

Males are more sensitive to reward and less sensitive to loss than females among people with internet gaming disorder: fMRI evidence from a card-guessing task

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Abstract

Background Many studies have found an interesting issue in the Internet gaming disorder (IGD): males are always observed to be the majority. Explore why males are more vulnerable to IGD than females could help in understanding the underlying neural mechanism of IGD.

Methods Data from functional magnetic resonance imaging (fMRI) were collected from 111 subjects (IGD: 29 male, 25 female; recreational gaming use (RGU): 36 male, 21 female) while they were performing a card-guessing task. We collected and compared their brain features when facing the win and loss conditions in different groups.

Results For winning conditions, the gender × addiction group interaction results showed hyperactivity in the thalamus, parahippocampal gyrus and hypoactive inferior frontal gyrus (IFG) in the males with IGD relative to females. For losing conditions, the gender × addiction group interaction results showed that compared to females with IGD, males with IGD showed decreased brain activities in the IFG and lingual gyrus.

Conclusions Males and females showed opposite activation patterns in IGD degree and rewards/losses processing. And male IGD subjects are more sensitive to reward and less sensitive to loss than females, which might be the reason for the gender different rates on IGD. **Keywords:** Internet gaming disorder; Gender; Reward processing; Loss processing

Abbreviations

IGD

Internet Gaming Disorder

RGU

Recreational Gaming Use

IFG

Inferior Frontal Gyrus

NIH

National Institutes of Health

IAT

Internet Addiction Test

GLM

General Linear Model

ACC

Anterior Cingulate Cortex

MFG

Middle Frontal Gyrus

VS

Ventral Striatum

DLPFC

Dorsolateral Prefrontal Cortex

Introduction

Internet gaming is widely used as a type of recreation. However, some people develop an internet gaming disorder (IGD) due to their excessive and uncontrolled gaming behaviors. In 2018, the World Health Organization has classified IGD as a mental illness (ICD-11: <http://www.who.int/features/qa/gaming-disorder/en/>). IGD refers to a mental disorder in which excessive and recurrent use of online games and impairs the physical and psychological functions of the individual (1, 2). Due to the pervasiveness and harmfulness of IGD, it has become a critical issue to which people should pay close attention to (3, 4).

However, most of the subjects in previous studies were male, and only a few studies focused on gender differences in the potential neurocognitive mechanisms of IGD. Abundant studies have also revealed that male adolescents with IGD have a higher detection rates than females (5-7). This indicates that males are more likely to be addicted to games than females.

At present, the National Institutes of Health (NIH) in the United States encourages the investigation of gender-related differences and hormonal effects in addiction studies (8). Some researchers believe that gender differences were quite important in exploring the relationships between addictions (including substance addiction and behavioral addiction) and impulsivity (9-12). Neuroimaging studies have reported gender-related differences in the functional connections of brain regions (striatum and dorsolateral prefrontal cortex (DLPFC)) that are responsible for executive control and reward processing (13). Another study also found that male players showed stronger cravings for game pictures than female players, and abnormal brain activity was observed in the striatum and the orbitofrontal cortex (OFC) which are involved in reward processing (14).

The reward system is supposed to be the most critical neurogenic basis for addiction and mainly includes the following brain regions: the limbic system, ventral striatum (VS), insula, amygdala, prefrontal

cortex and anterior cingulate gyrus (15, 16). Research has shown that there is an abnormality in the reward system in all types of addictions, including substance addictions and behavioral addictions. As there is no chemical input for IGD, the unique mechanism of the reward system in IGD is worth studying.

The card-guessing task, as one of the paradigms for studying reward/loss processing, has been used by many addiction studies (17–19). Using this task, some neuroimaging studies of substance addiction found that addicted subjects showed high reward sensitivity and showed higher activations in the brain regions associated with rewards such as the striatum and the caudate nucleus (20, 21). Similar features were also observed in IGD subjects, which showed increased activations in the bilateral striatum when facing winning outcomes, suggesting that individuals with IGD show enhanced reward sensitivity compared to healthy controls (22). However, there is still a research gap in exploring the differences in the neural mechanisms between males and females in reward processing among IGD groups, and there is no empirical research to explore them. The present study aimed to investigate the differences in neural mechanisms between males and females with IGD by a probabilistic guessing task. First, we can clarify the gender differences in the neural mechanism in reward/loss processing. Additionally, we could provide a reference for further comprehensive prevention and interventions of IGD.

The primary purpose of this study was to explore the reward/loss process based on the group (IGD compared to recreational gaming use (RGU)) and gender (male compared to female) for subjectively experienced monetary loss and reward while performing card-guessing tasks. It explores reward and loss evaluation and the activation of brain regions related to the reward system (23). A study by Dong et al. (2011) showed that internet addicts associated with increased activation in the orbitofrontal cortex in win trials and decreased anterior cingulate activation in loss trials than healthy controls, suggesting that internet addicts have enhanced reward sensitivity and decreased loss sensitivity compared with the healthy controls (24). The gender difference was considered an essential dimension in addictive studies (25, 26). A survey found that male tend to spend more time on games than females (8). More studies have shown that male players seem to be more sensitive to game rewards during the mandatory break (27). Therefore, our first hypothesis is that male game players are more sensitive to rewards and less sensitive to loss than females in the card-guessing task. Given that previous studies have observed significant gender differences in the whole reward network (including the DLPFC and caudate nucleus), which mediates rewards and addiction (28–30). we suspect that abnormal responses in reward-related brain regions (such as the caudate nucleus and ACC) could be observed. According to these descriptions, our second hypothesis is that males with IGD may be more sensitive to reward and nonsensitive to loss relative to females with IGD. A gambling study showed that the winning outcome of risk decision-making would induce stronger rewards for male gamblers than for female gamblers. That is, male gamblers have higher reward sensitivity (31, 32). As a kind of behavioral addiction, we speculated that male IGD subjects induced stronger reward when facing winning results than female subjects in IGD group. Related brain regions (such as the thalamus) will be activated in males with IGD when they face winning outcomes compared to females with IGD. Similarly, females showed more aversion to loss than males at all ages (33). Males with IGD may showed less sensitive to loss than females and related brain activation in the prefrontal cortex was observed.

Methods And Materials

Ethics Statement

This study was approved by the Institutional Review Board of the Department of Psychology, Zhejiang Normal University and adhered to the Declaration of Helsinki. All participants provided written informed consent before the experiment and received monetary compensation for their participation.

Participants

One hundred and eleven right-handed participants were recruited from universities by online advertisement in Shanghai, China, including 54 IGD (male: 29; female: 25) and 57 RGU (male: 36; female: 21). RGU refers to those who play internet games but do not show any symptoms of physical or psychological dependence on online games (34). In the current study, RGU can be used as the control group for IGD, which can better explore the neural basis of IGD. All subjects had normal or corrected to normal vision. The final participants were selected through Young's Internet Addiction Test (IAT) (35) and nine diagnostic criteria for IGD proposed by the DSM-5 Committee (36). The detailed selection criteria refer to articles by Wang et al. (37). We determined IGD subjects according to the following inclusion criteria: (1) scored higher than 50 on Young's IAT; (2) met at least 5 DSM-5 criteria; and (3) were familiar with the game League of Legends (Riot Games, Inc.). We selected RGU based on the following inclusion criteria: (1) scored lower than 50 on Young's IAT; (2) met fewer than 5 DSM-5 criteria; and (3) have played online games more than 14 h per week, for a minimum of 2 years. Participants ensured that they did not take any medicine or substances including tea and coffee on the day of scanning. On the day of the scanning, all participants were instructed not to use any substance of abuse, including caffeinated beverages. No participants reported having previously used illicit drugs (such as cocaine, marijuana) or tobacco. All subjects fit the following criteria: right-handed university students, normal or corrected-to-normal vision, no reported history of illegal drug use, scored lower than 5 on the Beck Depression Inventory questionnaire (38), and no Axis-I psychiatric disorders as per assessment from a 15-minute structured psychiatric interview (MINI) (39). See detailed demographic information in Table 1.

Task and procedure

It takes approximately 15 minutes for each participant to complete the entire experiment. The current task refers to the card-guessing task designed by Dong et al. to create winning and losing situations. Participants need to practice a short card-guessing task before the formal experiment, which aims to familiarize the participants with the formal experimental process (22).

The cards used in the present study were the J, Q, K of red hearts, spades, clubs and diamonds, for a total of 12 cards, and the squares and red hearts were red cards, while the plums and spades were black cards. The participants were told to select the card on the left or right by pressing the button ("1" refers to the left

card, “2” refers to the right card), one of which was a red card. If the selected card were red, they would win and vice versa.

The specific procedure is shown in Figure 1. In each trial of the card-guessing task, the fixation is first presented on the screen for 500 ms. Immediately thereafter, the backs of the two playing cards are presented for 1500 ms, and the participants are allowed to guess which card was a red card by the buttons (“1” refers to the left card, “2” refers to the right card). Then, the selected card flips over in the feedback phase which lasted approximately 2000 ms. The feedback presented depends on whether the selected card is a red playing card. If the selected card is red, it represents “win 10 yuan”, and if the selected card is black, it represent “loss 10 yuan”. The feedback presented depends on the color of the card and the participant either wins (selected playing cards are red) 10 yuan or loses (selected playing cards are black) 10 yuan. Next, a black screen is presented for 1000~1500 ms. The whole task consisted of 144 trials, and the results of loss or win were presented randomly in this experiment.

At the beginning of each study, each participant started with a principal of 50 yuan and was explicitly told that he would receive the full cash balance at the end of the scanning. If the participant misses the button during the selection, the result will also be “loss”. This procedure enabled us to control the sequence of wins and losses fully, and yet the participants think that was their choice. Since the reward is probabilistic, the proportion of positive and negative outcomes experienced by each participant was not exactly 1: 1, there are slight differences between the different participants.

Image acquisition and preprocessing

BOLD functional images were acquired using a 3.0- Tesla scanner (Siemens Trio) with gradient echo planar (EPI) T2*-weighted sensitive pulse sequence covering 33 interleaved axial slices of 3 mm thickness with the following parameters: repetition time (TR) = 2000 ms, echo time (TE) = 30 ms, flip angle = 90°, and 64×64 matrix with field of view = 220 mm×220 mm. A high-resolution T1-weighted structural scan was subsequently acquired for each participant. Stimuli were presented using the Invivo synchronous system (Invivo Company, <http://www.invivocorp.com/>) through a monitor in the head coil.

Preprocessing and statistical analyses of functional MRI data were conducted with SPM8 (<https://www.fil.ion.ucl.ac.uk/spm/software/spm8/>) and NeuroElf (<http://www.neuroelf.net>). All functional images were slice-time corrected concerning the first slice acquired, corrected for motion artifacts by realignment to the first volume, and spatially normalized to a standard T1-weighted template with a voxel size of 3 × 3 × 3 mm³. Then a 6 mm FWHM Gaussian kernel was used for spatial smoothing. No participants were excluded from further analysis due to the maximum translation that exceeds 2.5 mm or maximum rotation that exceeds 2.5 degrees for further analysis.

First-level fMRI analysis

Each participant's data set was then subjected to an event-related analysis. A general linear model (GLM) was applied to assess task-related changes in blood oxygen level dependence (BOLD) signals. Modeled task events included two types: win and loss. However, participants might miss some trials during their selection, and the missed trials were treated as loss in our study. Six head-movement parameters derived from the realignment were included as covariates. All regressors were subsequently convolved with the canonical hemodynamic response function (HRF). A high-pass filter with a cut-off of 128 s was applied to improve the signal-to-noise ratio. Contrast images were calculated based on the parameter estimates output by the general linear model and were passed in a second level group analysis.

Second-level fMRI analysis

First-level contrasts were submitted to second-level random effects analysis of variance for group analyses. A voxelwise 2×2 (group: IGD, RGU; sex: male, female) ANOVA was administered to examine statistically significant between-group differences in the outcome of win. Maps were initially thresholded at $P < 0.005$, and significant voxels were subsequently identified using a joint voxel and extent threshold that corresponded to corrected $P < 0.05$ as determined by the 3dClusterSim (https://afni.nimh.nih.gov/pub/dist/doc/program_help/3dClustSim.html). The cluster extent threshold was 51 voxels (smoothness estimate: 8.4 mm). For the outcome of loss data, processing steps are consistent with the win condition.

Correlation analyses between behavioral and brain performances

IAT score can indicate the degree of IGD to some extent: the higher the score, the deeper the degree of IGD. In the present task, we respectively compared the different brain activation in the interaction between group and gender during participants facing the win and facing the loss, and took the surviving clusters as ROIs for further analyses. A representative BOLD beta value was obtained by averaging the signal of all the voxels within the ROI, and then performing a correlation analysis between the BOLD signal and the IAT score.

Results

Brain responses when facing a win

Main effects in win conditions

In the win condition, when compared to the RGU group, the IGD group showed a hypoactive BOLD signal in the left lingual gyrus (see Figure 2a and Table 2).

We further examined the difference in brain activities between males and females. Males showed more hypoactive BOLD signals in the reward-related regions including the left caudate nucleus, bilateral cingulate gyrus, right middle frontal gyrus (MFG) and other brain regions such as the right precuneus and inferior parietal lobule relative to the females (see Figure 2b and Table 2).

Interaction effects in win conditions

Group \times gender effects were found in the thalamus, parahippocampus and inferior frontal gyrus (IFG) in win conditions. We further extracted these beta values of the thalamus, parahippocampus and IFG for simple effect analysis. In the IGD group, males showed higher brain activities in the thalamus and lower brain activities in IFG than females. In the RGU group, the results are reversed (see Figure 3 and Table 2).

Brain responses when facing a loss

Main effects in loss conditions

In the loss condition, we first compared the brain activities between the IGD and RGU groups. The IGD group showed more hypoactivation in the left lingual gyrus, left parahippocampal gyrus, and right anterior cingulate cortex (ACC) compared to the RGU group (see Figure 4a and Table 2). Then we examined the difference in brain activities between males and females. Males showed less hypoactive left caudate nucleus and decreased BOLD signal activation in the right middle occipital gyrus relative to females (see Figure 4b and Table 2).

Interaction effects in loss conditions

Group and gender have an interaction effect in the lingual gyrus and IFG in the loss condition. Similarly, we extracted the beta values of the lingual gyrus and IFG for simple effect analysis. Compared to females with IGD, males with IGD showed decreased brain activities in the IFG. In the RGU group, the results are reversed (see Figure 5 and Table 2).

Correlation results

When participants facing the win, a significant negative correlation was found between IAT scores and activation of the thalamus ($r = -0.293, p < 0.05$), parahippocampal ($r = -0.328, p < 0.05$) in the female group but not male group (see Figure 6a). And when they facing the loss, a significant negative correlation was found between IAT scores and activation of the lingual gyrus ($r = -0.315, p < 0.05$), IFG ($r = -0.300, p < 0.05$) in the male group but not female group (see Figure 6b).

Discussion

Win condition

In the present study, the hypoactivity in the left lingual gyrus was observed when IGD participants faced a winning outcome. A host of addiction studies also showed that addicts usually have abnormal activation in lingual gyrus (40–43). However, no research has confirmed that the lingual gyrus is related to the reward system. The lingual gyrus has always been reported to be involved in visual recognition and is believed to play a role in episodic memory consolidation (44, 45). Inconsistent with prior studies (46–48), there appeared to be no difference in reward processing between the two groups. The possible cause was that we used RGU participants as a control group in the current study. RGU participants are also big enthusiasts of online games, similar to those with IGD. Thus, there is no group difference in reward processing.

Then, we compared the differences in brain responses between males and females when rewards *were met* in the card-guessing task. Males showed a less hypoactive caudate nucleus, cingulate gyrus and MFG than females. The caudate nucleus, cingulate gyrus and MFG are all considered to be an essential part of the adjustment reward circuit (49–51). The caudate nucleus is a crucial brain area for dopamine delivery and is used to strengthen reward expectations (52). Several fMRI studies have reported that addiction (including substance addiction and behavior addiction) related reward promotes enhanced reward-related brain responses in addicts, which means that their motivation and impulse to pursue rewards are enhanced (53–55). These findings indicated that male players are more sensitive to reward and are easily dominated by impulses to pursue rewards. In the present study, strong rewards and the impulse to pursue rewards (56) seem to be more pronounced in males. This may be the reason why male players are more likely to have IGD.

In addition, consistent with our hypothesis, the present study found that gender (male, female) and group (IGD, RGU) have significant interactions in the thalamus, parahippocampal gyrus and IFG in the win condition. Further comparisons showed increased brain activities in the thalamus and parahippocampal gyrus in males with IGD as compared to females with IGD. The thalamus plays an important role in reward processing (57, 58) and goal-directed behaviors, alongside many other cognitive and motor functions (57). The thalamus is a part of the cortico-striato-thalamo-cortical circuits underlying both reward and motivated behaviors (55). The parahippocampus gyrus participates in the memory of rewards (59, 60). A study found that injecting maca into the parahippocampus can cause CPP and self-injection behavior, indicating that the hippocampus participates in reward processing (61). Abnormal activities of the parahippocampus gyrus and thalamus in drug addict indicate that they easily perceive and seek rewards (62). Hence the neural activities in the face of winning results reflect that males with IGD seem to be able to experience a higher sense of reward that drives them to seek rewards. Additionally, lower IFG activity was observed in males with IGD. IFG is mainly involved in the executive control processing, and the execution control tasks often weaken the function and activation of IFG, which leads to failure of self-control (63, 64). The fMRI study also found that the degree of IFG activation significantly predicted the

self-control behavior of individuals in real life (65, 66). In the present study, males with IGD showed weakened activities in the IFG indicating that they showed a lower sense of control over the winning outcomes (rewards) compared to females with IGD. Males with IGD indulge in the pleasure brought by reward and difficult to control. In a word, the motivation to obtain rewards represents a central feature of addictions and seems to be more pronounced in males with IGD. At the same time, they cannot suppress and deal with the motivation of pursuing reward well. This may be the reason why the number of male with IGD is higher - males with IGD more difficult to quit the game than females.

However, the present results showed that male and female brain activations in the RGU group were opposite to those in the IGD group, which is different from other studies. Compared with the males, female RGUs seem to be more sensitive to winning. We cannot provide a reasonable explanation based on the current data. The specific reasons need to be further explored.

Loss condition

In the loss condition, we observed more hypoactivation in the left lingual gyrus, right anterior cingulate cortex (rACC) and left parahippocampal gyrus in the IGD group than the RGU group. Unlike the results of facing win, IGD has more hypoactive reward-related brain regions including the rACC and parahippocampal gyrus in the loss condition which means that IGD has lower loss sensitivity than RGU participants. The ACC is considered to be a part of an integral network involved in decision-making and evaluation, but there is still much debate about its role (67). Early card guessing task found that the dorsal anterior cingulate cortex (dACC) activity was associated with greater “uncertainty” of outcome (68). The ACC plays an essential role in the motivation, cognition and action (69) and also in executive control and reward evaluation (70). Several neuroimaging studies have examined the impaired risk assessment capabilities by dysfunction or structural abnormalities in ACC in people with IGD (71, 72). The more hypoactive ACC were observed in the IGD indicated that they could not make an accurate assessment of the risk outcome or were not adequately sensitive to loss.

We also found that males showed less hypoactivity in the left caudate nucleus and less hyperactivity in the right middle occipital gyrus relative to the females. The right middle occipital gyrus is related to visual information processing and visual space attention (73). Males showed a less hyperactive right middle occipital gyrus might suggesting that females have better visual information processing ability relative to males. That may be due to innate gender differences. Similar to the response to winning, the less hypoactive caudate nucleus in males indicated that they also have more excitement in the losses caused by choices than females. We speculate that male do not pay much attention to the results of the current choices, and this uncertain risk decision-making task can also stimulate their interest.

There also has an interaction in the IFG and lingual gyrus in the loss condition. We also found decreased activities in the IFG in males with IGD in the loss condition compared to females with IGD. Similar to the win condition, males with IGD showed lower response control to monetary loss (unpleasant situations) indicating that they are insensitive to the losses relative to the females. In the RGU group, the results also

reverse to the IGD group. These results indicated that females with RGU appear to exhibit higher reward sensitivity and insensitivity to loss than males, which is inconsistent with our hypothesis and previous research. We cannot provide a reasonable explanation based on the current data. Thus we need to explore the reason further.

Following previous research, the present study proved that reward/loss processing is always associated with abnormal activation in the limbic system (thalamus, ACC, parahippocampal gyrus) and prefrontal cortex. The above results indicate that males with IGD were induced with a higher reward when they saw the winning outcome. Furthermore, the loss-insensitive feature in males with IGD was observed when they were facing the loss (74). We suspect that this may be the reason why the males with IGD find it easy to indulge in the game and more difficult to withdraw from the game.

Different gender showed opposite activation patterns in IGD degree and brain region response

A significant negative correlation was found between IAT scores and activation of the thalamus, parahippocampal in the female group but not male group when participants facing the win. This result showed the higher the degree of IGD in females, the lower the activation in the thalamus and parahippocampus gyrus. This means that with the increase of IGD level in the female group, they seem to be less and less sensitive to rewards. However, in the male group, although the degree of IGD did not reach a significant correlation with the activities of the thalamus and parahippocampus gyrus, it showed a positive trend. In addition, a significant negative correlation was found between IAT scores and activation of the lingual gyrus, IFG in the male group but not female group when they facing the loss. That showed the higher the degree of IGD in males, the lower the activation in the IFG and indicated that with the increase of IGD level in the male group, they seem to be less and less sensitive to losses. Therefore, we infer that different gender showed opposite activation patterns in IGD degree and rewards/losses processing. But we cannot provide a reasonable explanation based on the current data, the specific reasons need to be further explored.

Limitations

The current study has several limitations. First, behavioral performance during the game was not collected; therefore we cannot relate neural discovery to game performance. Second, we need to strengthen the causality of the neural mechanism of IGD. Third, due to the limitation of experimental procedures, control condition cannot be set, but we expect to balance the differences with large samples of participants. Finally, the present results showed that male and female brain activations in the RGU group were opposite to those in the IGD group, which is different from other studies and our hypothesis. We cannot provide a reasonable explanation based on current data and we believe a further study

focusing on the female IGD and female RGU could provide more evidence for an explanation. Additionally, we plan to recruit more female subjects to explore this issue.

Conclusion

In the present study, when participants were faced with the winning, there were no differences between IGD and RGU participants. Males were found to be more sensitive to rewards than females in gender comparisons. It was also found that males with IGD are even more sensitive to rewards than females.

When faced with loss, IGD participants were found to be insensitive to losses. Males were found to not pay attention to current losses, but instead generate expectations for the next win, in contrast to females. Finally, males with IGD were also found to be insensitive to loss relative to female. In summary, male IGD participants are more sensitive to reward and less sensitive to loss relative to females, which might be the mechanism that causes the gender different rates of IGD.

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' contribution

Jialin Zhang wrote the first draft of the manuscript; Guangheng Dong designed the task; Jialin Zhang, Ziliang Wang collected and analyzed the data and prepared the figures and tables. Xiaoxia Du contributed to collecting and preparing the data. Yan Hu contributed to the editing, interpretation and revision processes. All authors contributed to and approved the final manuscript.

Conflict of interest

The authors report that they have no financial conflicts of interest with respect to the content of this manuscript.

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Tables

Due to technical limitations, tables are only available as a download in the supplemental files section

Figures

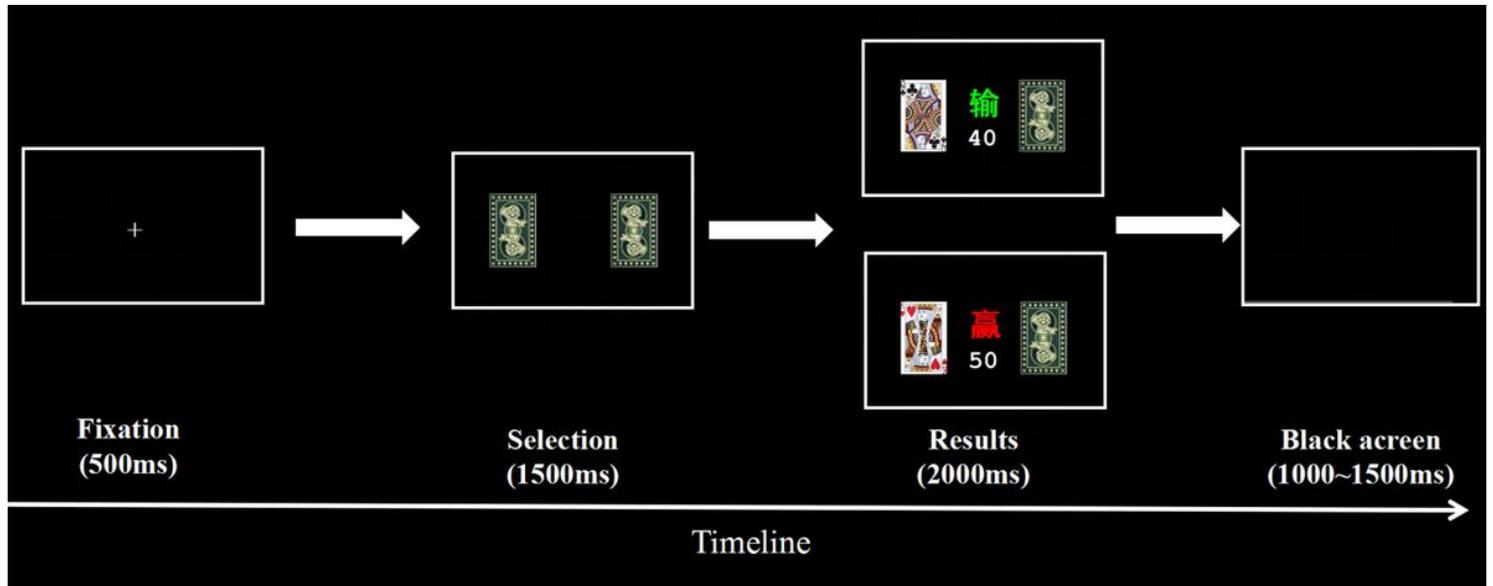
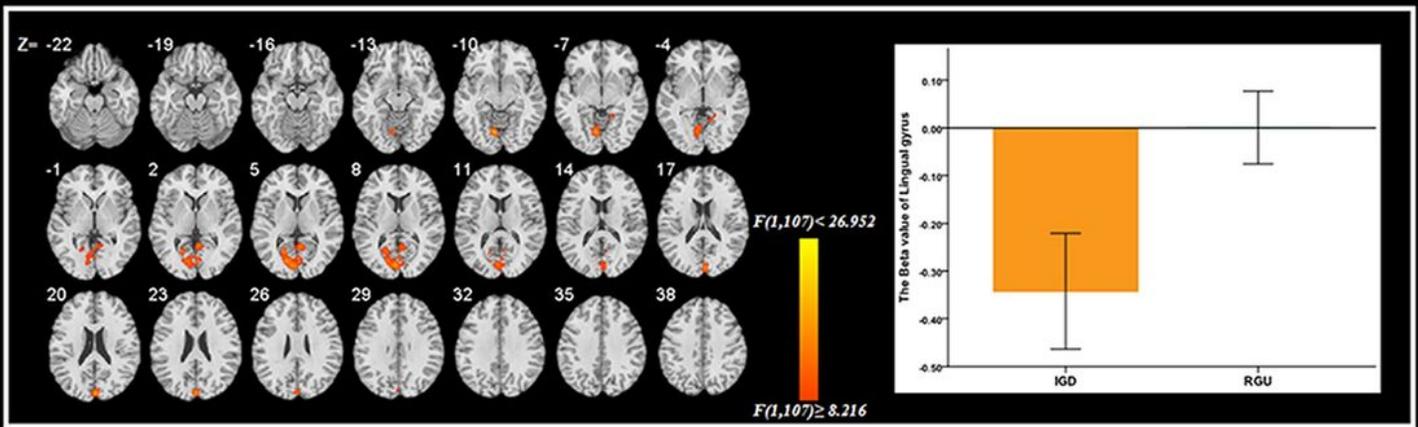


Figure 1

The timeline of one trial in the card-guessing task. First, a fixation was presented for 500 ms. The backs of the two playing cards were then presented for 1500 ms, and the participants were allowed to guess which card was a red card using buttons. Then, the selected card flipped over in the results phase which lasted approximately 2000 ms (“赢” refers to “win”; “输” refers to “loss”). Finally, a black screen of 500~1000 ms was presented.

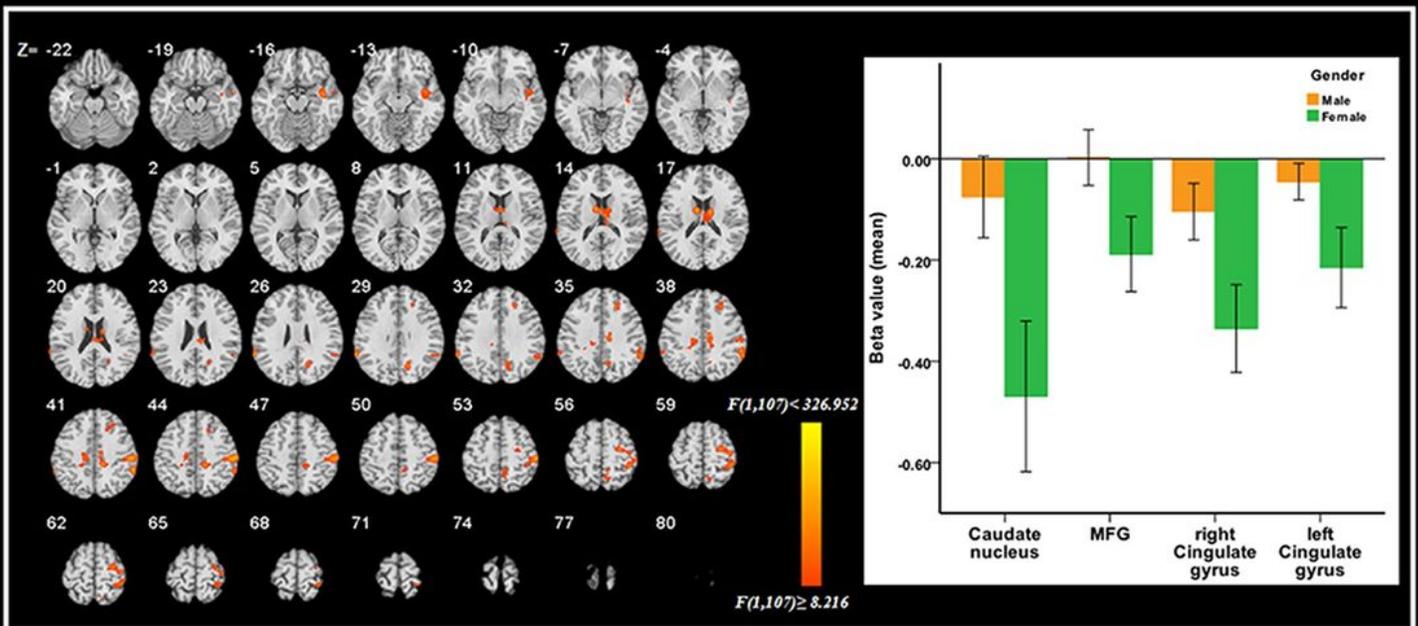
Win condition

IGD - RGU



(a)

Males - Females



(b)

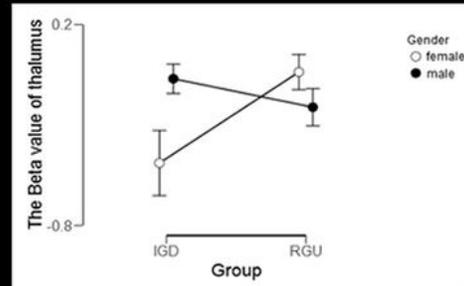
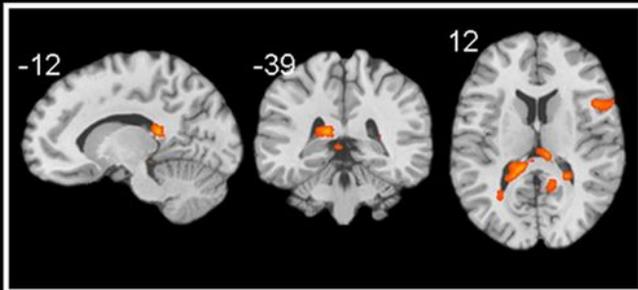
Figure 2

Brain regions showing significant differences by group and gender in winning conditions (a) The main effect in the group: the IGD subjects showed abnormal activation (shown in yellow) in the left lingual gyrus compared to the RGU group. (b) The main effect in gender: the males showed abnormal activation (shown in yellow) in the left caudate nucleus, bilateral cingulate gyrus, right MFG and right precuneus compared to females.

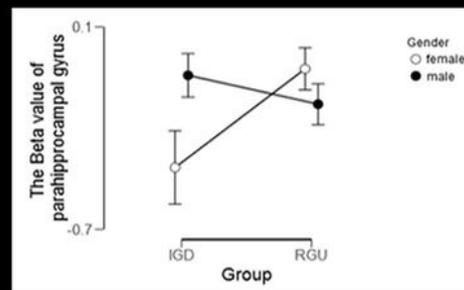
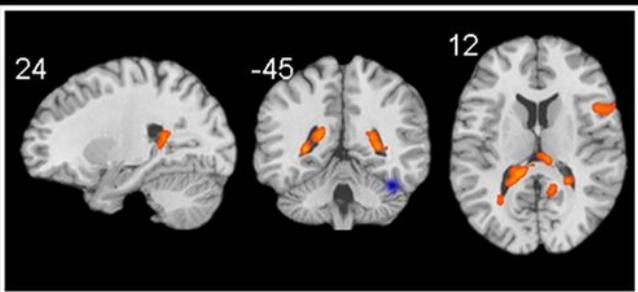
win condition

Group × Gender

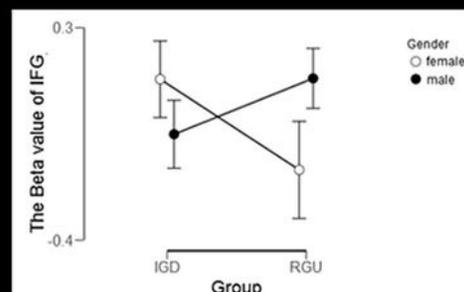
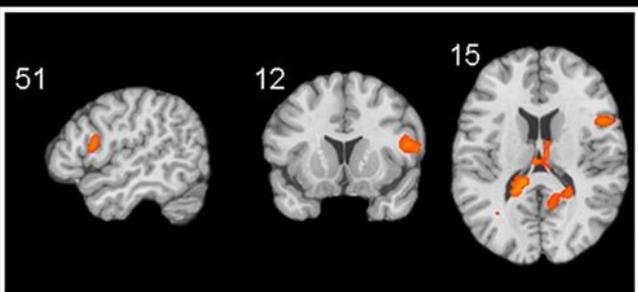
Thalamus



Parahippocampal gyrus



IFG



(a)

$F(1,107) < 26.952$

$F(1,107) \geq 8.216$

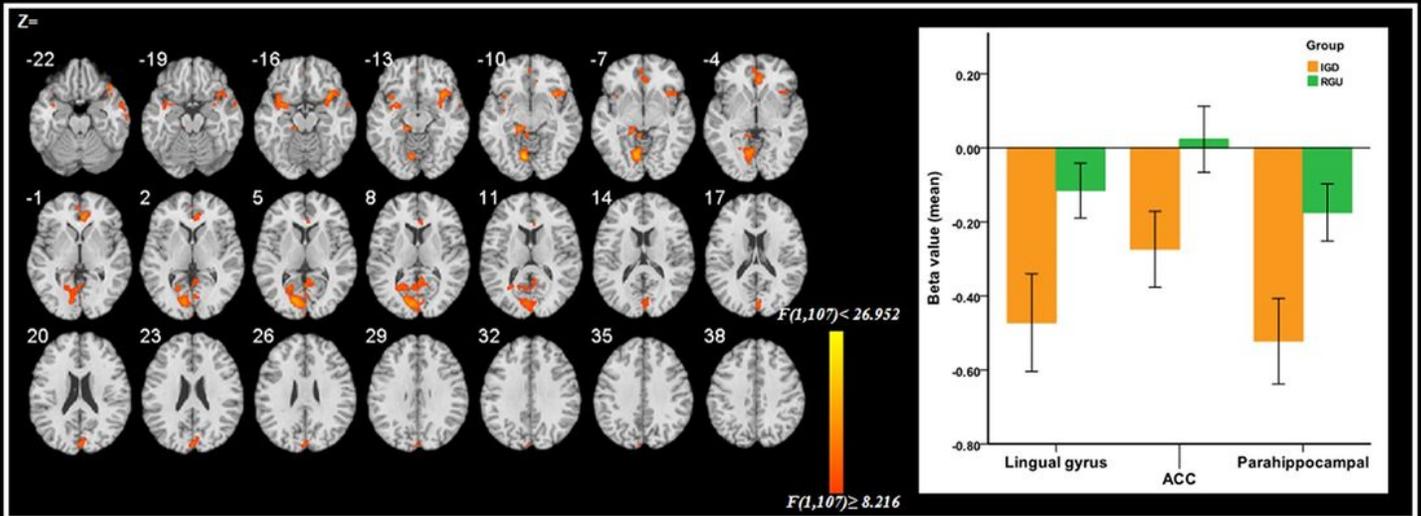
(b)

Figure 3

The interaction between group × gender in winning conditions (a) The interaction effect in group × gender: the brain areas with interactive effects are thalamus, parahippocampal gyrus and IFG. (b) Males with IGD showed increased activation in the thalamus, parahippocampal gyrus and decreased activation in the IFG compared to females with IGD.

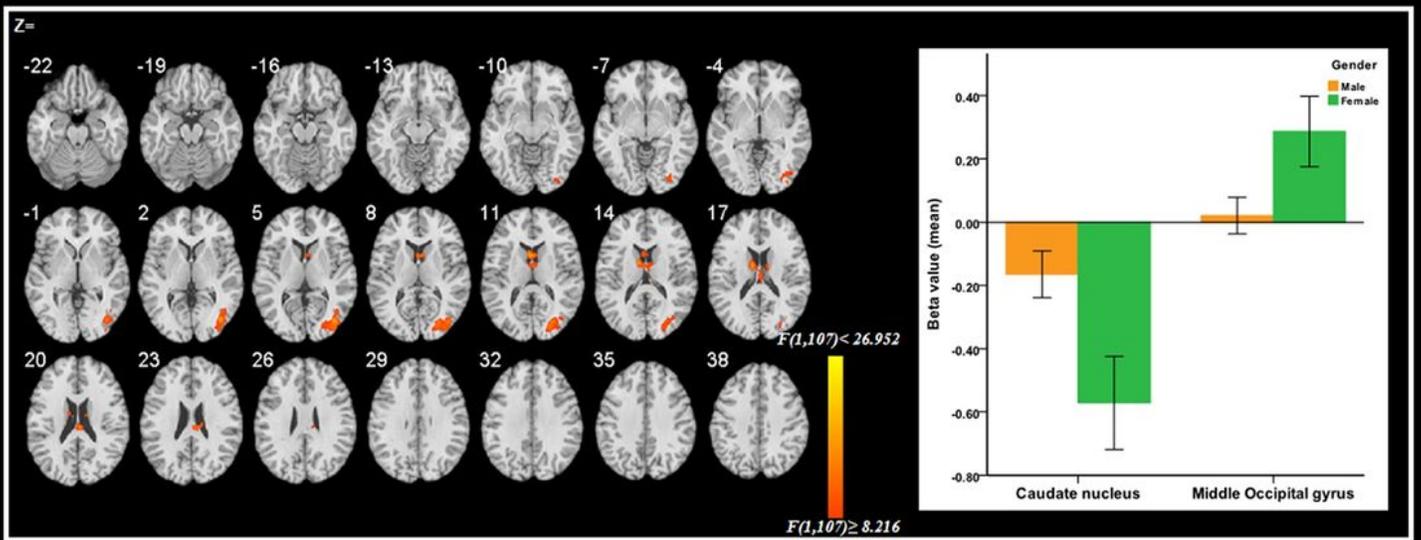
loss condition

IGD - RGU



(a)

Males - Females



(b)

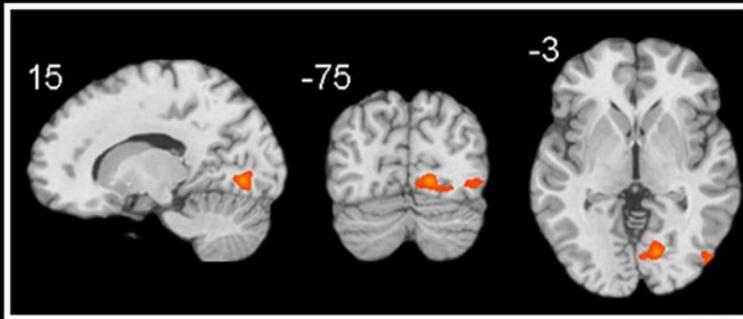
Figure 4

Brain regions showing significant differences by group and gender in lossing condition (a) The main effect by group: the IGD subjects showed abnormal activation (shown in yellow) in the left lingual gyrus, left precuneus and rACC compared to the RGU group. (b) The main effect by gender: the males showed abnormal activation (shown in yellow) in the caudate nucleus and right middle occipital gyrus compared to females.

loss condition

Group × Gender

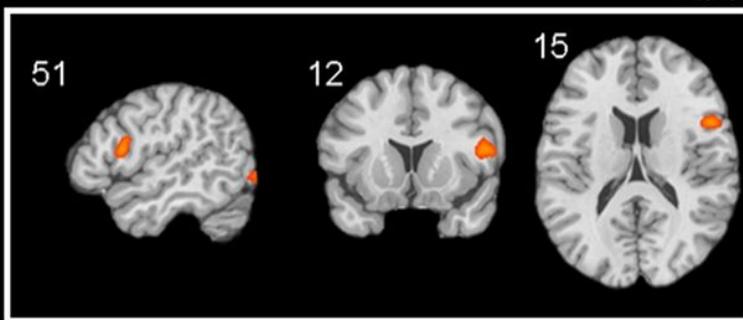
Lingual gyrus



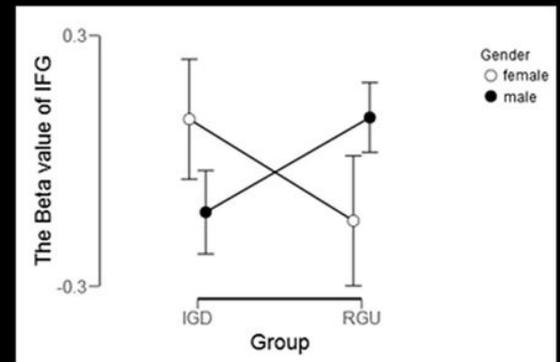
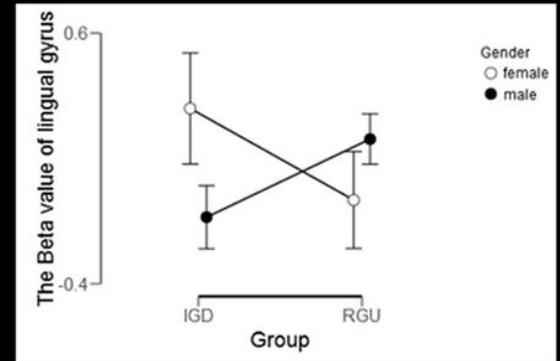
$F(1,107) < 26.952$



IFG



$F(1,107) > 8.216$



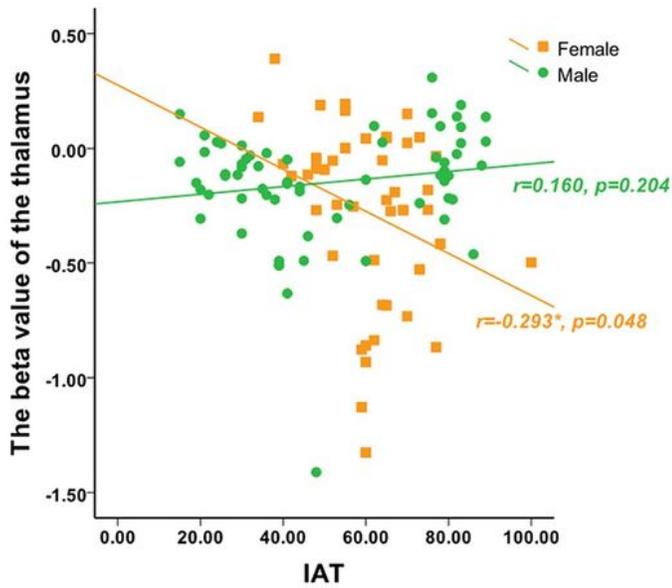
(a)

(b)

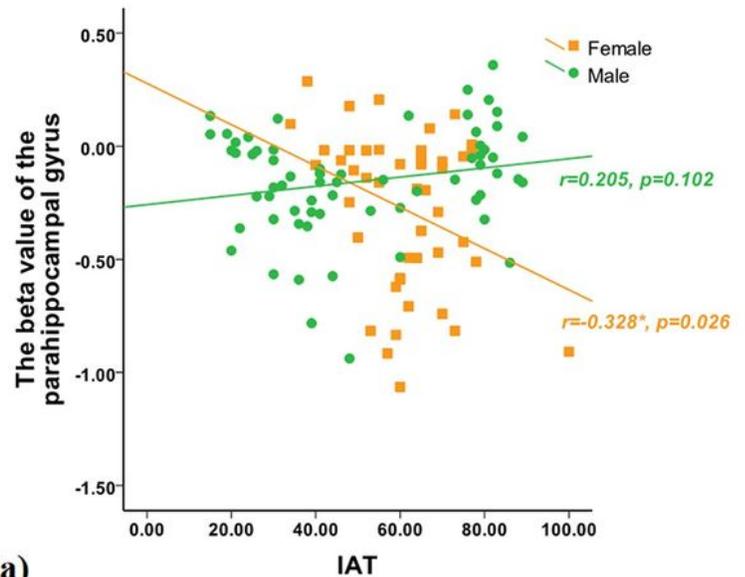
Figure 5

The interaction between group × gender in loss conditions (a) The interaction effect of group × gender: The brain area with the interactive effect is IFG and lingual gyrus. (b) The males with IGD showed decreased activation in IFG and lingual gyrus comparing to females with IGD.

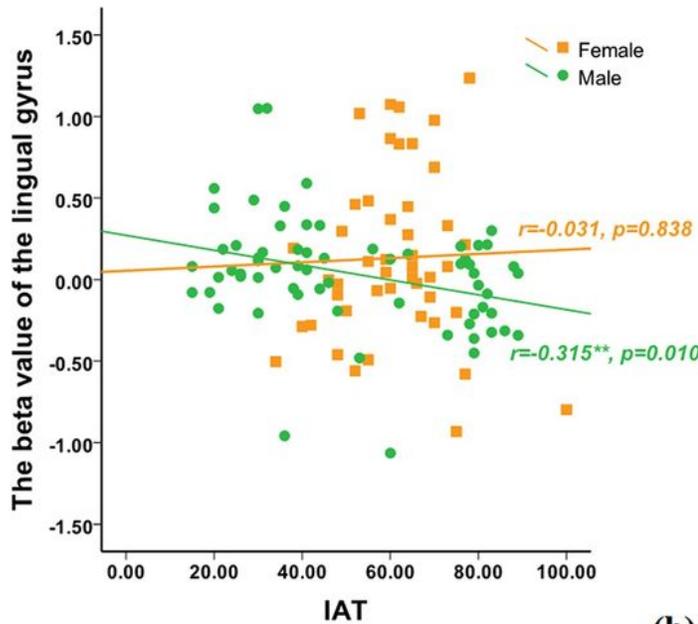
Win condition



(a)



Loss condition



(b)

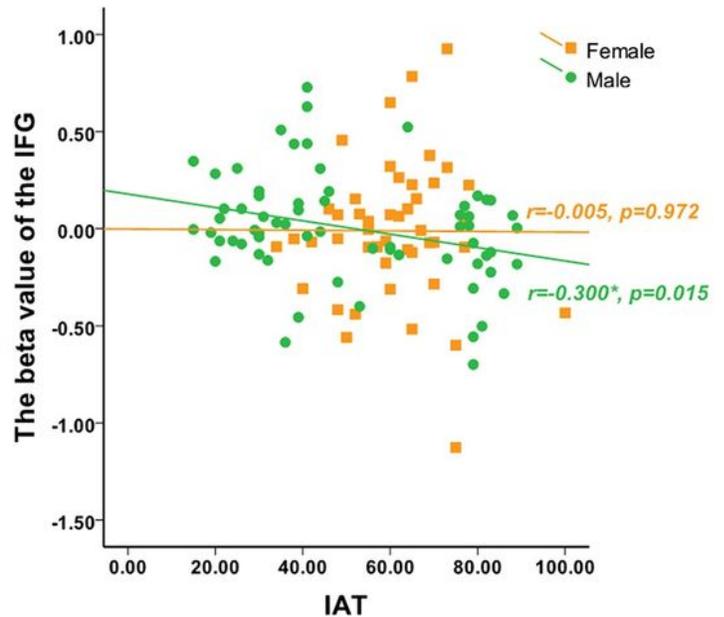


Figure 6

The correlation between IAT and ROIs (a) When participants facing the win, a significant negative correlation was found between IAT scores and activation of the thalamus, parahippocampal in the female group but not the male group. (b) When they facing the loss, a significant negative correlation was found between IAT scores and activation of the lingual gyrus, IFG in the male group but not female group..

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table2.docx](#)
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