

**Title:** Neural responses to gaming content on social media in young adults

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## **Abstract**

Excessive gaming can impair both mental and physical health, drawing widespread public and clinical attention, especially among young generations. People are now more exposed to gaming-related content on social media than before, and this exposure may have a significant impact on their behavior. However, the neural mechanisms underlying this effect remain unexplored. Using functional magnetic resonance imaging (fMRI), this study aimed to investigate the neural activity induced by gaming-related content on social media among young adults casually playing online games. While being assessed by fMRI, the participants watched gaming-related videos and neutral (nongaming) videos on social media. The gaming-related cues significantly activated several brain areas, including the medial prefrontal cortex, posterior cingulate cortex, hippocampus, thalamus, superior/middle temporal gyrus, precuneus and occipital regions, compared with the neutral cues. Additionally, the participants' gaming desire levels positively correlated with a gaming-related cue-induced activation in the left orbitofrontal cortex and the right superior temporal gyrus. These findings extend previous studies on gaming cues and provide useful information to elucidate the effects of gaming-related content on social media in young adults. Continued research using real-world gaming cues may help improve our understanding of promoting gaming habits and provide support to individuals vulnerable to gaming addiction.

## **Keywords**

cue reactivity; fMRI; gaming addiction; social media; superior temporal gyrus

## 1. Introduction

Online games have gained immense popularity, serving both as a means of recreation and mental, physical, and cognitive training (1, 2). These games provide individuals with some respite from routine obligations (3, 4). Despite the recognized benefits, excessive engagement in online gameplay may lead to addiction, replacing meaningful human interactions and potentially compromising mental and physical well-being. This issue has garnered widespread public and clinical attention, particularly concerning the younger generation (5, 6).

Several social media platforms, such as YouTube, Instagram, and Twitter, are increasingly utilized for communication, learning, and collaboration (7-9). Concurrently, people are exposed to abundant gaming-related content on these platforms in daily life (10). Such content can substantially impact individuals' behavior. In our previous study, gaming-related content on social media significantly influenced participants' behavior both explicitly and implicitly (11). Recognizing the neural correlates of this observation may elucidate the mechanisms involved in problematic game use, contributing to the development of practical intervention strategies.

Cue reactivity plays a vital role in the development and maintenance of addictive behaviors (12-16). In addiction research, many researchers evaluated the brain mechanism underlying cue reactivity using functional magnetic resonance imaging (fMRI). In line with this, several previous studies have investigated brain responses to gaming cues (17, 18). For example, a previous study showed that valence attribution and neural reactivity in a parietal network, including the posterior cingulate cortex (PCC), are more boosted by gaming-cue specific among regular gamers than among gaming naïve-controls (19). The comparison between post- and pre-gaming measures by Dong et al. (2017) showed that for Internet gaming disorder (IGD), gaming was associated with increased craving and increased activation of the medial prefrontal cortex (MPFC), striatum, and precuneus when exposed to gaming-related stimuli (20). However, most of the previous studies employed pictures or videos of familiar games as stimuli without contextual information. Consequently, neural responses to gaming-related content on social media remain largely unknown. Social media provides a real-world context in which gaming-related content is experienced parallel to various social and environmental factors, including interactive posts, live streams, user-generated content, advertisements, and discussions related to gaming content (8-11). This dynamic environment better

reflects how individuals encounter gaming content in their everyday lives, allowing us to evaluate neural responses in an ecologically valid setting.

In this study, we sought to investigate the neural responses to gaming-related content on social media by using fMRI among young adults casually playing online games. The participants watched gaming-related videos and neutral (nongaming) videos on social media during fMRI scanning. Substance-related advertisement stimuli, such as tobacco and alcohol, elicited brain regions in the same networks engaged in the processing of other corresponding substance-related stimuli (21-23). Gaming-related videos such as those showing persons enjoying a game, introducing a game, and teaching how to capture a game on social media platforms may effectively elicit gaming desire and cue-induced brain activation. Therefore, we hypothesized that gaming-related content on social media can activate brain regions similar to those in previous studies of gaming cues.

## **2. Methods**

### **2.1. Participants**

This study included 25 healthy volunteers (aged 19–25 years) casually playing online games. All participants played online games regularly for at least an hour weekly and did not meet the IGD criteria proposed by the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5). Considering the sex difference in the mechanism for gaming addiction and a higher gaming addiction potential in men than in women (24-26), we only enrolled male participants. After excluding 3 participants from the analyses because of excessive head motion (>3 mm), we finally included 22 participants for the analysis. The participants were recruited from the general population in Tokyo area through advertisements and acquaintances. All participants were right-handed, as assessed by the Edinburgh Handedness Inventory (27). None of the participants had psychiatric disorders, as evaluated by an experienced psychiatrist who used a structured clinical interview for DSM-5, as well as any history of head trauma, severe medical or surgical illness, or substance abuse. All participants were not current smokers. In line with previous studies (24, 25), all participants completed the Internet addiction test (IAT) (28, 29) to measure the degree of dependence on the Internet. In particular, the IAT measures the degree of involvement in online activities by using a five-point Likert scale. It classifies addictive behaviors into three categories as follows: a total score of <40 as “no

addiction,” 40–69 as “mild signs of addiction,” and  $\geq 70$  as “severe addictive behaviors.” Moreover, predicted IQ was estimated using the Japanese version of the National Adult Reading Test short form (30).

This study obtained approval from the institutional review board of Tokyo Medical and Dental University Hospital and conformed to the Code of Ethics of the World Medical Association. All participants provided written informed consent after being explained on the entire study.

## **2.2. fMRI task**

We selected eight gaming-related videos, such as those portraying persons enjoying a game, introducing a game, and teaching how to capture a game from social media platforms. Games differed in each video. The eight games featured in the videos were all popular online games (shooting games, role-playing games, puzzle games, or sports games) in Japan. We selected eight neutral videos (nongaming videos), such as furniture-, hygiene-, travel-, and work-related videos from social media platforms. Based on the previous studies (21-23), they were chosen to match as much as possible each gaming-related video on complexity, content, design, luminance, color, action, and presence of faces. Initially, we shortlisted 220 videos from social media platforms, and three researchers assessed the videos using rating sheets with criteria related to complexity, content, design, luminance, color, action, and the presence of faces. Finally, after discussions with our research team, we selected eight neutral videos that best matched the gaming-related videos.

The videos (20 s each) were displayed pseudorandomly. After watching each video, the participants rated the gaming desire from 1 (no desire) to 4 (extreme desire) within 6 s (Fig. 1). A fixation cross was displayed between the videos for 10 s. The experiment was conducted using E-Prime (Psychology Software Tools, Inc., Pittsburgh, PA, USA). To compute the participants’ gaming desire levels, we subtracted the mean scores of the gaming desire in gaming-related videos by those in neutral ones. Higher scores denote higher levels of explicit gaming desire. Outside the scanner, the participants were asked to rate the familiarity of each game presented in the fMRI task from 1 (very unfamiliar) to 9 (very familiar).

To mitigate the effects of anticipation, we instructed the participants on the nature of stimulus changes and encouraged them to focus on the current task rather than

anticipating changes. Before fMRI, participants practiced on a shorter version of the fMRI task at least once, and misunderstandings regarding task completion were clarified. During practice, we monitored participants' responses, addressed the tendencies of anticipation, and provided corrective feedback to enhance their focus on task-relevant processes.

### ***2.3. fMRI data acquisition, preprocessing, and analysis***

All participants underwent MRI scanning on a 3T whole-body scanner equipped with a 20-channel head/neck coil (Prisma, Siemens, Erlangen, Germany). Images were processed using SPM12 (Wellcome Trust Center for Neuroimaging, London, UK) in MATLAB (MathWorks, Natick, MA, USA). [Further details are shown in the Supplementary Methods for details.](#)

### ***2.4. fMRI data analysis***

After preprocessing, we fitted a general linear model to the fMRI data. In the first-level analysis, the design matrix contained two task-related regressors (gaming-related content and neutral content conditions) as regressors of interest. To minimize motion-related artifacts, we included six movement parameters (three displacements and three rotations) as additional regressors of no interest. Subsequently, we identified the differences in activation between gaming-related and neutral content conditions. The comparison produced a contrast image for each participant. The contrast images were then used for second-level fMRI analyses.

In the second-level analyses, inferences at the population level were made using a random-effects model. In line with previous findings (17-20), we focused on the following regions of interest (ROIs): MPFC, middle frontal gyrus, orbitofrontal cortex (OFC), anterior cingulate cortex, PCC, striatum, hippocampus, thalamus, superior temporal gyrus (STG), and precuneus. All of their anatomical masks were taken from the Automated Anatomical Labeling atlas using the WFU pickatlas toolbox (30, 31). An activity that survived family-wise error (FWE) correction for multiple comparisons with a cluster level of  $p < 0.05$  for each ROI (at voxel-level uncorrected  $p < 0.001$ ) was considered significant according to previous ROI studies (32, 33). Regarding the brain regions outside these ROIs, we reported activations with thresholds at voxel-level  $p < 0.01$  (FWE corrected) with a minimum cluster extent of 100 contiguous voxels after

whole-brain correction for multiple comparisons on the basis of the previous studies (33, 34). The differences between gaming-related and neutral content were analyzed using a one-sample t-test. In addition, brain regions associated with the levels of gaming desire were identified through multiple regression analyses using a general linear model framework in SPM12 (35).

### 3. Results

Table 1 presents participants' characteristics. No participants met the criteria for IGD. Overall, the participants performed the task well, missing an average of only  $0.18 \pm 0.50$  trials. Briefly, a missed trial is a trial wherein a participant could not rate the gaming desire within the time. The participants exhibited higher gaming desire by the gaming-related cues on social media than the neutral ones ( $2.14 \pm 0.63$  vs.  $1.09 \pm 0.17$ ,  $p < 0.01$ ). The levels of gaming desire did not significantly correlate with familiarity rating scores ( $r = 0.36$ ,  $p = 0.10$ ).

For the ROI analysis, regions such as the bilateral MPFC, left PCC, bilateral hippocampus, bilateral thalamus, right STG, and bilateral precuneus were significantly activated by the gaming-related cues on social media than by the neutral ones (Fig. 2 and Table S1). Conversely, no significant regions of deactivation (neutral cues > gaming-related cues) were noted at the same thresholds. As for those outside the ROIs, the left lingual gyrus extending into the bilateral inferior occipital gyrus, right middle occipital gyrus, and right middle temporal gyrus (MTG) were significantly activated by gaming-related cues than by the neutral cues. No significant areas of deactivation were observed (neutral cues > gaming-related cues). Details are described in Table S2.

To identify brain regions associated with gaming desire levels, we also conducted multiple regression analyses. For the ROI analysis, the gaming desire levels positively correlated with the activation of the left OFC and right STG induced by gaming-related cues (Fig. 3 and Table S3). In contrast, we found no significant regions where gaming-related cue-induced activation negatively correlated with the gaming desire levels. As for those outside the ROIs, we also found no significant areas where gaming-related cue-induced activation positively or negatively correlated with the gaming desire levels.

#### 4. Discussion

To our knowledge, this is the first fMRI study to investigate the neural responses to gaming-related content on social media among young adults. The results extend the findings of previous studies on gaming cues and may provide additional insights into the mechanisms of excessive gameplay.

The participants showed higher gaming desire for the gaming-related cues on social media than for the neutral ones during the fMRI task, consistent with our previous behavioral study (11). The results highlight that the effects of gaming-related content on social media deserve examination to increase our understanding of the pathogenesis of gaming addiction.

Several areas, including bilateral MPFC, left PCC, bilateral hippocampus, bilateral thalamus, right STG, bilateral precuneus, right MTG, and bilateral occipital regions, were significantly activated by the gaming-related cues on social media than by the neutral ones. Furthermore, the gaming desire levels positively correlated with the activation of the left OFC and right STG induced by gaming-related cues. These brain areas have been repeatedly reported to be associated with cue reactivity in both individuals with IGD and those at risk of IGD (17, 18).

The MPFC plays key roles in cognitive processing, emotional regulation, inhibitory control, and contextual processing (36-39). It is also interconnected with other brain regions involved in reward processing, such as the ventral striatum (40-41). Therefore, the MPFC may be necessary for cue reactivity, driving the desire to engage in gaming behavior when exposed to relevant cues. Indeed, it has been implicated in cue reactivity across various addiction-related disorders, including IGD (20, 42, 43). Our findings align with these previous studies and suggest that the MPFC is crucial in responding to gaming-related cues on social media among young adults.

Notably, the gaming desire levels positively correlated with left OFC activation induced by gaming-related cues. The OFC, through its interactions with the mesolimbic dopaminergic system, participates in representing reinforcement contingencies and the expected outcomes of stimuli previously linked to rewards (44, 45). This involvement contributes to the development of compulsive habits observed in addiction (44-46). According to multiple neuroimaging investigations, the OFC is significantly involved in the pathology of both substance addiction (e.g., methamphetamine, cocaine, and heroin) (47) and behavioral addiction, exemplified by IGD (48, 49). Individuals with IGD

exhibited heightened OFC activation during a cue reactivity task compared with recreational users; this finding correlated with the intensity of the desire to engage in gameplay (49). Consistent with these previous studies, our findings imply that the OFC is a key brain region linked to gaming desire induced by gaming-related content on social media. However, OFC activation did not significantly differ between gaming-related and neutral content conditions. This finding may be partly explained by the participants' characteristics; for example, participants were casual gamers in nonclinical populations, and their game use was relatively low. This issue should be further investigated in future studies involving patients with IGD who have diverse symptoms.

The hippocampus also plays a vital role in addiction because it participates in memory encoding and retrieval (50, 51). It has also been implicated in learning from experience (52), and motivational drives including those related to rewarding behaviors such as gaming (24, 53). The hippocampus in the memory system may provide the emotional significance of gaming-related cues based on gaming experience, although direct examination is required.

Moreover, the thalamus serves as a relay with reciprocal connections to the cerebral cortex, contributing to numerous functions and behaviors (54). It has also been implicated in motivational drives associated with addiction (55). Through its input to the nucleus accumbens, the thalamus reportedly influences opiate withdrawal-induced physical signs and aversive memories (56). Furthermore, cocaine and methamphetamine may induce synaptic alterations in thalamus-to-nucleus accumbens projections (57, 58). Interestingly, male Internet gamers have shown greater thalamic activation to gaming cues than females, suggesting to be a biomarker for male vulnerability in developing IGD (25). Given that our participants were all males, future studies should recruit female participants and discuss sex differences in the roles of this area through adequate statistical analyses.

The right STG was also significantly activated by the gaming-related cues on social media than the neutral ones, demonstrating a positive correlation with the gaming desire levels. The STG is crucial in auditory processing, language processing, multisensory integration, and social perception (59, 60). In gaming, visual, auditory, and sometimes haptic stimuli are combined to create a rich experience. Social interactions can occur through multiplayer settings or online communities. Thus, the STG may integrate multisensory stimuli and may influence how individuals perceive and respond to social situations within the gaming environment. A recent study revealed aberrant functional

connectivity and executive dysfunction of the posterior-superior temporal sulcus in adolescents with IGD and proposed that excessive exposure to game-related social stimuli during adolescence might affect the dynamic interaction between the salience network and social brain network; such an excessive exposure seems to be associated with executive dysfunction and cognitive problems (61). Taken together, the current results may encourage further investigation into the long-term impact of gaming-related content on social media on the young generation. As previously mentioned, left OFC activation was not significantly related to gaming content, but a positive correlation with the desire for gaming was observed. On the other hand, activation of the right STG was linked to gaming content and positively correlated with the desire for gaming. These observed regional differences might reflect the integration of sensory (visual, auditory) and reward-related signals during exposure to gaming content (59, 60). Although the role of OFC in reward valuation aligns with the desire for gaming, STG involvement suggests an additional layer of processing related to audiovisual cues or contextual relevance within gaming scenarios.

Additionally, the precuneus and the PCC were greatly activated; these areas have been implicated in cue reactivity in many addictions (20, 42, 62). The precuneus is crucial in processing visuospatial information and guiding spatial behavior (63). The PCC helps direct attention to the internal world, transmit internal information for subsequent evaluation, and facilitate functional integration (64, 65). Moreover, the regions are the core components of the default-mode network (DMN), a brain system implicated in introspection, self-monitoring, and emotional processing (65). During the early stages of regular gaming, the neural reactivity in posterior parietal regions engaged in DMN is already exaggerated, probably promoting continued engagement in gaming behavior (19). The current findings support the notion that the precuneus and the PCC are key regions in cue reactivity, and they should further be explored as biological markers aiming for early detection of problematic game use.

Furthermore, the right MTG and occipital regions were activated by gaming-related cues. Although these brain areas were outside our predefined ROIs, this finding largely parallels previous findings on cue reactivity. The MTG not only involves auditory functions but also retrieves and stores long-term memory (66). Its involvement during exposure to gaming cues may be associated with extracting and integrating individual online game memories (25). Furthermore, the brain areas in the occipital lobe are

repeatedly associated with gaming-related cue reactivity. For example, individuals with recreational game use and IGD exhibited increased activation in the bilateral occipital gyrus when comparing gaming-related cues with typing-related cues (67). In addition, [Ma et al. \(2019\)](#) reported that the levels of engagement of the temporo-occipital network positively correlated with IGD severity during a gaming-related cue reactivity task in participants with IGD (18).

To summarize, gaming-related content on social media elicited similar brain regions engaged in the processing of other gaming stimuli (e.g., pictures or videos of familiar games); these regions include brain areas related to reward (MPFC, thalamus), memory (hippocampus, MTG), attention (PCC, precuneus), and sensory processing (STG, occipital regions) (Fig. 4). Neuromarketing has made remarkable advances in elucidating how brain processes produce consumer decisions and behaviors (21, 68-70). For instance, e-cigarette advertisements featuring sweet or fruit flavors have a noteworthy influence compared with those featuring tobacco flavors. This impact included heightened neural cue reactivity, diminished memory retention for health warnings, heightened visual attention to advertising content, reduced focus on warning labels, and an increased inclination toward liking and intending to try these products (68). The authors proposed that depictions of sweet or fruit flavors may override the ability of the warning label to command attention and galvanize memory about health information (68). In addition, [Rapuano et al. \(2016\)](#) showed that compared with nonfood commercials, food commercials elicited stronger activations in regions associated with attention, saliency detection, and reward processing. Moreover, left OFC and right insula activities correlated with the participants' percentage of body fat during scanning. The findings suggest the intriguing possibility that adolescents with higher adiposity may mentally simulate eating behaviors, providing a potential neural mechanism for the development and reinforcement of unhealthy eating habits that may impede weight loss ability later in life (69). Taken together with these previous studies, our findings can help improve our understanding of habit formation and provide support to individuals vulnerable to addictive disorders. Furthermore, unlike passive forms of media consumption such as watching e-cigarette advertisements and food commercials, gaming involves active participation and interaction. People make decisions, engage in challenges, and experience rewards within the game environment (1-3). Moreover, games frequently incorporate complex reward systems, including achievements, progress levels, virtual

goods, and social rewards (3, 4, 10, 11). These reward mechanisms can elicit neural responses pertaining to motivation, decision-making, and reinforcement learning, which are distinct from responses to simple hedonic stimuli such as food or addictive substances. Continued research on gaming content on social media can capture the cognitive and emotional processes linked to active engagement and immersion, offering insights beyond traditional passive media stimuli.

Regarding future research directions, contrasting neural responses induced by gaming-related content on social media with those induced by pictures or videos of familiar games should offer valuable insights into the unique dimensions of digital media experiences. Social media platforms foster social interactions, peer feedback, and community engagement around gaming content (8-11). Contrasting neural responses can elucidate the mechanisms where social factors modulate brain activity, such as increased activity in areas related to social reward processing and empathy (e.g., mirror neuron system), which might not be as pronounced with static stimuli (19, 71). In addition, contrasting neural responses can help disentangle the impact of interactivity on cognitive processes, emotional reactivity, and reward mechanisms, providing insights into the allure and addictive potential of interactive digital media.

This study had several limitations. First, despite our efforts to select neutral stimuli, closely matching each gaming-related stimulus concerning complexity, content, design, luminance, color, action, and the presence of faces, the use of naturalistic stimuli for research on incorporating real-world content from social media posed challenges in achieving complete matching across multiple parameters, such as the foreground-background ratio and zooming speed. Second, the video stimuli used in the current study contained graphics of the actual gaming scenes. However, the proportion of actual gaming scenes varied throughout the videos, ranging from approximately 20% to 90%. This variability hampered precise calculation of its effects. This issue should be further investigated in future studies. Third, this study did not measure physiological measurements such as heart rate, which reflect autonomic activity and arousal levels (72). Incorporating such physiological measures would be beneficial for assessing whether neural responses are mainly driven by context-relevant gaming cues or general arousal and attention processes. This distinction is crucial for comprehending the mechanisms underlying gaming-related behaviors. Fourth, based on previous fMRI studies of cue reactivity that utilized event-related experimental designs (e.g., 21, 25, 67, 73), we

employed an experimental design with videos lasting 20 s each. The decision to use a 20-s video aimed to strike a balance between ecological validity and experimental control. Meanwhile, several previous studies used a block design, in which each video type is continuously viewed for a longer period, to promote sustained engagement with stimuli (16). However, prolonged exposure to the same type of stimulus can diminish neural responses over time, potentially masking differences between conditions (74). The neuroimaging results should be interpreted while considering the differences in the utilized task design. Considerably, rapid video switching can lead to anticipation effects, where participants anticipate changes in stimulus type (74). However, to minimize these effects, we provided clear instructions to participants regarding the nature of stimulus changes, and the task design (e.g., pseudorandomization) was carefully planned (Methods section). Therefore, we believe that our findings will be useful for obtaining a better understanding of neural responses to gaming content on social media. Fifth, this study utilized a cross-sectional design, which precludes any causal conclusions. In future longitudinal studies including patients with IGD, additional clues should be provided to better predict and mitigate the triggers for IGD onset and recurrence. Sixth, although the sample size was comparable to the previous fMRI studies on gaming addiction (61, 73), it was relatively small for analyzing individual differences. The low statistical power may have prevented reaching statistical significance in some relevant brain regions. Finally, our sample included only young adults; thus, our findings may not be generalizable to other generations.

Despite these limitations, this study may improve our understanding of the effects of gaming-related content on social media in young adults. Continued research using real-world gaming-related cues is needed to obtain significant insights into addressing the increasing popularity of problematic gameplay among the youth.

## **Contributors**

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## **Declarations of interest**

The authors declare no conflict of interest.

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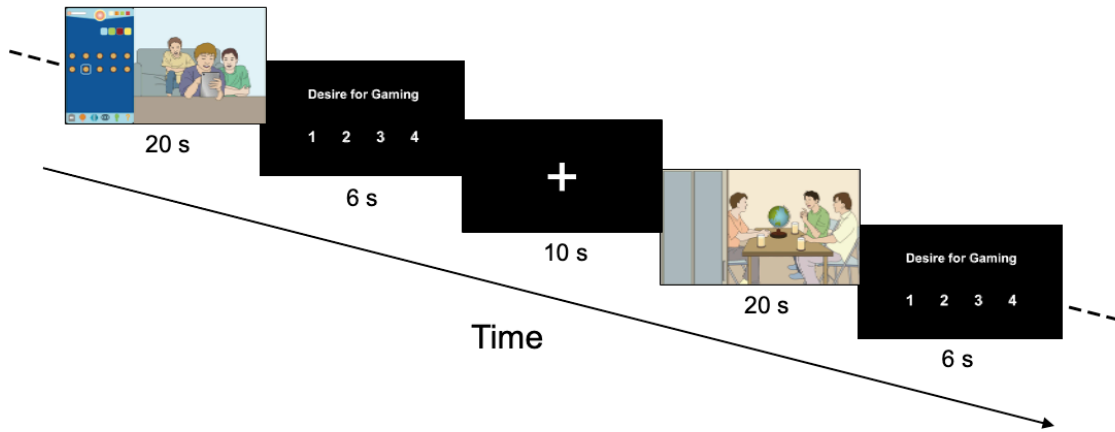
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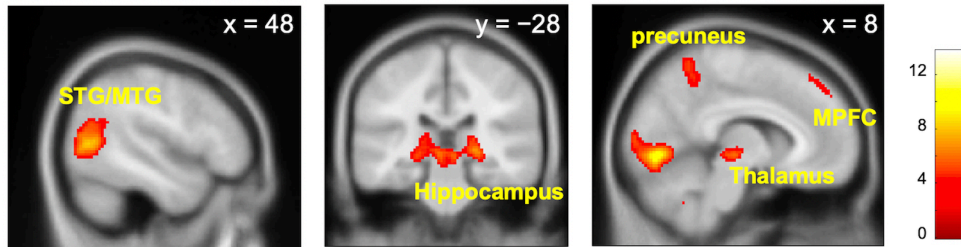
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**Fig. 1.**



**fMRI task.** Videos (20 s each) were displayed pseudorandomly, and after watching each video, the participants were asked to rate their gaming desire from 1 (no desire) to 4 (extreme desire). For display, the still-in comic-style picture illustrates a video from social media.

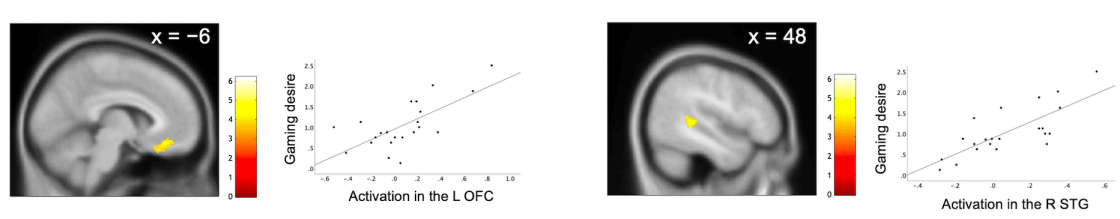
**Fig. 2.**



**Brain regions activated during the fMRI task (gaming-related cues > neutral cues).**

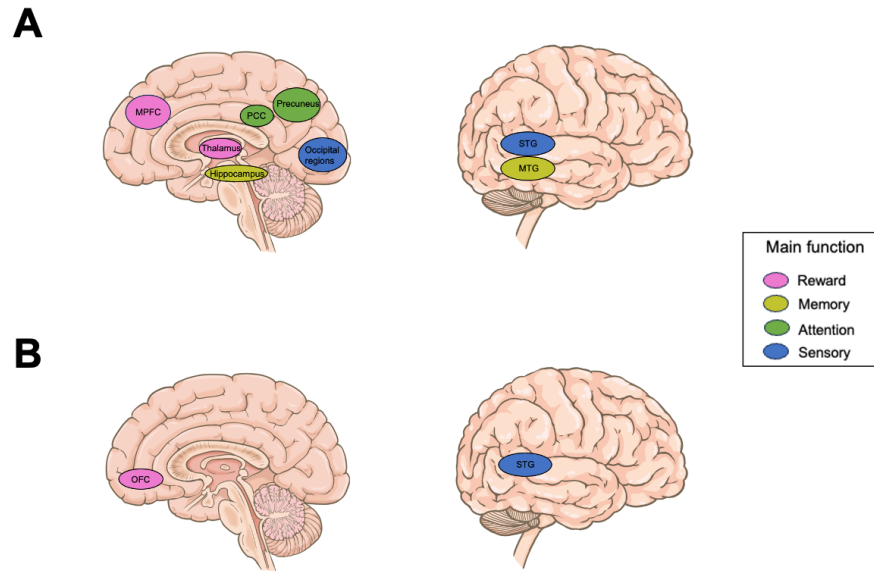
For display purpose, the threshold is set at  $p < 0.001$ , uncorrected. Abbreviations: MPFC = medial prefrontal cortex, MTG = middle temporal gyrus, STG = superior temporal gyrus

**Fig. 3.**



**Brain regions significantly correlated with gaming desire.** For display purpose, the threshold is set at  $p < 0.001$ , uncorrected. Abbreviations: L = left, OFC = orbitofrontal cortex, R = right, STG = superior temporal gyrus

**Fig. 4.**



**Brain regions crucial for processing gaming-related content on social media. (A)** Brain regions activated by the gaming-related cues. **(B)** Brain regions correlated with gaming desire. The main functions of each brain region are illustrated.

**Table 1. Demographic characteristics of the participants**

	Total (n = 22)
Age (years, mean $\pm$ SD)	21.5 $\pm$ 2.2
Education (years, mean $\pm$ SD)	13.1 $\pm$ 1.8
Predicted full-scale IQ (mean $\pm$ SD)	107.3 $\pm$ 7.2
IAT (mean $\pm$ SD)	34.2 $\pm$ 9.0
Weekly gaming time (hours, mean $\pm$ SD)	6.4 $\pm$ 5.6
Gaming history (years, mean $\pm$ SD)	10.2 $\pm$ 3.2

Abbreviations: IAT = internet addiction test, IQ = intelligence quotient; SD = standard deviation

## Supplementary Materials

### Supplementary Methods

#### *fMRI data acquisition and preprocessing*

All participants underwent MRI on a 3-T whole-body scanner equipped with a 20-channel head/neck coil (Prisma, Siemens, Erlangen, Germany). Functional images were obtained in a T2\*-weighted gradient-echo echo-planar imaging (EPI) sequence. The images were acquired using the following parameters: repetition time (TR) = 1000 ms, echo time (TE) = 32 ms, flip angle (FA) = 61°, field of view (FOV) = 231 × 231 mm, and 45 interleaved axial slices at 3.3 mm thick. To allow for signal stabilization, we did not save the first two volumes; then, we acquired the subsequent 626 volumes. Participants individually lied down in a supine position on a scanner bed with a hand-held button-response device. Their vision was corrected, and foam pads were used to reduce head motion. They viewed the visual stimuli back-projected onto a screen through a built-in mirror. Structural scans were also acquired using T1-weighted three-dimensional magnetization-prepared rapid gradient-echo (3D-MPRAGE) sequences (TR = 2250 ms; TE = 4.5 ms; inversion time = 950 ms; FA = 12°; FOV = 256 × 240 mm; matrix size; 320 × 300; resolution = 0.8 × 0.8 × 0.8 mm<sup>3</sup>; and 224 total sagittal slices).

Images were processed using SPM12 (Wellcome Trust Center for Neuroimaging, London, UK) in MATLAB (MathWorks, Natick, MA, USA). Functional images were corrected for differences in slice-acquisition timing and then spatially realigned to adjust for head motion. The T1-weighted anatomical image (3D-MPRAGE) was co-registered with the functional images' mean. Subsequently, the co-registered T1-weighted anatomical image was normalized to a standard T1 template image, as defined by the Montreal Neurological Institute space. The parameters from this normalization process were applied to each EPI image. Finally, we resampled the anatomically normalized EPI images to a voxel size of 2 mm × 2 mm × 2 mm and spatially smoothed them by using a Gaussian kernel with a full width at a half-maximum of 8 mm in the x, y, and z axes.

## Supplementary References

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**Table S1. Brain regions activated during the fMRI task (ROI analyses)**

Brain Region	Coordinates (mm)			<i>T</i>	Cluster (voxels)
	x	y	z		
<i>Gaming-related cues &gt; neutral cues</i>					
L medial prefrontal cortex	-10	50	42	6.27	156
L posterior cingulate cortex	-2	-50	20	4.34	22
L hippocampus	-22	-30	-4	5.00	41
L thalamus	-4	-22	-2	7.91	326
L precuneus	-12	-54	68	7.54	288
R medial prefrontal cortex	12	40	52	4.85	80
R hippocampus	22	-30	-4	5.78	36
R thalamus	6	-22	-2	7.20	149
R superior temporal gyrus	56	-38	14	4.96	119
R precuneus	12	-54	64	5.74	255
<i>Neutral cues &gt; gaming-related cues</i>					
None					

$p < 0.05$ , cluster-level *FWE* corrected (at voxel-level uncorrected  $p < 0.001$ )

MNI coordinates and *T*-values were provided for the respective local voxel maximum of each respective cluster.

Abbreviations: *FWE* = family-wise error, L = left, MNI = Montreal Neurological Institute, R = right, ROI = region of interest

**Table S2. Brain regions activated during the fMRI task (outside the ROIs)**

Brain Region	Coordinates (mm)			<i>T</i>	Cluster (voxels)
	x	y	z		
<i>Gaming-related cues &gt; neutral cues</i>					
L inferior occipital gyrus	-26	-80	-6	13.76	1396
L lingual gyrus	-20	-86	-6	11.45	
R inferior occipital gyrus	32	-66	-8	11.20	
R middle occipital gyrus	30	-72	22	10.50	310
	32	-70	12	8.39	
	38	-70	20	7.65	
R middle temporal gyrus	44	-68	4	9.32	113
<i>Neutral cues &gt; gaming-related cues</i>					
None					

$p < 0.01$  (FWE corrected) and  $k = 100$  voxels

Three local maxima more than 8.0 mm apart are reported.

The coordinates are in the MNI space.

We interpreted the clusters' anatomical location by consulting the Talairach Daemon database ([http:// www.talairach.org](http://www.talairach.org)), Anatomic Automatic Labeling toolbox (1), and neuroanatomy atlas books (2, 3).

Abbreviations: FWE = family-wise error, L = left, MNI = Montreal Neurological Institute, R = right, ROIs = regions of interest

**Table S3. Brain regions associated with gaming desire (ROI analyses)**

Brain Region	Coordinates (mm)			<i>T</i>	Cluster (voxels)
	x	y	z		
<i>Positive</i>					
L orbitofrontal cortex	-6	34	-18	4.49	199
R superior temporal gyrus	66	-38	8	4.93	67
<i>Negative</i>					
None					

$p < 0.05$ , cluster-level *FWE* corrected (at voxel-level uncorrected  $p < 0.001$ )

MNI coordinates and *T*-values were provided for the respective local voxel maximum of each cluster.

Abbreviations: *FWE* = family-wise error, L = left, MNI = Montreal Neurological Institute, R = right, ROI = region of interest