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FULL-LENGTH REPORT

The effects of emotional working memory training on internet use, impulsivity, risky decision-making, and cognitive emotion regulation strategies in young adults with problematic use of the internet: A preliminary randomized controlled trial study into possible mechanisms

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ABSTRACT

Introduction: Considering adverse correlates of problematic use of internet use (PUI), the present study evaluated an intervention aimed at PUI and several putative underpinnings. *Methods:* A randomized controlled trial study investigated the efficacy of emotional working memory training (eWMT) in improving impulsivity, risky decision-making, and cognitive emotion-regulation (CER) strategies among individuals with PUI in comparison with a placebo group. Young adults ($N = 36$) with PUI 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:* Twenty continuous sessions of eWMT significantly improved participants' impulsivity, risky decision-making, CER, internet use and PUI symptoms in the short term, compared to the placebo condition. *Discussion:* These preliminary results suggest that eWMT may constitute a promising intervention for PUI and improving cognitive and emotional functioning, and larger, longer studies are warranted.

KEYWORDS

problematic use of internet, addictive behaviors, impulsivity, risky decision-making, cognitive emotion regulation strategies, emotional working memory training, human computer interactions

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INTRODUCTION

Theoretical background

With the recent rapid growth of and easy access to the internet globally, the internet has become an integral part of most individual's daily lives (Király et al., 2020; Lozano-Blasco, Robres, & Sánchez, 2022; Marzilli, Cerniglia, Ballarotto, & Cimino, 2020). Despite benefits of using the internet, such as facilitating access to information, promoting education, enhancing social communications and improving relationships (Anderson, Steen, & Stavropoulos, 2017; Kim, Chen, & De Zúñiga, 2013), excessive use may generate significant concerns and subsequent mental health problems (Emadi Chashmi, Hasani, Kuss, Griffiths, & Shahrajabian, 2022; Kaess et al., 2021; Sariyska, Lachmann, Markett, Reuter, & Montag, 2017; Shahrajabian & Emadi Chashmi, 2020; Shahrajabian, Hasani, Griffiths, Aruguete, & Chashmi, 2023; Zhao, Qu, Chen, & Chi, 2023; Zhou & Ding, 2023). Maladaptive overuse of the internet has been described using various terms including internet addiction, problematic use of the internet (PUI), compulsive internet use, and internet use disorder (Huang, Chen, Wang, & Wang, 2014; Király et al., 2020). PUI has been considered by some to be a behavioral addiction (Griffiths, 2005). Nevertheless, this point has been debated (Hellman, Schoenmakers, Nordstrom, & Van Holst, 2013), and main nomenclature systems (e.g., the fifth edition of the Diagnostic and Statistical Manual (DSM-5) and eleventh revision of the International Classification of Diseases (ICD-11)) do not include PUI but rather disorders (e.g., gambling and gaming disorders) that may be performed on the internet. Nonetheless, PUI constitutes a major public health concern and has been the focus of large-scale initiatives and is relevant to multiple behaviors and stakeholders. The present study uses the term 'PUI' rather than 'internet addiction', in part as it has argued that addictions on the internet (e.g., online gambling disorder) should not be regarded as addictions to the internet (American Psychiatric Association, 2013; Griffiths, 2000; Griffiths & Pontes, 2014; World Health Organization, 2019a, b).

PUI may be addressed as an excessive engagement with the internet or inadequate control over internet use, generating psychological, educational, family, social, and/or occupational concerns (Davis, 2001; Young, 1996). PUI appears particularly common among young adults (Holdoš, 2017; Liang, Zhou, Yuan, Shao, & Bian, 2016), with an estimated prevalence of 28.6% reported recently (Hassan, Alam, Wahab, & Hawlader, 2020). Furthermore, psychological distress and social distancing may contribute to the increased use of the internet during the COVID-19 pandemic (Allahyari, Emadi Chashmi, Mahmud, & Ahmadi, 2022; Shahrajabian et al., 2021, 2022), with concomitant concerns regarding mental health (Gjoneska et al., 2022; Király et al., 2020).

Risk-taking and suboptimal decision-making often contribute importantly to PUI and drug addictions (Balogh, Mayes, & Potenza, 2013; Brand et al., 2016, 2019; Dong & Potenza, 2014). Online experiences may alter brain function and related cognitive processes in ways that may lead to PUI (Dong, Huang, & Du, 2011; Dong & Potenza, 2016; Weinstein & Lejoyeux, 2010). Theoretically, PUI may involve imbalances between neural systems underlying decision-making processes, and these may be effectively targeted by specific interventions (Dong & Potenza, 2014). One model of drug addiction proposes two systems involving emotion-based impulsive and cognitive-control-based reflective systems (Bechara, 2003). Another drug-addiction model suggests that hyperactive-impulsive processing may generate resistance to environmental stimuli to increase risk of engaging in addictive behaviors (Goldstein & Volkow, 2011). Executive functions, including cognitive control (Müller et al., 2021; Papenberg, Salami, Persson, Lindenberger, & Bäckman, 2015) and decision-making (i.e., tendencies to reflect on options and control rapid emotional reactions to external or internal stimuli) have also been implicated in PUI (Cipolotti et al., 2016; Müller et al., 2021) and have been described as being relevant to theoretical models of PUI (Brand et al., 2016, 2019).

In adolescence, impulsive tendencies typically precede the development of mature self-regulatory processes (King, Lengua, & Monahan, 2013). Therefore, adolescence has been described as a vulnerability epoch to addictions and PUI (Wang, Tao, Fan, Gao, & Wei, 2017). PUI has been linked to altered function of the prefrontal cortex, a later-developing brain region (Brand, Young, & Laier, 2014; Shahrajabian et al., 2023). Adolescents may thus exhibit relatively poorer cognitive emotion-regulation (CER) relative to adults. Taken together, prefrontal cortical function, which has been linked to impulsivity, risky decision-making, and CER, is typically immature during adolescence (Steinberg, 2008), and this may make adolescents vulnerable to PUI, particularly in the current digital-technology environment.

Therefore, in the current study, we aimed to examine the potential of emotional working memory training (eWMT), an approach proposed to operate through enhancing prefrontal cortical function (Schweizer, Hampshire, & Dalgleish, 2011), to reduce PUI, impulsivity, risky decision-making and poor CER. Specifically, we hypothesized that eWMT would reduce symptoms of PUI, time spent on the internet, impulsivity, and risky decision-making and improve CER.

PUI sub-types

Different subtypes of PIU have been proposed. According to Young (1999), internet addiction could be classified into five categories: net compulsions (e.g., addiction to online gambling and gaming), cybersexual addictions (e.g., addiction to pornography online), cyber-relationship addictions (e.g., addiction to chatting with romantic partners online), information overload (e.g., addiction to surfing the web) and computer addiction (e.g., addiction to playing computer games like Solitaire). However, this typology was criticized by Griffiths (2000) who suggested that these sub-types may involve addictions *on* the internet rather than addiction *to* it. In 2001, Davis described two types of PUI: specific PUIs (individuals with problems concerning one specific online behavior; e.g., online gaming) and generalized PUIs (problems with a general set of online behaviors). According to Tiego et al. (2019), there may be two severity levels of PUI: high severity "compulsive" (associated with obsessive-compulsive personality traits) and low severity "impulsive" (associated with attention-deficit hyperactivity disorder (ADHD)). Internet gaming disorder was the only mental disorder included in the DSM-5 (American Psychiatric Association, 2013), and gaming disorder was included in the ICD-11 (World Health Organization, 2019a, 2019b). However, additional internet use behaviors may be considered as "other specified disorders due to addictive behaviors" (Brand et al., 2016).

PUI and impulsivity

People with PUI may show cognitive impairments, especially in executive functioning (Brand et al., 2014; Shafiee-Kandjani et al., 2020; Young, 2017; Zhou, Zhou, & Zhu, 2016). Such executive dysfunction may be reflected in impulsivity (Choi et al., 2014; Zsidó et al., 2019) and risky behaviors involving risk-taking tendencies and disadvantageous decision-making (Ko et al., 2010). Impulsivity has been implicated in addictive disorders and PUI (Diotaiuti et al., 2023; Robbins & Clark, 2015). Poor impulse control is often present in PUI, and high impulsivity may predispose individuals with PUI to immediate versus delayed rewards, which may put them at greater risk for PUI (Cao, Su, Liu, & Gao, 2007a, 2007b). In PUI, impulsivity may involve repeated failures to resist impulses to engage in using the internet and feelings of poor control over engaging in internet use (Lee, Hoppenbrouwers, & Franken, 2019; Tzang, Chang, & Chang, 2015; Wang et al., 2017). Specific neurobehavioral characteristics related to impulsivity have been implicated regarding why people with PUI repeat behaviors that lead to negative consequences (Zhang, Liu, & Zhao, 2021; Zsidó et al., 2019). Impulsivity may transcend behavioral and substance addictions (Cao et al., 2007a, 2007b; Diotaiuti et al., 2023; Grant, Potenza, Weinstein, & Gorelick, 2010; Zsidó et al., 2019). In general, impulsivity is a multidimensional concept and can involve unplanned and rapid reactions to internal or external stimuli in which the individual disregards others' feelings or has negative consequences impacting himself/herself or others as a result of the reactions (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). High levels of impulsivity may promote risky or harmful behaviors, such as PUI (Diotaiuti et al., 2023; Giustiniani et al., 2019; Ríos-Bedoya, Wilcox, Piazza, & Anthony, 2008). Given these data, it is possible that PUI may be reduced by targeting interventions on functions of brain structures related to impulsivity, such as the prefrontal cortex.

PUI and risky decision-making

In addition to impulsivity, risky decision-making is another neurobehavioral variable that has been implicated in PUI (Clark, Cools, & Robbins, 2004; Ko et al., 2017; Verdejo-Garcia, Pérez-García, & Bechara, 2006). It has been hypothesized that individuals with PUI are more likely to engage in risk-taking processes that provide immediate gratification despite an increased risk of experiencing loss, and that these individuals give less attention to long-term consequences (Brand et al., 2014; Dong, Hu, & Lin, 2013; Seok, Lee, Sohn, & Sohn, 2015). In an fMRI study, disadvantageous decision-making in people with PUI was purportedly related to altered brain function related to executive functions (Dong, Huang, & Du, 2011, 2013), resonating with findings in gambling disorder (Cavedini, Riboldi, Keller, D'Annucci, & Bellodi, 2002; Leeman & Potenza, 2012; Seok et al., 2015). Over-reliance on reward systems and underuse of prefrontal control systems may underlie risky behaviors such as PUI in young adults (Galvan, et al., 2006; Ryan, MacKillop, & Carpenter, 2013). Biological developmental changes that occur in adolescence and continue into young/emerging adulthood have been linked to elevated sensation-seeking and poor self-control, which may promote problematic behaviors including PUI (Balogh et al., 2013; Brezing, Derevensky, & Potenza, 2010). Consequently, interventions for PUI may involve altering functioning of reward systems and the prefrontal cortex, in order to generate better self-control and reduce risk-taking behaviors (Wu et al., 2020a). Therefore, targeting risky decision-making might help reduce PUI symptomatology.

PUI and cognitive emotion regulation

Impulsivity may precede the development of self-regulation (Harden & Tucker-Drob, 2011; King et al., 2013; Wang et al., 2017), and other factors including emotions warrant consideration. Cognitive regulation of emotion may also contribute to vulnerability to PUI in young adults (Amendola, Spensieri, Guidetti, & Cerutti, 2019; Kökönyei et al., 2019; Moniri, Pahlevani Nezhad, & Lavasani, 2022). CER involves a range of processes by which people may change the types and durations of emotions they experience. CER addresses the cognitive management of emotionally provoking information (Garnefski, Kraaij, & Spinhoven, 2001). The use of maladaptive CER strategies, including rumination, suppression, and avoidance, has been linked to psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Estévez, Jáuregui, Sánchez-Marcos, López-González, & Griffiths, 2017). Individuals with poor emotion regulation may be more prone to regulate their negative emotions by engaging in activities, such as using the internet, that have immediate gratification (Estévez et al., 2017; Kökönyei et al., 2019). Accordingly, implementation of adaptive emotion regulation strategies instead of maladaptive ones may decrease PUI (Moniri et al., 2022; Wu et al., 2020; Wu et al., 2021).

Underlying mechanisms

Understanding and targeting common underlying mechanisms that may exist between impulsivity, risk-taking, and CER strategies may help alleviate symptoms of PUI. Overlap of neural circuits implicated in impulsivity, risk-taking and cognitive regulation of emotion have highlighted the prefrontal cortex (Eldaief, Deckersbach, Carlson, Beucke, & Dougherty, 2012; Schreiber, Grant, & Odlaug, 2012). A role for the prefrontal cortex exists in executive functioning (Churchwell & Kesner, 2011; Ellis, Rothbart, & Posner, 2004). Therefore, the prefrontal cortex may be a target for improving impulse control and emotional regulation (Churchwell & Kesner, 2011; Schreiber et al., 2012). Based on this hypothetical mechanism and empirical data from people with gaming disorder (Wu et al., 2020a, b; Wu et al., 2021), PUI may involve poor cognitive control in emotional contexts that may be targeted through interventions. Thus, reducing maladaptive CER strategies may promote use of adaptive strategies instead of the internet in a maladaptive way, reducing symptoms of PUI.

Emotional working memory training

Since PUI is not a recognized disorder in main nomenclature systems, there are no therapies or treatments with formal indications (Griffiths, 2005; Musetti et al., 2016). Therefore, in the current study, we will terms such as "training" and "intervention" to describe the current study.

Interventions for PUI may have the potential to improve cognitive and emotional control and reduce impulsivity and risk-taking. Hence, the current study used eWMT as described and tested by Schweizer, Grahn, Hampshire, Mobbs, and Dalgleish (2013, 2011). The main purpose of eWMT involves improving emotional dysfunctions and cognitive impairments (i.e., executive functions linked to the prefrontal cortex; (Krause-Utz, Winter, Niedtfeld, & Schmahl, 2014). eWMT focuses on improving working memory, CER, risk-taking, and impulsivity. Individuals are provided with emotional training (by auditory and visual stimuli) alongside cognitive training. Individuals determine whether faces they view on-screen are located in the same spatial locations as ones they saw previously or whether words with which they are presented are ones they encountered previously. To improve performance, a person should disregard affective content of faces and focus instead on the content of the words. eWMT training sessions (20–40 min) showed improvement in short-term memory of individuals involving retrieval, manipulating, storing, and encrypting of emotional information (Schweizer et al., 2011, 2013). The literature has demonstrated the effectiveness of eWMT in improving executive functions and emotional regulation in people with post-traumatic stress disorder (PTSD) (Schweizer et al., 2017), borderline personality disorder (Krause-Utz et al., 2014), social anxiety (Du Toit et al., 2020), and anxiety and depression (Beloe & Derakshan, 2020). Based on such studies, we hypothesized that eWMT would improve PUI and CER and reduce impulsivity and risk-taking.

The current study

The extant literature suggests that various interventions may reduce the negative outcomes related to PUI, including acceptance and commitment therapy (Firouzkouhi Berenjabadi et al., 2021), emotion-focused group therapy (Amini, Lotfi, Fatemitabar, & Bahrampoori, 2020), and cognitive-behavioral group therapy (Alavi, Jannatifard, Eslami, & Rezapour, 2011). Each of these interventions focuses on behavioral, emotional, cognitive, or interpersonal aspects or impacts of PUI (Zajac, Ginley, Chang, & Petry, 2017). These interventions generally require significant resources, such as a trained and licensed therapist. Computer-mediated cognitive training that can be completed at home may be useful for individuals with fewer resources. At study onset, no research had investigated the potential of eWMT in intervening PUI. Therefore, we undertook such a study. Initial findings from the study (under consideration elsewhere) indicated that eWMT was efficacious in improving attention, working memory, and inhibitory control in patients with PUI. To our best knowledge, we are the first to examine the efficacy of eWMT on impulsivity, risk-taking, CER strategies and internet-use behaviors among young adults with PUI. It was hypothesized that in comparison with a placebo group, eWMT would decrease internet use (H1) and reduce symptoms of PUI (H2), impulsivity (H3), risk-taking (H4), and employment of maladaptive CER strategies and increase employment of adaptive strategies (H5). The study focuses on the effectiveness of eWMT on the cognitive impairments and emotional dysfunctions of individuals with PUI. The first paper of this study was published on the journal of Addictive Behaviors (Shahrajabian et al, 2022) focusing on inhibition, attention, and working memory. Using the same database, the current paper is focusing on Internet Use, Impulsivity, Risky Decision-making, and Cognitive Emotion Regulation Strategies of individuals with PIU.

METHODS

Participants, design, and procedure

Thirty-six high-school and university students aged 18–40 years (25 females, 11 males; mean age = 20.27 years; SD = 1.54 years) were recruited in Karaj (Iran) by sharing an invitation link via social media platforms (i.e., *LinkedIn* and *Instagram*) and paper-based recruitment advertisements. G*Power software was implemented to estimate the sample size for the current study, based on the proposed effect size (0.25), a (0.05), power (0.90), number of groups (2), number of measurements (3) and statistical test (mixed-design ANOVA). Consequently, the total sample size was calculated to be 36. Moreover, by considering attrition, 40 subjects were recruited and randomly assigned into two groups.

The Internet Addiction Test (IAT; Young, 1998) was used to screen participants initially recruited (N = 103) for PUI. Study participants with IAT scores below 80 were excluded. Young proposed a cut-off of 50, and 80 was selected to recruit individuals with more severe PUI. The IAT consists of 20 items related to online internet use, including psychological dependence, compulsive use, withdrawal, PUI-related issues at school or work, sleep problems, family problems, and time management issues. In Widyanto, Griffiths, and Brunsden (2011) and Widyanto and McMurran (2004), the IAT was found to be a valid and reliable instrument for the classification of PUI.

The study included only adults aged 18–40 years who used the internet at least 6 h per day for non-essential purposes in the past three months. Two clinical psychologists evaluated the remaining participants to confirm PUI symptoms, ensure no other comorbid disorders were present (participants with mild to severe depression or anxiety disorders were excluded), and assess their readiness for the study. No psychotropic medication was administered to participants, and their vision was normal or corrected to normal.

Sixty-three participants were excluded (21 excluded because of co-occurring disorders, 42 as they did not meet the inclusion criteria). The selected participants reported using the internet more than 40 h per week (on average, more than six hours daily) for non-school or non-work-related reasons. Forty individuals met the criteria for inclusion in the study. Of these, 36 individuals completed the sessions, post-test, and follow-up. Therefore, the final sample included 36 participants. The participant selection and study procedure processes are shown in Fig. 1.

The study's aims were explained to participants. Participants provided written informed consent. A question was also asked of all participants regarding their most frequent online activity. Most participants ($n = 26$) reported using social media (14 in the intervention group), nine reported playing online video games (four in the intervention group), and five reported surfing the web (two in the intervention group) as the focus of their PUI. Researchers randomly assigned participants to either the eWMT group ($n = 18$; 12 females, 6 males, mean age = 20.44 years; $SD = 1.42$) or a placebo group ($n = 18$; 13 females, 5 males, mean age = 20.11 years; $SD = 1.67$). The placebo and treatment groups did not differ on demographic characteristics, PUI severity,

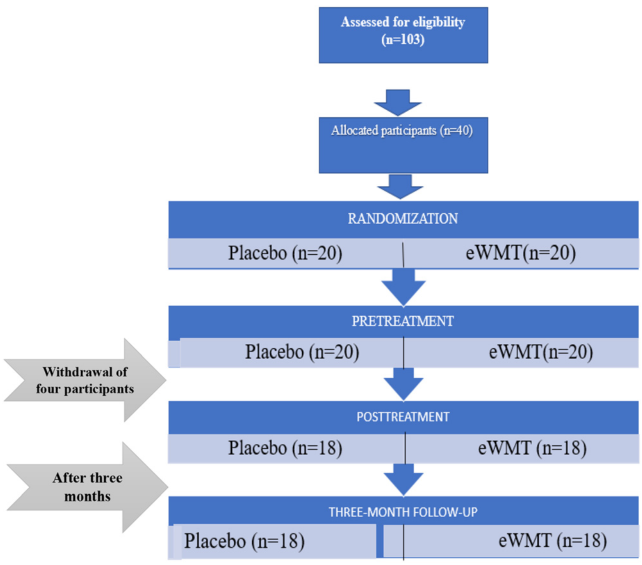

Fig. 1. Consort flow diagrams of study development

and implementation conditions (number of sessions and duration of each session). The study was single-blind and randomized. The research team was aware of the participants' training groups, and participants were unaware of differences among groups. Overall, participants were assessed at three stages: the pre-intervention period (T0), post-intervention period (T1), and three-month follow-up period (T2). Thus, the experimental design consisted of three phases: pretest, intervention, and posttest. Before starting the intervention, three participants (two in the intervention group and one in the placebo group) discontinued attending the intervention without declaring a reason for the cancellation (see Fig. 1). Therefore, 36 individuals completed the study. In the pretest phase, all participants completed the Cognitive Emotion Regulation Questionnaire (CERQ-short) (Garnefski & Kraaij, 2006), Barratt Impulsiveness Scale-11 (BIS-11) (Patton, Stanford, & Barratt, 1995), and Balloon Analog Risk Task (BART) (Lejuez et al., 2002).

For the intervention phase, the eWMT group received training while the placebo group received placebo training (detailed below). The intervention phase of the eWMT group began with a brief explanation of the eWMT training to the patients. Then, they started their training (three sessions per week and 20 sessions in total) of eWMT lasting between 30 and 45 min (depending on the amount of n-back obtained) on weekdays through a program installed on the participants' personal computers. Before session ten, two additional patients in the intervention group and two individuals in the placebo group declined to participate further, reporting that the words used in the emotional work memory training program made them reluctant to continue. Some patients were also removed due to irregular attendance at training sessions. For the post-test phase, all participants again completed the CERQ-short, BIS-11, and BART. Due to COVID-19 pandemic restrictions (e.g., maintaining social distance), assessment and training were performed individually under the supervision of a psychology postgraduate. After three months, all participants were asked to complete measures for a third time for the follow-up phase. A total of 36 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.

Training tasks

eWMT Training Intervention. eWMT (adapted from the task used by Schweizer et al., 2011) is an affective dual n-back task. The dual n-back exercise is one to strengthen active memory. First, the 'dual' part of this exercise requires individuals to remember two different stimuli - the place of a presented square on a computer screen and the letter of the alphabet pronounced with it, heard via headphones. These stimuli are presented in a random order, either individually or simultaneously. If participants were presented with a visual stimulus before, they were asked to press the letter "L" on their keyboards, and if the auditory stimulus was the one that participants perceived before, they were asked to press the letter "A". If both stimuli were presented before, they were asked to press both "A" and "L" at the same time. The task consists of a series of trials involving concurrent demonstration of a face (500 ms on a 4 × 4 grid on a screen) and a word (500 ms over headphones). There was an interval of 250 ms following the presentation of each picture-word pair, by that time participants reacted by pressing a button on the keyboard 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., 'rape' and 'death') and faces (sad, angry, fearful expressions) was evident. Each trial began with the concurrent demonstration of $n = 1$ visual and auditory stimuli, 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 kinds of feedback. For auditory targets, a disturbing sound was heard if the target was missed, and a pleasant sound if it was correctly determined. Upon accurately identifying visuospatial targets, a green happy emoji was presented, while a red sad emoji was presented upon missing them. The procedure is described in Fig. 2.

Placebo training. Participants in this group were shown two panels with geometrical shapes on a screen. On the top panel, there were three shapes that individuals were asked to note by clicking on the mouse. The panels also contained five to 13 distractor shapes. The quantity of distractors included with the targets was random (i.e., not based on performance).

Measures

Internet Addiction Test-Short Form (IAT-SF). The IAT-SF was developed by Young (1998), and the short form was developed by Pawlikowski, Altstötter-Gleich, and Brand (2013). In the Short Form version, there are 12 items rated on a five-point scale (Never = 1 to Very often = 5). Scores above 37 indicate pathological internet use. The Cronbach alpha reliability coefficient of the scale was 0.86 (Pawlikowski et al., 2013). We used the Persian version of the IAT-SF developed by Amiri and Sepehrianazar (2018) who reported a Cronbach's alpha of 0.89.

Balloon Analog Risk Task (BART). The BART assesses risk-taking (Lejuez et al., 2002). Individuals were asked to sequentially press a button to inflate a series of 30 balloons that were presented on their screen. There are two types of points on the screen, one temporary and one permanent. The screen presented a tiny, simulated balloon alongside a balloon pump, a "Collect Points" button, and a record of points earned, labeled "Total Earned". Every time the balloon was pumped, 50 points were added to the person's impermanent score. At any point during each balloon inflation, the individual was able to halt pumping the balloon and press the "Collect" button. Then, a new balloon was substituted and the amount of points acquired from inflating the balloon was added to the constant score. Balloons could explode or expand. A bigger balloon was related to a greater possibility of bursting and a larger virtual reward. Once a balloon was pumped past its individual burst point, it burst with a "pop" tone, at which time all money in the impermanent reserve disappeared. After each balloon burst or reward was collected, the individual's exposure to that balloon finished and a new balloon appeared until all 30 balloons had been presented. Here, participants received another 50 points which were added to the temporary score each time they inflated the balloon. Individuals were instructed to increase their virtual reward in the task. The balloons burst at unspecified points. People with high risk-taking tended to inflate each balloon more to gain more points by assuming the risk of the balloon exploding. The BART score was computed by the subject's overall score (this score is inversely related to a high-risk decision-making style) and the number of times balloons burst (this score is directly related to a high-risk decision-making style).

Barratt Impulsiveness Scale-11 (BIS-11) (Patton et al., 1995, translated by Javid, Mohammadi, & Rahimi, 2012). The BIS-11 is an instrument on which individuals range their

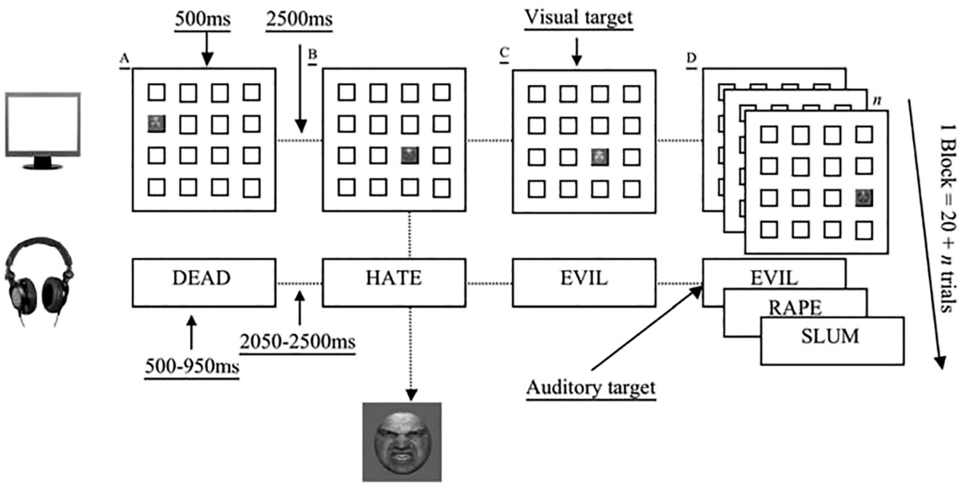

Fig. 2. Overview of affective dual n-back task (Schweizer et al., 2011)

frequency of various common impulsive or non-impulsive behaviors/tendencies on a scale from 1 (rarely/never) to 4 (almost always/always). The 11th version of the BIS includes 30 questions and can be separated to 3 subscales, including non-planning, motor, and, attentional to indicate total impulsiveness scores. All items were summed, with greater scores reflecting higher impulsivity (Patton et al., 1995). Javid et al. (2012) reported its Cronbach's alpha was 0.81.

Cognitive Emotion Regulation Questionnaire (CERQ-short; Garnefski and Kraaij (2006) translated to Persian by Hasani, 2011). The CERQ-Short was used to assess cognitive emotion-regulation strategies (CERS). The instrument includes 18 questions to examine maladaptive (i.e., catastrophizing, rumination, other-blame, and self-blame) and adaptive (i.e., refocus on planning, positive reappraisal, positive refocusing, acceptance, and putting into perspective) CERS. individuals' responses are rated on a 5-point Likert scale ranging from 1 (never) to 5 (always). The Cronbach's alpha in the current study was 0.74.

Statistical analysis

We used IBM SPSS software version 24.0 to analyze data. Before analysis, basic assumptions of mixed-design ANOVAs (including no significant outliers in any cell of the design checked by box plot; normality checked using the Shapiro-Wilk normality test; homogeneity of variances assessed using the Levene's test; sphericity checked using the Mauchly's test; homogeneity of covariance tested by Box's M) were checked and met. Due to the random pattern of missing data, participants with values greater than 5% were removed. In this process, one individual in the experimental group and two in the placebo group had more than 5% missing data and were removed. Therefore, data from 36 participants (18 in each group) remained for the final analysis. Analyses were performed on individuals in both groups that had completed measurements at T0 (baseline), T1 (post-intervention), and T2 (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 a within-participants factor; group (intervention and placebo) as a between-participants factor; and PIU, CERS, impulsivity and risky decision-making as dependent variables. To examine if trajectories of outcome variables in the intervention and placebo groups differed between individuals, a series of mixed models was applied with internet use, PUI, CERS, impulsivity and risky decision-making scores as the dependent factors and group (intervention and placebo), time (T0-T2), and the interaction between time and group as independent factors (fixed effects).

Ethics

The ethics committee of Kharazmi University (IR.KHU.REC.1400.003) and the Iranian Registry of Clinical Trials (IRCT20210828052309N1) approved the study protocol. All subjects were informed about the study and all provided informed consent.

RESULTS

Demographic characteristics

Table 1 illustrates the demographic characteristics of the samples. As evident in Table 1, demographic variables did not differ between the two groups.

Emotional working memory training (eWMT) effects relative to placebo

Mixed-design ANOVAs were used to test major outcomes comparing intervention and placebo groups. The mixed-design ANOVAs showed overall significant main effects of time and time*group interaction effects in all outcomes (internet use, PUI, CERS, impulsivity and risky decision-making). The results of multivariate tests (Wilks λ) are presented in Table 2 with regard to time and time*group interactions.

These differences require further investigation because they did not show which group differed from the other group in terms of the interest variables. Further results are summarized in Table 3.

Table 1. Demographic characteristics of the two study groups

Variable		Intervention group ($n = 18$)	Placebo group ($n = 18$)	T/χ	p
Age *M* (SD)		20.50 (1.69)	20.61 (1.72)	0.20	0.85
Sex *n* (%)	Female	12 (66.7)	13 (72.2)	0.60	0.71
	Male	6 (33.3)	5 (27.8)		
Education *n* (%)	Bachelor	11 (61.1)	12 (66.7)	0.59	0.73
	Master's	7 (38.9)	6 (33.3)		
Marital Status *n* (%)	Married	3 (16.7)	2 (11.1)	0.80	0.63
	Single	15 (83.3)	16 (88.9)		

Table 2. Results of multivariate tests (Wilks λ) according to time and time*group interactions

	Time			Time* Group		
	Wilks λ	F (2, 33)	η^2	Wilks λ	F (2, 33)	η^2
IU	0.24	52.55***	0.76	0.14	101.35***	0.86
PUI	0.53	14.17***	0.46	0.48	0.17.65***	0.52
MCERS	0.58	11.66***	0.41	0.44	21.15***	0.56
ACERS	0.50	16.24***	0.49	0.53	14.46***	0.47
IM	0.15	90.43***	0.84	0.87	115.61***	0.87
RDM	0.40	11.26***	0.40	0.43	12.92***	0.43

Note: IU = internet use, PUI = problematic use of the internet, MCERS = Maladaptive Cognitive Emotion Regulation Strategies, ACERS = Adaptive Cognitive Emotion Regulation Strategies, IM = impulsivity, RDM = risky decision-making, T0 = pre-intervention, T1 = post-intervention, T2 = three-month follow-up, ***$p < 0.001$.

Table 3. Means, standard deviations of outcome variable's scores, and results of mixed design ANOVAs

	Measures	Intervention group (n = 18)	Placebo group (n = 18)	Time		Group		Time* Group	
				F (1, 34)	η^2	F (1, 34)	η^2	F (1, 34)	η^2
IU	T0	7.28 (0.96)	7.22 (1.43)	87.70***	0.72	167.45***	0.79	115.97***	0.77
	T1	2.72 (0.83)	7.72 (1.12)						
	T2	2.28 (0.67)	8.16 (0.92)						
PUI	T0	68.17 (9.4)	67.05 (8.8)	130.87***	0.84	128.51***	0.79	41.24***	0.83
	T1	40.28 (8.14)	66.6 (8.3)						
	T2	41.22 (9.19)	66.44 (8.6)						
MCERS	T0	25.11 (5.44)	23.94 (2.34)	22.93***	0.40	17.55***	0.34	41.24***	0.54
	T1	16.88 (2.34)	25.16 (4.46)						
	T2	16.72 (25.16)	25.16 (4.46)						
ACERS	T0	27.50 (5.80)	31.77 (5.10)	21.27***	0.38	0.11	0.003	161.34***	0.83
	T1	32.55 (5.17)	31.94 (5.59)						
	T2	33.94 (2.28)	31.94 (5.59)						
IM	T0	85.55 (5.44)	83.22 (8.59)	126.04***	0.78	66.47***	0.99	161.66***	0.82
	T1	59.44 (5.53)	82.77 (6.88)						
	T2	54.77 (4.59)	84.77 (4.59)						
RDM	T0	16.27 (3.49)	11.66 (5.03)	21.27***	0.38	5.85***	0.14	26.62***	0.28
	T1	8.00 (3.54)	11.27 (4.94)						
	T2	7.61 (3.23)	12.11 (5.66)						

Note: IU = internet use, PUI = problematic use of the internet, MCERS = Maladaptive Cognitive Emotion Regulation Strategies, ACERS = Adaptive Cognitive Emotion Regulation Strategies, IM = impulsivity, RDM = risky decision-making, T0 = pre-intervention, T1 = post-intervention, T2 = three-month follow-up, ***p < 0.001.

Al within-subject effects (i.e., times of measurements) for all outcomes were significant. Moreover, the effect of the interaction of two independent variables (group) and the number of measurements (at pre-test (T0), post-test (T1) and follow-up (T2)) were significant. Regarding between-subject factors, the effects of group (i.e., the effects of the experimental intervention) on all outcomes were significant except for adaptive cognitive emotion regulation strategies (ACERS).

Regarding internet use, the daily internet use (average hour/day) of individuals in both placebo and intervention group are presented (Table 3). Daily internet use in the intervention group was reduced from 7.28 h/day (pre-test) to 2.72 (post-test) and 2.28 (follow-up), while in the placebo group, it increased from 7.22 h/day (pre-test) to 7.72 (post-test) and 8.16 (follow-up). In addition, regarding PUI scores, the scores in the intervention group were reduced from 68.17 (pre-test) to 40.28 (post-test) and 41.22 (follow-up), while in the placebo group, they did not change substantiall, ranging from 67.05 (pre-test) to 66.6 (post-test) and 66.44 (follow-up).

To explore trajectories of outcome variables in the intervention and placebo groups, paired-samples t-tests were conducted in the two groups from T0 to T1 and T0 to T2 for all outcome variables (Table 4). The paired-samples t-tests revealed significant changes in all outcome variables in the intervention group from T0 (baseline) to T1 (post treatment) and T2 (three-month follow-up), but not in the placebo group.

Finally, to explore the superiority of the intervention group compared to the placebo group, direct pairwise comparisons (independent t-tests) between groups at each time (T0, T1, T2) were made (Table 5).

As shown in Table 5, at baseline (T0) there were no significant differences between the intervention group and the placebo group. 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 all outcomes. In sum, the findings indicated the superiority of the eWMT intervention to the placebo throughout the study.

DISCUSSION

Considering the multiple facets of PUI, which may include cognitive, emotional and behavioral aspects, multidimensional interventional approaches may be needed. In the present study, by using eWMT, we sought to alter emotional regulation, cognitive functioning, and linked domains of impulsivity and risky decision-making, and to reduce problematic behaviors.

Previously, we have found efficacy for eWMT on attention, working memory, and inhibitory control in patients with PIU (published elsewhere). Here we examined potential effects of eWMT on impulsivity, risky decision-making, and use of maladaptive and adaptive CER strategies. In the current research, the main hypothesis was that in comparison with a placebo group, eWMT would reduce PUI symptoms, impulsivity, and risky decision-making, and improve CERS. The results showed that in comparison with a placebo group, eWMT reduced symptoms of PUI, as published elsewhere. Internet use also decreased. The average self-reported daily use of the internet was initially

Table 4. Paired-samples *t*-tests in intervention group and placebo group for trajectories of outcome variables

	Experimental 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	*P*	T(17)	Cohen's *d*	effect-size	*P*	T(17)	Cohen's *d*	effect-size	*P*	T(17)	Cohen's *d*	Effect -size	*P*
IU	20.96	10.17	0.96	0.001	19.55	9.49	0.95	0.001	−2.29	1.11	0.23	0.03	−2.64	1.28	0.29	0.17
PUI	17.82	8.65	0.97	0.001	12.71	6.17	0.69	0.001	1.61	0.78	0.13	0.81	0.000	0.000	0	1.00
ACERS	−5.72	−2.77	0.63	0.001	−5.63	−2.73	0.64	0.001	−0.35	−0.17	0.007	0.73	−0.35	−0.17	0.007	0.73
MCERS	7.04	3.60	0.74	0.001	6.76	3.29	0.72	0.001	−1.45	−0.73	0.11	0.16	−1.45	−0.73	0.11	0.16
IM	20.18	9.78	0.95	0.001	22.99	11.17	0.96	0.001	−0.24	−0.11	0.035	0.81	−1.56	−0.75	0.041	0.163
RDM	6.4	3.10	0.71	0.001	5.08	2.46	0.70	0.001	1.09	0.52	0.069	0.29	1.2	0.58	0.0049	0.22

Note: IU = internet use, PUI = problematic use of the internet, MCERS = Maladaptive Cognitive Emotion Regulation Strategies, ACERS = Adaptive Cognitive Emotion Regulation Strategies, IM = impulsivity, RDM = risky decision-making, T0 = pre-intervention, T1 = post-intervention, T2 = three-month follow-up.

around 7 h. At post-test and follow-up, this average decreased significantly to 2–3 h in the experimental group, but no significant change was found in the placebo group. In addition, the results indicated a significant decrease in the levels of impulsivity, risk-taking and the use of MCERS. However, eWMT had no significant effect on ACERS.

Schweizer et al. (2017) demonstrated the efficacy of eWMT in the treatment of PTSD. The results indicated that eWMT was linked to increases in cognitive control and usage of adaptive emotion-regulation strategies. As discussed in the introduction, people with PUI often display poor cognitive and emotional control. Therefore, considering the results of Schweizer et al.'s (2017) study on the efficacy of eWMT in improving cognitive and emotional control, we hypothesized that PUI may be successfully addressed using eWMT. In both studies, eWMT led to improvement of cognitive and emotional control in individuals with PTSD (Schweizer et al., 2017) and PUI (current study). In order to measure emotional changes, we, like Schweizer et al. (2017), used the CERQ, a scale assessing maladaptive (i.e., catastrophizing, rumination, other-blame, and self-blame) and adaptive (i.e., refocusing on planning, positive reappraisal, positive refocusing, acceptance, and putting into perspective) CERS. However, no prior research had examined the effectiveness of eWMT in reducing symptoms of PUI prior to our study reported here and elsewhere. The effects of eWMT on cognitive and emotional symptoms in a range of psychological disorders have been demonstrated by Beloe and Derakshan (2020), Du Toit et al. (2020). According to the present findings, combined with previous research, deficits in cognitive control and working memory are closely related to poor emotional regulation and psychiatric symptomology (Schweizer et al., 2013). In cognitive functioning, working memory plays a crucial role in retaining and manipulating information (Xiong & Yao, 2010; Zhou et al., 2016). When working memory is impaired, cognitive functions may be impaired, which can affect education, employment, and other aspects of daily life (Zhou et al., 2016). As a result of ineffective cognitive strategies to deal with problems of daily life (Engel, 2002), PUI may occur (Park et al., 2011).

Neurobiological studies implicate the prefrontal cortex and hippocampus in PUI, with lower levels of activation in the prefrontal cortex reported (Brand et al., 2014; Han, Hwang, & Renshaw, 2011a, 2011b). Prefrontal cortical dysfunction has also been related to disorders involving emotional dysregulation (Brand et al., 2014), impulsivity (Robbins & Clark, 2015) and risky decision-making (Dong et al., 2011, 2013). Thus, cognitive eWMT may speculatively improve functioning of the prefrontal cortex and thus related domains and disorders (Schweizer et al., 2011, 2013, 2017). The effects of eWMT may include the development of new skills and reorganization of emotional strategies that promote changes in cognitive, emotional and behavioral domains. The efficacy of eWMT in the present study may involve simultaneous focus on cognitive, emotional and behavioral domains, and this possibility should be tested in future studies.

Table 5. Independent-samples *t*-tests of intervention group compared to placebo group in relation to variables of interest

	T0			T1			T2		
	T (df = 34)	Cohen's *d*	effect-size	T (df = 34)	Cohen's *d*	effect-size	T (df = 34)	Cohen's *d*	effect-size
IU	0.136	0.003	0.005	−15.17	5.20	0.87	−21.11	7.24	0.93
PUI	0.62	0.21	0.001	−8.74	2.99	0.69	−8.55	2.93	0.68
ACERS	−2.19	−0.73	0.12	0.34	0.11	0.003	1.4	0.46	0.054
MCERS	0.63	0.21	0.01	−6.96	−2.32	0.58	−7.38	−2.46	0.61
IM	0.93	0.31	0.02	−10.96	−3.65	0.77	−15.81	−5.27	0.88
RT	−0.50	0.51	0.007	−3.21	−1.06	0.23	−3.12	−1.04	0.22

Note: IU = internet use, PIU = problematic use of the internet, MCERS = Maladaptive Cognitive Emotion Regulation Strategies, ACERS = Adaptive Cognitive Emotion Regulation Strategies, IM = impulsivity, RDM = risky decision-making, T0 = pre-intervention, T1 = post-intervention, T2 = three-month follow-up.

eWMT and PUI

Using eWMT during continuous sessions appears to improve emotional working memory (Schweizer et al., 2017). Working memory deficits have been implicated in PUI (Nie, Zhang, Chen, & Li, 2016; Xiong & Yao, 2010; Zhou et al., 2015, 2016). Speculatively, eWMT may operate through involvement of the ventrolateral prefrontal cortex, which contributes to inhibition, and this possibility should be directly investigated in future studies. The present study's results may be partly explained by the developmental plasticity of neural substrates engaged in controlling emotions.

eWMT, impulsivity and risky decision-making

Consistent with the results of Schweizer et al. (2011, 2013, 2016, 2017), eWMT appeared to have a significant effect on reducing impulsivity and risky decision-making in the current study. eWMT has been linked to improvement of cognitive inhibition in healthy people (Schweizer et al., 2013). Both impulsivity and compulsivity may contribute to poor recovery and relapse (Lee et al., 2019). Impulsivity may involve poor response inhibition or inhibitory control (Choi, et al., 2014). Therefore, one strategy to address impulsivity in PIU may involve strengthening cognitive control (Cuzen & Stein, 2014).

Risky decision-making has been associated with impairments in the prefrontal cortex, an area involved in executive function/cognitive control (Cavadini et al., 2002; Seok et al., 2015). Over-reliance on reward systems and underuse of prefrontal control systems may underlie risky decision-making in individuals with PUI (Galvan et al., 2006; Ryan et al., 2013).

Since eWMT sessions led to increased emotional working memory capacity (Schweizer et al., 2013), and emotional working memory capacity has been positively related to cognitive control, cognitive control may also improve in the training process (Harrison et al., 2013; Schweizer et al., 2013). Working memory, impulsivity, and risky decision-making may have common neurobiological foundations (Bomyea & Lang, 2016), consistent with eWMT leading to reduced impulsivity and risky decision-making (Schweizer et al., 2017). Possible mechanisms for reductions in internet use and PUI severity warrant additional direct examination.

eWMT and CER

The effects of eWMT may rely upon the development of new skills and the reorganization of emotional strategies. Prefrontal cortical dysfunction has been linked to impaired emotion regulation, poor working memory and PUI (Brand et al., 2014; Han et al., 2011a, 2011b). As the neural foundations of emotional working memory and emotion regulation both involve the dorsolateral prefrontal cortex, anterior cingulate cortex and hippocampus, improving working memory may improve emotion regulation strategies (Schweizer et al., 2013, 2017). The results of the present study and previous research indicate that eWMT improves emotional control (Schweizer et al., 2011, 2013, 2017), and further studies should investigate the neural correlates of this improvement.

eWMT had a significant effect on the reduction of MCERS, but it did not have a significant effect on ACERS. These results resonate with prior ones. For example, Schweitzer et al. (2011) demonstrated that eWMT not only improves cognitive functioning but also improves emotion regulation in healthy and emotionally distracted people. Also, Schweizer et al. (2013) reported that participants in the experimental group improved in emotional control after undergoing eWMT in comparison with the control group. Furthermore, Schweizer et al. (2017) found that eWMT improved CERS for people suffering from PTSD compared to a placebo group.

In explaining the results, people who use maladaptive coping strategies to manage stressful events might turn to the internet as a way to compensate for the disturbing thoughts and feelings linked to these maladaptive strategies (Extremera, Quintana-Orts, Sánchez-Álvarez, & Rey, 2019). Individuals with PUI may surf the internet to deal with negative emotions as a maladaptive coping strategy (Elhai et al., 2018; Kuss et al., 2017), rather than using adaptive coping strategies (e.g., problem-solving or social support). During eWMT, the capacity of emotional working memory is strengthened by emotional stimuli presented to the participants during the sessions, leading to decreases in the use of maladaptive emotion-regulation strategies (Schweizer et al., 2017). ACERS may have less of a role in predicting PUI, and no significant difference was found in ACERS between groups with PUI and those without (Extremera et al., 2019; Kökönyei et al., 2019).

According to the literature and the results of the present study, impulsivity, risky decision-making, and CERS are factors involved in PUI and may have common underlying mechanisms that may lead to functional improvement through eWMT. Based on changes in impulsivity, risky decision-making, and CERS at the post-test stage, eWMT may lead to sustained improvement of cognitive and emotional control over time, although longer studies are needed.

Practical implications

The study design highlights the feasibility of running digital interventions for PUI. These kinds of interventions are not expensive and easily accessible as they do not need professional healthcare personnel working with individuals with PUI. Schweizer et al. (2017) indicated that eWMT may benefit students and professionals in academic settings. School and university students have high rates of PUI (Holdoš, 2017; Liang et al., 2016). Hence, school healthcare professionals may potentially use eWMT to help students with PUI. Further studies are needed to examine if eWMT is beneficial in these settings and for other conditions.

Future studies may investigate the efficacy of eWMT on other mental disorders or in other settings (for example, in primary healthcare clinics or hospitals). While we examined the efficacy of eWMT on reducing impulsivity, risky decision-making, CERS, internet use, and symptoms of PUI, future research may focus on other domains (for example, decision-making involving tolerance for ambiguity).

Limitations

Study limitations should be noted. The study took place during the COVID-19 pandemic. Thus, the extent to which findings generalize to other times/settings warrants direct examination. Additionally, 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 included words such as 'execution' and 'death' which may have generated stress for some participants and reduced their desire to continue. Other limitations include the lack of easy access to brain imaging tools such as EEG and fMRI, which could have explored brain changes associated with eWMT effects. Another limitation was the homogeneity of the participant pool (e.g., all being aged 18–23 years and from Iran). Future studies should examine other groups. Similarly, PUI is heterogeneous. While participants reported different types of internet use (e.g., gaming, use of social media), the study was not designed or powered to examine specific types of PUI (such as the diagnostic entity of gaming disorder), and future studies should do so. The IAT was in part used for inclusion purposes, and other more current (and arguably less criticized) measures exist. Further, high severity of PUI was needed for inclusion, and the extent to which findings extend to less severely affected individuals warrants additional study. Training-related changes in CER and impulsivity were examined via self-report measures, which are vulnerable to demand effects. PUI is a heterogenous entity, and future studies should examine specific forms. Given the limitations mentioned, future studies are needed to determine if it would be of benefit to develop and streamline eWMT software developed specifically for PUI.

While the chosen dependent variables (impulsivity, risk-taking, emotional regulation strategies, internet use and symptoms of PUI) are important in the context of PUI, there are no definite measures to determine the success of an intervention. As an example, while impulsivity may be a good predictor of PUI, it may not be treatable with an intervention, possibly limiting the validity of impulsivity as an outcome variable. Similarly, risky decision-making is not a usual measure of therapeutic success. Nonetheless, it has been argued that approaches aiming to investigate efficacy of interventions consider the use of such experimental medicine measures (Beckenstrom et al., 2023). Considering these factors, the positive results of the study may be limited in determining the success of the intervention, in turn potentially limiting the transferability of findings to other contexts. As most data were collected via self-report scales, biased or distorted responses were possible. Additional behavioral assessments would be beneficial and were excluded due to subject burden. Temporal duration is another potential limitation. A standard short-term therapy usually lasts at least 20–25 h. In this study, the intervention was approximately 13 h. While a shorter duration may be beneficial, it may limit durability, although this possibility is speculative. Furthermore, multiple psychological factors (e.g., psychological strain) in PIU were not considered, and these may have also influenced results. The study was of relatively short duration. As long-term effects of the training were not assessed, it is not clear how long improvement lasts.

CONCLUSION

In the current study, the primary goal was to evaluate the effectiveness of a low-cost intervention for PUI among Iranian young adults. Participation in eWMT sessions were linked to significant improvements in executive functions and symptoms of PUI compared to a placebo group. EWMT appears to be a promising technique for reducing the symptoms of PUI and improving individuals' impulsivity, decision-making and emotional functioning.

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Conflict of interest: The authors report no conflict of interest with respect to the content of this manuscript. Dr. Potenza has consulted for Game Day Data, Addiction Policy Forum, AXA, Idorsia, Baria-Tek, and Opiant Therapeutics; been involved in a patent application involving Novartis and Yale; received research support from the Mohegan Sun Casino, Children and Screens and the Connecticut Council on Problem Gambling; consulted for or advised legal, gambling and non-profit entities on issues related to impulse control, internet use and addictive behaviors; performed grant reviews; edited journals/journal sections; given academic lectures in grand rounds, CME events and other clinical/scientific venues; and generated books or chapters for publishers of mental health texts. Dr. Potenza is an associate editor of the Journal of Behavioral Addictions.

Data sharing: The data supporting this study's findings are available on request from the corresponding author. Data are not publicly available due to containing information that could compromise research participant privacy/consent.

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