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The data supporting this study's findings are available on request from the corresponding author [Email addresses: **hasanimehr57@khu.ac.ir**]. The data are not publicly available due to containing information that could compromise research participant privacy/consent.

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Running head: **Emotional Working Memory Training and Problematic Internet Use**

- Emotional working memory training (EWMT) can strengthen cognitive and emotional brain function
- Problematic Internet Use show significant positive changes in executive functions after 20 EWMT sessions.

- Cognitive functions (inhibition, attention, working memory) can be improved among Problematic Internet Users.
- Problematic Internet Use can be reduced following EWMT.

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Abstract
Problematic internet use (PIU) has been defined as an inability to control impulses to use the internet, and is associated with psychological, social, educational, and/or occupational problems. Considering the harmful effects of PIU, the present study evaluated a treatment intervention aimed at controlling PIU. A randomized control study investigated the effectiveness of emotional working memory training (eWMT) in improving inhibition, attention, and working memory among individuals with PIU in comparison with a placebo group. Young adults (*N*=36) with PIU were either trained for 20 sessions in an n-back dual emotional task (eWMT; *n*=18) or a feature matching task (placebo; *n*=18). Results showed that 20 continuous sessions of eWMT significantly reduced the symptoms of PIU and improved participants' working memory, attention, and inhibition (compared to the placebo group). These preliminary findings suggest that eWMT can be considered a promising treatment to reduce PIU by improving individuals' cognitive and emotional functioning.

Keywords: problematic internet use, inhibition, attention, working memory, emotional working memory

1. Introduction

For young adults, internet use has become an integral part of daily life (Marzilli et al., 2020). Maladaptive overuse of the internet is common, and has been described using various terms including 'problematic internet use (PIU),' 'internet addiction,' 'compulsive internet use,' and 'internet use disorder' (Huang et al., 2014). PIU has been defined as an excessive preoccupation with the internet or inadequate control over internet use, leading to impaired psychological, educational, family, social, and/or occupational capacities (Davis, 2001; Young, 1996; Emadi Chashmi et al., 2022). The behavioral pattern of PIU includes impairment in daily life, repeated failure to reduce or quit, withdrawal, and tolerance, similar to substance abuse disorders (Kurniasanti et al., 2019).

PIU is most prevalent between the ages of 20 to 40 years (Azher et al., 2014; Cudo & Zabielska-Mendyk, 2019; Shaw & Black, 2008), and has become a common mental health concern in many countries (Park et al., 2011; Rumpf et al., 2014). It has been estimated that 2.4% to 36.5% of Asian adults show symptoms of PIU (Babakr et al., 2019; Cudo & Zabielska-Mendyk, 2019). Some scholars claim that PIU increased during the COVID-19 pandemic due to psychological distress and social distancing (Brailovskaia et al., 2021; Luo et al., 2021). However, a recent systematic review of PIU during the pandemic was unable to confirm this (Burkauskas et al., 2022). Nonetheless, symptoms of PIU appear to be relatively common across the globe.

Neurological and imaging studies suggest that PIU is related to abnormal activity in the prefrontal cortex (Brand et al., 2014). Executive functions (e.g., attention, inhibition, working memory) are largely under the control of the prefrontal cortex. While executive functions may be particularly susceptible to the effects of PIU and improving executive functions may have a positive impact on the treatment of PIU, to the present authors' knowledge, no previous study has targeted executive functions in the treatment of PIU. Also, most traditional treatment approaches (e.g., cognitive behavioral therapy) require significant resources (e.g., trained therapists). Therefore, modern approaches requiring fewer resources are needed. Consequently, the present study investigated the efficacy of emotional working memory training (eWMT) as an inexpensive intervention targeting impaired executive functions among young adults with PIU.

1.1 PIU sub-types

A number of scholars have posited different sub-types of PIU. For instance, Young (1999) claimed there were five types of internet addiction: net compulsions (e.g., online gambling addiction and online gaming addiction), cybersexual addiction (e.g., online pornography addiction), cyber-relationship addiction (e.g., addiction to chatting with a romantic partner online), information overload (e.g., addiction to web-surfing) and computer addiction (e.g., addiction to playing games like Solitaire on computers). However, this typology was heavily criticized by Griffiths (2000) who noted that many of these sub-types involved addictions *on* the internet rather than addiction *to* it. Davis (2001) posited there were two subtypes of PIU: specific PIU (individuals who have problems concerning one specific online behavior; e.g., online gaming) and generalized PIU (problems with a global set of online behaviors). More recently, Tiego et al (2019) proposed two subtypes of PIU which differ in severity: high severity "compulsive" (related to obsessive-compulsive personality traits) and low severe "impulsive" (related to attention-deficit hyperactivity disorder). It should be noted that only Internet Gaming Disorder was included in the fifth edition of *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association, 2013) and Gaming Disorder in the eleventh revision of the International Classification of Diseases (ICD-11; World Health Organization, 2019).

1.2. PIU and executive functions

Poor executive functioning has been associated with PIU (Zhou et al., 2016; Young, 2017; Shafiee-Kandjani et al., 2020). In addition to reasoning, problem-solving, planning, decision-making, task flexibility, and inhibition of impulsive actions, executive functions cover a wide range of cognitive functions controlled by the prefrontal cortex (Diamond, 2013; Alvarez & Emory, 2006). These abilities are essential to successfully perform most daily activities (Alvarez & Emory, 2006). In the long-term, impairments in executive functioning can contribute to poor academic performance, social difficulties, and other negative psychological outcomes among young people (Biederman et al., 2004; Ellis, Rothbart & Posner, 2004).

Impulse control disorders are characterized by deficits in executive functions (e.g., response monitoring). Studies have shown negative associations between PIU and executive functions (e.g., inhibition, working memory, and attention) (Shafiee-Kandjani et al., 2020; Nie et al., 2016; Zhou et al., 2016; Kuo et al., 2018; Choi et al., 2014). Cognitive control is a cognitive domain that may be particularly vulnerable to the effects of individuals' PIU. An individual's ability to select and attend to goal-relevant information while inhibiting their attention and responses to irrelevant stimuli is called cognitive control (Koechlin et al., 2003). The underlying neural substrates in the frontoparietal control network develop rapidly during adolescence and into early adulthood (Blakemore & Choudhury, 2006).

In previous studies, cognitive control has been shown to be impaired in PIU with concurrent changes in frontoparietal control networks (Wang et al., 2019; Cai et al., 2016). However, cognitive control impairments are poorly understood among people with PIU. A number of pathways are possible, including: failure to inhibit inappropriate immediate responses that give other processes time (e.g., formulating predictions of possible outcomes; Smith et al., 2014); difficulty disengaging attention from internet-related stimuli (Marin et al., 2021); and a lack of ability to inhibit maladaptive emotion regulation strategies (e.g., avoidance) in favor of more adaptive strategies (e.g., reappraisal; Aldao et al., 2010).

1.2.1 PIU and inhibition

Wright et al. (2003) indicated that PIU is related to impairments in the executive function of inhibition. Inhibition has been defined as an individual's ability to consciously suppress unwanted automatic responses, often to provide more appropriate and targeted responses (Barkley, 1997). In fact, diminished control or loss of control has been regarded as a core concept to understanding addiction (Király & Demetrovics, 2017). In one study, individuals with PIU failed to control their internet activities or experienced withdrawal symptoms (e.g., feelings of depression, anxiety) when asked to stop using the internet (Tzang, Chang, & Chang, 2015).

1.2.2 PIU and attention

Another executive function related to PIU is attention (Park et al., 2011). Attention refers to maintaining readiness to receive a stimulus without being affected by irrelevant stimuli (Knudsen, 2007). Long-term problematic internet use is associated with attention impairments (Park et al., 2011). Moreover, attention deficit disorder might be one of the strongest predictors of PIU (Yen et al. 2009; Yoo et al. 2004). These findings suggest similar neurological mechanisms for attention deficit and addiction disorders such as PIU (Frodel, 2010; Stark et al., 2011). There are two main brain circuits in the neurobiology of addiction and attention deficit: the dopamine (DA) mesolimbic and mesocortical circuits (Patrick et al., 2016; U.S. Department of Health and Human Services, Office of the Surgeon General, 2016). The DA neurons in both circuits ascend from the ventral tegmental area of the brain, which is part of the basal ganglia group located deep within the brain. The nucleus accumbens is the critical connection in the mesolimbic pathway. Motivation, incentive salience, and impulsivity are closely associated with this pathway. Cingulate, orbital/frontal, and prefrontal cortices play an important role in the mesocortical pathway. Cognitive functions such as error detection, executive functions, and goal-directed behavior are associated with this pathway. The mesolimbic DA system is also controlled by this pathway. A disruption in one circuit can adversely affect the functioning of the other circuit due to their close feedback/feedforward relationships.

1.2.3. PIU and working memory

Working memory is another executive function associated with PIU. Working memory is the ability to temporarily store and manipulate information required for complex cognitive tasks, such as language comprehension, learning, and reasoning (Zhou et al., 2014). Research shows that, like substance abuse and alcohol dependence, working memory impairments are associated with PIU (Xiong & Yao, 2010; Zhou et al., 2015).

1.3. Emotional working memory training

Another related process believed to be associated with PIU is emotional regulation (Amendola et al., 2019; Young, 1999). Executive functions (e.g., planning, inhibition) are associated with emotional regulation insofar as they tend to reduce maladaptive emotional regulation strategies (Aldao et al., 2010). Not surprisingly, individuals with PIU often resort to maladaptive emotion regulation strategies (Garnefski et al., 2001; Trinidad et al., 2004). It remains to be determined whether there are mechanisms through which executive functions may be involved in the development and/or maintenance of symptoms of PIU. However, putative mechanisms are likely to involve cognitive control problems in emotional contexts. Therefore, a logical focus of PIU interventions is to improve executive functions in emotional contexts.

Therapy for PIU may have the potential to rehabilitate impaired executive functions such as inhibition and working memory. Therefore, the present study examined the efficacy of treating cognitive and emotional deficits associated with PIU using the dual eWMT protocol developed by Schweizer et al. (2013; 2011). The basic goal of this treatment is to strengthen cognitive and emotional functions (i.e., functions related to the prefrontal lobe; Krause-Utz et al., 2014). The program focuses on improving attention, inhibition, emotional regulation, and working memory. In addition to cognitive training, individuals also receive emotional training using visual (pictures of faces) and auditory (spoken words) stimuli. On a single trial, the task requires that participants indicate whether a face picture is in the same spatial location as one they previously viewed. They are also asked to judge whether a word they hear is the same word they heard before. For optimal task performance, the individual should disregard the affective content of the faces, yet focus on the content of the words. Continuous eWMT training (20-40 minute sessions) has resulted in significantly improved short-term memory performance in encrypting, storing, manipulating, and retrieving emotional information (Schweizer et al., 2011; 2013). The literature has demonstrated the effectiveness of eWMT in improving executive functions and emotional regulation in posttraumatic stress disorder (Schweizer et al., 2017), borderline personality disorder (Krause-Utz et al., 2020), social anxiety (Du Toit et al., 2020), and anxiety and depression (Beloe, & Derakshan, 2020; Heath, 2018; Leone de Voogd, 2016).

1.4. The present study

The extant research literature demonstrates the efficacy of various treatments to reduce the negative consequences of PIU, including emotion-focused group therapy (Amini et al., 2020), dialectical behavior therapy (Siste et al., 2022), occupational therapy (Zhang, 2022) and cognitive-behavioral group therapy (King et al., 2012). Each of these therapies focuses on behavioral, emotional, cognitive, or interpersonal aspects of PIU (Xu et al., 2021; Zajac et al., 2017). The interventions concerning PIU and internet gaming disorder mainly focus on cognitive behavioral methods (Zhang et al., 2020; Malak, 2018), therapies that generally require significant resources, such as trained and licensed therapists. Modern interventions comprising more cost-effective therapies are needed.

A recent study showed that interventions comprising less time and resources such as future imagination training can be effectively implemented (Li, 2021). Computer-mediated cognitive training that can be completed at home may be useful for individuals with fewer resources. To date, no prior research has investigated the effectiveness of eWMT on PIU. While most of the previous interventions targeting PIU have focused on either cognition or emotion, eWMT, focusing on both emotion and cognition (Schweizer et al, 2017), might be a potentially beneficial treatment for PIU-related symptoms. Inability to inhibit maladaptive emotion regulation strategies following impaired cognitive control might lead to PIU, and Schweizer et al (2017) showed that eWMT can effectively improve cognitive control impairments.

The present study is the first to evaluate the effectiveness of eWMT on internet use and executive function among young adults with PIU. It was hypothesized that in comparison with a placebo control group, eWMT would: reduce PIU symptoms (H_1), improve inhibition (H_2), improve attention (H_3), and improve working memory (H_4).

2. Methods

2.1. Participants and design

High school and university students (*N* = 36; 25 females, 11 males; mean age=20.27 years; SD=1.54) were recruited in Karaj (Iran) by sharing an invitation link via social media platforms (i.e., *LinkedIn* and *Instagram*) and paper-based recruitment adverts. The study was approved by the ethics committee of Kharazmi University (IR.KHU.REC.1400.003) and the study protocol was registered at the Iranian registry of clinical trials (IRCT20210828052309N1). *G*Power* software was used to determine the sample size for the study, based on effect size (0.25), α (0.05), power (0.90), number of groups (n=2), number of measurements (n=3) and statistical test (mixed-design ANOVA). Accordingly, the total sample size was estimated to be 36 participants. Moreover, by considering the attrition of participants in experimental designs, 40 participants were selected and randomly assigned into two groups (treatment intervention and placebo). However, only 36 participants completed the study protocol: 18 in the intervention group (12 females, mean age= 20.50 years, SD=1.69) and other half in the placebo group (13 females, mean age=20.61 years, SD=1.72). There was no significant difference in age ($t[35]=0.20$, $p=0.85$) and gender ($\chi^2[1]=0.71$, $p=0.72$) between two groups. It was a single blind, randomized study, in which the research team was aware of the participant group assignment, but the participants were unaware of the differences between groups.

2.2. Measures

Internet Addiction Test (IAT). The IAT (Young, 1998; Persian version: Alavi et al., 2011) was used to determine PIU in this study. The scale was initially developed to screen for participants at risk of internet addiction. The IAT comprises 20 items (e.g., *"How often do you stay online longer than you would like?"*) with four factors (lack of control; social withdrawal and emotional conflict; time management problems; and concealing problematic behavior; Samaha et al., 2018). Items are rated on a five-point scale, from 1 (*not applicable*) to 5 (*always*) (Young, 1998; Young & Rogers, 1998). Scores range from 20 to 100, with higher scores indicating a greater risk of internet addiction/PIU. A score of 49 or less on the scale indicates the individual has control over their internet use. Scores of 50-79 indicate that the individual experiences frequent or occasional problems due to their internet use. Scores of 80-100 indicate severe internet addiction. The IAT has shown good validity and reliability in previous studies (e.g., Canan et al, 2022; Kesici, & Sahin, 2010). In the present study, Cronbach's alpha was 0.81 for the IAT. Participants with a score of over 80 on the IAT were then interviewed clinically to see if they were appropriate for study participation.

Continuous Performance Test (CPT). The CPT (Rosvold et al., 1956; Persian version: Khodadadi et al., 2014) was used to assess sustained attention. The test was used to examine whether eWMT could improve the executive function of attention among participants with PIU. The Persian version of the test presents participants with 30 Persian numbers one at a time as stimuli. When the number '4' is presented, participants are instructed to press the 'space' bar. The number '4' is presented in 20% of trials. Each stimulus number is presented for 150 milliseconds. The interval between the presentation of stimulus numbers is 500 milliseconds. To score well on the task, participants must sustain their attention on the numbers presented, pressing the space key only when the number '4' appears, and refrain from pressing the space key when other numbers appear on the screen. Scores on the CPT includes the number of errors, omission errors, and correct responses.

Go/No-go Task. The Go/No-go (move/stop) Task (Kelly et al., 2004; Persian version: Khodadadi et al., 2014) was used to assess motor inhibition. The task was used to examine whether participants with PIU improved the executive function of inhibition following eWMT training. Participants in the present study were presented with rectangular shapes on a computer screen. They were instructed to respond to the changing colors of the rectangles. If the right rectangle turned green, the participant was instructed to press the '?' key. Participants were instructed to press the 'z' key if the left rectangle turned green. These color changes were defined as 'Go' stimuli. Any other color changes were defined as 'No-go' stimuli (in which participants were instructed to inhibit key pressing). The total number of stimuli was 40, each of which was presented for 0.2 to 3 seconds. The interval between the presentations of stimuli varied from 1 to 5 seconds. In all cases, 'Go' stimuli comprised 70% of the total stimuli (Khodadadi et al., 2014). Therefore, the participant tended to be biased towards the 'Go' response. Lack of proper restraint or committing error is manifested when providing a response to a 'No-go' stimulus (Fassbender, 2004; Kehl, & Liddell, 2001). The following results were recorded in the present study: (i) number and percentage of commission errors (responding to 'No-go' stimuli with the answer to 'Go' stimuli), and (ii) number and percentage of omission errors (not responding to 'Go' stimuli) (Khodadadi et al., 2014).

Wechsler Digit Span Test (WDST). The WDST was used to assess working memory. This test is one of the subscales of the Wechsler Intelligence Test (Wechsler, 1997; Persian version: Abedi et al., 2007). The present study used a computer version of the WDST, which includes four stages (Khodadadi & Amani, 2020). In the first stage, participants are instructed to memorize three to seven numbers read aloud. Subsequently, memory is tested by having participants select the recalled numbers in the same order when they appear on the screen. In the second stage, the numbers are again expressed aurally but inversely. In the third stage, the numbers are presented visually on the screen, and must be selected from the screen in the same order. In the fourth stage, the process of presenting the figures is visual but inverse. The test-retest reliability of this test is very good (Abedi et al., 2007) and the validity of this test has also been reported through positive correlation with other proportional memory tests (Khodadadi & Amani, 2020).

2.3. Procedure (five steps of the present study)

Step 1 (Participant selection and allocation). In the first step, the participants that were initially recruited (*N*=103) were screened for PIU using the Internet Addiction Test (IAT; Young, 1998). Individuals who scored below 80 on the IAT were excluded from participation in the study. Only individuals aged 18-40 years who had scores above 80 in IAT were included. A trained psychologist then clinically assessed the remaining participants to confirm PIU symptoms, ensure the absence of other comorbid disorders (participants with mild to severe depression, anxiety, stress was excluded), and assess readiness to participate in the study. As a result, six additional participants were excluded (three for severe anxiety symptoms and three for severe depressive symptoms). A total of 40 participants met the criteria for inclusion in the study (inclusion criteria: being aged between 18-40 years and score >80 in IAT; exclusion criteria: inconsistency in PIU symptom reporting, comorbid psychological disorders, and participation unreadiness). All participants were also asked to name their most frequent online activity. Most (n=26) reported social media use (14 in intervention group), nine reported online gaming (four in intervention group), and five reported internet surfing (two in intervention group). Of these, 36 individuals completed the sessions. Therefore, the final sample consisted of 36 participants. The study's aims were explained to participants, who provided written informed consent. The placebo control and treatment intervention groups were matched in terms of age, gender, and severity of internet addiction. Researchers randomly assigned participants to either the eWMT group or a placebo control group. The participant selection process and study development are shown in Figure 1.

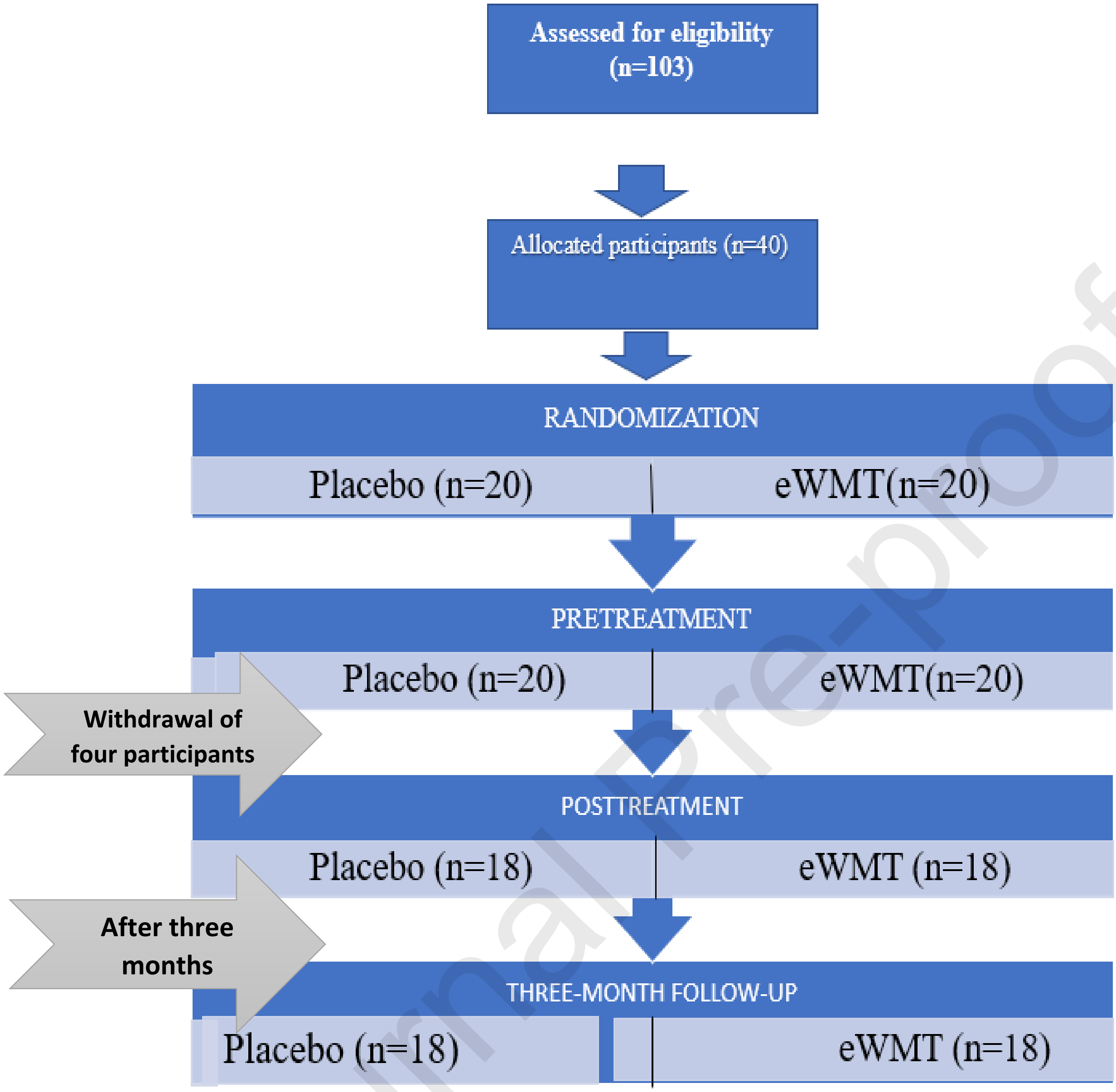

Figure 1. Consort flow diagram of participant allocation and study development

Step 2 (Pre-test). In the pretest phase, all participants completed the IAT, the Continuous Performance Test, a Go/No-Go task, and the Wechsler Working Memory Scale (described below).

Step 3 (Experimental design). Before starting the intervention, three participants (two in the treatment intervention group and one in the placebo group) stopped attending sessions without declaring a reason (see Figure 1). For the intervention, the eWMT group received training while the control group received placebo training (detailed below). The intervention for the eWMT group began with a brief explanation of the training task to the participants. Participants then completed

20 sessions of eWMT (three sessions per week) lasting between 30 and 45 minutes (depending on the amount of n-back obtained) on weekdays through a program installed on the participants' personal computers. Before Session 10, two additional participants in the treatment intervention group and two individuals in the placebo group declined to participate further, reporting that the words used in the eWMT program made them reluctant to continue. Some of them were also removed due to irregular attendance at training sessions.

Step 4 (Post-test). For the post-intervention phase, all participants again completed the measures. Due to the COVID-19 pandemic restrictions (e.g., maintaining social distance), assessment and training was performed individually under the supervision of a psychology postgraduate.

Step 5 (Follow-up). Three months later, participants were invited to complete measures for a third time for the follow-up phase. Participants who completed all the sessions of the study were given a mobile phone SIM card (50000 Tomans; approximately $12 [US]) as remuneration for their time.

2.4. Training tasks

eWMT Training Intervention. eWMT (adapted from the task used by Schweizer et al. [2011]) is an affective dual n-back task consisting of a series of trials involving simultaneous presentation of a face (500ms on a 4x4 grid on a computer screen) and a word (500ms over headphones; Leon-Dominguez et al., 2015). There was an interval of 250ms following the presentation of each picture-word pair, during which participants responded by pressing a button to indicate whether either or both stimuli matched those presented n-trials previously (where n is a variable amount). The negative valence of words (e.g., 'death', 'rape') and faces (fearful, angry, sad expressions) was evident. Each trial started with n = 1, and increased by one when participants correctly identified 60% or more of the targets; or, decreased by one if fewer than 20% of the target trials were correctly identified. In this task, participants received two types of feedback. For auditory targets, an unpleasant tone was heard if the target was missed, and a pleasant tone if it was correctly identified. Upon correctly identifying visuospatial targets, a green happy emoji appeared, while a red sad emoji appeared upon missing them.

Placebo training. Participants in the placebo group were shown two panels with geometrical shapes on a computer screen. On the top panel, there were three target shapes that participants were asked to identify with a mouse click at the bottom. The panels also contained 5 to 13 distractor shapes. The number of distractors included with the targets was determined randomly (i.e., not based on performance).

2.6. Statistical analysis

IBM SPSS software version 24.0 was used to analyze the data. Before analyzing data, all assumptions were checked and met. Due to the random pattern of missing data, participants with values greater than 5% were omitted (Tabachnick et al., 2018). Of the participants who had a missing value of over 5% of the total verification, one was in the treatment intervention group and two were in the placebo group. Therefore, data from 36 participants (18 in each group) remained for the final analysis. Analyses were performed on participants in both groups that had completed measurements at T0 (baseline), T1 (post-intervention), and T3 (three-month follow up). The analysis considered differences between T0 vs. T1 and T0 vs. T2 as major outcomes, using mixed-design ANOVAs. In all mixed-design ANOVAs, time (T0, T1, and T2) was considered as the within-participant factor; group (treatment intervention and placebo) as the between-participants factor; and PIU/internet addiction, inhibition, attention, and working memory as dependent variables. To examine if trajectories of outcome variables in the treatment intervention and placebo groups differed between participants, a series of mixed models were applied with IAT, inhibition, attention, and working memory scores as the dependent factors; and group (treatment intervention and placebo), time (T0-T2), and the interaction between group and time as independent factors (fixed effects).

3. Results

3.1. The effect of eWMT intervention on PUI

As aforementioned, a mixed design ANOVAs was used to compare the effect of the treatment intervention and placebo groups on PIU. Mixed design ANOVAs showed overall significant main effects of time (Wilks λ= 0.12; F (2, 33) =146.26, p< 0.001, η^2= 0.90) and a time*group interaction (Wilks λ= 0.12; F (2, 33) =138.47, p< 0.001, η^2= 0.89) in IAT scores. The results are summarized in Table 1.

Table 1. Means, standard deviations of IAT scores, and results of mixed design ANOVAs

Group	T0	T1	T2	Time		Group		Time* Group	
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*F* (1, 34)	η^2	*F* (1, 34)	η^2	*F* (1, 34)	η^2
TIG (n=18)	68.17 (9.46)	40.22 (8.14)	41.22 (9.19)	176.61***	0.84	37.05***	0.52	161.34***	0.83
PG (n=18)	67.05 (8.89)	66.67 (8.38)	66.44 (8.68)						

Note: TIG= Treatment intervention group; PG= Placebo group; PIU=problematic internet use; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up; ***p<0.001

Table 1 indicates that there were significant main effects of time and group as well as time*group interactions in relation to the IAT scores. Next, to test the efficacy of the treatment intervention in reducing PIU (compared to the placebo), paired-samples *t*-tests were conducted. The results of *t*-test showed significant changes in IAT scores in the treatment intervention group (*t* [17] =21.19, *p*< 0.001, **Cohen's** *d*=10.76*,* **effect-size** *r=0.*98) but not in the placebo group (*t* [17] = 0.40, *p*=0.19, **Cohen's** *d= 0.19,* **effect-size** *r=0.09*), from T0 (baseline) to T1 (post-intervention). In addition, there were significant changes in IAT scores in the treatment intervention group (*t* [17] =15.81, *p*<0.001, **Cohen's** *d*=7.67**, effect-size** *r=0.*97) but not in the placebo group (*t* [17] = 0.52, *p*=0.61, **Cohen's** *d= 0.25,* **effect-size** *r=0.12*), from T0 (baseline) to three-month follow-up (T2). Furthermore, to demonstrate the superiority of the treatment intervention compared to placebo, direct pairwise comparisons (independent *t*-tests) between groups at each time (T0, T1, T2) were applied (see Table 2).

Table 2. Independent-samples *t*-tests for superiority of treatment intervention group compared to the placebo group in relation to IAT scores

Time	*Group*	*M*	*SD*	***t* (34)**	**Cohen's** ***d***	**Effect-size** ***r***
T0	Intervention	68.17	9.46	0.36	0.07	0.03
	Placebo	67.05	8.89			
T1	Intervention	40.22	8.14	-9.58	1.32	0.55
	Placebo	66.67	8.38			

T2	Intervention	41.22	9.19	-8.40	1.71	0.65
	Placebo	66.44	8.68			

Note: IAT=Internet Addiction Test; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up.

Table 2 shows that there was no significant difference between the treatment intervention and placebo groups at baseline (T0), but there was a significant difference between the two groups in both stages after the intervention (T1) and follow-up (T2), and the superiority of the treatment is noticeable and continuous in reducing PIU.

3.2. The effect of treatment intervention on executive functions (inhibition, attention, and working memory)

A mixed design ANOVA was used to investigate the major effects of the treatment intervention compared to the placebo. The mixed design ANOVAs showed overall significant main effects of time and time*group interaction effects in all executive functions outcomes except the time effect of commission in Go-No-go Task. The results of multivariate tests (Wilks λ) are presented in Table 3 with regard time and time*group interactions.

Table 3. Results of multivariate tests (Wilks λ) according to time and time*group interactions

		Time Wilks λ	F(2, 33)	η^2	Time* Group Wilks λ	F(2, 33)	η^2
WM	FDS	0.47	18.87***	0.53	0.69	7.51***	0.31
	BDS	0.65	8.96***	0.35	0.88	2.23	0.12
Go-No-Go	COM	0.96	0.64	0.04	0.61	10.70***	0.39
	OMI	0.26	47.04***	0.74	0.53	14.51***	0.47
	INH	0.20	66.72***	0.80	0.25	48.98***	0.75
CPT	COM	0.69	7.50***	0.31	0.60	10.81***	0.40
	OMI	0.54	13.75***	0.45	0.52	14.89***	0.47
	Hit	0.47	18.21***	0.52	0.39	25.99***	0.61

Note: WM=Working Memory; CPT=Continuous Performance Test; FDS=Forward Digit Span; BDS=Backward Digit Span; COM=Commission; OMI=Omission; INH= Inhibition; ***p<0.001.

These differences require further investigation because they did not indicate which group differed from the other group in terms of the study variables. The results are summarized in Table 4.

Table 4. Means, standard deviations of executive functions, and results of mixed design ANOVAs groups

		Group	T0 *M (SD)*	T1 *M (SD)*	T2 *M (SD)*	Time F(1, 34)	η^2	Group F(1, 34)	η^2	Time* Group F(1, 34)	η^2
WM	FDS	TIP	6.44 (2.23)	10.00 (2.00)	11.11 (1.87)	38.85***	0.53	7.83***	0.19	13.29***	0.28
		PG	7.22 (2.58)	7.50 (2.36)	8.44 (1.88)						
	BDS	TIP	7.00 (2.25)	9.55 (2.79)	9.56 (2.01)	18.05***	0.35	6.94***	0.17	2.15***	0.05
		PG	6.17 (3.58)	6.67 (3.07)	7.50 (2.04)						
CPT	COM	TIP	3.39 (4.09)	1.17 (1.09)	1.00 (1.08)	0.85	0.02	27.89***	0.73	22.03***	0.39
		PG	4.22 (3.61)	7.05 (4.18)	7.78 (3.12)						
	OMI	TIP	16.55 (7.01)	1.72 (2.51)	.94 (1.21)	96.93***	0.74	29.43***	0.89	29.59***	0.46
		PG	15.44 (6.25)	11.39 (4.04)	10.94 (3.11)						
	INH	TIP	20.05 (6.61)	37.11 (3.23)	38.00 (1.64)	121.74***	0.78	47.89***	0.58	84.93***	0.71

		PG	20.33 (6.31)	21.55 (6.05)	21.94 (5.37)						
Go-No-go	COM	TIP	8.83 (5.85)	1.61 (1.78)	2.33 (1.45)	10.71***	0.24	25.71***	0.42	22.12***	0.39
		PG	8.50 (4.33)	8.50 (4.71)	9.67 (3.18)						
	OMI	TIP	13.44 (8.18)	2.55 (3.38)	1.67 (1.68)	28.30***	0.45	14.47***	0.30	23.45***	0.41
		PG	11.44 (6.47)	12.67 (7.26)	10.89 (4.68)						
	Hit	TIP	172.72(12.17)	145.83(4.14)	146.00(2.58)	29.91***	0.47	26.13***	0.43	32.96***	0.49
		PG	130.05 (8.77)	128.83 (7.15)	129.61 (6.30)						

Note: WM=Working Memory; CPT=Continuous Performance Test; FDS=Forward Digit Span; BDS=Backward Digit Span; COM=Commission; OMI= Omission; INH= Inhibition; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up, n=18; ***p<0.001.

To investigate the trajectories of outcome variables in treatment intervention and placebo groups, paired-samples *t*-tests were applied in two groups from T0 to T1 and T0 to T2 for all outcome variables. These paired comparisons are presented in Table 5. The paired-samples *t*-tests showed significant changes in all outcome variables in the treatment intervention group from T0 (baseline) to T1 (post treatment) and T3 (three-month follow-up), but not in the placebo group.

Table 5. Paired-samples *t*-tests in treatment intervention group and placebo group for trajectories of outcome variables

	Treatment intervention group (*n*=18)						**Placebo (*n*=18)**					
		T0 vs. T1		T0 vs. T2			T0 vs. T1			T0 vs. T2		
	t (17)	**Cohen's *d***	**Effect-size *r***	*M* (17)	**Cohen's *d***	**Effect-size *r***	*M* (17)	**Cohen's *d***	**Effect-size *r***	M (17)	**Cohen's *d***	**Effect-size *r***
FDS	-5.07	2.45	0.77	-5.80	2.81	0.81	-.47	0.23	0.11	-2.47	1.20	0.51
BDS	-3.82	1.85	0.68	-4.29	2.08	0.72	-.72	0.35	0.17	-1.92	0.93	0.42
COM	2.78	1.35	0.56	2.50	1.21	0.52	-3.21	1.56	0.61	-4.27	2.07	0.72
OMI	8.37	4.06	0.90	9.08	4.40	0.91	4.22	2.05	0.71	4.08	1.98	0.70
INH	-11.16	5.41	0.94	-11.84	5.74	0.94	-2.78	1.35	0.56	-1.75	0.85	0.39
COM	5.54	2.69	0.80	5.14	2.49	0.78	0.00	0.00	0.00	-1.33	0.64	0.31
OMI	6.08	2.95	0.83	6.07	2.94	0.83	-0.95	0.46	0.22	.44	0.21	0.11
Hit	-7.17	3.48	0.87	-6.58	3.19	0.85	1.07	0.52	0.35	.26	0.13	0.06

Note: WM=Working Memory; CPT=Continuous Performance Test; FDS=Forward Digit Span; BDS=Backward Digit Span; COM=Commission; OMI=Omission; INH= Inhibition; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up.

To test the superiority of the treatment intervention group compared to the placebo group, direct pairwise comparisons (independent *t*-tests) between groups at each time (T0, T1, T2) were applied. These results are presented in Table 6.

Table 6. Independent-samples *t*-tests of treatment intervention group compared to placebo group in relation to executive functions

	T0			**T1**			**T2**		
	***t* (34)**	**Cohen's *d***	**Effect-size *r***	***t* (34)**	**Cohen's *d***	**Effect-size *r***	***t* (34)**	**Cohen's *d***	**Effect-size *r***
FDS	-0.97	0.33	0.16	3.43	1.18	0.51	4.25	1.46	0.59
BDS	0.83	0.28	0.14	2.95	1.01	0.45	3.05	1.05	0.46
COM	-0.64	0.21	0.11	-5.78	1.98	0.70	-8.71	2.99	0.83
OMI	0.50	0.17	0.08	-8.61	2.95	0.83	-12.69	4.35	0.91
INH	-0.13	0.04	0.02	9.50	3.26	0.85	12.26	4.20	0.90
COM	0.19	0.06	0.03	-5.80	1.99	0.70	-8.89	3.05	0.84

OMI	0.81	0.28	0.14	-5.35	1.83	0.68	-7.85	2.69	0.80
Hit	-0.66	0.23	0.11	8.72	2.99	0.83	10.21	3.50	0.87

Note: WM=Working Memory; CPT=Continuous Performance Test; FDS=Forward Digit Span; BDS=Backward Digit Span; T0=pre-intervention; T1=post-intervention; T2=three-month follow-up.

At baseline there were no significant differences between the treatment intervention group and the placebo group (see Table 6). However, in the post-intervention period (T1) and three-month follow-up period (T2), the treatment intervention group was superior to the placebo group in executive functions. In sum, the findings indicated the superiority of the eWMT treatment intervention to the placebo throughout the study.

4. Discussion

The present study investigated the effectiveness of eWMT on internet use and executive function among young adults with problematic internet use (PIU). The findings of the present study indicated that, in comparison with a placebo control group, eWMT decreased PIU symptoms, and improved inhibition, attention, and working memory. Although no previous studies have examined the effectiveness of eWMT in the treatment of PIU, the results of the present study concur with previous research (Beloe & Derakshan, 2020; Du Toit et al., 2020; Leone de Voogd et al., 2016; Schweizer et al., 2017), demonstrating the effectiveness of eWMT on cognitive and emotional symptoms in a range of other psychological disorders. For example, Schweizer et al. (2017) found that eWMT improved the cognitive and emotional skills of adolescents with PTSD. The present findings, combined with previous research, indicate that deficits in cognitive control and working memory are closely related to emotional control and disordered symptomology (Schweizer et al., 2013). Working memory is crucial for cognitive functioning due to its role in retaining and manipulating information (Xiong & Yao, 2010; Zhou et al., 2016). When working memory is disturbed, cognitive functions are impaired, which can lead to disadvantages in education, occupation, and other aspects of daily life (Zhou et al., 2016). Ineffective cognitive strategies to deal with problems of daily life (Engel, 2002) may, in turn, lead to PIU (Park et al., 2011).

The use of eWMT during continuous sessions appears to improve capacity of emotional working memory (Schweizer et al., 2017). This evidence supports the suggestion that working memory deficits are important predictors of PIU (Zhou et al., 2016; Nie et al., 2016). Working memory deficits have been documented among individuals with PIU (Xiong & Yao, 2010; Zhou et al., 2015). Neurological studies also suggest that prefrontal cortex and hippocampus abnormalities are implicated in PIU (Brand et al., 2014; Han et al., 2011). Since eWMT improves the function of these areas (Schweizer et al., 2013), there is good evidence to suggest that improving working memory and the performance of associated brain areas will reduce symptoms of PIU.

Excessive use of the internet is associated with a lower level of activation in the prefrontal cortex (Brand et al., 2014; Han et al., 2011). Impaired activity of the prefrontal cortex is related to impaired emotion regulation (Brand et al., 2014; Han et al., 2011). Accordingly, it may be necessary to include cognitive emotional regulation training to improve the functioning of the prefrontal cortex. According to the results of the present study and previous research, the use of eWMT leads to improved emotional control (Schweizer et al., 2011, 2013, 2017). eWMT may enhance the salience of emotional stimuli (Schweizer et al., 2017). Moreover, since the neural foundations of emotional working memory and emotion regulation are similar (dorsolateral prefrontal cortex and anterior cingulate cortex), improving the function and capacity of working memory may improve emotional regulation strategies. In other words, emotional working memory plays an important role in controlling an individual's emotions (Schweizer et al., 2013). The effects of eWMT may include the development of new skills and the reorganization of emotional strategies. It appears that the changes caused by this intervention lead to simultaneous changes in cognitive, emotional, and behavioral functioning. The observed efficacy of eWMT in the present study may be dependent on simultaneous focus on cognitive, emotional, and behavioral domains.

Other therapies have rarely considered cognitive, emotional, and behavioral aspects of PIU simultaneously. For example, a common treatment for PIU is cognitive-behavioral therapy. The main goals of this treatment are to change a person's thoughts and harmful behaviors such as compulsive internet use. There is little focus on emotions (King et al., 2012). Emotion-focused group therapy is another approach used to treat PIU. The goal of such an intervention is to reduce negative emotions and increase positive emotions. The focus of this approach is on emotional schemas. Despite the focus on emotions, simultaneous attention on the improvement of other dimensions related to PIU (i.e., cognitive, emotional and behavioral dimensions; Amini et al., 2020) is lacking. Since PIU is a multidimensional disorder that includes cognitive, emotional, and behavioral symptoms, a multidimensional approach that simultaneously focuses on all three symptoms may be needed to create lasting therapeutic changes. Therefore, eWMT appears to be successful at addressing PUI via attention to a broad array of symptomology.

4.1. Impulsivity

Consistent with the results of Schweizer et al. (2011, 2013, 2016, 2017), eWMT showed a positive effect on the ability to inhibit impulsive behavior in the present study. Impulse inhibition is associated with symptom relief. For example, Schweizer et al. (2011, 2013) found that eWMT improved cognitive and emotional inhibition among individuals with emotional disorders. Schweizer et al. (2016) also found that eWMT improved executive control components due to the effect of training on the frontal and hippocampal brain circuits. Barkley (1997) considers inhibition as a prerequisite to other executive functioning skills such as self-regulation, self-control, and purposeful behavior (Barkley, 1997; Tomlinson et al., 2015). Research suggests that defects in inhibition are at the core of behavioral addictions such as PIU (Wright et al., 2003). Individuals with PIU do not have the ability to successfully control their online activities (Zhang et al., 2015). Since eWMT sessions increase emotional working memory capacity (Schweizer et al. 2013), and emotional working memory capacity is positively related to cognitive control, cognitive control also improves in the training process (Harrison et al., 2013; Schweizer et al., 2013). In fact, working memory and inhibition ability have a common neurological foundation (Bomyea & Lang, 2016). Therefore, eWMT appears to lead to improved inhibition (Schweizer et al., et al., 2017).

4.2. Attention

We observed a significant effect of the eWMT intervention on the executive function of attention. Schweizer et al. (2011, 2013, 2016, 2017) and Basharpoor et al. (2020) have reported similar results. Furthermore, Samimi et al. (2016) demonstrated the effectiveness of eWMT on attention among children with attention deficit hyperactivity disorder. One of the strongest predictors of PIU is attention deficit (Yen et al., 2009; Yoo et al., 2004). These findings suggest that there may be similar neurological mechanisms for attention deficit and potentially addictive behaviors such as PIU. Indeed, researchers have speculated the involvement of similar brain regions in attention deficit and behavioral addiction (Frodl, 2010; Stark et al., 2011). Studies show that changes in prefrontal cortex reactivity are common in attention deficits and PIU (Brand, Young, & Lyer, 2014; Han et al., 2011). Since eWMT improves executive functions related to the prefrontal-parietal-temporal cortex, it leads to improved attention among individuals with PIU (Krause-Utz et al., 2014; Schweizer et al., 2013).

4.3. Working memory

Finally, the findings of the present study showed that eWMT had a significant effect on improving working memory. Schweizer et al. (2013) showed that eWMT improves functioning in the hippocampus and prefrontal cortex. This is not surprising since working memory is an important executive function that involves many cognitive tasks. Therefore, deficits in this system lead to many problems (Luerding et al, 2008). Working memory impairment is associated with a greater likelihood of addiction (Zhou et al. 2016). From a neurological perspective, eWMT improves individuals' working memory capacity through activation of the prefrontal cortex (Schweizer et al., 2013; 2017), frontal-parietal network, and the amygdala (Krauss-Yutz et al., 2014; Schweizer et al., 2013). Other studies also indicate the role of the dorsolateral prefrontal cortex in the encoding of information in working memory tasks (León-Domínguez, Martín-Rodríguez, & León-Carrión, 2015). Therefore, eWMT facilitates neural networks related to emotion regulation and thereby strengthens executive actions such as working memory. The findings of the present study indicate that eWMT has a positive effect on working memory among individuals with PIU.

4.4. Practical implications

This study supported the feasibility of running computerized training interventions for individuals with PIU. This intervention is inexpensive and easily accessible because it does not require professional staff or dedicated settings for treating people with PIU. Schweizer et al. (2017) suggested that eWMT may be implemented in school settings. Young adults and adolescents have high rates of PIU (Liang et al., 2016; Holdoš, 2017). Therefore, school counselors, teachers, and other professionals may potentially use eWMT to help students overcome PIU.

4.5. Limitations and future research

Since the study took place during the COVID-19 pandemic, there are a number of limitations that should be noted. Participants conducted training at home which made it difficult to standardize the training environment. Another limitation was related to the eWMT program. The emotional stimuli used in the program included words such as 'execution' and 'death' which may have created a defensive mood for some participants and reduced their desire to continue. Other limitations of the present study include the lack of easy access to brain imaging tools such as EEG and fMRI, which could have validated the brain changes associated with eWMT effects. The small and homogeneous participant pool (e.g., all participants being aged 18-23 years) suggests that the study should be replicated among other participant groups with bigger sample sizes. Given the aforementioned limitations, it would be of benefit for future researchers to develop and streamline eWMT software developed specifically for PIU. Moreover, the present study did not recruit individuals without PIU as a control group. Also, detailed demographic data on the sample, such as education level, and duration of problematic internet use were not collected. Therefore, it is unknown whether eWMT is more effective among individuals with varying education levels or those had been experiencing problematic online behavior for short or long periods.

It should also be noted that those in the intervention group were primarily social media users and online gamers. There is a growing consensus that PIU or 'internet addiction' is a misleading category which groups disparate problems concerning excessive internet use such as internet gaming disorder or problematic social media use. eWMT may be useful in the treatment of specific types of problematic internet use (e.g., social media addiction, online gaming addiction) and further evaluation of the efficacy of eWMT on these specific types of PIU is needed. Future studies could also investigate the effectiveness of eWMT for other mental health disorders or other settings (for example, in primary health care clinics or hospitals). While the present study examined the efficacy of eWMT on internet use, inhibition, attention, and working memory, future research could focus on other domains (e.g., decision-making or tolerance for ambiguity).

5. Conclusion

Considering the cost and time necessary for most psychotherapies, modern cost-effective interventions are needed to help individuals overcome PIU. In the present study, the primary objective was to evaluate the effectiveness of a low-cost treatment (i.e., eWMT) for PIU among young adults. Participants treated with eWMT showed significant improvements in executive functions and symptoms of PIU compared to a placebo group. Reduced symptoms of PIU were associated with improved executive functions. eWMT appears to be a promising technique for reducing PIU by improving individuals' cognitive and emotional functioning.

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