellow smiling face appeared, participants were instructed to press “1” on the keyboard, using the right hand. The task was used to keep participants focusing on the images.

2.4. Procedure

After arriving at the laboratory, participants read and signed an informed consent form, which included a brief description of the study. Participants then filled in questionnaires and scales. Afterward, we placed electrodes on participants' heads after participants sat in a soundproof and dimly lit room. Images were displayed on a 49-cm monitor, with a maximum size of 27 cm × 37 cm, presented approximately 1.25 m from the participant's eyes with a visual angle of 16° horizontally and 12° vertically. Stimuli were presented in 6 blocks of 231 images each, and the images in each block were randomly selected from five categories. Stimuli presentation was controlled by *E*-Prime software.

Each block started with a black fixation cross (5 cm × 5 cm) in the center of the white computer screen and lasted for 500 ms. All stimuli were randomly presented for 1000 ms, and the blank time between stimuli was 500 ms. Images in the same categories appeared randomly within each block. Each category contained eight images, and each image was presented 15 times in all. Thus, the study consisted of 1386 trials, including 66 trials of the yellow smiling face and lasted approximately 40 min. Furthermore, once participants found the drawing of the yellow smiling face appeared in the center of the screen and pressed “1” on the keyboard, (Fig. 2) the next stimuli appeared. There were several times for resting during the experiment. An experimenter was present in the room to monitor participants' behavior. If participants became inattentive or restless, stimulus presentation could be suspended until the participant was ready to continue with the task.

2.5. Electroencephalogram (EEG) recording and signal processing

The electroencephalogram (EEG) was recorded using a 64-channel amplifier (SynAmps2, Neuroscan) and data acquisition software (SCAN4.3, Neuroscan). The 64 Ag–AgCl active electrodes were placed on the scalp by means of ahead cap, according to the 10–20 International System. Scalp impedance for each electrode was kept below 5kΩ. the vertical electro-oculogram (VEOG) was recorded by attaching additional electrodes above and below the left eye. The REF electrode served as reference, and the forehead GND electrode was used as ground. All signals were digitized with a sample rate of 500 Hz, a 24-bit A/D conversion and a 0.05–100 Hz bandpass filter.

The offline analysis of ERP data was performed with Neuroscan4.3 software. Data were filtered using a low pass filter of 25 Hz with zero

Fig. 1. Examples of each category.

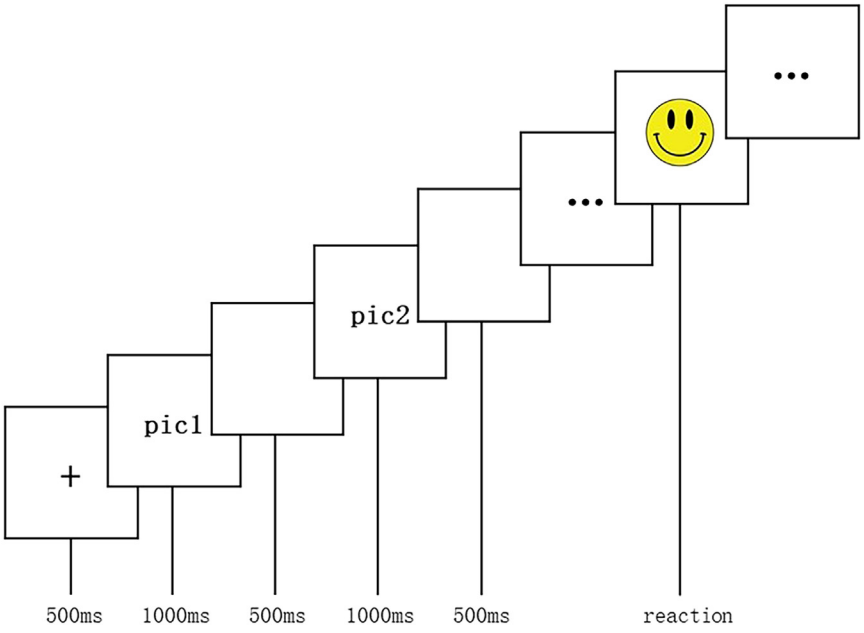

Fig. 2. The Experimental Flow Chart.

phase shifts (24 dB/octave slope). Ocular artifact correction was applied according to the Gratton and Coles algorithm. Data epochs were extracted from a time window between 200 ms before and 1200 ms after the stimuli on set. The mean 200 ms pre-stimuli period was used for baseline correction. Artifact rejection criteria were minimum and maximum baseline-to-peak −100 to +100 μV. According to previous studies and the purpose of the current study, average ERPs were then computed for each participant and the six images categories (parents, father-child, mother-child, peer, one person and neutral). The following electrode positions were analyzed: P3, P4, O1, O2, and Oz. The voltages and waves that were elicited by parents, father-child, mother-child, peer, one person, and neutral stimuli images during the experiment were recorded.

2.6. Analysis

2.6.1. Behavioral data

To investigate participants' attention, the reaction time and the accuracy rate to the smiling face probes between the two groups (non internet-addicts versus internet-addicts) were analyzed by independent sample *t*-test.

2.6.2. Questionnaire data

As for the difference of two groups in each questionnaire, the scores of each scale between the two groups (non internet-addicts versus internet-addicts) were analyzed by the method of independent sample *t*-test.

2.6.3. ERP data

The questionnaire and ERP data were analyzed using SPSS11.0 for Windows. Based on previous studies, the mean ERP voltages in the time windows 100–140 ms (referred to as P1 component), 140–190 ms (referred to as N1 component), 200–350 ms (referred to as N2P3 component), 400–650 ms (referred to as LPP component) were tested at several electrodes (P3, P4, O1, O2, Oz) and the latency in the time windows 100–140 ms (referred to as P1 component), 140–180 ms (referred to as N1 component), were also tested at several electrodes (P3, P4, O1, O2, Oz) (Gao, 2006; Zhang, 2008). The effects between different waves (intimate and conflict) and the between-subject factors two groups (non internet-addicts versus internet-addicts) were analyzed by employing repeated measurement ANOVA. Only effects involving the factor condition of interest were reported. Greenhouse-Geisser correction for violations of the sphericity assumption in repeated measures analyses was used when appropriate. Effects were considered significant when $p < 0.05$.

3. Results

3.1. Behavioral data

Responses to attention probes (smiling face) revealed that all participants-maintained attention to the stimuli during the test session. One data was discarded because the accuracy rate was 0.24. There were group and test session related differences in the number of responses to the attention probe [t (60) = 2.44, $p = 0.02 < 0.05$, Cohen's $d = 0.06$]. The accuracy rate of non internet-addicts (mean rate = 0.97, $SD = 0.04$) was higher than that of internet-addicts (mean rate = 0.93, $SD = 0.09$). In addition, there were no test or group differences in the reaction time [t (61) = −0.58, $p = 0.57$, Cohen's $d = 0.15$].

3.2. Questionnaire data

Independent sample *t*-test was used to analyze the difference between the two groups in each questionnaire (see Table 2). The internet-addicts had significantly higher scores on the loneliness scale than the non internet-addicts [t (60) = −3.72, $p < 0.001$, Cohen's $d = 0.94$].

3.3. ERP data

3.3.1. P1 (100–140 ms)

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (100–140 ms) utilizing the mean of ERP voltages. The main effect of group was not significant [F (1,62) = 1.033, $p = 0.313$, $\eta_p^2 = 0.016$]. However, both the main effect of wave [F (1, 62) = 13.495, $p = 0.001 < 0.01$, $\eta_p^2 = 0.179$] and the main effect of electrodes [F (4,248) = 14.61, $p < 0.001$, $\eta_p^2 = 0.191$] was significant. The interaction between group and stimuli categories (wave) was not a significant level [F (1, 62) = 3.138, $p = 0.08$, $\eta_p^2 = 0.048$].

Table 2
Differences in scores between non-addicted group and internet-addicted group.

	Non-addicts (M ± SD)	Internet-addicts (M ± SD)	*t*	Cohen's d
Parental conflict scale	21.54 ± 7.58	23.61 ± 9.77	−0.905	0.24
Parental intimacy scale	18.06 ± 4.03	17.93 ± 3.95	0.126	0.03
Parent-child conflict scale				
Parent-child conflict frequency	24.68 ± 6.65	28.00 ± 10.02	−1.539	0.39
Parent-child conflict intensity	25.59 ± 7.88	30.13 ± 11.43	−1.830	0.46
Parent-child intimacy scale				
Father-child intimacy	29.72 ± 7.26	27.07 ± 7.01	1.462	0.37
Mother-child intimacy	31.78 ± 7.23	30.35 ± 6.91	0.800	0.20
Friendship quality scale	94.40 ± 18.83	89.90 ± 17.10	0.977	0.25
Loneliness scale	51.80 ± 4.56	55.84 ± 4.01	−3.72***	0.94

*** $p < .001$.

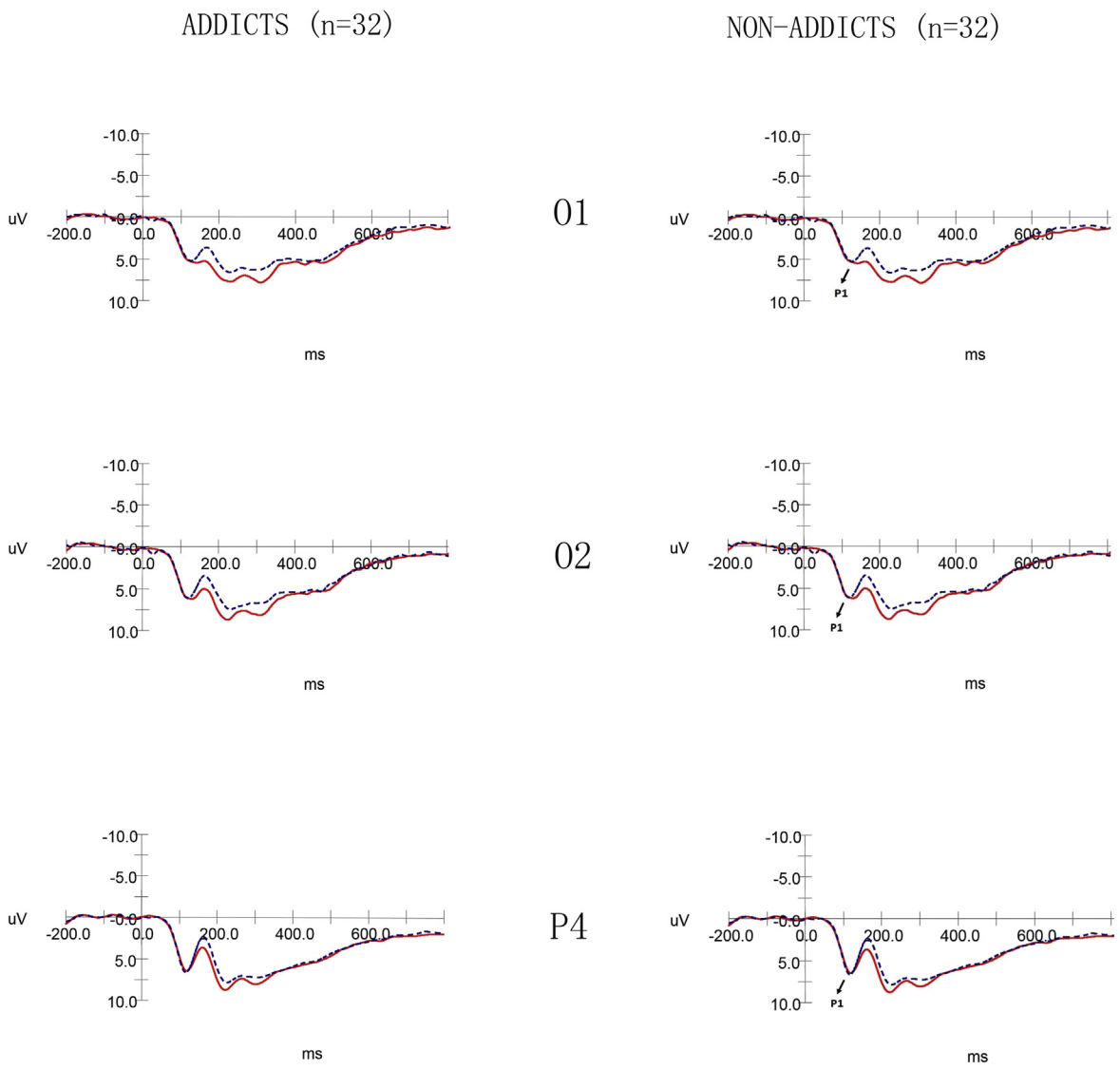

Fig. 3. Grand-average (n = 64) event-related potentials (ERPs) at various electrodes as a function of difference waveforms types (INTIMATE wave, CONFLICT wave).

In order to further test the difference of stimuli categories in each group, we used the method of repeated measure ANOVA with 2(intimate wave, conflict wave) x 5 (electrodes) in each group. The main effect of wave was significant in non-addicted group [F (1, 31) = 11.016, $p = 0.002 < 0.01$, $\eta_p^2 = 0.262$] while it was not significant in addicted group [F (1, 31) = 2.765, $p = 0.106$, $\eta_p^2 = 0.082$] (Fig. 3). More specifically, the P1 amplitude of conflict images was significantly higher than intimate images in the non-addicted group, but internet-addicts had no significant difference.

In addition, we found the main effect of wave voltages (happiness and loneliness) was significant in the addition group [F (1,31) = 9.072, $p = 0.005 < 0.01$, $\eta_p^2 = 0.226$], but not significant in non-addicted group [F (1,31) = 1.362, $p = 0.252$, $\eta_p^2 = 0.042$]. Compared with happy images, lonely images produced higher amplitude in the internet-addicted group (Fig. 4).

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group,

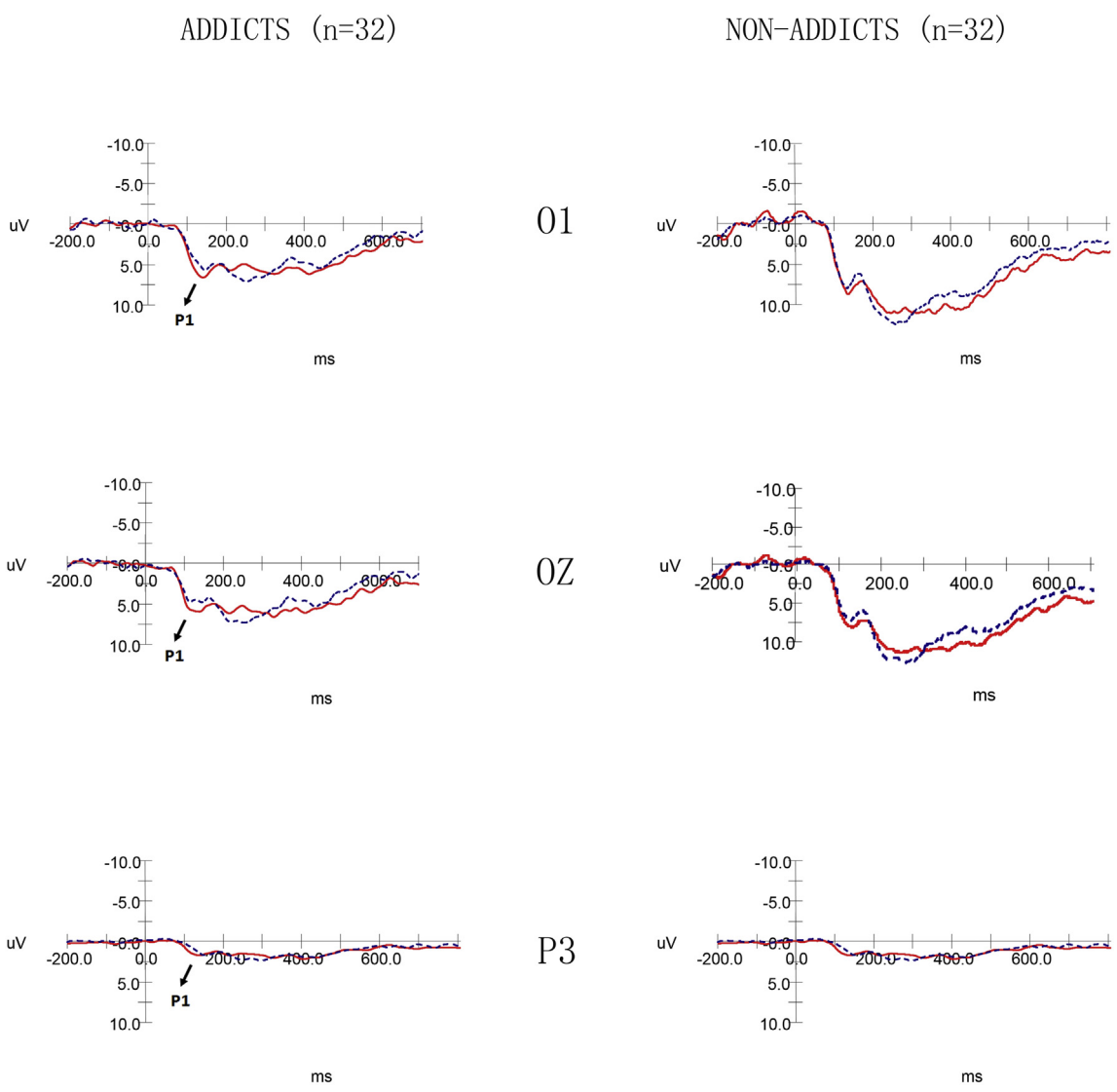

Fig. 4. Grand-average (n = 64) event-related potentials (ERPs) at various electrodes as a function of difference waveforms types (HAPPINESS wave, LONELINESS wave).

non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (100–140 ms) utilizing the latency. The main effect of group was not significant [F (1,62) = 1.154, p = 0.287, η_p^2 = 0.018]. However, both the main effect of wave [F (1,62) = 5.268, p = 0.025 < 0.05, η_p^2 = 0.078] and the main effect of electrodes [F (4,248) = 5.580, p < 0.001, η_p^2 = 0.086] was significant. All the interactions were not significant except the interaction of stimuli categories × electrodes [F (4,248) = 4.378, p = 0.002 < 0.01, η_p^2 = 0.066].

3.3.2. N1 (140–190 ms)

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measurement ANOVA was tested on this time window (140–190 ms) utilizing the mean of ERP voltages. The main effect of group was not significant [F (1,62) = 2.10, p = 0.152, η_p^2 = 0.033]. However, both the main effect of wave [F (1,62) = 116.97, p < 0.001, η_p^2 = 0.654] and the main effect of electrodes [F (4,248) = 28.80, p < 0.001, η_p^2 = 0.317] was significant. All the interactions were not significant.

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (140–190 ms) utilizing the latency. Two data were discarded because the waves during this time window have no peak. The results of latency were not significant except the main effect of electrodes [F (4,240) = 8434, p < 0.001, η_p^2 = 0.123] and the interaction of stimuli categories × electrodes [F (4,240) = 3.286, p = 0.012 < 0.05, η_p^2 = 0.052].

3.3.3. N2P3 (200–350 ms)

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (200–350 ms) utilizing the mean of ERP voltages. The main effect of group was not significant [F (1,62) = 1.622 p = 0.208, η_p^2 = 0.837]. However, both the main effect of wave [F (1,62) = 69.03, p < 0.001, η_p^2 = 0.527] and the main effect of electrodes [F (4,248) = 20.43, p < 0.001, η_p^2 = 0.248] was significant. All the interactions were not significant.

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (200–350 ms) utilizing the latency. The results of latency were not significant except the main effect of electrodes [F (4,248) = 3.618, p = 0.007 < 0.01, η_p^2 = 0.055].

3.3.4. LPP (400–650 ms)

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (400–650 ms) utilizing the mean of ERP voltages. The main effect of group was not significant [F (1,62) = 2.799, p = 0.099, η_p^2 = 0.798]. However, both the main effect of wave [F (1,62) = 35.18, p < 0.001, η_p^2 = 0.362] and the main effect of electrodes [F (4,248) = 15.79, p < 0.001, η_p^2 = 0.203] was significant. All the interactions were not significant except the one of stimuli categories × electrodes [F (4,248) = 6.344, p < 0.001, η_p^2 = 0.093].

A 2 (intimate wave, conflict wave) × 2 (internet-addicted group, non-addicted group) × 5 (electrodes) repeated measure ANOVA was tested on this time window (400–650 ms) utilizing the latency. The results of latency were not significant except the main effect of electrodes [F (4,248) = 30.05, p < 0.001, η_p^2 = 0.326].

4. Discussion

In the present study, we found that the accuracy rate of internet-addicts for probe stimuli (smiling face) was significantly lower than that of non internet-addicts; whereas there was no significant difference in reaction time between two groups. Based on the electrophysiological data, there was no significant difference in stimuli categories between two groups (internet-addicts and non internet-addicts) in P1, N1, N2P3, or LPP. However, we found that the impact of stimuli categories was significantly different between the two groups. That is, in the internet-addicts, there was no significant difference in the mean amplitude of P1 caused by intimate and conflict images, whereas the P1 amplitude of conflict images was significantly higher than intimate images in the non internet-addicts. The P1 amplitude of lonely images was significantly higher than that of happy images in the internet-addicts, but not in the non internet-addicts. According to the questionnaire data, we found that the two groups were significantly different in loneliness, and the scores of loneliness in internet-addicts were significantly higher than those in non internet-addicts. What is more, there was no significant difference in the questionnaires related to the interpersonal relationships between the two groups. This result was consistent with that of EEG.

4.1. Behavioral data

This study found that the accuracy rate of internet-addicts for probe stimuli was significantly lower than that of non internet-addicts, indicating that the internet-addicts showed a decline in attention function. There have been studies confirming that there was a significantly positive correlation between IA and attention deficit hyperactivity disorder (ADHD) symptoms (Isa & Hashim, 2017; Seyrek, Cop, Sinir, Ugurlu, & Şenel, 2017). Specifically, the group with a high risk of IA had a higher score of deficit/hyperactivity symptoms (Dalbudak et al., 2015). Attention as an essential component of cognitive function is the point and focus of a specific object, which sustains attention for some time to focus on completing a task (Tian & Gan, 2011). In this study, the two groups need to view images for some time, so the accuracy rate of probe stimuli reflects the sustained attention of subjects. The results showed that there were defects in the sustained attention function of internet-addicts, which was consistent with the findings of the previous study (Tian & Gan, 2011).

4.2. Cognitive mechanism of intimate interpersonal relationships in internet-addicts

According to the ERP data analysis, we found the significant interaction between group and stimuli categories (wave). The P1 amplitude caused by conflict images was significantly higher than that caused by intimate images in non internet-addicts; whereas, there was no significant difference in internet-addicts. It can be seen that, in the two groups, the P1 amplitude was different due to the difference in stimulus types. In the attention bias of ERP study, P1 was considered to represent the neural activity of the visual cortical area. When more attention is focused on visual stimulation, there are more exogenous neuronal processing stimuli that cause greater amplitude of P1 (Gao, 2006). In the non internet-addicts group, the conflict images significantly induced higher P1 amplitude, indicating that non internet-addicts focus more attention on the conflict images. We can explain this phenomenon from the neural mechanism of attention. The neural basis of attention is orientating reflex, which is a type of reflex activity caused by extraneous stimulus. Compared with repeated stimuli, new stimuli can attract more attention resources and cause greater neural activation (Li, Huang, Bi, & Chen, 2013; Ranganath & Rainer, 2003). Previous researches about the interpersonal relationships of the internet-addicts confirmed that internet-addicts were unresponsive to the affiliation and the competitive relations as well as the Methamphetamine dependence patients. That is, they were difficult to recognize and understand the affiliation and the competitive situation (Feng, 2016). Our results were similar to this finding, and it was probably because internet-addicts' social cognition about the conflict situation had been passivated compared to the non internet-addicts.

Thus, significant differences in non internet-addicts may because that non internet-addicts experience fewer conflict situations, and conflict images as extraneous stimuli can attract more attention to non internet-addicts. Moreover, the performance of internet-addicts can be explained by the passivation of social cognition. Previously, basic cognitive researches demonstrated this phenomenon that when internet-addicts confronted with internet-related cues, the response inhibition of internet-addicts were impaired by the interference of internet-related cues (Liu et al., 2014), and they indicated a lower level of working memory for pornographic picture than non internet-addicts (Laier, Schulte, & Brand, 2013). The individual responses were diminished for repeated stimuli which is known as habituation (Thompson, 2009). From this theory, internet-addicted group may be accustomed to interpersonal conflict after experiencing more conflict situations, which leading to passivation of interpersonal conflict. Therefore, conflict situations do not evoke significant amplitude compared to intimate situations. However, it should be pointed out that the performance of internet-addicts is not only caused by the passivation of interpersonal conflict relationships, but also results from the inaccurate cognition of conflicting interpersonal relationships, which can be explained from the perspective of psychological resilience. It has been pointed out that children with high-level resiliency can accurately judge interpersonal relationships compared with children with low-level resiliency, and their perceptions of interpersonal relationships tend to be cautious and positive (Xi, Sang, & Zuo, 2011). Individuals with high-level resiliency successfully respond and actively adapt to serious stress/adversity (Li & Xie, 2012), tend to have better interpersonal relationships and are more intimate with adults and peers (Masten, Cutuli, Herbers, & Reed, 2009). In this study, the non-addicted group was more likely to induce higher P1 amplitude in the conflict situation, but this difference was not significant in internet-addicted group. It can be seen that the non-addicted group has a higher accuracy of social cognition, can accurately determine the intimate and conflict situations, which guide them to make appropriate social behavior decisions (Xi & Zuo, 2015). Therefore, the conflict situation can stimulate more cognitive resources in non internet-addicts. That is, non internet-addicts try to seek adaptive strategies to solve the problem and effectively deal with the conflict in their daily lives. Good interpersonal relationships depend on adaptive social cognition (Byrd, 2010; Xi & Zuo, 2015). internet-addicts lack psychological resilience and feel challenging to cognize interpersonal relationships accurately, so their interpersonal relationships may be worse, and they less sensitive to conflict situations than non internet-addicts. When facing conflict situations, they cannot be evoked intensity and deal with conflict timely and effectively.

4.3. Loneliness in internet-addicts

Many studies have reported the relationship between internet addiction and loneliness (Ezoe & Toda, 2013; Wang, Zhou, et al., 2011; Ghassemzadeh, Shahraray, & Moradi, 2008; Takahira, Ando, & Sakamoto, 2008). Loneliness was the most important variable associated with Internet addiction (Bozoglan et al., 2013; Ceyhan & Ceyhan, 2008). The cognitive-behavioral model for pathological Internet use (PIU) claimed that loneliness predisposes adolescents to internet addiction (Toda, Monden, Kubo, & Morimoto, 2004). Internet-addicts access the internet due to loneliness. With the aggravation of IA, internet surfing time continues increasing, and a variety of loneliness will increase so that they enter the Internet again to get rid of loneliness (Casale & Fioravanti, 2011).

Mou (2011) found that the scores of loneliness among internet-addicts were higher than those of non internet-addicts, which was consistent with the results of this study. The results demonstrated that the amplitude of P1 induced by lonely images was also significantly higher than that induced by happy images in the internet-addicted group, but not in the non-addicted group. Although the internet-addicted group did not show a significant difference in conflict situations compared to the non-addicted group in a conflict scene due to passivation or inaccurate cognition of interpersonal relationships. The internet-addicted group produced a higher amplitude of P1 on the lonely images, indicating that the addiction group was more sensitive to a lonely scene, distributing more attention resources on it. Although the results of habituation or inaccurate cognition in the internet-addicted group were not shown on the data, we found that the significant difference of happiness and loneliness in the internet-addicted group. Many studies have shown that there is a significant positive correlation between loneliness and interpersonal conflict (Li, 2013). Excessive interpersonal conflicts tend to create a stronger sense of loneliness in the addictive college students, thereby enhancing their desire for sociality. Zhou et al. (2017) found that family emotional security plays a mediated role in the relationship between parental conflict and IA of adolescents. The psychological problems such as depression and loneliness are the causes of IA, and the relationship between depression and IA is not significant in the cross-lagged regression analysis, and there is a significant vicious circle between IA and loneliness (Yao & Zhong, 2014). It can be seen that, compared with depression, loneliness is a more important factor in the formation of IA. Therefore, these results indicated that poor interpersonal relationships are not closely linked to IA, but the loneliness from interpersonal conflicts. Perhaps the loneliness makes addicts more inclined to social networking than non internet-addicts, but social networking can only result in an increase of social loneliness, because the indulgence of social networking led to the reduction of contacts with other people in real life.

In general, this study found that the non-addicted group had significant differences in the P1 amplitude induced by the intimate and conflict scene, and this difference was not significant in the internet-addicted group, which may be due to the inaccurate cognition of conflict scene by internet-addicts, which also lead to the deterioration of interpersonal relationships. The study also found that the P1 amplitude induced by the lonely scene was significantly higher than the pleasant scene in the internet-addicted group, but this difference was not significant in the non-addicted group. So, internet-addicts have poor interpersonal relationships, bringing more loneliness, so that they try to eliminate loneliness through the Internet. They, however, form a negative schema about the lonely situation after experiencing more loneliness. It can offer a reason why P1 amplitude was significantly higher in addicts than in non internet-addicts. Moreover, although this study did not conclude that there was a significant difference between internet-addicts and non internet-addicts, we also confirmed that the social cognitive function of internet-addicts was impaired, especially in terms of the cognition of interpersonal conflict. Due to inaccurate cognition of conflicting interpersonal relationships, internet-addicts were unable to seek effective strategies to deal with conflicts in the face of conflict situations. And it also led to the deterioration of interpersonal relationships, which in turn led to loneliness. Internet-addicts want to get rid of loneliness through the Internet but did not know that this way cannot get rid of the emotional loneliness, but results in a vicious circle between IA and loneliness (Yao & Zhong, 2014).

5. Limitation and future study

This study did not distinguish between subtypes of IA. Some researchers have pointed out that different subtypes of IA and social avoidance have different correlations (Wang, Wang, & Duan, 2012), indicating that the impact of actual interpersonal relationships is different for different subtypes of internet-addicts. At present, there are few studies on the causes of different subtypes of IA, and these studies focus on the personality traits and ignore the differences caused by interpersonal relationships among different subtypes of internet-addicts. Therefore, future studies could select different types of internet-addicts, compare their differences in social cognition and the corresponding differences in brain mechanisms.

In conclusion, this study found that internet-addicts had the passivation or inaccurate cognition of conflicting interpersonal relationships, and the scores of loneliness were higher and they were more sensitive to lonely scene. So, we speculated that internet-addicts had poor interpersonal relationships, and this interpersonal relationship brings loneliness, resulting in a vicious circle of internet-addicts' addictive behavior. Therefore, this study provides a reference for the clinical psychological intervention of adolescents with IA. For example, some researchers found that behavioral therapy used in intervention of IA, emotional and social loneliness symptoms have achieved remarkable curative effect (Ma, 2011; Zhao, 2011), which can be used as an effective intervention for IA (Wu, 2013). In view of the results of this study, future study can explore a more effective intervention from the relationship between IA, interpersonal relationships, and loneliness.

Author contributions

Conceived and designed the experiments: JH, YJ, SC, YH, JW, NF, XF. Performed the experiments: JH, YJ, SC, YH, JW. Analyzed the data: JH, YJ, SC. Contributed reagents/materials/analysis tools: JH, YJ, SC, YH, JW, NF. Wrote the paper: JH, YJ, SC, YH, NF, XF. Discussed the result: JH, YJ, SC, YH, JW, NF, XF. Final approval of the version to be published: JH, YJ, SC, YH, NF, XF.

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Declaration of Competing Interest

The authors have declared that no conflict of interest exists.

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