



Adolescent Internet Gaming Disorder and sensitivity to money and social rewards

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ABSTRACT

Internet Gaming Disorder (IGD) is a behavioural addiction characterised by excessive exposure to addictive stimuli, resulting in reduced sensitivity of the brain's reward system towards everyday rewards. Online game addiction is prevalent among adolescents; however, it remains unclear if there are variations in reward processing patterns among adolescents with online game addiction.

We compared differences in sensitivity to two types of rewards between patients with IGD and patients with Recreational Game Use (RGU) using the Monetary Incentive Delay (MID) paradigm and the Social Incentive Delay (SID) paradigm (Experiment 1). Additionally, we used a mixed reward latency paradigm, including both monetary and social rewards, to further explore the processing characteristics of IGD towards a mixture of these two rewards (Experiment 2).

There were significant differences in the sensitivity of IGD and RGU to monetary and social rewards. Adolescents with IGD had significantly shorter reaction times to the four mixed rewards compared to RGU, while no significant differences were found between groups regarding sensitivity to specific individual rewards. However, the simultaneous presence of two rewards affected the processing speed and preference of adolescents with IGD.

The reward processing characteristics observed in adolescents with online gaming disorder show specificity concerning the type and presentation of rewards, providing a theoretical foundation for diagnosing and treating adolescent online gaming addiction.

1. Introduction

Internet addiction (IA) refers to individuals who are unable to control their use of the Internet, ultimately leading to psychological, social or occupational difficulties (Young, 1998). It includes five main types: internet pornography addiction, internet relationship addiction, compulsive online behaviour, information seeking addiction and Internet Gaming Disorder (IGD) (Armstrong, 2001). Among them, IGD is the most common form of internet addiction and the main type of behavioural addiction among adolescents (Derevensky et al., 2019). Internet Gaming Disorder (IGD) has emerged as a prevalent behavioural addiction and a global mental health issue that has received significant attention worldwide (Petry et al., 2014). The prevalence of Internet gaming addiction varies globally, ranging from approximately 0.7 % to 27.5 % depending on population, geographic location, and other characteristics (Mihara & Higuchi, 2017; Przybylski & Weinstein, 2017),

with higher rates observed in Asia (Mihara & Higuchi, 2017; Yu & Cho, 2016) and among adolescents (Kuss & Griffiths, 2012; Zhang et al., 2018). Adolescents are more susceptible to online gaming addiction than the adult population due to a combination of factors. On the one hand, compared to adults, adolescents are more susceptible to the negative influences of internet abuse due to their underdeveloped rational-analytical processing system and increased activity of their intuitive-heuristic system (Orsolini et al., 2021; Perris et al., 2019). Furthermore, the internal incongruity of their perceptual awareness system may increase adolescents' vulnerability to compulsive internet use and cravings (Aboujaoude et al., 2021). On the other hand, adolescence is a pivotal developmental period marked by significant behavioural adjustments and pronounced changes in reward sensitivity. Genetic polymorphisms in adolescents, particularly in genes encoding dopamine D2 receptors and dopamine-degrading enzymes, may increase their susceptibility to online gaming addiction (Han et al., 2007).

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Dopamine's effects on the nervous system may increase the risk of addictive behaviours or cause pathological damage that can reduce the pleasure experienced from natural rewards in people addicted to online gaming, a phenomenon known as reduced reward sensitivity (Zhou et al., 2021).

IGD is characterised by seeking psychological rewards and experiencing pleasure through engaging in online gaming activities (King et al., 2018; Pontes & Griffiths, 2014). This suggests that the reward system plays a unique role in the formation, development and maintenance of online gaming addiction. A PET study of internet gaming addiction found that prolonged engagement in online gaming leads to increased dopamine release in the ventral striatum of individuals with IGD (Tian et al., 2014). In other words, people with IGD persistently engage in online gaming because they derive positive emotional experiences from it (Cai et al., 2016; Tian et al., 2014). Internet gaming addicts exhibit a strong craving for game-related cues, which is a core feature and the most direct manifestation of addiction. The driving force behind addiction is not limited to sensitivity to immediate addictive stimuli such as game cues (Kim et al., 2021); it may also stem from a reduced response to natural rewards by the mesolimbic dopamine system, leading addicts to crave higher-level rewarding stimuli (Zheng et al., 2019). And neuroimaging studies have shown that the abnormal brain structure and function in individuals with Internet Gaming Disorder (IGD) are similar to those observed in other types of addiction, such as substance and behavioural addiction, indicating a dysfunction of the reward system in the brain (Petry et al., 2014; Volkow et al., 2016). The high levels of craving and motivation induced by addiction lead to different levels of activation in reward-related brain regions in IGD individuals, suggesting a greater tendency to seek rewards (Ko et al., 2012; Zhang et al., 2016). Furthermore, numerous studies have shown that compared to controls without IGD symptoms (RGU), individuals with IGD show more seeking behaviour towards different types of rewards (Kuss & Griffiths, 2012), including higher-level natural rewards such as money, power or praise (Luijten et al., 2017; Volkow et al., 2016). In addition, dopamine's effects on the neural system may contribute to addiction risk factors or pathological damage manifested as dysregulation in the processing of natural rewards in online gaming addicts (Han et al., 2007; Hou et al., 2012; Koeppe et al., 1998), which is crucial for assessing addictive behaviour and predicting its persistence (Koob, 2013).

The concept of natural rewards is not a homogeneous structure (Nestler & Carlezon Jr, 2006; Sescousse et al., 2013). It includes not only hedonic reinforcers such as money and material gains, but also social information with rewarding attributes such as social recognition, social belonging and social agency, as well as other types of stimuli such as food, drink and shelter (Nestler & Carlezon Jr, 2006; Ruff & Fehr, 2014; Sescousse et al., 2013). Monetary and social rewards are two important types of rewards in everyday life (Fehr & Camerer, 2007; Gunaydin et al., 2014). On the one hand, they share neural mechanisms at the brain level (Olino et al., 2015), with the midbrain dopamine system (Izuma et al., 2008) and the prefrontal cortex (Lin et al., 2012) being key regions for reward processing. This common mechanism is particularly evident in reward processing for both monetary and social rewards. On the other hand, different age groups show different behavioural characteristics in response to these two types of rewards (Goerlich et al., 2017; Gu et al., 2019; Morelli et al., 2015), with adults being more motivated by monetary incentives (Wang, Liu, & Shi, 2017; Wang, Wu, Wang, Li, Liu, et al., 2017; Wang, Wu, Wang, Li, Liu, Du, & Dong, 2017). Researchers have found that only the medial prefrontal cortex (mPFC) is activated by social reward stimuli alone (Izuma et al., 2008). The mPFC is associated with higher cognitive functions such as self-awareness (Johnson et al., 2002) and theory of mind processes (Gallagher & Frith, 2003), suggesting a close relationship between social reward and higher-level social cognition.

Previous studies have examined reward dysfunction in Internet Gaming Disorder (IGD) from the perspective of monetary rewards.

However, it is only in recent years that researchers have begun to focus on social reward dysfunction and its important role in addiction interventions. He et al. (2019) found that in tasks involving monetary rewards, individuals with IGD showed higher levels of risk-taking decisions than healthy individuals. They also showed weaker sensitivity to monetary punishments, but stronger sensitivity to monetary rewards. In contrast, Yao et al. (2020) found different results. They found no significant differences between IGD individuals and healthy individuals in their expectations and experiences of monetary rewards, but IGD individuals showed significantly less activation in brain regions associated with monetary punishment induced by monetary penalties compared to healthy individuals. Furthermore, compared to non-addicts, IGD individuals showed a greater delay discounting rate for money, suggesting that they find it difficult to consider sacrificing immediate small benefits for larger long-term gains (Wang, Liu, & Shi, 2017; Wang, Wu, Wang, Li, Liu, et al., 2017; Wang, Wu, Wang, Li, Liu, Du, & Dong, 2017). When comparing IGD participants to recreational gaming users (RGUs), Dong et al. (2017) found weaker activation in the left dorsolateral prefrontal cortex and bilateral inferior frontal gyrus in IGD participants. In addition, Wei et al. (2020) conducted a study on the social reward function of addicts and found that their experience of social rewards was significantly reduced. Parvaz et al. (2015) suggested that there is a dysregulation in the reward function of addicted individuals, leading to a loss of flexibility in reward processing. The dysregulation in expectancy violation processing may affect the individual's 'approach-avoidance' mechanism. Tobler et al. (2016), using MRI technology combined with a social reward task, found that compared to healthy individuals, addicts showed lower activation in the ventromedial prefrontal cortex, an area associated with social rewards, suggesting dysfunction in their experience of social rewards. Ouednow (2017) reviewed the impairment of both social reward and cognitive functions in substance abusers, concluding that these dysfunctions are important factors in the maintenance of addictive behaviours. Therefore, both social and monetary rewards are impaired in behavioural addicts. However, due to differences in stimulus selection methods, experimental designs and participant selection among researchers, research findings are not consistent. Therefore, this study will further investigate two aspects of natural rewards: monetary rewards and social rewards.

The monetary incentive delay (MID) paradigm, whose reliability has been demonstrated in numerous studies, is a classic paradigm for studying reward processing in both healthy and clinical populations (Gu et al., 2019; Wilson et al., 2018). The social incentive delay (SID) paradigm provides socially relevant information, such as friendly faces, instead of monetary feedback (Rademacher et al., 2010; Spreckelmeyer et al., 2009). In recent studies comparing the effects of monetary and social rewards on neural activity, researchers have begun to compare MID and SID data within the same sample (Distefano et al., 2018) to accurately assess the effects of these two types of rewards. This approach helps to mitigate biases arising from different paradigms and stimulus valences, and thus elucidates whether different patterns emerge in the processing of monetary versus social rewards. It also facilitates a deeper understanding of the neural underpinnings of reward processing and provides further empirical support for future research efforts in this area.

However, current research findings and interpretations of reward processing in adolescents with online gaming addiction are controversial, leaving uncertainty about potential differences in reward dysfunction. In light of this, the present study aims to investigate the reward processing mode of young online gaming addicts for two types of natural rewards, namely monetary and social rewards (Experiment 1). In addition, in many everyday situations, monetary and social rewards usually occur at the same time. Whether this pattern changes when more realistic mixed monetary and social rewards are processed (Experiment 2). Therefore, studying the natural reward processing patterns and characteristics (including monetary and social rewards) of adolescents with online gaming addiction may help us to fully understand the unique

characteristics associated with reward processing in this particular population. This has theoretical and clinical implications, as it highlights potential therapeutic targets.

1.1. Experiment 1

Differences in Sensitivity to Monetary and Social Rewards in Adolescents with IGD.

2. Methods

2.1. Participants

We recruited middle school students from a specific school in Gansu Province to participate in our research by administering game use surveys, the Self-Rating Depression Scale, the Self-Rating Anxiety Scale, the DSM-5 Internet Gaming Disorder diagnostic questionnaires, and the offline Internet Addiction Test (IAT) questionnaires. Of these, 43 individuals met the criteria for Internet Gaming Disorder, while 49 individuals were classified as recreational gamers (aged 12–16 years), see Table 1 for details. None of the participants had a history or current presence of neurological/psychiatric disorders or other emotional disorders such as depression and anxiety. They also had no other addictions, including substance abuse or dependence on alcohol and nicotine. Performance-based incentives were implemented for participants during the experimental paradigms.

Internet Gaming Disorder (IGD) participants were screened using the following criteria: (1) had an IAT score of ≥ 50 ; (2) fulfilled five or more of the nine DSM-V criteria; (3) playing the game continuously for at least 1 year; (4) playing online games > 8 h per week in the last year; and (5) gaming addiction is the main type of Internet addiction. Exclusion criteria: presence of mental illness such as depression or anxiety.

The inclusion criteria for Recreational Gaming Users (RGU) participants were as follows: (1) engaged in continuous gaming for at least one year; (2) had an IAT score ≤ 50 ; (3) Fewer than five of the nine DSM-5 criteria are met; (4) played online games for > 8 h per week in the past year; and (5) Participants verbally confirm that their gaming habits do not have a negative impact on learning, interpersonal relationships, daily life activities, family dynamics or career decisions. Exclusion criterion: Presence of mental illnesses such as depression or anxiety disorders.

Table 1
Demographic and behavioural characteristics of the two groups (mean & standard deviation).

Characteristics	IGD (<i>n</i> = 43)	RGU (<i>n</i> = 49)	IGD v. RGU
Gender (male/female)	24/19	19/30	$\chi^2 = 2.671, p = 1.02$
Age (year)	13.74 (0.69)	13.59 (0.71)	$t = 1.04, p = 0.300$
Duration of play	3.00 (1.21)	2.93 (1.65)	$t = 0.23, p = 0.816$
Week of gameplay	9.53 (4.66)	9.19 (2.36)	$t = 0.45, p = 0.654$
Self-reported game cravings	4.09 (2.71)	1.59 (1.68)	$t = 5.24, p < 0.001^{***}$
DSM-5 score	4.81 (1.82)	2.43 (1.74)	$t = 6.42, p < 0.001^{***}$
IAT score	54.33 (14.37)	35.76 (10.63)	$t = 7.10, p < 0.001^{***}$
SDS score	37.79 (5.85)	36.63 (6.10)	$t = 0.93, P = 0.357$
SAS score	34.47 (7.01)	32.92 (5.50)	$t = 1.18, P = 0.239$
RSAS score	15.56 (6.33)	12.94 (5.34)	$t = 2.15, P = 0.034^*$

Note. IGD, Internet Gaming Disorder; RGU, recreational game use. IAT, Internet addiction test; DSM-5, Diagnostic and Statistical Manual of Mental Disorders-5. SDS, Self-rating Depression Scale; SAS, Self-rating Anxiety Scale; RSAS, Social Anhedonia Scale. The IAT scores and DSM-5 scores of the IGD group were significantly higher than those of the RGU group, per the inclusion criteria. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, the same as below.

2.2. Procedure

The monetary incentive delay (MID) and social incentive delay (SID) are experimental paradigms used by Zhang et al. (2020) to study reward processing. The formal paradigm consisted of two MID and two SID blocks, with the sequence randomized across participants. In both the MID and SID blocks (Fig. 1), each trial began with a cue indicating a small ('I') or large ('II') potential reward for 500 ms, followed by a random delay ranging from 2 to 4 s. Participants were then required to quickly press the space button upon presentation of a white square target in order to receive the reward. If their reaction time was shorter than the duration of target presentation, it was labeled as a 'hit' trial; otherwise, it was labeled as a 'miss' trial. The presentation time of the target was initially set according to the average performance in the simple reaction time task (see above) for each participant and then was slightly adjusted (± 10 ms) in a trial-by-trial manner so as to keep the hit rate at approximately 50 % (Ait Oumeziane et al., 2017; Landes et al., 2018). After responding to the target, participants received either monetary or social feedback for 1 s during the consumption stage. Each MID or SID block consisted of 40 trials with small rewards and 40 trials with large rewards, resulting in a total of 320 trials for approximately 35 min, see Fig. 1 for details.

Regarding the MID blocks, participants were presented with a picture of ¥0.1 Chinese yuan (approximately US\$0.015) as a reward for successfully hitting the target, while they received a scrambled picture of ¥0.1 (indicating no monetary gain) when they missed the target in each trial of the small-reward condition. In contrast, in the large-reward condition, feedback consisted of a picture (or scrambled picture) of ¥1 (approximately \$0.15). As for the SID blocks, participants were shown an image depicting a person with a smiling face as positive feedback for hitting the target successfully and an image showing a person with a neutral facial expression when they missed that target in each trial of the small-reward condition. Conversely, in the large-reward condition, hits were rewarded with an image displaying a person who smiled and gave thumbs up while misses were associated with an image featuring someone with neutral facial expression. The researchers also invited fifty-nine additional adolescents who did not participate in the formal experiment to rate their preference and desire for these reward pictures on a 7-point scale.

2.3. Measures

The DSM-5 criteria for IGD include nine criteria, and each criterion represents a symptom associated with Internet gaming use, such as increased tolerance to gaming and abstinence syndrome. Participants were asked to indicate whether they met these criteria, as confirmed by a clinical interview with an experienced psychiatrist. Based on the study by Petry et al. (2014) and previous studies (Ko et al., 2014; Wang, Liu, & Shi, 2017; Wang, Wu, Wang, Li, Liu, et al., 2017; Wang, Wu, Wang, Li, Liu, Du, & Dong, 2017; Yao, Chen, et al., 2017; Yao, Liu, et al., 2017; Yuan et al., 2016), a cut-off point of meeting five DSM-5 criteria was proposed for the diagnosis of IGD.

Young's Internet Addiction Test (IAT) (Young, 1998) and the diagnostic criteria proposed by the DSM-5 (Petry et al., 2014) were used in the present study to classify IGD and RGU participants. The IAT has been validated as reliable for the diagnosis of Internet addiction (Dong et al., 2019; Dong & Potenza, 2016). It is a 20-item test on a 5-point scale (1-rarely, 5-always) that measures the level of problems associated with online Internet use, such as withdrawal, compulsive use, and other problems with work/school, sleep, or time management. Self-report scores above 50 indicate occasional or frequent Internet-related problems due to uncontrolled Internet use. Therefore, we used 50 as the cut-off score for the diagnosis of IGD, which has been widely used in studies on IGD (Cai et al., 2016; Dong et al., 2019; Dong & Potenza, 2016; Xing et al., 2014).

In addition, the Game Craving Scale (Cox et al., 2001), the Self-

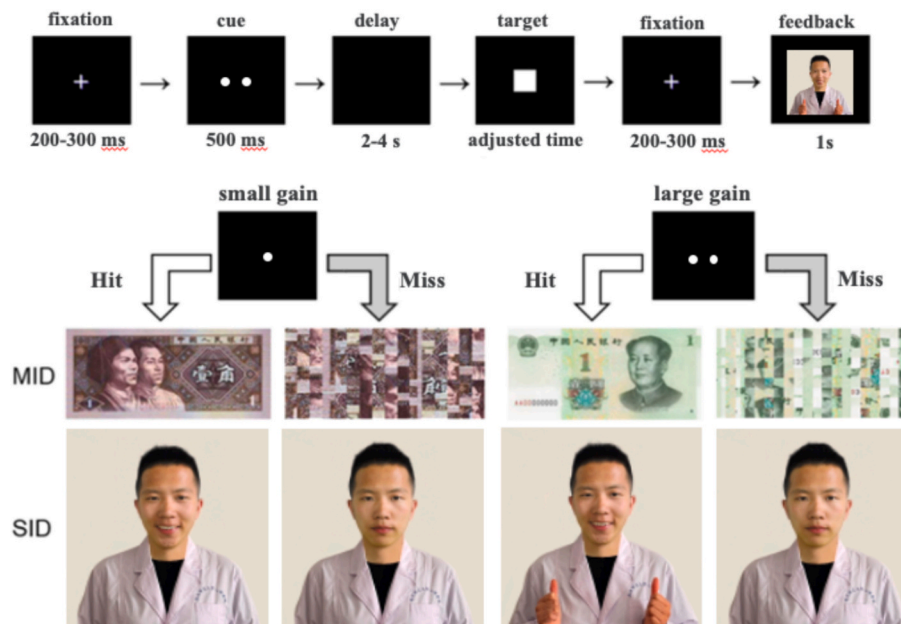


Fig. 1. Illustration of the experimental design. Upper panel: an exemplar trial of the social incentive delay (SID) paradigm. Lower panel: the correspondence between cues and feedback (for hits or misses) in the monetary incentive delay (MID) paradigms and SID paradigms.

Rating Depression Scale (SDS) (Zung, 1965), the Self-Rating Anxiety Scale (SAS) (Zung, 1971) and the Reward Sensitivity Absence Scale (RSAS) (Eckblad et al., 1982) serve as additional assessment and screening criteria.

2.4. Data analysis plan

Descriptive data are presented as mean \pm standard deviation unless otherwise stated. The significance level was set at 0.05. Repeated measures analysis of variance (ANOVA) was performed on hit rate, reaction time to hits, and interest in reward data. In Experiment 1, reward category (monetary vs social) and reward size (small vs large) were treated as within-subject factors, while group (IGD vs RGU) was treated as a between-subject factor. In Experiment 2, four levels of reward type and reward mix were treated as within-subject variables, with group (IGD vs. RGU) as a between-subject factor. Given that levels of depression (Stavrakaki & Vargo, 1986) and anxiety may also influence the processing of social and monetary rewards (Bishop & Gagne, 2018; Luo et al., 2014), we considered depression and anxiety scores (measured by SDS and SAS, respectively) as covariates. Significant interaction effects were analysed using simple effect models. Reward sensitivity refers to an individual's reactivity in the presence of reward cues or the withdrawal of punishment cues (Shao-Dan et al., 2009). Individuals with high reward sensitivity tend to experience more positive emotions and exhibit more reward-seeking behaviour in the presence of external reward information, while disregarding punishment information (Avila, 2001). Reward sensitivity is an important research topic in the field of addiction, as individuals with high reward sensitivity are more likely to seek out rewarding stimuli to satisfy their psychological needs, often overlooking the impact of punishment information on themselves. We are currently investigating differences in sensitivity to two types of reward (monetary and social) in online game addicts by analysing correct feedback (hit rate), speed of response (hit reaction time) and preference for rewards (level of interest) across reward types using behavioural data from the MID and SID tasks.

3. Results

3.1. Reaction time (RT)

RT was averaged across hit trials in each condition (He et al., 2019). A three-way analysis of variance (ANOVA) was performed on reaction time in the paradigm, with the factors being participant group (IGD, RGU), reward type (monetary reward, social reward) and reward size (low reward, high reward). The descriptive statistical analysis is shown in Table 2 and the analysis of variance is shown in Table 3. The results showed that participant group had no significant effect on the main effect ($F(1, 90) = 1.84, p = 0.179, \eta^2 = 0.02$). Similarly, there was no significant main effect of reward type ($F(1, 90) = 1.01, p = 0.317, \eta^2 = 0.011$). Furthermore, the main effect of reward size was also not significant ($F(1, 90) = 0.01, p = 0.917, \eta^2 < 0.001$).

The interaction between reward type and group membership yielded a significant result ($F(1, 90) = 22.83, p < 0.001, \eta^2 = 0.202$). Further analysis of simple effects revealed that adolescents diagnosed with Internet Gaming Disorder (IGD) had significantly shorter reaction times to monetary rewards compared to the Regular Gaming User (RGU) group ($F(1, 90) = 8.73, p = 0.004, \eta^2 = 0.088$; IGD vs. RGU: 108.04 ± 2.99 vs. 120.16 ± 2.80). However, there were no statistically significant differences in reaction times to social rewards between the IGD and RGU groups ($F(1,90) = 0.54, p = 0.088, \eta^2 = 0.006$; IGD vs. RGU: 116.95 ± 2.59 vs. 114.35 ± 2.42). Adolescents with IGD showed significantly faster reaction times to monetary rewards compared to social rewards ($F(1,90) = 15.71, p < 0.001, \eta^2 = 0.149$; monetary vs. social reward: 108.04 ± 2.99 vs. 116.95 ± 2.59), whereas the RGU group showed significantly faster reaction times to social rewards than monetary rewards ($F(1,90) = 7.606, p = 0.007, \eta^2 = 0.078$; Monetary Reward vs. Social Reward: 117.62 ± 4.16 vs. 114.12 ± 3.65). See Fig. 2 for more details.

The interaction effect between reward type and reward size approached statistical significance ($F(1, 90) = 3.81, p = 0.054, \eta^2 = 0.041$). However, the interaction between reward size and participant group was not significant ($F(1, 90) = 0.10, p = 0.756, \eta^2 = 0.041$), nor was the three-way interaction between reward type, reward size, and participant group ($F(1, 90) = 0.23, p = 0.631, \eta^2 = 0.03$).

Table 2

Descriptive statistics of reaction time and hit rate for both groups of subjects in different paradigms.

	Reaction time (ms) (<i>M</i> ± <i>SD</i>)		Hit rate (%) (<i>M</i> ± <i>SD</i>)	
	IGD (<i>n</i> = 43)	RGU (<i>n</i> = 49)	IGD (<i>n</i> = 43)	RGU (<i>n</i> = 49)
Low monetary rewards	108.62 ± 23.38	120.65 ± 15.40	46.23 ± 4.75	43.76 ± 4.39
High monetary rewards	107.46 ± 23.96	119.66 ± 17.16	46.79 ± 4.58	43.98 ± 4.79
Low social reward	116.11 ± 15.70	113.98 ± 17.96	45.42 ± 3.42	43.88 ± 5.08
High social reward	117.79 ± 16.14	114.71 ± 19.33	45.65 ± 3.41	43.78 ± 5.50

Note. IGD, Internet Gaming Disorder; RGU, recreational game use.

Table 3

ANOVA results of reaction time and hit rate for both groups of subjects in different paradigms.

	<i>F</i>	<i>p</i>	η^2
Reaction time			
Group of subjects	1.84	0.179	0.020
Type of Reward	1.01	0.317	0.011
Magnitude of reward	0.01	0.917	<0.001
Type of Reward × Group of subjects	22.83	<0.001	0.202
Magnitude of reward × Group of subjects	0.10	0.756	0.041
Type of Reward × Magnitude of reward	3.81	0.054	0.041
Type of Reward × Magnitude of reward × Group of subjects	0.23	0.631	0.003
Hit rate			
Group of subjects	6.16	0.015	0.064
Type of Reward	2.79	0.099	0.030
Magnitude of reward	1.59	0.211	0.017
Type of Reward × Group of subjects	2.36	0.128	0.026
Magnitude of reward × Group of subjects	0.85	0.359	0.009
Type of Reward × Magnitude of reward	1.55	0.216	0.017
Type of Reward × Magnitude of reward × Group of subjects	<0.01	0.999	<0.001
Level of interest			
Group of subjects	2.76	0.100	0.030
Type of Reward	12.48	0.001	0.122
Type of Reward × Group of subjects	25.09	<0.001	0.218

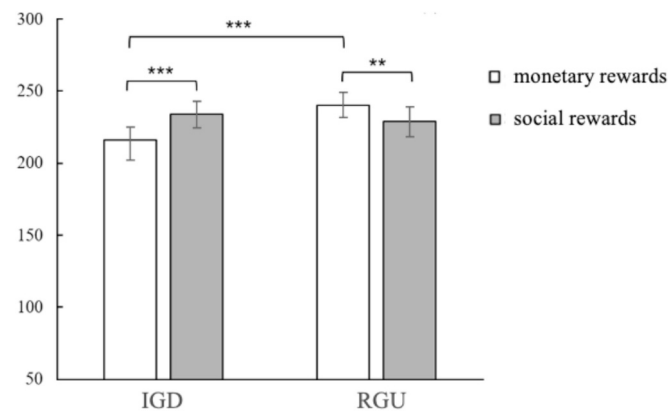


Fig. 2. Reaction times of the two groups of subjects in different paradigm types.

3.2. Hit rate

A repeated measures analysis of variance was performed on the hit rate, with a 2 (participant group: IGD, RGU) × 2 reward type (monetary reward, social reward) × reward size (low reward, high reward) three-factorial design. The descriptive statistical analysis is shown in Table 2, and the analysis of variance is shown in Table 3.

The results showed that the main effect was significant ($F(1, 90) = 6.16, p = 0.015, \eta^2 = 0.064$). The main effect of reward type was not significant ($F(1, 90) = 2.79, p = 0.099, \eta^2 = 0.030$). The main effect of

reward amplitude was not significant ($F(1, 90) = 1.59, p = 0.211, \eta^2 = 0.017$). Reward type × subject group ($F(1, 90) = 2.36, p = 0.128, \eta^2 = 0.026$), reward range × subject group ($F(1, 90) = 0.85, p = 0.359, \eta^2 = 0.009$), reward type × reward range ($F(1, 90) < 0.001, p = 0.216, \eta^2 = 0.017$), reward type × reward size × group interaction ($F(1, 90) < 0.001, p = 0.999, \eta^2 < 0.001$) were not significant.

3.3. Level of interest

The level of interest was examined using a 2 (participant group: IGD, RGU) × 2 reward type (monetary reward, social reward) repeated measures analysis of variance. The descriptive statistical analysis is shown in Table 2; and the analysis of variance is shown in Table 3. The main effect of experimental group did not reach statistical significance ($F(1, 90) = 2.76, p = 0.1, \eta^2 = 0.05$), while the main effect of reward paradigm type showed significant results ($F(1, 90) = 12.48, p = 0.001, \eta^2 = 0.122$).

A significant interaction between reward paradigm type and participant group was observed ($F(1, 90) = 25.09, p < 0.001, \eta^2 = 0.218$). Further analysis of simple effects revealed that adolescents with Internet Gaming Disorder (IGD) showed significantly less interest in the social reward delay paradigm compared to the Regular Gamers' Use (RGU) group ($F(1, 90) = 14.70, p < 0.001, \eta^2 = 0.14$; IGD vs. RGU = 4.21 ± 0.28 vs. 5.65 ± 0.26). However, there was no significant difference in interest between adolescents with IGD and RGU in the monetary reward delay paradigm ($F(1, 90) = 0.929, p = 0.338, \eta^2 = 0.01$; IGD vs. RGU = 5.74 ± 0.27 vs. 5.39 ± 0.25 , see Fig. 3).

Compared to delay paradigms with social rewards, adolescents diagnosed with Internet Gaming Disorder (IGD) showed a significantly higher level of interest in delay paradigms with monetary rewards ($F(1, 90) = 34.24, p < 0.001, \eta^2 = 0.276$; monetary reward delay paradigm vs. social reward delay paradigm = 5.74 ± 0.27 vs. 4.21 ± 0.28). However, there was no significant difference in the level of interest among adolescents experiencing Reward-Gain-Urging (RGU) for both delay paradigms with monetary and social rewards ($F(1, 90) = 1.17, p = 0.283, \eta^2 = 0.013$; monetary reward delay paradigm vs. social reward delay paradigm = 5.39 ± 0.25 vs. 5.65 ± 0.26).

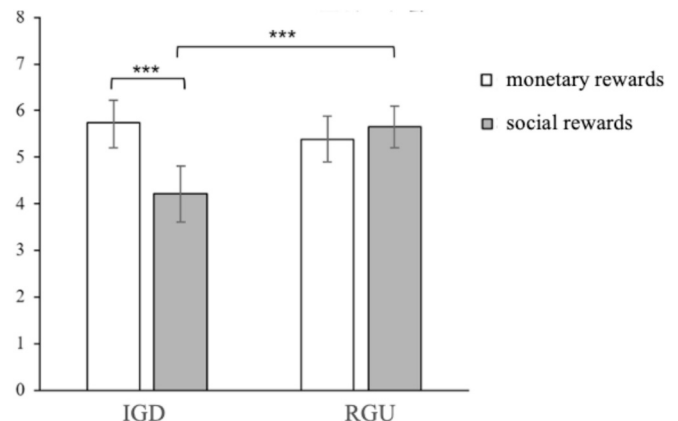


Fig. 3. The level of interest in money and social rewards in both groups.

4. Discussion

In Experiment 1, we observed preliminary evidence that adolescent IGD is more sensitive to monetary rewards than RGU, and that both adolescent IGD and RGU are more sensitive to monetary rewards than social rewards. Studies investigating the neural processing of monetary and social stimuli have produced conflicting results. On the one hand, some fMRI studies support the idea that non-social stimuli (such as money) and social reward stimuli share common neural mechanisms, including the mesolimbic dopamine system and prefrontal cortex (Izuma et al., 2008; Lin et al., 2012; Olino et al., 2015). On the other hand, there is evidence for differences in the neural processing mechanisms between these two types of stimuli (Beesdo et al., 2007). This suggests that the encoding of social rewards may also involve brain regions associated with the potential for social processing, such as the temporo-parietal junction (Liu et al., 2020; Strombach et al., 2015). The results of Experiment 1 revealed differences in responsiveness to monetary and social rewards between adolescents diagnosed with Internet Gaming Disorder (IGD) and those engaged in Regular Gaming Use (RGU), supporting the existence of different neural processing mechanisms underlying these two types of rewards. Interestingly, RGUs' subjective ratings of interest in the monetary reward paradigm did not differ from those in the social reward paradigm. However, the behavioural results showed that RGUs were more sensitive to social reward than to monetary reward. This may be due to various defensive behaviours that adolescents exhibit when faced with psychological confusion, such as reverse psychology, which serves as a means of self-defence and self-protection during adolescence (Donnell & Walter, 2010). Furthermore, this developmental stage is characterised by an increase in time spent with peers, which peaks in mid-adolescence (Lam et al., 2014). Peers play a central role in adolescents' development, as they strive for conformity to maintain relationships with them (Knoll et al., 2015), while at the same time becoming more attentive and sensitive to societal evaluations within themselves, despite resistance from parents and teachers (Kessler et al., 2017). Importantly, healthy individuals are motivated to participate in social interactions and seek social approval because it has motivational value for them (Chevallier et al., 2012). Conversely, a lack of motivation to engage in social interaction is indicative of impaired social reward processing (Aldridge-Waddon et al., 2020). The rewarding nature of social interaction plays a crucial role in the development and maintenance of social relationships. From this perspective, it can be further explained that adolescents tend to find normal development more socially rewarding (Kessler et al., 2017).

Although experiment 1 again confirmed the differences in processing patterns of monetary and social rewards between online game addicts and healthy individuals (Dong et al., 2017; Lei et al., 2020; Li et al., 2020). However, real-life rewards are often not presented in isolation (Experiment 1). When the two are presented together (Experiment 2), do adolescent IGD still have a preference for monetary rewards, and does this preference differ from that of healthy individuals? In addition, do financial and social rewards presented at the same time influence each other? Is this effect different in adolescents with IGD and RGU? The four types of mixed rewards in Experiment 2 were created by combining and categorising the two conditions: low-mixed reward (low monetary reward + low social reward), medium-mixed reward 1 (low monetary reward + high social reward), medium-mixed reward 2 (high monetary reward + low social reward) and high-mixed reward (high monetary reward + high social reward) for further investigation.

4.1. Experiment 2

The Processing Characteristics of a Mixed Model of Monetary and Social Rewards in Adolescents with IGD.

5. Methods

5.1. Participants

Using surveys, the Depression Self-Rating Scale, the Anxiety Self-Rating Scale, the DSM-5 Internet Gaming Disorder Diagnosis Questionnaire, and the Offline Internet Addiction Test (IAT) questionnaire, we again recruited middle school students from a school in Gansu Province as research participants. Among them, 44 individuals met the diagnostic criteria for Internet Gaming Disorder, while 43 were classified as recreational gamers (aged 12–16 years), as shown in Table 4.

5.2. Procedure

The second experiment used an adapted mixed reward delay paradigm: building on the traditional MID and SID paradigms, both monetary and social rewards were presented simultaneously as a combined monetary-social reward (as shown in Fig. 4).

The revised MID and SID paradigms include different types and levels of reward. The rewarded outcomes following a hit include the following scenarios: low mixed reward (low monetary reward + low social reward), moderate mixed reward 1 (low monetary reward + high social reward), moderate mixed reward 2 (high monetary reward + low social reward), and high mixed reward (high monetary reward + high social reward). In the case of a miss, a neutral mixed-reward picture is presented, consisting of corresponding randomly ordered pictures representing monetary rewards and neutral social rewards. Cueing cues consist of two sets of dots positioned on the left and right of the centre of the screen. The number of dots on the left side indicates the magnitude of the monetary reward (1 dot represents low magnitude, whereas 2 dots represent high magnitude), whereas the number of dots on the right side indicates the magnitude of the social reward (1 dot represents low magnitude, whereas 2 dots represent high magnitude).

6. Results

6.1. Reaction time (RT)

As shown in Fig. 5, a two-factor repeated measures analysis of

Table 4

Demographic and behavioural characteristics of the two groups (mean & standard deviation).

Characteristics	IGD (n = 44)	RGU (n = 43)	IGD v. RGU
Gender (male/female)	23/21	17/26	$\chi^2 = 1.421, p = 0.233$
Age (year)	13.55 ± 0.70	13.79 ± 0.68	$t = -1.67, p = 0.099$
Duration of play	2.88 ± 1.13	2.73 ± 0.79	$t = 0.68, p = 0.499$
Week of gameplay	9.13 ± 2.62	9.26 ± 1.88	$t = -0.28, p = 0.779$
Self-reported game cravings	4.32 ± 3.49	1.79 ± 2.32	$t = 3.97, p < 0.001^{***}$
DSM-5 score	5.66 ± 1.01	2.00 ± 1.27	$t = 14.87, p < 0.001^{***}$
IAT score	57.00 ± 6.04	34.91 ± 8.75	$t = 13.68, p < 0.001^{***}$
SDS score	45.61 ± 6.46	42.40 ± 7.47	$t = 2.15, p < 0.034^*$
SAS score	38.45 ± 8.81	36.72 ± 6.40	$t = 1.05, p < 0.298$
RSAS score	17.48 ± 7.13	14.67 ± 5.67	$t = 2.03, p < 0.046^*$

Note. IGD, Internet Gaming Disorder; RGU, recreational game use. IAT, Internet addiction test; DSM-5, Diagnostic and Statistical Manual of Mental Disorders-5. SDS, Self-rating Depression Scale; SAS, Self-rating Anxiety Scale; RSAS, Social Anhedonia Scale. The IAT scores and DSM-5 scores of the IGD group were significantly higher than those of the RGU group, per the inclusion criteria. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, the same as below.

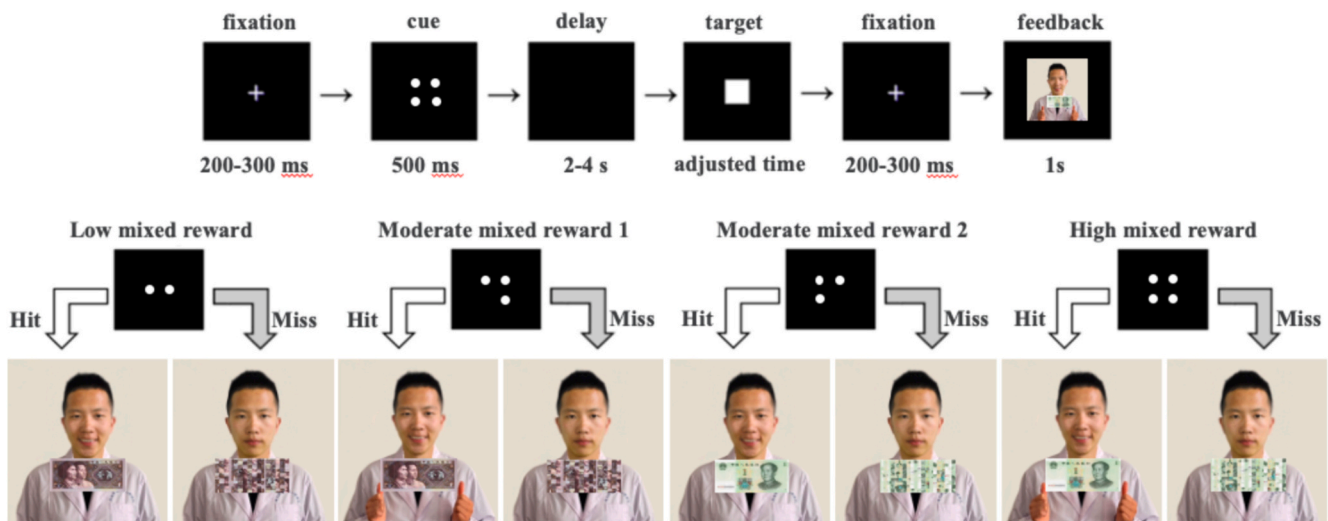


Fig. 4. Flow chart of Experiment 2.

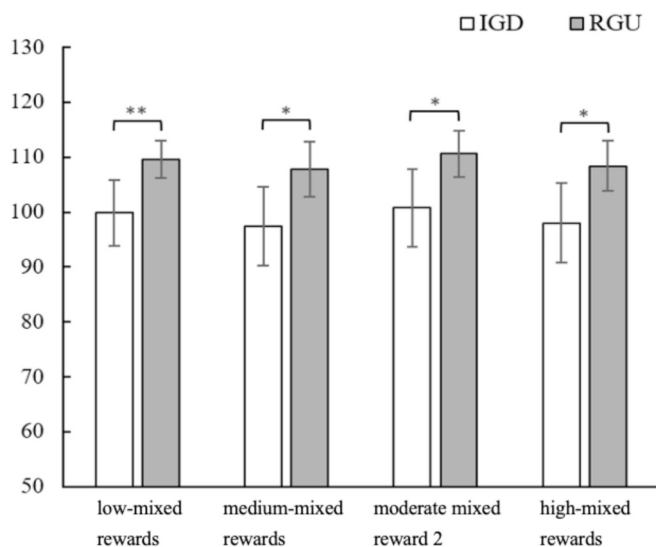


Fig. 5. Reaction times of the two groups of subjects to different mixed rewards.

variance (ANOVA) was conducted on reaction time, with 2 participant groups (IGD and RGU) and 4 reward types (low mixed reward, moderate mixed reward 1, moderate mixed reward 2, high mixed reward). The descriptive statistical analysis is shown in Table 5; and the analysis of variance is shown in Table 6. The main effect of experimental group was found to be significant ($F(1, 85) = 6.52, p = 0.012, \eta^2 = 0.071$), as was the main effect of reward type ($F(1, 85) = 3.13, p = 0.036, \eta^2 = 0.035$). Further post-hoc tests revealed that adolescents diagnosed with Internet Gaming Disorder (IGD) had significantly shorter reaction times to low-mixed rewards compared to adolescents with Regular Gaming Use (RGU) ($F(1, 85) = 7.43, p = 0.008, \eta^2 = 0.08$; IGD vs. RGU: 99.84 ± 20.57 vs. 109.59 ± 11.43). Adolescents with IGD also showed significantly shorter reaction times to moderately mixed rewards than to those with RGU ($F(1,85) = 5.52, p = 0.021, \eta^2 = 0.061$; IGD vs. RGU: 97.41 ± 23.97 vs. 107.85 ± 16.73); the reaction time of adolescents with IGD to moderately mixed reward 2 was significantly shorter than that of adolescents with RGU ($F(1,85) = 5.39, p = 0.023, \eta^2 = 0.006$; IGD group vs. RGU: 100.72 ± 24.12 vs. 110.57 ± 13.97); Adolescents diagnosed with IGD also showed significantly shorter reaction times to highly mixed rewards compared to those with RGU ($F(1,85) = 5.54, p = 0.021, \eta^2 = 0.061$; IGD vs. RGU: 98.02 ± 24.63 vs. 108.39 ± 15.28). There was no

Table 5

Descriptive statistical results of reaction times and hit rates for both groups of subjects in the mixed reward paradigm.

	Reaction time (ms) (<i>M</i> ± <i>SD</i>)		Hit rate (%) (<i>M</i> ± <i>SD</i>)	
	IGD (<i>n</i> = 44)	RGU (<i>n</i> = 43)	IGD (<i>n</i> = 44)	RGU (<i>n</i> = 43)
Low mixed reward	99.84 ± 20.57	109.59 ± 11.43	46.08 ± 7.25	47.47 ± 4.77
Medium mixed reward 1	97.41 ± 23.97	107.85 ± 16.73	45.86 ± 8.30	47.12 ± 3.53
Medium mixed reward 2	100.73 ± 24.12	110.57 ± 13.97	46.59 ± 7.32	47.61 ± 5.21
High mixed reward	98.02 ± 24.63	108.39 ± 15.28	46.06 ± 7.84	47.78 ± 4.71

Note. IGD, Internet Gaming Disorder; RGU, recreational game use.

Table 6

ANOVA results for reaction time and hit rate in the mixed reward paradigm for both groups of subjects.

	<i>F</i>	<i>p</i>	η^2
Reaction time			
Group of subjects	6.52	0.012*	0.071
Type of Reward	3.13	0.036*	0.035
Type of Reward × Group of subjects	0.05	0.972	0.001
Hit rate			
Group of subjects	0.10	0.749	0.001
Type of Reward	1.67	0.178	0.019
Type of Reward × Group of subjects	0.09	0.958	0.001

significant interaction between reward type and participant group ($F(1,85) = 0.05, p = 0.972, \eta^2 = 0.001$).

6.2. Hit rate

A two-factor repeated measures analysis of variance (ANOVA) was performed to examine hit rates, controlling for participant group (IGD, RGU) and reward type (low mixed reward, moderate mixed reward 1, moderate mixed reward 2, high mixed reward). The descriptive

statistical analysis is shown in Table 5, and the analysis of variance is shown in Table 6. The results indicated that there were no significant main effects for participant group ($F(1, 85) = 0.103, p = 0.749, \eta^2 = 0.001$) or for reward type ($F(1, 85) = 1.672, p = 0.178, \eta^2 = 0.019$). Furthermore, there was no significant interaction between reward type and participant group ($F(1, 85) = 0.09, p = 0.958, \eta^2 = 0.001$).

6.3. Level of interest

By using random sampling methods and ensuring the homogeneity of the participant samples in terms of demographic and clinical characteristics, a comparative analysis is made between two groups of participants from Experiment 1 and Experiment 2 in terms of their level of interest in the experimental paradigms. According to the independent samples *t*-test (see Table 7), there was no statistically significant difference in the level of interest in delayed monetary reward paradigms and mixed reward delay paradigms between adolescents diagnosed with Internet Gaming Disorder (IGD) and those classified as Regular Gaming Users (RGU). Furthermore, adolescents with IGD showed significantly less interest in social reward delay paradigms compared to mixed reward delay paradigms. However, no significant difference was found between interest levels in social reward delay and mixed reward delay paradigms among adolescents with RGU.

7. Discussion

In Experiment 2, using the MID and SID paradigms, four different combinations of mixed monetary and social reward types were presented simultaneously. The results showed no significant differences in sensitivity to monetary and social rewards between the adolescent IGD and RGU groups as observed in Experiment 1. These results suggest that when presented in a mixed format, the processing patterns of monetary and social rewards for adolescent IGD differ from those observed when they are presented separately.

Previous studies have shown that people with addictions, including those addicted to online gaming, experience an impairment in the brain's reward system as a result of prolonged exposure to addictive stimuli. This is characterised by increased sensitivity to addiction-related rewards and decreased sensitivity to natural rewards (Nestor et al., 2010; Robinson & Berridge, 1993). However, Experiment 2 of this study found that, compared to adolescent recreational gamers (RGUs), individuals diagnosed with Internet Gaming Disorder (IGD) exhibited heightened responsivity to natural rewards. In the context of gaming, monetary incentives can be used to acquire virtual items within the game, thereby associating monetary rewards not only with natural rewards, but also with game-related rewards. In addition, research on monetary incentives has shown that individuals suffering from Internet gaming addiction show increased responsivity to such incentives. This is evidenced by increased reward-seeking behaviour during the anticipation and outcome monitoring stages of reward processing and increased

Table 7

Level of interest in monetary, social and mixed rewards (Experiment 1, Experiment 2).

	Monetary incentive delay (MID) paradigm	Mixed reward delay paradigm	t(85)	p
IGD	5.74 ± 1.79(n = 43)	5.55 ± 2.07(n = 44)	0.48	0.634
RGU	5.39 ± 1.96(n = 49)	5.93 ± 1.37(n = 43)	-1.64	0.105
	Social incentive delay (SID) paradigm	Mixed reward delay paradigm		
IGD	4.21 ± 1.98(n = 43)	5.55 ± 2.07(n = 44)	-3.07***	0.003
RGU	5.65 ± 1.63(n = 49)	5.93 ± 1.37(n = 43)	-0.877	0.383

Note. IGD, Internet Gaming Disorder; RGU, recreational game use.

activation levels in brain regions associated with reward processing, such as the prefrontal cortex, nucleus accumbens (NAcc) and caudate nucleus (Dong et al., 2013; Wang et al., 2021). The high sensitivity of adolescent IGD to monetary reward may be the reason that promotes motivation to hit correctly. In addition, the difficulty of the experimental paradigm increases, which also enhances the performance of the overall paradigm. Even in specific situations, addicts are still highly sensitive to monetary rewards (Wang et al., 2021), and their reaction time is significantly shorter than that of adolescent RGUs, which may account for the results of this experiment. The results of Experiment 1 showed no significant difference in self-reported interest levels between monetary and social rewards. Furthermore, combining these two types of reward did not produce the expected result of $1 + 1 > 2$; instead, self-reported levels of liking remained the same as when each reward was presented separately. This suggests that healthy adolescents without Internet gaming addiction perceive both monetary and social rewards as equally important forms of reinforcement. Whether presented separately or in combination, both types represent intrinsic rewards rather than a combination of two different stimuli.

8. General discussion

In this study, we focused on adolescents with Internet Gaming Disorder (IGD) and used the Monetary Incentive Delay (MID), Social Incentive Delay (SID), and an adapted Money-Social Mixed Incentive Delay paradigms to examine the reward processing patterns of IGD adolescents to two types of natural rewards: monetary rewards and social rewards. In addition, we investigated whether these patterns would change when processing more realistic money-social mixed rewards. The results showed that IGD adolescents showed increased sensitivity to monetary rewards compared to RGU, while their sensitivity to social rewards remained constant. Furthermore, IGD adolescents showed greater responsiveness to monetary than to social incentives, whereas RGU adolescents showed greater sensitivity to social than to monetary incentives (Experiment 1). Notably, IGD adolescents' reaction times to the four types of mixed incentives were significantly shorter than those of RGU adolescents; however, there were no within-group differences in sensitivity to these mixed incentives. These results suggest that both monetary and social incentives, when presented as a combination of different reward types, elicit different reward processing patterns in IGD adolescents than when presented individually (Experiment 2).

8.1. Processing characteristics for different rewards and mixed rewards

First, this study shows that, compared with adolescent recreational gamers (RGUs), individuals with Internet Gaming Disorder (IGD) exhibit heightened sensitivity to monetary rewards, whereas there is no significant difference between the two groups in sensitivity to social rewards. The processing characteristics of monetary rewards in individuals with Internet gaming addiction are inconsistent. Results from one fMRI study suggest reduced activation in the striatum during monetary reward acquisition in individuals with IGD compared to RGU (Dong et al., 2017). However, another study found that individuals with Internet gaming addiction show increased responsivity to monetary rewards (Dong et al., 2013; Wang et al., 2021). Following consecutive wins in a card guessing paradigm, brain regions involved in reward processing, such as the prefrontal cortex, show increased activity in these individuals (Dong et al., 2013). Individuals with Internet gaming addiction show increased reward-seeking behaviour during both the anticipation and outcome monitoring stages of reward processing, accompanied by increased activation in the nucleus accumbens and caudate nucleus. In other words, they show an enhanced response to monetary rewards (Wang et al., 2021). The results of this study support the conclusion that adolescents with IGD have an increased sensitivity to monetary rewards.

In addition, the research suggests that interest levels were self-

reported by participants at the end of the experimental paradigms. Notably, subjective interest ratings in monetary reward paradigms did not differ from those in social reward paradigms in adolescents with Reward Related Genetic Variation (RGU), despite their behavioural responses in Experiment 1 suggesting greater sensitivity to social rewards than monetary rewards. This may be because healthy individuals are motivated to participate in social interactions and seek social approval because of its motivational value to them (Chevallier et al., 2012). Adolescence is a critical developmental period characterised by rapid physical and psychological changes, including hormonal increases and shifts in social-emotional tendencies, such as increased independence and desire for social interaction (Peper & Dahl, 2013). It is also an important time for behavioural adjustments and significant changes in reward sensitivity.

Studies have shown an inverted U-shaped pattern in adolescents' self-reported reward-seeking, with a peak between the ages of 12 and 15 (Crone & Dahl, 2012; Steinberg et al., 2009). During adolescence, when faced with significant psychological confusion, individuals often exhibit various self-protective and defensive behaviours, including the use of reverse psychology as an effective coping mechanism for personal growth (Donnell & Walter, 2010). Furthermore, this developmental stage is characterised by a gradual increase in peer interaction, reaching its peak in mid-adolescence (Lam et al., 2014). Peers play a crucial role in adolescent development, requiring conformity in order to maintain social connections (Knoll et al., 2015). However, while rebelling against parental and educational authority figures, adolescents simultaneously experience increased anxiety and sensitivity to social evaluation (Kessler et al., 2017).

8.2. Differences in sensitivity to monetary and social rewards

Firstly, this study found that adolescents diagnosed with Internet Gaming Disorder (IGD) show an increased sensitivity to monetary rewards as opposed to social rewards, whereas adolescents with Restricted Gaming Use (RGU) show a greater responsiveness to social rewards as opposed to monetary incentives. The results of both experiments were consistent and convergent. In a study of individuals with mental disorders, researchers specifically isolated social rewards from non-social rewards (such as monetary incentives) for the purposes of the study, and found that individuals diagnosed with schizophrenia demonstrated increased neural sensitivity to social rewards compared to non-social stimuli (Lee et al., 2019). Furthermore, individuals who experience a lack of social pleasure in schizophrenia exhibit domain-specific deficits in the processing of social emotional information outside of the realm of monetary reward. It is part of human nature to have an innate desire for interpersonal interaction and belonging, although this varies considerably between individuals. However, individuals suffering from social anhedonia are thought to lack the motivation to seek out social connections and derive satisfaction from social incentives (Xie et al., 2014). Research has shown that when presented with socially relevant and irrelevant information in the same context, humans - being naturally sociable creatures - tend to pay more attention to the former (Frazier et al., 2017; Mesoudi et al., 2006). For individuals addicted to online virtual gaming worlds, their diminishing capacity for effective real-life social interaction gradually undermines their propensity to assign value and receive positive evaluations through interpersonal interactions.

In this study, individuals with Internet Gaming Disorder (IGD) gradually develop a reduced sensitivity to social rewards, which may affect their ability to process such rewards. Research on the neural processing of monetary and social stimuli is conflicting. On the one hand, some fMRI studies support the idea that non-social and social reward stimuli share common neural mechanisms, including the mesolimbic dopamine system and prefrontal cortex (Izuma et al., 2008; Lin et al., 2012; Olinio et al., 2015). On the other hand, other studies have found distinct neural networks involved in the processing of monetary

and social rewards (Chan et al., 2016; Rademacher et al., 2010), suggesting different mechanisms for the neural processing of these two types of stimuli (Beesdo et al., 2007). Different brain regions show different activation responses during different stages of reward processing for monetary and social stimuli. In the anticipatory phase of delayed monetary paradigms, activation was observed in the striatum and insular cortex; however, no corresponding brain region activation was found in this phase compared to social rewards. Similarly, during the reward completion phase, monetary rewards were associated with activation in the medial prefrontal cortex, whereas social rewards were associated with activation in the posterior insula and frontal lobe (Chan et al., 2016). The results of Experiment 1 also revealed differences in sensitivity to monetary and social rewards between adolescents with Internet Gaming Disorder (IGD) and Recreational Game Use (RGU), supporting previous research that has demonstrated different neural processing mechanisms for these two types of stimuli. Specifically, monetary reward stimuli are thought to activate the striatum, insula and medial prefrontal cortex, whereas social rewards are associated with activation in the posterior insula and frontal lobe (Chan et al., 2016).

The research also confirms that individuals with Internet Gaming Disorder (IGD) have shorter reaction times to four types of mixed rewards compared to adolescents with recreational gaming use (RGU). Prolonged exposure to addictive stimuli can damage the brain's reward system in addicted individuals, including those addicted to online gaming. This results in increased sensitivity to addiction-related rewards and decreased sensitivity to natural rewards (Nestor et al., 2010; Robinson & Berridge, 1993). However, the results of Experiment 2 of this study suggest that IGD exhibit greater sensitivity to natural rewards compared to adolescent RGU. For gamers, the act of 'recharging' may blur the distinction between monetary and natural rewards as they acquire attributes associated with game-related rewards. In addition, some adolescents planned to use their compensation from this experiment for in-game purchases.

According to incentive sensitisation theory, engagement in gaming during adolescence influences the reward system through game-specific stimuli, thereby increasing sensitivity to addiction-related rewards (Robinson & Berridge, 2008). The association between monetary rewards and game-related rewards may explain why adolescent online gaming addicts show greater sensitivity and interest in game-related monetary rewards compared to natural (non-game-related) social rewards. Research on monetary rewards has shown that individuals addicted to online gaming exhibit heightened responsivity to such incentives, as evidenced by increased reward-seeking behaviour during both the anticipation and outcome monitoring stages of reward processing. In addition, greater activation is observed in brain regions involved in reward processing, including the prefrontal cortex, nucleus accumbens (NAcc), and caudate nucleus (Dong et al., 2013; Wang et al., 2021).

Finally, some limitations of this study and potential future directions should be noted. Future studies can increase clinical samples or combine ERP, fMRI, and other technologies to examine the effects of different dimensions of social reward on reward sensitivity in adolescent online game addicts. In addition, longitudinal studies can be conducted with individuals at different stages of online gaming addiction, or an aggregate crossover design can be used. These approaches aim to further explore the cognitive neural basis and psychological mechanisms underlying impaired social functioning in relation to abnormal reward processing and online gaming addiction. The aim is to more accurately reflect the cognitive and neural behaviour of online gaming addicts, and to provide better prevention and intervention measures for both society and individuals.

9. Conclusion

The main aim of this study is to examine differences in the processing of monetary and social rewards in adolescent online gaming addicts.

Compared to adolescents with RGU, adolescents with IGD have an impaired ability to process monetary rewards. In addition, the processing patterns of monetary and social rewards are abnormal in IGD. Adolescents with IGD are more sensitive to monetary rewards than to social rewards, whereas adolescents with RGU are more sensitive to social rewards than to monetary rewards. This also suggests that monetary and social rewards share a neural response mechanism at the neural level. The simultaneous presentation of different types of reward will influence the reward processing pattern in adolescents with IGD. These findings enhance our understanding of IGD-related misbehaviour and help to identify unique changes that occur in adolescents' online gaming addiction behaviour, thereby promoting more targeted psychological interventions.

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Institutional review board statement

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Northwest Normal University. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

CRediT authorship contribution statement

Yuetan Wang: Writing – original draft, Conceptualization. **Yiyao Li:** Data curation, Conceptualization. **Beichen Liu:** Data curation. **Xuan Zhao:** Data curation. **Xicong Geng:** Methodology. **Wenjing Zhu:** Formal analysis. **Xiaobin Ding:** Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The data that has been used is confidential.

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