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Attentional Processes in Problematic Internet Use

Supervisor:
Professor Giulia Buodo

Candidate: Kritika Sharma
Student ID number: 2054052

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Abstract

Problematic Internet Use (PIU) is a burgeoning topic of research interest considering our dependence on the Internet today and in the time to come. Although PIU is not included in the two main diagnostic classification systems, i.e., the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) and the International Classification of Diseases (ICD-11), substantial research has found PIU to have overlapping features with Substance Use Disorder. Indeed, PIU has been found to have substantial links with depression, anxiety, low self-esteem, sleep disturbances, and other psychological dysfunctions. One such intriguing association is between PIU and attentional problems. The present literature review examines different attentional processes in PIU. Some studies will be described where different tools have been used to probe attentional abilities in problematic internet users, and how they can help in understanding PIU. Additionally, this review explores the link between PIU and ADHD. The findings highlight how attentional processes can be impaired in problematic users. Further investigation in this regard is useful to design new studies or confirm the existing ones.

Introduction

Internet use has skyrocketed ever since its emergence in the 1990s and its accessibility in the early 2000s. We now live in a digital world where everything is at our fingertips– news, shopping, learning, gaming, and social networking. Researchers recognized the potentially addictive nature of the internet soon after the widespread popularity of smartphones and social media in the mid-2000s. It was realized that the internet would not only bring a wave of change in technology but also a wave of change in human psychology. The internet has changed the way we feel, the way we perceive, and the way we behave, often more detrimentally than beneficially.

A meta-analysis by Huang (2022) reveals the dark sides of internet use when it becomes problematic. This meta-analysis synthesizes findings from 133 different studies examining problematic use of all social media platforms, revealing moderate positive correlations between problematic social media use and depression and loneliness, as well as a small but noteworthy negative correlation with well-being indicators such as life satisfaction and self-esteem.

The association between Problematic Internet Use (PIU) and attention is another intriguing yet underexplored area. Most research has focused on PIU and attentional disorders like ADHD, or ADHD-like symptoms. For instance, Hee et al. (2004) found a significant association between ADHD symptoms and the severity of internet addiction in elementary school students. Similarly, Yen et al. (2007) found that adolescents with internet addiction had higher self-reported ADHD symptoms.

Attentional processes are worth being explored in PIU, especially in today's attention economy. We have limits in our ability to sustain attention on content and focus on specific information. This makes human attention a scarce and valuable commodity. As a result, businesses, especially in media, compete to capture and hold people's attention making it difficult to disengage from the online world. This may encourage the potentially addictive nature of the internet. This competition explains the attention economy. The more businesses succeed in capturing and holding our attention, the higher the likelihood that we are influenced by their ads and ultimately become consumers of their products. Therefore, our attention drives higher conversion rates, fulfilling business goals. The interaction between our limited-capacity attention and the attention economy may create a cycle facilitating addiction to the internet, influencing how we pay attention.

Thus, it becomes an infinite loop.

Luck and Vecera (2002) mention different ways to understand attention.

1. **Task-Defined Attention:** This type of attention is determined by the demands of a task. It requires focusing on certain stimuli or aspects while ignoring others as per the rules of the task. For example, the Go/No-Go Task and the Inhibition Control Task (see Chapter 2).

2. Maintaining Attention: This type of attention refers to the ability to sustain focus on a task over time. For example, in the Go/No-Go Task participants have not only to pay attention to Go and No-Go stimuli to respond (to Go stimuli) or withhold responding (to No-Go stimuli), but they also have to sustain attention over time.

3. Process-Oriented Attention: This type of attention is determined by the cognitive process of selecting certain stimuli or tasks over others to improve efficiency. For example, the Dot Probe Task and the Stroop Task (see Chapter 2).

Exploring different aspects of attention is useful in understanding PIU. Such insights can hint at explaining symptoms like maintenance and salience in problematic internet users. This knowledge can also help to design interventions that may improve symptoms in individuals dealing with PIU.

1. Problematic Internet Use

The Internet has become an integral part of our life. It is difficult to imagine our day-to-day activities without it. As of January 2024, there were 5.35 billion internet users worldwide, which amounted to 66.2 percent of the global population. Of this total, 5.04 billion, or 62.3 percent of the world's population, were social media users (Statista, 2024). Be it for social networking purposes to stay connected with followers, to write an essay on current affairs, to send or receive a myriad of emails in a day, to shop, to read the news or simply to pass time watching online videos, the internet is for all and trying to live without it is far from possible. With the increasing shift from offline to online, the popularity of social media influencers and online gamers, and the need to create and maintain a digital identity through social media profiles, there's no going back.

Problematic Internet Use (PIU), also known as Internet Addiction, refers to a behavioral pattern characterized by compulsive internet use, leading to significant impairment in the social and occupational life of the affected individual. PIU encompasses a range of online activities that become excessive and problematic, including gaming, social media, internet browsing, and online shopping. Therefore, PIU is a broader term that goes beyond Internet Gaming Disorder (IGD), encompassing various forms of problematic online behavior. Symptoms of PIU include preoccupation with the internet, the need to spend increasing time online to achieve satisfaction, withdrawal symptoms when offline, continued use despite negative consequences, and inability in controlling the amount of time spent online.

However, not every person who spends an excessive amount of time on the internet can be categorized as problematic internet user. Take social media influencers and professional online gamers for instance, who build their career on the internet, their workspace. Kuss and Griffiths (2017) point out that social media, especially social networking is a way of being. It was even suggested that social networking meets basic human needs, as described in Maslow's hierarchy of needs. A universally accepted diagnostic criteria would set them apart from problematic internet users. Although PIU is a concerning condition with many psychological implications, it has not been recognized as a formal diagnosis in the two main diagnostic systems, DSM and ICD, to date. This creates complications in establishing a universally accepted set of symptoms specific to PIU and comparable to other psychological disorders, especially substance use disorders. Therefore, different studies use different assessment measures like the

Internet Addiction Test (IAT; Young, 1998), the Chen Internet Addiction Scale (CIAS; Chen, Weng, Su, Wu, & Yang, 2003), or adapted versions of other tests to measure PIU. This further complicates new research on this topic and in the designing and application of treatments.

The comorbid nature of PIU with depression, anxiety, and stress has gained attention among researchers. One such example is the systematic analysis and meta-analysis study by Shannon et al. (2022), reviewing 18 studies that concluded moderate but statistically significant correlations between problematic social media use and depression, anxiety, and stress.

In addition, adolescents are the largest users of the Internet and many studies are focused on adolescents to investigate possible associations between PIU and other psychological disorders. The societal implication of this is that PIU may cause a burden in future workforce, productivity, and healthcare. Therefore, the need for a universally agreed-upon diagnosis is paramount, because a formal diagnosis can lead to better interventions.

The closest we have gotten to include symptoms relating to problematic internet use is including “Internet Gaming Disorder (IGD)” in the Diagnostic and Statistical Manual of Mental Disorders (DSM), fifth edition, which was published in 2013, in Section III, among the"Conditions for Further Study." This section includes conditions that require further research before they can be considered formal disorders with specific diagnostic criteria. Positively, the International Classification of Diseases (ICD) in its eleventh edition which was published in 2018, has recognized "Gaming disorder (IGD/GD)" as a diagnosis under the section "Disorders due to substance use or addictive behaviors"

Table 1 shows the diagnostic criteria for IGD/GD as reported in the DSM-5 (American Psychiatric Association, 2023) and the ICD-11 (World Health Organization, 2018), respectively

Criteria for Gaming Disorder in the ICD-11 (World Health Organization, 2018)	**Criteria for Internet Gaming Disorder in the DSM-5 (American Psychiatric Association, 2023)**
Essential (Required) Features: - **Impaired control** over gaming behavior (e.g., onset, frequency, intensity, duration, termination, and context). - **Increasing priority** given to gaming behavior to the extent that gaming takes precedence over other life interests and daily activities. - **Continuation or escalation** of gaming behavior despite negative consequences (e.g., family conflict due to gaming behavior, poor scholastic performance, negative impact on health). The pattern of gaming behavior may be continuous or episodic and recurrent but is manifested over an extended period of time (e.g., 12 months). The gaming behavior is **not better accounted for by another mental disorder** (e.g., Manic Episode) and is not due to the effects of a substance or medication. The pattern of gaming behavior results in **significant distress or impairment** in personal, family, social, educational, occupational, or other important areas of functioning.	- **Preoccupation** with gaming. - **Withdrawal symptoms** when gaming is taken away or not possible (e.g., sadness, anxiety, irritability). - **Tolerance**, the need to spend more time gaming to satisfy the urge. - **Inability to reduce playing**, unsuccessful attempts to quit gaming. - **Giving up other activities**, loss of interest in previously enjoyed activities due to gaming. - **Continuing to game** despite problems. - **Deceiving** family members or others about the amount of time spent on gaming. - **Using gaming to relieve negative moods**, such as guilt or hopelessness. - **Risk**, having jeopardized or lost a job or relationship due to gaming. **Note:** A diagnosis of Internet Gaming Disorder requires experiencing five or more of these symptoms within a year. The condition can include gaming on the internet with others or alone.

In both sets of diagnostic criteria, a period of 12 months of persistent problematic gaming and its effects is the time duration to be considered for the diagnosis of IGD/GD. As we can see in the table, IGD/GD shares symptoms with Substance Use Disorder and Behavioral Addictions. Symptoms like salience, tolerance, withdrawal, continued use even after negative consequences, and loss of control can be traced in IGD.

As of now, we have to consider PIU to share features with IGD/GD and look at the diagnostic criteria for IGD/GD instead. Formal recognition of PIU as a diagnosis would allow the development of a standardized measure that will ensure the reliability of research in this area.

In recent times, Problematic Social Media Use (PSMU) has been recognized as a subtype of Problematic Internet Use (PIU), with research on PSMU gradually increasing. PSMU involves the compulsive use of social media platforms like Facebook, Twitter, and Instagram, which disrupts an individual's daily life. It is characterized by a persistent and problematic behavioral pattern within the broader context of PIU. As highlighted earlier, with approximately 5 billion people globally using social media as of January 2024, the recognition of PSMU as a specific condition is increasingly justified.

For the sake of ease, in this review, we will consider PIU to encompass IGD and Problematic Social Media Use (PSMU) as subcategories.

2. Attentional Processes in Problematic Internet Use

Researchers investigate attentional processes in individuals with Problematic Internet Use (PIU) because these cognitive functions are crucial in understanding the mechanisms that underlie addictive behaviors. Attentional processes, particularly attentional bias, has always been extensively studied in the context of substance use disorders. For example, a meta-analysis by Field, Munafò, and Franken (2009) found that individuals with substance use disorders who exhibit greater attentional bias towards substance-related cues are more likely to experience stronger cravings, which in turn sustains their addiction. This is just one of many examples, other examples explore different attentional processes like selective attention and inhibition control.

Given the similarities between PIU and substance use disorders, both of which involve compulsive behavior and symptoms like tolerance and withdrawal, it is reasonable to hypothesize that similar attentional biases and, more broadly, attentional processes attentional processes could be inferred in PIU.

Therefore, researchers are motivated to investigate attentional processes in PIU to better understand how these cognitive dysfunctions might contribute to transition from regular, non-problematic internet use to problematic use or how does impairment in attentional processes worsen PIU or vice versa.

2.1 Dot-probe tasks: Main findings

In dot-probe/visual probe tasks that have been employed to investigate spatial attention in individuals with PIU, a pair of stimuli is presented briefly: one stimulus is an internet-related word (e.g., "Facebook," "Click," "Search") and the other is a neutral word. When the two words disappear, a dot appears in the location of either word. The task includes congruent and incongruent trials. In the congruent trials, the dot appears in the same location as the internet-related word, while in the incongruent trials, the dot appears in the location of the neutral word. The participant's task is to indicate the location of the dot as quickly as possible by pressing the corresponding button. Reaction time (RT) is measured for each trial, and the researcher compares the RTs when the dot probe replaces the internet-related word (congruent trials) to when the dot replaces the neutral word (incongruent trials).

In the visual dot-probe task, instead of words, internet-related images (e.g., a social media logo or a website screenshot) are simultaneously presented with neutral images (e.g., everyday objects like a car or a tree, or natural scenes like landscapes).

Figures 1 and 2 show an example of dot-probe task with words and pictures, respectively.

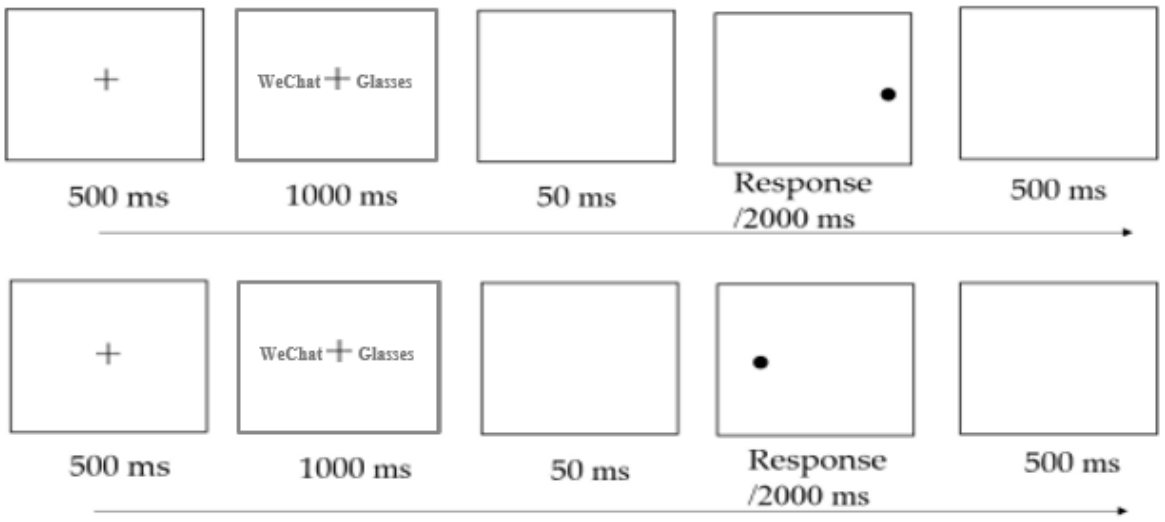

Figure 1. Example of a Dot-Probe task (modified from Zhao et al., 2022)

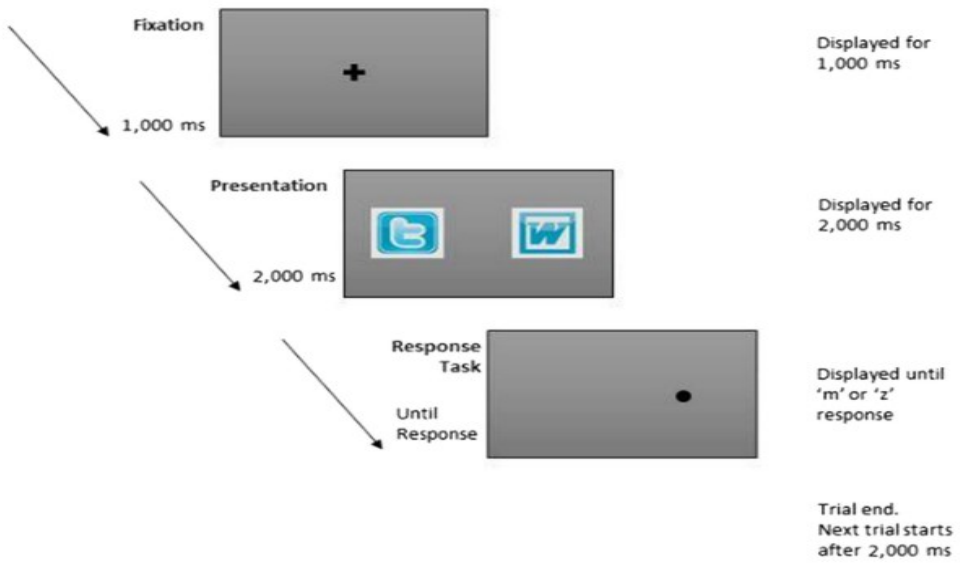

Figure 2. Example of Visual Dot-Probe task (from Stanton Fraser et al., 2019).

The dot-probe task is an indirect primary method for measuring attentional bias toward a stimulus. Attentional bias refers to the tendency to selectively pay attention to certain stimuli over others. Faster RTs to trials in which the dot probe replaces internet-related cues (i.e., congruent trials) vs, trials where the dot replaces neutral cues suggest an attentional bias towards internet-related cues.

The attentional bias has been extensively studied in conditions such as anxiety and anxiety-related disorders, depression, ADHD, and substance use disorders. In conditions like anxiety, individuals might show an attentional bias towards threatening stimuli, while in depression, the bias may be towards negative information. In ADHD, attentional bias might create difficulties in sustaining attention on a task. Later, it was adapted and modified to measure attentional bias in conditions such as PIU.

Incentive sensitization theory has been used to explain attentional bias towards addictive stimuli. According to Jeromin et al. (2016), "since the conditioned stimulus (CS) predicts the drug, it is more salient than other stimuli and the person shifts their attention towards it." Based on classical conditioning principles, internet cues become associated with gratification due to the concurrent activation of the reward system in the brain. With repeated exposure, the reward system becomes hyper sensitized, so just seeing these cues can strongly induce a desire for engaging in the rewarding behavior (online activities). This increased sensitivity makes internet-related stimuli highly salient and difficult to ignore, thereby explaining the attentional bias observed in problematic internet users. This framework helps us understand how attentional bias towards internet-related cues develops and sustains PIU.

In this dissertation, PIU encompasses problematic gaming behavior and problematic social media use. This is crucial as initial studies were focused on problematic gaming behavior.

A study by Van Holst et al. (2012) examined the attentional bias towards game cues in problematic computer and video game-playing male adolescents. Two attentional bias tasks were used for this reason: a Dot-Probe task and an Addiction-Stroop task (see below). The game addiction scale (Lemmens, Valkenburg, & Peter, 2009), based on the criteria for pathological gambling in DSM-IV, and gaming problems measured on a continuous scale (i.e., low, medium, and high problem gaming scores) were used to define problematic gaming behavior, rather than strict categorization.

To assess the attentional bias towards game cues, Reaction Time (RT) bias and Error bias were measured. RT-bias was calculated by subtracting RTs to probes replacing game pictures (i.e., congruent trials) from RTs to probes that replaced animation pictures (i.e., incongruent trials). A positive score indicates faster responses to probes that appear at the location of the game pictures compared with probes at the location of the animation pictures. Therefore, a positive score would indicate the presence of an attentional bias. Similarly, error bias was measured as the number of erroneous responses toward probes replacing animation pictures (i.e., responding toward the location of the game picture, when the probe was presented in place of the animation picture). Higher error rates would indicate that the participants are allocating their attention to game cues over neutral stimuli. While RT bias is a well-established and commonly used measure of attentional bias, error bias is not as widely recognized. However, error bias suggests how game cues become salient to the extent that this salience interferes with cognitive processes involved in decision-making, leading participants to make mistakes in attention allocation to the demanded stimuli (here, the neutral one).

The study did not find an association between RT bias and self-reported levels of problem gaming in the dot-probe task, i.e. the participants with higher gaming problems did not respond faster to game cues than the participants with lower gaming problems. However, the study found a positive correlation between self-reported levels of problem gaming and error bias to game picture locations. This suggests an attentional bias towards game cues in individuals with problematic gaming.

Another study worth mentioning is by Jeromin et al. (2016). This study used the Visual Probe task and Addiction Stroop task (see below) to assess the attentional bias in problematic online gamers as a response to the inclusion of Internet Gaming Disorder in the DSM-5. In the Visual Probe task, participants viewed computer-related (e.g., a monitor) and neutral (e.g., a radio) black-and-white pictures. The sample was divided into excessive internet gamers and non-gamers rather than recognizing problem gaming on a continuous scale.

The results showed that even though the gamers reacted faster overall than the non-gamers, no interaction with picture type was found. This means that excessive gamers did not show faster RTs to probes presented in the position of a computer-related stimulus compared to probes presented in the position of a neutral picture. However,

the study concluded that excessive gamers have an attentional bias towards computer-related cues through the results from the Addiction Stroop task, which will be discussed later on.

Stanton Fraser et al. (2019) studied the attentional bias in individuals with PSMU using a Visual Dot-Probe task while recording eye movements as a more direct measure of the attentional bias than RTs. Social media use was used as a continuum, with Social Networking Sites (SNS) use ranging from non-problematic to problematic, and the level of urge to be online, measured using the Questionnaire on Internet Use Urges (QIUU), categorized into high vs. low. QIUU was adapted from the original Questionnaire on Smoking Urges-Brief (QSU-B; Cox, Tiffany, & Christen, 2001; Tiffany & Drobes, 1991). Eye movements were recorded; specifically, dwell time was measured. It is the time spent fixating on each SNS-related image and control image. Longer dwell time for SNS-related images would indicate an attentional bias for SNS-related cues.

The results showed that both problematic and high-engagement users spent more time looking at the SNS-related pictures compared to the control images and had faster RTs to probes replacing SNS-related images (i.e. congruent trials) compared to incongruent trials. Overall, this study provides evidence for an attentional bias in problematic SNS users towards SNS-related images compared to control images. Moreover, the attentional bias towards SNS-related images positively correlated with urges to be online among problematic SNS users. This suggests that an attentional bias may drive the 'maintenance' behavior in problematic SNS users who frequently feel the urge to be online.

An even more recent study also found evidence for an attentional bias for social media-related cues in problematic social media users. Zhao et al. (2022) investigated the relationships between attentional bias and negative emotions. Attentional bias was measured using Dot-Probe and Addiction Stroop tasks. Compared to non-problematic users, problematic users showed an attentional bias toward social media-related cues (i.e., RTs in the congruent trials were shorter than in the incongruent trials; see Figure 3). A positive correlation was reported between attentional bias and severity of problematic social media use, suggesting the stronger the attentional bias, the more severe the use.

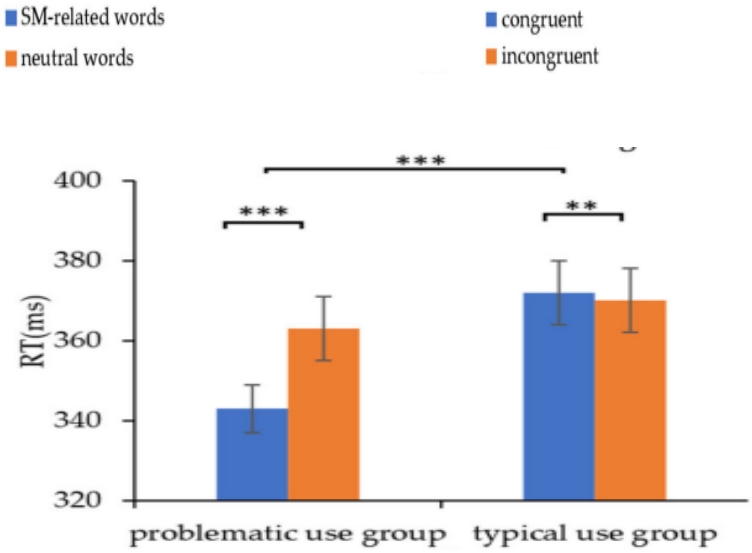

Figure 3. Faster RTs in problematic SNS users for congruent trials suggest an attentional bias towards social media-related cues (from Zhao et al., 2022).

Moreover, according to the theory of the affective processing model of negative reinforcement, the removal of negative emotions that occur during the use of social media is a key factor in maintaining its problematic use. It may not be incorrect to suggest that problematic social media use serves as a coping mechanism for individuals experiencing negative emotions. The attentional bias was positively correlated with anxiety, depression, and social fear in the Dot-Probe Task. Whether problematic social media use is a mediator or moderator between attentional bias and negative emotions, expansion in research about attentional bias is needed to dig deeper into the mechanisms of maintenance and dependence in PIU.

Negative emotions may not be the only reason for users to escape from reality and indulge in the world of the internet. A study by Loreta Cannito et al. (2023) suggested that the boredom trait has a significant positive correlation with Attentional Bias scores and Internet Addiction Test scores. The authors suggested that boredom traits could predict PIU through the mediation role of attentional bias. Simply, people with a high level of boredom trait use the internet to distract themselves. Over time, these people will be sensitive to allocating attentional resources to internet-related cues over neutral ones, which may lead their internet use from recreational to problematic.

2.2 Addiction Stroop task: Main findings

In the Addiction Stroop task, participants are shown a series of words, some related to social media (e.g., WeChat) and others neutral (e.g., glasses), each in different colors. They are asked to name the color of each word as quickly as possible, ignoring the word's meaning. Longer RTs for social media-related words indicate that cognitive processing of the word's meaning delays the response. This suggests that more attentional resources are invested in salient words, making them harder to ignore. This phenomenon is known as the interference effect.

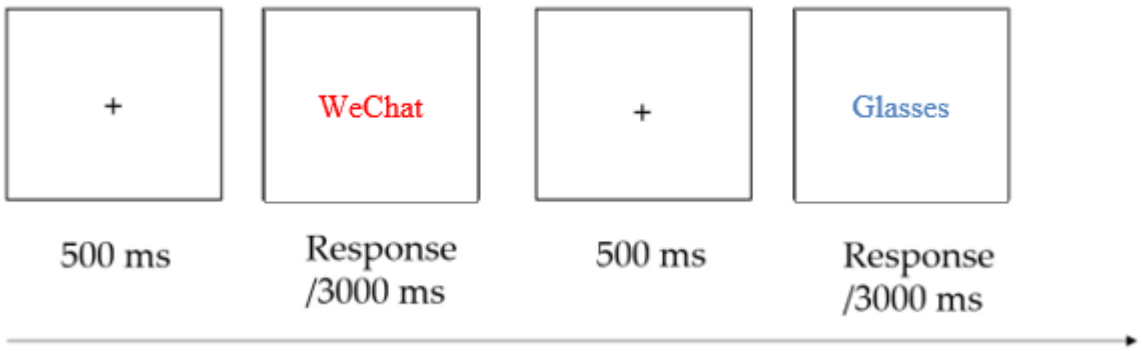

Figure 4. Example of Addiction Stroop task (modified from Zhao et al., 2022)

Similar to the Dot-Probe task, the Addiction Stroop task also measures the attentional bias towards internet-related stimuli. In a scoping review by Chia and Zhang (2020) on cognitive bias in internet addiction and internet gaming disorders, the Stroop task was the most commonly used method for assessing attentional bias, being utilized in four of the six studies reviewed. It has been mostly used to study attentional biases in individuals with substance use disorders or behavioral addictions. It could further increase the evidence of how problematic internet users are sensitive to internet-related stimuli.

Similar to the Dot-Probe task, the Addiction Stroop task provides evidence for the individual's ability to focus on relevant information while ignoring the irrelevant one, i.e., selective attention. Moreover, it also measures the individual's ability to suppress automatic responses, i.e. response inhibition.

The study by Van Holst et al. (2012) mentioned earlier, where the Dot-Probe task was used, also examined the attentional bias using the Addiction Stroop task. In this study,

RT bias and the number of errors during game-related stimuli were measured. In agreement with the Dot-Probe task findings, there was a significant correlation between the number of errors and game addiction scores, suggesting that higher error rates provide evidence for heightened attention to/prioritized processing of the meaning of game-related words.

Similarly, Jeromin et al. (2016) confirmed an attentional bias in excessive gamers using the Addiction Stroop task. Participants were presented with neutral words (e.g., telephone) and computer-related words (e.g., keyboard). The results showed an interaction of group × word type, with excessive gamers displaying longer RTs for computer-related words, whereas non-gamers took longer to react to neutral words. This interference effect suggests an attentional bias.

The researchers have majorly investigated the content related to gaming until now but not the gaming environment (Jeromin et al., 2016 is an exception, as they used computer-related words). The same is true in case of problematic social media use. Therefore, not only the content representing gaming, like “minecraft” and “multiplayer” but even the neurtral words like "monitor," representing the context in which gaming is performed, capture the attention of excessive internet gamers as concluded by Jeromin et al. (2016). If contextual factors significantly contribute to the development or persistence of problematic behavior then failing to address the context could increase the risk for relapse. To tackle this, researchers should investigate the gaming environment that reinforces problematic gaming. If reliable findings show that individuals with gaming disorder have an attentional bias toward the gaming environment, it may be possible to effectively intervene in problematic gaming behavior.

The Addiction Stroop task can also consist of congruent and incongruent trials. In congruent trials, the color of the ink in which the words are printed matches the meaning of the word (e.g., the word "YouTube" printed in red ink, because YouTube is commonly associated with the color red). In incongruent trials, the color of the ink is unrelated to the meaning of the word (e.g. the word “YouTube” is printed in blue ink, where there is no association between the color blue and YouTube). A study by Tekin et al. (2018) used a modified Stroop task to explore cognitive dysfunctions in problematic internet users. Stroop color naming and interference times were measured. Interference time is the additional time taken to name the color of a word when the word’s meaning and color do not match (incongruent trials) compared to when they do (congruent trial).

Higher interference time indicates difficulty ignoring the word's meaning, suggesting lower cognitive control and greater attentional bias towards internet-related cues. Participants with PIU had higher Stroop color naming and interference times compared to those without PIU.

A more real-life version was used in a study by Xie et al. (2021), who investigated distraction using a modified Stroop task in excessive microblog users. Distraction occurs when participants have an attentional bias for irrelevant stimuli, diverting focus from relevant stimuli. Eye tracking was used to measure fixation on distractors and saccades between the target and distractor, providing a more direct measure. The modified task involved Chinese characters (distractors) that represent colors and color blocks (targets) shown on different sides of the screen. In congruent trials, the color blocks matched the meaning of the Chinese characters (e.g., the character "红" (red) with a red color block). In incongruent trials, there was no match between the distractor and the target (e.g., the character "红" (red) with a blue color block).

The results revealed that excessive microblog users struggled to suppress their attention towards distractors and showed longer RTs than non-users in incongruent trials. Eye tracking results indicated that excessive users had longer fixation times in incongruent trials and more saccades between target and distractor stimuli. This suggests that problematic internet users are prone to switching attention from relevant to irrelevant but salient stimuli, impacting their performance.

In contrast, Zhao et al. (2022) did not find evidence of an attentional bias toward social media cues using a Stroop task, as there was no interaction effect of group × trial type. The authors suggested this might be due to the task being too easy or the stimulus duration being too long (3000ms). However, the attentional bias was confirmed using a Dot-Probe task.

2.3 Attentional Network Task, Go/No-Go task: Main findings

Apart from the Dot Probe task and the Addiction Stroop task, which are the most widely employed tasks to measure attentional processes, especially in people with addictions, there have been attempts to assess attentional processes using other tasks such as the Attention Network Task (ANT), the Go/No-go task, the Flanker task, and the Approach-Avoidance task. In this section, the main findings obtained using the Attention Network Task (ANT), the Go/No-go task will be discussed.

2.3.1 Attentional Network Task (ANT)

Fu et al. (2018) investigated the performance in the ANT in individuals with internet addictions and healthy controls. This work is the first of its kind which helps us understand three distinct networks of attention and their potential deficits in internet addiction. The ANT assesses alerting, orienting, and executive control processes by measuring a participant's ability and efficiency to sustain alertness, shift attention, and to inhibit irrelevant stimuli (see Figure 5).

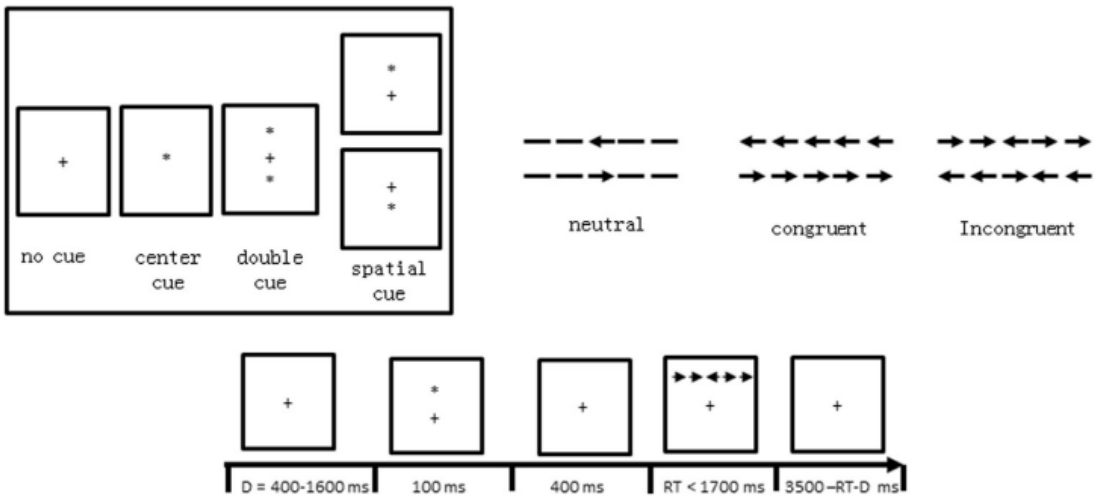

Figure 5. Sample trials of the Attentional Network Task (ANT; from Fu et al., 2018)

The three attentional networks were analyzed by computing:

- RTs of trials with cue (center/double) - RTs of trials without cue; faster RTs in trials with cues indicate an efficient alerting network (**Alerting)**;
- RTs of trials with spatial cue - RT of trials with center/double cue; faster RTs with

spatial cues indicate the ability to shift attention efficiently (**Orienting);**

- RTs for targets with incongruent flankers - RT for targets with congruent flankers; the smaller the difference, the better the management of cognitive interference and inhibition control (**Executive Control)**

The results showed that the orienting efficiency was lower for the internet addiction group than for the control group. Since the spatial cue indicates the exact location of the upcoming target, a slower RT indicates difficulty in shifting attention. Therefore, lower orienting efficiency fits with the presence of an attentional bias in individuals with problematic internet use, as they may find it difficult to shift attention from internet-related cues to other stimuli.

The ANT is often used with children with ADHD to assess their attentional deficits. It can also be utilized to identify similarities and differences in attentional processes between individuals with ADHD and those with PIU, helping to understand the overlapping nature of these conditions.

2.3.2 Go/No-go task

In the Go/No-Go task, participants are asked to respond as quickly as possible to frequent Go stimuli and inhibit their response to unfrequent No-Go stimuli. Therefore, the Go/No-Go task measures the participant's inhibitory control. It is expected that problematic internet users would respond faster to internet-related cues in the Go trials and show lower accuracy in inhibiting responses to internet-related cues in the No-Go trials.

Van Holst et al. (2012), in addition to the Dot Probe and the Addiction Stroop tasks mentioned earlier, investigated inhibitory control using a Go/No-Go task in a sample of individuals with problematic gaming. Participants were tested in two conditions: a neutral motor inhibition condition (with pictures of cars) and a game-related condition (with pictures related to games). Accuracy in the No-Go trials was analyzed, with more errors indicating disinhibition or reduced inhibition capacity. Indeed, the results showed that the higher the participant scored in game addiction, the more errors they made in No-Go trials in the game condition.

A more recent study by Gao et al. (2019) recorded the Event-Related Potentials (ERPs) in a Go/No-Go task to investigate inhibitory control in excessive social networking users.

Three ERP components were analyzed: N1, N2, and P3. A larger N1 amplitude is present when a stimulus is attended to, indicating attentional enhancement. The N2 component indicates conflict detection, while the P3 component indicates response inhibition.

The results for the behavioral performance were not significant in providing evidence for inhibition control deficits in the problematic users group. In contrast, analysis of the N1 amplitude revealed that problematic users paid more attention to internet-related images than to non-internet-related images. Moreover, a larger N2 amplitude in problematic users reflected heightened neural activity in response to conflicting demands between the Go and No-Go conditions. Additionally, the P3 amplitude in the No-Go condition was smaller in problematic users.

A lack of inhibitory control for stimuli that require to withold a motor response can indicate automatic processing that makes certain stimuli more readily attended to than others, i.e., selective attention. This further suggests the presence of an attentional bias toward those specific stimuli (e.g., internet-related stimuli). In real-life, this translates into a difficulty disengaging from the Internet to attend to tasks outside of the internet world. Moreover, it becomes challenging to restrain oneself from using the internet, which can lead to relapse in problematic internet users.

Similarly, a study by Moretta and Buodo (2021) investigated response inhibition through ERP measurements in Facebook users while they performed an emotional Go/No-Go task including Facebook-related, unpleasant, pleasant, and neutral pictures. The emotional Go/No-Go task was used because highly arousing pleasant and unpleasant stimuli help measure how emotions influence attention and behavior. Three ERP components were analyzed: N2, P3, and P2, with P2 reflecting the allocation of attention toward a stimulus.

Consistent with Gao et al. (2019), P3 amplitude in the No-Go condition was reduced for Facebook-related along with pleasant, and neutral stimuli compared to unpleasant stimuli, indicating problematic users have less efficiency in evaluating their ability to suppress a response toward Facebook-related and pleasant stimuli. N2 amplitude in the No-Go condition was larger for Facebook-related stimuli in both problematic users and non-problematic users. This indicates greater conflict in inhibiting responses to that stimuli. P2 amplitude in problematic users were larger for Facebook-related and

emotional stimuli. This indicates problematic Facebook users already tend to allocate more attention toward Facebook-related and affective stimuli. All in all, it can be concluded that problematic users have impaired response inhibition.

3. Attention deficit hyperactivity disorder (ADHD) and Problematic Internet Use

A large body of work on attentional processes in PIU has focused on the association of PIU with ADHD or ADHD-related symptoms. If ADHD is a risk factor that leads to PIU, then recognizing this vulnerability is crucial for monitoring internet usage in individuals with ADHD. Conversely, if PIU worsens ADHD symptoms, this knowledge is essential for developing more effective interventions. As of now, the association is considered bidirectional without a clearcut cause-and-effect relationship.

Hee et al. (2004) conducted one of the earliest studies investigating the association between ADHD symptoms and Internet addiction. Participants were categorized into ADHD and non-ADHD based on ADHD symptom assessments using various methods. The Internet Addiction Test (Young, 1998) was used to measure PIU. The study revealed that the ADHD group had higher Internet addiction scores compared to the non-ADHD group. This suggests that individuals with higher levels of ADHD symptoms are more likely to experience PIU.

ADHD has three components:

1. **Inattention**: Difficulty in sustaining attention and being easily distracted
2. **Hyperactivity**: Difficulty staying still and excessive movement; it is more of a behavioral symptom
3. **Impulsivity**: Difficulty waiting and disinhibition

Boer et al. (2020) attempted to provide directionality by investigating whether ADHD symptoms lead to PIU or if PIU leads to ADHD symptoms. For this reason, they measured ADHD symptoms, social media use intensity, and social media use problems at three different time points (T1, T2, and T3).The adolescents whose PIU increased one year later also experienced an increase in inattention, both from T1 to T2 and from T2 to T3. Additionally, PIU problems at T2 were associated with increased impulsivity at T3. Although a unidirectional relationship was found, where PIU problems increased ADHD symptoms over time, the directionality remains controversial and requires more investigation.

Inattention and impulsivity are rooted in the attentional processes discussed in earlier chapters. While inattention refers to problems with sustained attention and being distracted by internet-related stimuli, hinting at an attentional bias toward internet-related stimuli, impulsivity means the inability to inhibit responses toward internet-related stimuli.

Thus, ADHD symptoms have their roots in the impairment of attentional processes. Regardless of the direction of the relationship, focusing on the specific attentional processes involved, rather than broadly on the association of ADHD with PIU, is significant. By exploring and understanding attentional processes in the context of PIU, we can better grasp the association between ADHD and PIU. This understanding will allow us to differentiate between individuals with PIU alone and those with both PIU and ADHD.

Conclusions

The common theme across almost all the studies reviewed here is that attentional bias plays a crucial role in PIU. Both indirect measures like the Dot-Probe and the Addiction Stroop tasks, and direct measures like eye tracking and the ERPs, provide evidence for deficits in attentional processes among problematic internet users.

Investigating attentional processes helps us understand the symptoms of PIU. Deficits in attentional processes can explain the nature of PIU, including salience, maintenance, negative consequences, dependence, and relapse. Studies investigating attentional bias towards internet-related cues in problematic internet users show that these cues are particularly salient for these individuals. They selectively allocate more attention to these cues, even when they are irrelevant to the ongoing task. Over time, this selective attention can become automatic, as explained by the incentive sensitization theory.

Furthermore, a positive correlation between the urge to be online and attentional bias towards SNS-related images in problematic internet users suggests that attentional bias likely increases the urge to be online, thus maintaining PIU. The studies that investigated inhibitory control also highlight the salient nature of internet-related stimuli over neutral stimuli. The difficulty in inhibiting (disengaging from) these stimuli contributes to the maintenance of PIU and may be involved in the risk of relapse.

Therefore, when attentional processes are carefully and separately investigated, they provide evidence that fundamental symptoms of PIU are similar to those of substance use disorders. Additionally, these investigations imply that deficits in attentional processes lead to or worsen the symptoms of PIU. Focusing on specific attentional processes, rather than broadly examining the association between ADHD/ADHD symptoms and PIU allows for understanding the overlapping mechanisms between the two. This could help to develop targeted prevention strategies or design effective interventions to address both PIU and PIU with ADHD/ADHD symptoms.

Interventions like Attentional Bias Modification (ABM) seem promising. Nasiry et al. (2022) confirmed the effectiveness of ABM in reducing game-related attentional bias and the severity of Internet Gaming Disorder (IGD) in adolescents. This further confirms the crucial role of attentional bias and suggests that future research in this area could increase our understanding of PIU. Additionally, a scoping review by Chia et al. (2020) reports the effectiveness of Cognitive Bias Modification (CBM) in problematic gamers.

CBM aims to modify various cognitive biases and not just attentional biases. This can include biases in interpretation, memory, and other cognitive processes. CBM was found to be effective in reducing approach bias- automatic response to approach game-related cues.

To summarize, attentional processes in PIU should be investigated separately rather than mainly examining how PIU and attentional disorders are related. Specifically, increasing our knowledge on the attentional bias in PIU can help develop interventions such as Attention Bias Modification (ABM) and/or Cognitive Bias Modification (CBM) as possible standalone treatments for PIU. In order to do the above, PIU must be established as a formal diagnosis.

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