

Secondary Publication



Lörsch, Frank; Schmid, Anna M.; Thomas, Tobias A.; u. a.

The effect of individual differences on Pavlovian conditioning in specific Internet-use disorders

Date of secondary publication: 19.03.2025

Version of Record (Published Version), Article

Persistent identifier: urn:nbn:de:bvb:473-irb-1070771

Primary publication

Lörsch, Frank; Schmid, Anna M.; Thomas, Tobias A.; u. a. (2024): The effect of individual differences on Pavlovian conditioning in specific Internet-use disorders, in: Behavioural brain research : an international journal, Amsterdam: Elsevier, Vol. 476, Nr. 115254, pp. 1–16, doi: 10.1016/j.bbr.2024.115254.

Legal Notice

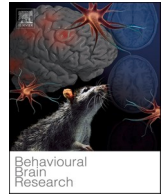
This work is protected by copyright and/or the indication of a licence. You are free to use this work in any way permitted by the copyright and/or the licence that applies to your usage. For other uses, you must obtain permission from the rights-holders.

This document is made available under a Creative Commons license.



The license information is available online:

<https://creativecommons.org/licenses/by/4.0/legalcode>



Research article

The effect of individual differences on Pavlovian conditioning in specific Internet-use disorders

Frank Lör sch ^{a,*}, Anna M. Schmid ^a, Tobias A. Thomas ^b, Matthias Brand ^c, Astrid Müller ^b, Sabine Steins-Loeber ^a

^a Department of Clinical Psychology and Psychotherapy, Otto-Friedrich-University of Bamberg, Bamberg, Germany

^b Department of Psychosomatic Medicine and Psychotherapy, Hannover Medical School, Hanover, Germany

^c Department of General Psychology: Cognition and Center for Behavioral Addiction Research (CeBAR), University of Duisburg-Essen, Duisburg, Germany

ARTICLE INFO

Keywords:

Behavioral addictions
Compulsive buying-shopping disorder
Gaming disorder
Pavlovian conditioning
Cue reactivity
Individual differences

ABSTRACT

The I-PACE model suggests that Internet-use disorders result from the interplay of individual vulnerabilities and cognitive and affective processes. As in substance use disorders, Pavlovian conditioning processes are attributed a key role. However, and despite progress in identifying individual vulnerabilities, factors influencing appetitive conditioning remain poorly understood. We therefore conducted a Pavlovian conditioning experiment in which individuals with risky as well as non-problematic use of either gaming or buying-shopping applications learned to associate different abstract stimuli with either gaming or buying-shopping. Regression analyses were used to identify individual characteristics influencing awareness of the experimental contingencies, speed of acquisition of awareness and the magnitude of the conditioned emotional responses regarding pleasantness and arousal ratings of the stimuli. Results demonstrated successful Pavlovian conditioning and an attentional bias towards reward-predicting cues. Awareness of the experimental contingencies was linked solely to cognitive abilities, while the speed of acquisition of awareness and the magnitude of conditioned responses was influenced by specific personality characteristics, experiences of compensation from using the application and severity of problematic use. Importantly, certain characteristics specifically predicted the magnitude of the conditioned response towards gaming, while others specifically predicted the response towards buying-shopping, highlighting differing vulnerabilities. These findings underscore the importance of targeted interventions and prevention strategies tailored to these specific vulnerability factors. Further implications and limitations are discussed.

1. Introduction

Current theories on the development and maintenance of addictive behaviors emphasize the role of both Pavlovian and instrumental learning processes. The incentive sensitization theory posits that cues that were repeatedly associated with substance intake acquire appetitive properties and an enhanced incentive salience (e.g., [1]). Subsequently, the exposure to conditioned substance-associated stimuli elicits conditioned stimulus-associated responses, which motivate instrumental drug seeking behavior. It is assumed that stimulus-response habits develop, and compulsive drug use emerges as the result of diminished inhibitory control [2]. As summarized in the Interaction of Person-Affect-Cognition-Execution (I-PACE) model [3] similar processes are assumed for behavioral addictions and there is a growing body of

research demonstrating cue reactivity when individuals with risky use of games are confronted with gaming-related cues [4]. In addition, cue reactivity and disadvantageous decision making have been demonstrated for compulsive buying-shopping disorder in several studies [5]. In previous research [6], we demonstrated that during the Pavlovian conditioning phase of a Pavlovian-to-instrumental transfer (PIT) task, participants learnt to associate abstract stimuli with different Internet applications, namely gaming or buying-shopping. By the end of the training, the stimulus associated with buying-shopping, though not the one associated with gaming, was rated as more pleasant than the control stimuli. Importantly, during the later transfer phase these stimuli then biased instrumental responding for rewards related to either gaming or buying-shopping. Regression analysis indicated that the symptom severity of gaming was associated with the magnitude of this effect for

* Correspondence to: Department of Clinical Psychology and Psychotherapy, Otto-Friedrich-University of Bamberg, Markusplatz 3, Bamberg 96047, Germany.

E-mail address: frank.loersch@uni-bamberg.de (F. Lör sch).

<https://doi.org/10.1016/j.bbr.2024.115254>

Received 7 May 2024; Received in revised form 16 September 2024; Accepted 17 September 2024

Available online 20 September 2024

0166-4328/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

gaming-related rewards.

Although learning mechanisms are considered important in recent theories on the development and maintenance of addictive behaviors (e. g., the I-PACE model), empirical research on the process through which cues that are repeatedly associated with addictive behaviors acquire appetitive properties is very rare. In the field of substance use disorders, Loeber and Duka [7] presented an experimental study that demonstrated that acute alcohol does not impair conditioned learning in an appetitive monetary learning paradigm which is an important observation regarding alcohol use disorders. However, only a few studies have examined the factors that facilitate this process, thus putting individuals at risk for the development and maintenance of addictive behaviors. Only very recently, Ebrahimi and colleagues [8] investigated *de novo* appetitive Pavlovian conditioning with monetary rewards and found that compared to healthy control participants, individuals with alcohol use disorder showed stronger amygdala activation during appetitive conditioning. The authors interpret their finding as reflecting stronger susceptibility of individuals with alcohol use disorder to assign incentive salience to reward-related cues. In addition, Flemming and colleagues [9] found that individuals with an increased risk to develop an alcohol use disorder, as indicated by self-reported sensitivity to the acute effects of alcohol, were more susceptible to the conditioned reinforcing properties of alcohol-related cues. These findings suggest that factors moderating Pavlovian conditioning may be related to the development and maintenance of substance use disorders.

Regarding behavioral addictions, Klucken et al. [10] reported that individuals with compulsive sexual behavior showed increased amygdala activity during appetitive conditioning with sexual stimuli suggesting facilitated appetitive conditioning. In another study of this group, a facilitating effect of extraversion on appetitive conditioning was observed [11]. In our own previous research [6] we found that in a convenience sample from the general population the severity of problematic use of gaming predicted awareness of the experimental contingencies at the end of Pavlovian conditioning training with abstract stimuli related to either gaming or buying-shopping, an important prerequisite for conditioned responses. This was not observed for buying-shopping probably due to overall low severity of problematic buying-shopping in this community sample. Perceived stress, neuroticism, extraversion, female gender, and younger age emerged as further predictors for awareness of experimental contingencies.

As outlined in the I-PACE model [3], it can be assumed that in the development of addictive behaviors predisposing variables interact with affective and cognitive mechanisms resulting in experiences of gratification or compensation from using a specific behavior which strengthens affective and cognitive responses to cues related to this behavior. General vulnerability factors for the development of addictive behaviors include a genetic predisposition, negative early childhood experiences and insecure attachment style, personality traits (e.g., impulsivity, sensation seeking, extraversion), dysfunctional emotion regulation, stress sensitivity, anxiety, depression, low social support, and a problematic family background [3]. There are also more specific vulnerability factors with regard to certain addictive behaviors. For example, higher aggressiveness and attention-deficit/hyperactivity symptoms have been associated with gaming disorder [12,13]. In contrast, materialistic value endorsement and perceived stress may be risk factors for developing compulsive buying-shopping disorder [14-17]. Furthermore, narcissistic personality traits as well as a wide range of using motives (e.g. compensation of psychological needs and stress) have been linked to both gaming disorder as well as compulsive buying-shopping disorder [18,12,19-24].

However, while the effects of extraversion, sensation seeking and neuroticism on appetitive conditioning have been previously demonstrated [11,25,6], to the best of our knowledge, the facilitating effects of other vulnerability factors on appetitive conditioning as an important mechanism contributing to the development and maintenance of addictive behavior have not been investigated so far.

From a theoretical point of view, it is important to enhance our understanding of the mechanisms that make a person more vulnerable to develop a specific addictive behavior [26]. This may also have important implications for prevention strategies. As outlined above, while several individual characteristics have been identified as risk factors for the development of behavioral addictions, it is not clear how these characteristics interact with cognitive and affective mechanisms. Against this background, the aim of the study presented here was to investigate whether specific characteristics identified as risk factors for the development of gaming and compulsive buying-shopping disorder facilitate the acquisition of conditioned appetitive responses as a key component in the development of addictive behavior. We therefore administered a Pavlovian training with abstract stimuli and stimuli related to gaming and buying-shopping applications to individuals with risky use of gaming or buying-shopping as well as healthy controls. Awareness of the experimental contingencies (as indicated by expectancy ratings), subjective ratings on valence and arousal of the abstract conditioned stimuli as well as attention allocation (using an eye-tracking system) to the conditioned stimuli were assessed as indicators of conditioned responses. Based on theoretical considerations and the current literature we assumed that awareness of the experimental contingencies would be predicted by cognitive abilities, lower impulsivity, lower chronic stress and higher severity of problematic Internet use, particularly gaming and buying-shopping. In contrast, we assumed that narcissistic personality traits, materialistic values endorsement as well as use motives and the severity of problematic use would predict subjective ratings on pleasantness and arousal of the abstract stimuli. The two online activities were chosen because gaming disorder is now recognized as a formal mental disorder in the ICD-11 [27] which occurs mainly in men [28]. Compulsive buying-shopping disorder is considered as another candidate for the ICD-11 category disorders due to addictive behaviors [29] which, according to the majority of population-based surveys, affects women more often than men [30]. Our main research question was whether certain predictors differentially relate to stronger conditioned responses regarding gaming versus those regarding compulsive buying-shopping. This would imply the existence of potential divergent vulnerability pathways in the development of both addictive behaviors.

2. Materials and methods

2.1. Procedure

The procedure applied and test battery assessed here is part of a multi-center DFG-funded addiction research unit (FOR2974) on affective and cognitive mechanisms of specific Internet-use disorders (ACSID; [31]. The study was conducted from October 2021 to July 2023 and testing took place at the University of Bamberg or the Hannover Medical School. The study protocol was pre-registered at [https://osf.io/f27qw/?view_only=4bcea30152d54aab8d6c191e269cbe7d]. The study was approved by the respective local ethics committee (Hanover: 9025_BO_K_2020; 17.04.2020; Bamberg: 2019-12/33; 18.12.2019). The study protocol adhered to the declaration of Helsinki and all study participants provided informed consent. Participants received a reimbursement of 10euro/hour or course credits if they were psychology students. Participant data was pseudonymized using ALIAS: Anonymization/Pseudonymization with LimeSurvey Integration and two-factor Authentication for Scientific research [32].

Testing comprised a single test session lasting about six hours and included the administration of different questionnaires and cognitive tasks as part of the FOR 2974 core battery [31] as well as the project specific Pavlovian-to-instrumental transfer (PIT) paradigm and a stress induction. As in our previous research [6] the PIT-paradigm comprised three different phases: a Pavlovian training phase in which participants learned to associate different abstract stimuli with the presentation of either gaming- or shopping-related pictures (see below). In the

instrumental training phase, participants learned to press two different buttons to receive gaming- or shopping-related rewards. In the transfer phase, participants could earn gaming- and shopping-related rewards as before, but the abstract pictures from the Pavlovian training phase as well as a grey square as control stimulus were displayed to investigate whether conditioned stimuli bias responding. For the research question addressed here, we report data from the first part of the PIT-paradigm, i. e. Pavlovian training.

2.2. Participants

Sixty-seven individuals at risk for gaming disorder (9 females, $\text{mean}_{\text{age}} = 24.18$ years, $SD = 4.62$), 66 individuals at risk for compulsive buying-shopping disorder (52 females, $\text{mean}_{\text{age}} = 26.21$ years, $SD = 8.96$) as well as control participants matched regarding age and gender to either the risky gaming ($n=67$; 10 females, $\text{mean}_{\text{age}} = 24.19$ years, $SD = 3.67$) or risky buying-shopping group ($n=67$; 51 females, $\text{mean}_{\text{age}} = 25.48$ years, $SD = 8.09$) were recruited. Participants were recruited at Bamberg and Hannover from the general population by posts on social networks, mailing lists, flyers, and word-of-mouth recommendations. Individuals interested to take part in the study were screened for eligibility via a telephone interview. The main exclusion criteria were learning or developmental disorders, psychosis, substance-use disorder (except tobacco), and consumption of any psychoactive substances known to interfere with the performance in cognitive tasks. A standardized clinical interview for the assessment of specific Internet-use disorders [33] was performed at the test day. Being at risk for gaming disorder or compulsive buying-shopping disorder was defined as meeting at least two, but not more than four DSM-5 criteria for gaming disorder or compulsive buying-shopping disorder (criteria were adapted). The DSM-5 criteria for gaming disorder include several key features [34]. First, individuals often show a constant preoccupation with Internet games, making it the main focus of their daily lives and overshadowing other interests and activities (1). When gaming is no longer available, individuals may experience withdrawal-like symptoms, such as irritability, anxiety, or sadness, although there are no physical withdrawal symptoms as seen with substances (2). Over time, they may need to spend increasing amounts of time gaming to achieve the same level of satisfaction, indicating tolerance (3). Efforts to limit or stop gaming are typically unsuccessful (4), and individuals may continue playing despite recognizing the negative effects on their personal and social lives (5). This can lead to a diminished interest in other forms of entertainment (6). Furthermore, individuals might lie to family members, therapists, or others about the extent of their gaming (7). Gaming is often used as a

way to escape or relieve negative emotions like helplessness, guilt, or anxiety (8). Lastly, significant relationships, job opportunities, or educational and career prospects may be jeopardized or lost due to excessive gaming (9). Individuals of the control group were required to game or shop via the Internet at least occasionally but must not fulfil more than one DSM-5 criterion.

2.3. Pavlovian training

Pavlovian training was identical to our previous research and is depicted in Fig. 1; see also Vogel et al. [6]. In short, each trial started with a fixation cross. As soon as the participants fixated on the cross, the two abstract stimuli were presented for 2300 ms, followed by the question, “What picture do you expect? 1= shopping-related, 5= I don’t know, 9= gaming-related” (the anchors were counterbalanced across participants). Then a gaming- or a shopping-related picture was presented depending upon which abstract stimuli had been shown at the start of the trial. Four abstract stimuli were presented: one stimulus served as the CS^G and was always followed by a gaming-related picture, another stimulus served as the CS^S and was always followed by a shopping-related picture, while the other two abstract stimuli were control stimuli and were equally often presented in combination with the CS^G as well as the CS^S . Which stimulus served as CS^G , CS^S or control stimulus was counterbalanced across participants). Repeated measures ANOVAs with age and gender as covariates indicated that before Pavlovian training, the four abstract stimuli did not differ regarding pleasantness ($F(3, 783) = 1.04, p = 0.38$) and arousal ratings ($F(3, 783) = 0.61, p = 0.61$) and no interaction effects with group or behavior were observed (all $F_s \leq 1.40$, all $p_s \geq 0.24$). The gaming-related and shopping-related pictures were validated in a pilot study and selected from an initial pool of 100 gaming-related and 100 shopping-related pictures representing the games/shopping websites with the highest sales figures and/or popularity. Selection criteria were based on high mean ratings regarding representativeness for gaming/shopping (on a scale ranging from 0 to 10), craving, pleasantness, and arousal (possible values ranging from 0 to 8) provided by a sample of 129 individuals who indicated to game at least occasionally and 225 individuals who indicated to shop at least occasionally. The selected 64 gaming-related pictures had a mean craving rating of 4.45 ($SD = 2.83$), a mean pleasantness rating of 4.39 ($SD = 1.35$), a mean arousal rating of 3.45 ($SD = 1.80$), and a mean representativeness rating of 6.74 ($SD = 2.27$). The 64 shopping-related pictures had a mean craving rating of 2.90 ($SD = 2.56$), a mean pleasantness rating of 4.12 ($SD = 1.24$), a mean arousal rating of 2.59 ($SD = 1.81$), and a mean representativeness rating of 7.30

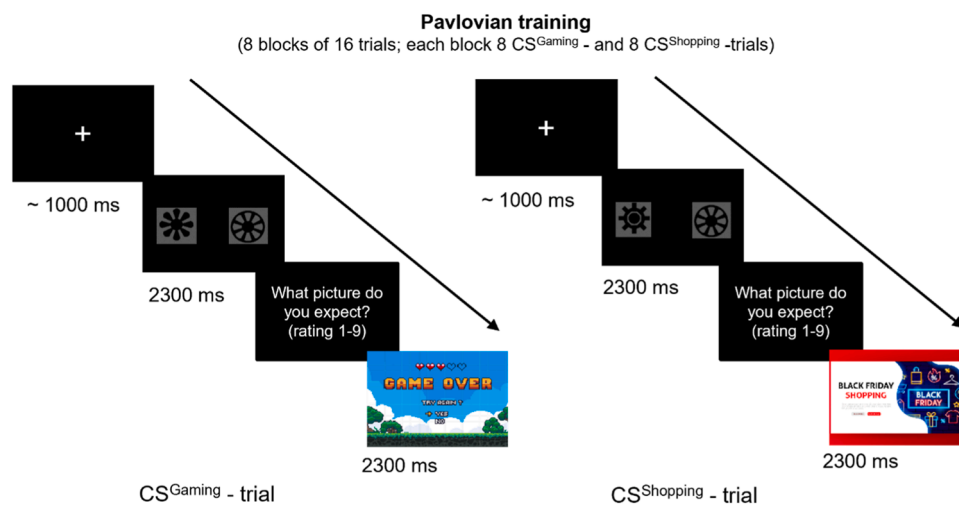


Fig. 1. Illustration of the Pavlovian training phase with a $\text{CS}^{\text{Gaming}}$ - trial (left) and a $\text{CS}^{\text{Shopping}}$ - trial (right). Placeholder images for gaming and buying-shopping are used in the figure due to copyright restrictions (Source: Colourbox, © 2024).

($SD = 2.06$). In each block, 16 trials were presented (8 CS^G, 8 CS^S). Compared to our previous research [6], eight blocks instead of four were presented to increase the number of participants aware of the experimental contingencies.

Different outcome measures were assessed from Pavlovian training. Participants were coded as aware, if expectancy ratings in the final block of Pavlovian training were significantly different in CS^G trials compared to CS^S trials [35]. Additionally, to assess the speed of acquisition, a counting variable was calculated as the number of blocks required for expectancy ratings of the CS^G to become significantly different from those of the CS^S, ranging from 1 to 8. Attention allocation to the different experimental stimuli was assessed using an eyetracker system. For the CS^G as well as the CS^S the raw data were log-transformed and for each block the mean dwell time and time to first fixation for the control stimuli was subtracted from the dwell time and time to first fixation for the CS^G or the CS^S resulting in a dwell time and time to first fixation bias score for the CS^G and the CS^S.

Before and after Pavlovian training an emotional evaluation of the different stimuli was administered and each stimulus was presented twice, in random order, with the questions: "How pleasant do you find this picture on a scale from 1 to 9? (1=not pleasant at all, 9=very pleasant)?" and "How arousing do you find this picture on a scale from 1 to 9? (1=not arousing at all, 9=very arousing)?" Mean scores for pleasantness and arousal ratings were calculated for the CS^G, the CS^S as well as the combined control stimuli. In addition, we calculated two difference scores between the emotional ratings for the stimuli by subtracting the ratings of pleasantness and arousal towards the CS^S from those towards the CS^G. A positive difference score indicated higher ratings towards the CS^G, while a negative difference score indicated higher ratings towards the CS^S.

2.4. Apparatus

Participants were seated in front of a 24-inch screen on which Pavlovian training was presented. A desktop-mounted EyeLink 1000 Plus eyetracker from SR-Research Ltd (5516 Main Street, Osgoode, Ontario, Canada K0A 2W0; available at: <http://www.sr-research.com>) was used to assess attention allocation to the experimental stimuli.

2.5. Questionnaires and paradigms

The following questionnaires and paradigms were used (in alphabetical order).

2.5.1. Assessment of criteria for specific internet-use disorders (ACSID-11)

In addition to the clinical interview, a self-report measure for the severity of problematic Internet behavior (in this study gaming and buying-shopping) was used. The Assessment of Criteria for Specific Internet-use Disorders [36] is based on the ICD-11 criteria for gaming disorder and was also adapted for compulsive buying-shopping disorder. The scale consists of 11 items, which are answered on a two-part response scale, capturing both the frequency (0 = never, 1 = rarely, 2 = sometimes, 3 = often) and intensity (0 = not at all intense, 1 = rather not intense, 2 = rather intense, 3 = intense) of the symptoms. For the purpose of this study, mean frequency was used (frequency gaming: Cronbach's $\alpha = 0.90$; frequency shopping: Cronbach's $\alpha = 0.91$).

2.5.2. Big five inventory 2 (BFI-2)

To measure Extraversion, the Big Five Inventory 2 (BFI-2; [37]) was used in its German adaptation [38]. Cronbach's alpha was 0.88 in our sample.

2.5.3. Barrat impulsiveness scale short form (BIS-15)

Impulsiveness was assessed using the German adaptation [39] of the Barratt Impulsiveness Scale short Version (BIS-15; [40]), comprising 15 items categorized into three subscales: nonplanning, motor, and

attentional impulsivity. Participants rated each item on a four-point Likert scale, ranging from 1 (*never/rarely*) to 4 (*almost always/always*). Due to the learning nature of the main paradigm applied in this study, the subscale attentional impulsivity was used for further analyses. Internal consistency was acceptable in our sample (Cronbach's $\alpha = 0.62$).

2.5.4. Cue-reactivity paradigm

In the addiction-specific Cue-Reactivity Paradigm, participants view a total of 48 pictures, evenly split between 24 depicting the target behavior (e.g., gaming) and 24 showing a distractor behavior (e.g., porn) divided up into four blocks. Each picture displays a distant cue, evaluated for valence, arousal, and urge to use the application on a five-point Likert scale. Before each block, participants rate their urge to engage in both the target and distractor behaviors using visual analogue scales ranging from 0 to 10.

2.5.5. Experience of gratification and compensation scale (EGS & ECS)

Experiences of gratification and compensation due to use of specific online applications were assessed using the Experience of Gratification Scale (EGS) and the Experience of Compensation Scale (ECS) by [41]. The EGS comprises two scales including gratification of needs and experience of pleasure, while the ECS also comprises two scales including compensation of needs and compensation of stress. Each scale consists of three items which are rated on a four-point Likert scale, ranging from 0 (*never*) to 4 (*very often*). Internal consistency was good for both scales (EGS: Cronbach's $\alpha = 0.85$; ECS: Cronbach's $\alpha = 0.88$).

2.5.6. Leistungsprüfsystem [Performance assessment system] (LPS)

To assess logical thinking abilities, subtest four of the German intelligence test battery Leistungsprüfsystem (LPS; [42]) was employed. This paper-based test presents participants with 40 rows of numbers and/or letters arranged in a logical sequence. Within eight minutes, participants must identify and mark the single item in each row that does not adhere to the sequence's logic. The number of accurately identified rows serves as a measure of proficient logical reasoning skills.

2.5.7. Modified card sorting test (MCST)

In the computerized Modified Card Sorting Test (MCST; [43]), which assesses cognitive functions such as rule detection, feedback processing, and cognitive flexibility, participants have to sort 48 cards one by one into four decks. These cards must be sorted according to a pre-determined rule, initially unknown to participants, which they must infer through trial and error with feedback provided on screen. Sorting criteria include symbols (circle, square, cross, and star), symbol colors (green, yellow, blue, and red), or the number of symbols depicted on the cards (one, two, three, and four). The rule changes after 6 consecutive correct responses. Error scores in the MCST indicate reduced cognitive functions.

2.5.8. Material values scale (MVS)

The German translation [44] of the short Materialistic Values Scale (MVS; [45]) was used to assess endorsement of materialistic values. The scale comprises 15 items rated on a five-point Likert scale from 1 (= *not true*) to 5 (= *completely true*). Higher total MVS scores indicate stronger endorsement of materialistic values. Internal consistency was good in the current sample (Cronbach's $\alpha = 0.87$).

2.5.9. Dirty dozen

Trait Narcissism was measured using the respective items of the Dirty Dozen questionnaire by Jonason and Webster [46] in its German adaptation [47]. In our sample, internal consistency was good (Cronbach's $\alpha = 0.86$).

2.5.10. Chronic stress screening scale (SSCS)

The Chronic Stress Screening Scale (SSCS), a short version of the Trier Inventory of Chronic Stress [48,49] was used to measure

self-reported chronic stress. This screening tool comprises 12 items, assessing chronic stress stemming from high demands or unmet needs in both work and personal life. Participants rated the frequency of encountering these situations and experiences over the past three months on a five-point Likert scale, ranging from 0 (*never*) to 4 (*very often*). Cronbach's alpha was 0.88 for our sample.

2.6. Statistical analysis

The acquisition of awareness of the experimental contingencies was analyzed twofold. Firstly, a repeated measures ANOVA with expectancy ratings as dependent variable and stimulus category (CS^G , CS^S) and experimental block (1, ..., 8) as repeated measures factor and group (non-problematic use, risky use) and behavior (gaming, buying-shopping) as between-subject factors was calculated. Secondly, the percentage of participants coded as aware at the end of Pavlovian training was compared between groups and behaviors using the Chi-square test. To analyze attention allocation to the experimental stimuli, repeated measures ANOVAs with the dwell time bias score or the time to first fixation bias as dependent variables and stimulus category (CS^G , CS^S) and experimental block (1, ..., 8) as repeated measures factor and group (non-problematic use, risky use) and behavior (gaming, buying-shopping) and awareness as between-subject factors were calculated. Awareness was entered as between-subject factor to assess whether any learning has taken place. All of the analyses above involved the full sample ($N = 267$). A sensitivity analysis was performed using G*Power 3.1.9.7 [50] to assess the smallest effect size detectable with our current sample size. The analysis revealed that with a sample size of $N = 267$, the repeated measures ANOVA could detect a minimum effect size of $\eta_p^2 = 0.10$ with 80 % power.

The subsequent analysis on emotional ratings regarding pleasantness and arousal of the experimental stimuli, were calculated for aware participants only ($N = 185$). Thus, repeated measures ANOVAs were calculated with time (before Pavlovian training, after Pavlovian training) and stimulus category (CS^G , CS^S , control stimuli) as repeated measures factor and group and behavior as between-subject factors. In all the analyses described above group was entered as between-subject factor to analyze the impact of the severity of risky use of gaming or buying-shopping applications on the development of expectancy ratings, attention allocation and conditioned emotional responses. Gender and age were entered as covariates.

The assumptions of all statistical procedures applied were checked. In the case of violation of the assumption of homogeneity of variances, the Greenhouse-Geiser-adjustment was applied and adjusted degrees of freedom are reported. Effect size statistics (partial η^2 , η_p^2) are reported for the main outcome measures. Two-sided planned contrasts were calculated for significant main or interaction effects and corrected for multiple testing; adjusted p-values are reported.

The predictive validity of individual characteristics on the acquisition of awareness of the experimental contingencies was analyzed using stepwise binary logistic regression analysis. Age, gender, logical thinking and problem-solving ability were entered as control variables in the first step. In the second step, chronic stress, extraversion, narcissism, materialistic value endorsement and attentional impulsivity were entered. In the final step, experiences of gratification or compensation as using motives as well as cue reactivity and severity of problematic online behavior (gaming and buying-shopping) were entered.

The predictive validity of individual characteristics on the speed of acquisition of awareness was analyzed using Poisson regression with number of blocks required for expectancy ratings of the CS^G to become significantly different from those of the CS^S as dependent variable. Additionally, this difference had to stay significant in every block until Pavlovian training was completed for a participant to be included in the regression analyses. The same predictor variables as in the binary logistic regression analysis were included in this model. Since the primary objective of this analysis was to understand the factors that influence the

speed at which awareness is acquired, participants who never achieved awareness ($N = 82$) were excluded from this analysis, resulting in a sample size of $N = 185$ aware participants.

Regarding the magnitude of the conditioned emotional responses, multiple stepwise hierarchical regression analyses were conducted separately for pleasantness and arousal ratings after Pavlovian training, again including only participants who were categorized as aware ($N = 185$). For completeness, results of the regression analyses for the full sample, which includes both aware and unaware participants ($N = 267$), are provided in the [supplementary material \(Tables S1 and S2\)](#). The analysis regarding the prediction of the magnitude of the conditioned emotional responses represents a deviation from the initial preregistered protocol, where awareness data was stated as the only dependent variable of interest. However, we now regard the conditioned emotional response as an at least equally important aspect of Pavlovian conditioning, as individuals with behavioral addictions often exhibit strong emotional reactions to conditioned stimuli, which can significantly influence their behavior and relapse potential (e.g., [51]). Therefore, two multiple stepwise hierarchical regression analysis were calculated with arousal and pleasantness ratings of the CS^G compared to the CS^S at the end of Pavlovian training as dependent variables. Age and gender were entered as control variables in the first step of the regression models. In the second step, extraversion, narcissism, material values endorsement and attentional impulsivity were entered. In the final step, experiences of gratification or compensation as using motives as well as cue reactivity and severity of problematic online behavior (gaming and buying-shopping) were entered.

A separate sensitivity analysis using G*Power 3.1.9.7 [52] was conducted to determine the smallest effect size that can be detected with our sample size. The results indicate that with the current sample size ($N = 185$), the regression analyses could detect a minimum effect size of $R^2 = 0.011$ with 80 % power, justifying the sample size as sufficient to reliably detect the effects of interest in the present study. Due to technical problems, questionnaire data from three participants were missing and these participants were thus excluded from all regression analyses. To control for multiple comparisons and reduce the likelihood of Type I errors, the False Discovery Rate (FDR) correction [53] was applied to the p-values obtained from the regression analyses. All continuous predictor variables were standardized prior to analysis, allowing for the direct comparison of the relative importance of each predictor. To assess multicollinearity among the predictors, Variance Inflation Factor (VIF) was calculated for each predictor in the regression models. All predictors had VIF values below 4, indicating no significant multicollinearity. The Durbin-Watson test indicated no significant autocorrelation in the residuals of the linear regression models. All analyses were performed using IBM SPSS Statistics (Version 26).

3. Results

3.1. Participant characteristics

Participant characteristics are depicted in [Table 1](#).

3.2. Acquisition of awareness of the experimental contingencies

3.2.1. Awareness of the experimental contingencies

As training progressed, participants learned to discriminate between the CS^G and the CS^S as indicated by expectancy ratings. A repeated measures ANOVA indicated a significant main effect of stimulus ($F(1, 263) = 509.91, p < 0.001, \eta_p^2 = .66, 90\% \text{ CI } [0.61, 0.70]$) as well as a stimulus by block interaction effect ($F(3.42, 898.22) = 178.17, p < 0.001, \eta_p^2 = .40, 90\% \text{ CI } [0.36, 0.44]$). Planned contrasts indicated that the expectancy of the gaming-related stimuli was significantly higher in CS^G than in CS^S trials in all blocks of training (all $ps < 0.001; \eta_p^2 \geq 0.27$). The stimulus by block interaction was further qualified by a stimulus by block by behavior interaction effect ($F(3.42, 898.22) = 6.53, p < 0.001,$

Table 1
Descriptive statistics of the individual participant characteristics for the four groups.

Variables	Participant characteristics			
	Gaming		Buying-shopping	
	Risky (n = 67)	Non-problematic (n = 67)	Risky (n = 66)	Non-problematic (n = 67)
Age (years)	24.18 (4.62)	24.19 (3.69)	26.21 (8.96)	25.48 (8.09)
Gender, n (%)				
Female	9 (13.4)	10 (14.9)	51 (76.1)	52 (78.8)
Male	58 (86.6)	57 (85.1)	15 (22.4)	14 (21.2)
Logical thinking (LPS 4)	30.99 (3.34)	31.80 (3.19)	30.21 (3.72)	30.21 (3.88)
Impaired problem-solving ability (MCST)	1.46 (1.99)	2.18 (2.75)	3.11 (4.35)	3.94 (4.77)
Chronic stress (SSCS)	18.33 (8.59)	14.06 (6.98)	22.35 (7.46)	18.04 (8.39)
Extraversion (BFI 2)	2.86 (0.73)	3.40 (0.62)	3.49 (0.61)	3.30 (0.73)
Narcissism (D4)	4.41 (2.11)	4.52 (2.09)	4.72 (2.25)	4.35 (2.27)
Material values endorsement (MVS)	37.70 (9.30)	36.70 (10.31)	43.13 (11.22)	37.51 (10.05)
Attentional impulsivity (BIS 15)	10.37 (2.56)	9.81 (2.48)	10.29 (2.49)	9.64 (2.47)
Experience of hedonism (EGS)	3.01 (0.62)	2.81 (0.57)	2.66 (0.79)	2.01 (0.83)
Gratification of needs (EGS)	2.07 (0.72)	1.87 (0.78)	1.23 (0.74)	0.75 (0.64)
Compensation of needs (ECS)	1.51 (0.84)	1.26 (0.92)	1.05 (0.91)	0.38 (0.62)
Compensation of stress (ECS)	2.00 (0.88)	0.94 (0.83)	1.52 (0.86)	0.57 (0.67)
Cue reactivity	1.90 (0.69)	1.66 (0.55)	2.35 (0.69)	1.55 (0.63)
Symptom severity gaming (ACSID 11)	0.96 (0.58)	0.47 (0.37)	0.11 (0.27)	0.03 (0.09)
Symptom severity buying-shopping (ACSID 11)	0.13 (0.29)	0.15 (0.30)	0.90 (0.54)	0.34 (0.47)

Note. All values are displayed as means and standard deviations (SD) in brackets if not otherwise specified. Due to missing values, sample sizes for the descriptive statistics ranged from 66 to 67. ACSID-11 = Assessment of Criteria for Specific Internet-use Disorders; BFI-2 = Big Five Inventory 2; BIS-15 = Barrat Impulsiveness Scale Short-version; EGS & ECS = Experience of Gratification and Compensation Scale; LPS-4 = Leistungsprüfsystem [Performance assessment system]; MCST = Modified Cart Sorting Test; MVS = Material Values Scale; SSCS = Chronic Stress Screening Scale.

$\eta_p^2=.02$, 90 % CI [0.01, 0.04]). Thus, as depicted in Fig. 2, while all participants learned to discriminate between the CS^G and the CS^S, participants with risky or non-problematic gaming showed a stronger discrimination between the CS^G and the CS^S compared to participants with risky or non-problematic buying-shopping as indicated by significantly greater differences in expectancy ratings in CS^G compared to CS^S trials from the seventh block onwards (all $ps \leq 0.05$; Bonferroni-corrected).

The stimulus by block by group interaction effect was approaching significance ($F(3.42, 898.22) = 2.42, p = 0.06, \eta_p^2=.01$, 90 % CI [0.00, 0.02]), but planned contrasts did not indicate any reliable differences. The stimulus by block by group by behavior interaction effect ($F(3.42, 898.22) = 0.51, p = 0.70$) was not significant. Given the significant group differences regarding gender and age between individuals with risky or non-problematic gaming and participants with risky or non-problematic buying-shopping, the analysis was calculated again with age and gender as covariates. This did not affect the findings reported above. However, to disentangle effects of problematic behavior and gender, we provide an additional figure in the [supplementary material \(Figure S1\)](#) showing expectancy ratings of the two control groups. As this figure is very similar to Fig. 2 it can be assumed that the behavioral differences observed here are driven by gender-differences.

At the end of Pavlovian training, 64.31 % of participants were coded as aware of the experimental contingencies. This percentage did neither for gaming-related ($\chi^2(1) = 0.02, p = 1.00$) nor shopping-related behavior ($\chi^2(1) = 1.48, p = 0.30$) differ significantly between participants with risky or non-problematic behavior. However, 72.60 % of participants with risky or non-problematic gaming compared to 56.00 % of participants with risky or non-problematic buying-shopping were aware of the experimental contingencies and this difference achieved significance ($\chi^2(1) = 8.10, p = 0.005$).

3.2.2. Prediction of awareness of the experimental contingencies

The logistic regression analysis showed that lower number of perseverative errors in the MCST emerged as the only significant predictor (see Table 2). The initial model in Block 1 was significant ($\chi^2(4) = 19.26$; Nagelkerkes $R^2 = .099, p < 0.001$), correctly classifying 69 % of the participants. In Block 2, the model remained significant ($\chi^2(9) =$

21.22; Nagelkerkes $R^2 = .109, p = 0.012$), correctly classifying 72 % of the participants. However, in Block 3, the overall model was only approaching significance ($\chi^2(16) = 24.55$; Nagelkerkes $R^2 = .125, p = 0.078$), indicating that the additional predictors in this block did not significantly improve the model fit. Despite this, while gender was no more a significant predictor after FDR correction, lower number of perseverative errors in the MCST remained as significant predictor ($p < 0.001$). Each additional perseverative error on the MCST was associated with a 14 % decrease in the odds of being aware of the experimental contingencies (OR = 0.860, 95 % CI [0.789, 0.937], $p < 0.001$).

3.2.3. Prediction of the speed of acquisition of awareness

The Poisson regression regarding the prediction of the speed of acquisition of awareness showed a significant model fit ($\chi^2(16) = 41.58, p < 0.001$). The results of the Poisson regression are presented in Table 3.

Specifically, age was a significant predictor of the speed of acquisition, indicating that younger participants acquired awareness more quickly. Gender was also a significant predictor, suggesting that females had a higher expected count of the number of blocks to achieve awareness compared to males. Material values endorsement was another significant predictor, suggesting that lower scores were associated with a faster acquisition of awareness. Contrary to our expectations, lower cue reactivity and lower symptom severity of gaming were significant predictors for faster acquisition of awareness. Other variables did not significantly predict the speed of acquisition. However, after applying the FDR correction, only material values endorsement and symptom severity of gaming remained significant.

3.3. Acquisition of conditioned responses

3.3.1. Attention allocation

As training progressed the dwell time bias scores for the CS^G as well as the CS^S increased in participants aware of the experimental contingencies as indicated by a significant main effect of block ($F(4.48, 1146.12) = 3.91, p < 0.001, \eta_p^2 = .02$, 90 % CI [0.003, 0.025]) which was qualified by a significant block by awareness interaction effect ($F(4.48, 1146.12) = 11.44, p < 0.001, \eta_p^2 = .04$, 90 % CI [0.02, 0.06]). Again,

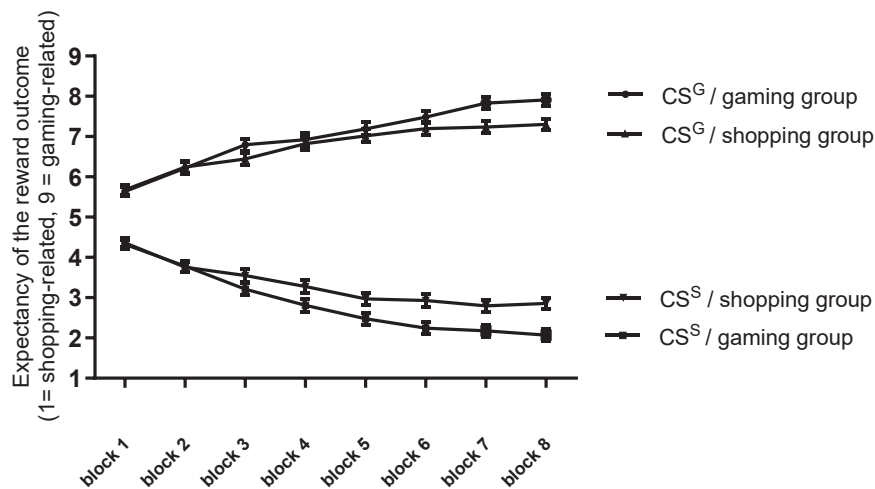


Fig. 2. Expectancy ratings (mean, SEM) of the shopping-related or gaming-related outcomes after presentation of the CS^G or the CS^S; data from individuals with risky and non-problematic gaming were collapsed in the gaming group and data from individuals with risky and non-problematic buying-shopping in the shopping group as no significant group differences were observed.

Table 2

Results of the stepwise binary logistic regression analysis to predict awareness of the experimental contingencies.

Variables and steps	Awareness								
	Step 1			Step 2			Step 3		
	B	SE	P	B	SE	P	B	SE	P
Age	0.21	0.15	0.160	0.22	0.15	0.163	0.23	0.16	0.157
Gender	0.36	0.27	.190	0.46	0.29	0.115	-0.70	0.35	0.045
Logical thinking (LPS 4)	0.36	1.00	.720	0.35	0.93	0.706	0.34	0.88	0.697
Impaired problem-solving ability (MCST)	-0.52	0.16	<0.001	-0.53	0.16	<0.001	-0.57	0.17	<0.001
Chronic stress (SSCS)				0.12	0.16	0.434	0.14	0.18	0.426
Extraversion (BFI 2)				0.07	0.15	0.643	0.01	0.16	0.975
Narcissism (D4)				0.13	0.16	0.429	0.09	0.16	0.600
Material values endorsement (MVS)				0.15	0.16	0.340	0.12	0.17	0.482
Attentional impulsivity (BIS 15)				0.02	0.15	0.909	0.02	0.16	0.975
Experience of hedonism (EGS)							0.00	0.19	0.993
Gratification of needs (EGS)							0.01	0.22	0.982
Compensation of needs (ECS)							0.23	0.27	0.387
Compensation of stress (ECS)							0.01	0.27	0.974
Cue reactivity							0.16	0.18	0.378
Symptom severity gaming (ACSID 11)							0.07	0.18	0.678
Symptom severity buying-shopping (ACSID 11)							0.13	0.18	0.482
R ²	.099		<0.001	.109		0.012	.125		0.078

Note. B is the unstandardized regression coefficient; SE standard error; control variables were entered in the first step. Personality variables were entered in the second step. In the final step, variables related to gaming and buying-shopping were entered. Participants were coded as aware if expectancy ratings in trials with a gaming-related outcome (CS^G) were significantly higher than in trials with a shopping-related outcome (CS^S) in the final block of Pavlovian training. Significant effects are highlighted in bold. ^ not significant after FDR correction

similar findings were observed when age and gender were entered as covariates in the analysis. Thus, as shown in Fig. 3a, in participants aware of the experimental contingencies, the CS^G as well as the CS^S were fixated longer than the control stimuli as indicated by an increase in the dwell time bias score. In contrast, participants unaware of the experimental contingencies did not show a dwell time bias (see Fig. 3b) suggesting a failure to learn. Unaware participants were thus excluded from the analysis on the emotional evaluation of the stimuli. However, for transparency, results for unaware participants are presented in the supplementary material (e.g., Figure S2).

In addition, a significant stimulus by block by behavior ($F(6.12, 1563.80) = 2.41, p = 0.02, \eta_p^2 = 0.01, 90\% \text{ CI } [0.001, 0.015]$) as well as a significant stimulus by block by behavior by awareness interaction effect ($F(6.12, 1563.80) = 2.77, p = 0.01, \eta_p^2 = 0.01, 90\% \text{ CI } [0.001, 0.017]$) emerged. Although effect-size estimates were small and findings should be interpreted with caution, planned contrasts indicated no significant increases in the dwell time bias for the CS^G or the CS^S (all $ps \geq$

0.09) in unaware participants. In contrast, in aware participants with risky or non-problematic gaming, the dwell time bias for the CS^G was significantly higher from the fourth block onwards compared to the first block (all $ps \leq 0.007, \eta_p^2 = 0.15$). For participants with risky or non-problematic shopping, this difference approached significance only in the last block of training ($p = 0.06, \eta_p^2 = 0.05, 95\% \text{ CI } [-1.050, 0.005]$).

This analysis was also calculated using the time to first fixation as indicator of attention allocation. However, while a significant stimulus by block by behavior by group interaction effect emerged ($F(6.59, 1615.54) = 2.24, p = 0.03, \eta_p^2 = 0.01, 90\% \text{ CI } [0.0004, 0.0142]$) which was further qualified by a significant stimulus by block by behavior by group by awareness interaction effect ($F(6.59, 1615.54) = 2.64, p = 0.01, \eta_p^2 = 0.01, 90\% \text{ CI } [0.001, 0.012]$), the main effects of stimulus ($F(1, 245) = 0.02, p = 0.89, \eta_p^2 < 0.001, 90\% \text{ CI } [0.000, 0.001]$), as well as block ($F(6.65, 1628.96) = 1.44, p = 0.18, \eta_p^2 = 0.01, 90\% \text{ CI } [0.00, 0.01]$), did not achieve significance. We thus refrained from interpreting these interaction effects.

Table 3
Results of the Poisson regression analysis to predict speed of awareness acquisition.

Variables	Speed of awareness acquisition			
	B	SE	χ^2 (95 % CI)	P
Age	0.09	0.04	4.84 (0.01, 0.17)	0.028[^]
Gender	0.22	0.10	4.78 (0.02, 0.42)	0.029[^]
Logical thinking (LPS 4)	5.84	7.66	0.58 (20.86, 9.18)	0.446
Impaired problem-solving ability (MCST)	0.03	0.05	0.33 (0.08, 0.14)	0.564
Chronic stress (SSCS)	0.00	0.05	0.00 (0.97, 0.10)	0.964
Extraversion (BFI 2)	0.00	0.05	0.00 (0.09, 0.10)	0.957
Narcissism (D4)	0.01	0.05	0.02 (0.88, 0.10)	0.893
Material values endorsement (MVS)	0.13	0.05	7.54 (0.04, 0.23)	0.006
Attentional impulsivity (BIS 15)	0.01	0.04	0.06 (0.72, 0.93)	0.803
Experience of hedonism (EGS)	0.03	0.06	0.25 (0.16, 0.09)	0.616
Gratification of needs (EGS)	0.04	0.07	0.36 (0.18, 0.09)	0.548
Compensation of needs (ECS)	0.06	0.08	0.44 (0.22, 0.11)	0.509
Compensation of stress (ECS)	0.11	0.08	2.11 (0.27, 0.04)	0.146
Cue reactivity	0.10	0.05	3.95 (0.00, 0.19)	0.047[^]
Symptom severity gaming (ACSID 11)	0.14	0.05	8.95 (0.05, 0.24)	0.003
Symptom severity buying-shopping (ACSID 11)	0.07	0.05	1.84 (0.03, 0.18)	0.176
Model Fit			41.58	<0.001
AIC	785.930			
Log-Likelihood	375.965			
Deviance	223.898			

Note. B is the unstandardized regression coefficient; SE standard error; Participants were included in the analysis based on their expectancy ratings. Specifically, participants were considered aware from the block where their expectancy ratings for gaming-related outcomes (CS^G) were significantly higher than for shopping-related outcomes (CS^S). This criterion had to be met in one block and maintained through all subsequent blocks. Significant effects are highlighted in bold. [^] = not significant after FDR correction

3.3.2. Emotional evaluation of the stimuli

With regard to pleasantness ratings a significant main effect of time emerged ($F(1, 176) = 5.44, p = 0.02, \eta_p^2 = .03, 90\% \text{ CI } [0.00002, 0.06887]$), which was qualified by a significant time by stimulus by behavior interaction effect ($F(1.82, 320.14) = 9.45, p < 0.001, \eta_p^2 = .05, 90\% \text{ CI } [0.02, 0.09]$). Planned contrasts indicated for participants with risky or non-problematic gaming (see Fig. 4a) a significant increase in pleasantness ratings of the CS^G ($p = 0.03, 95\% \text{ CI } [-1.324, 0.059]$) which was not observed for the CS^S ($p = 0.31, 95\% \text{ CI } [0.059, 1.324]$). Participants with risky or non-problematic shopping (see Fig. 4b) reported an increase in pleasantness ratings of the CS^S ($p = 0.06, 95\% \text{ CI } [-1.067, 0.014]$) and a decrease of pleasantness ratings of the CS^G ($p = 0.06, 95\% \text{ CI } [-0.014, 1.152]$), although these latter changes only approached significance. For both groups, an increase in pleasantness ratings of the control stimuli was observed (gaming: $p = 0.01, 95\% \text{ CI } [-1.150, 0.131]$); shopping: $p = 0.02, 95\% \text{ CI } [-1.033, 0.094]$). After Pavlovian training, participants with risky or non-problematic shopping

rated the CS^S as significantly more pleasant than the CS^G ($p < 0.001, 95\% \text{ CI } [0.548, 2.530]$) and the control stimuli ($p = 0.03, 95\% \text{ CI } [0.067, 1.577]$). For participants with risky or non-problematic gaming these differences were not significant ($p \geq 0.39$).

With regard to arousal ratings a significant main effect of time was found ($F(1, 176) = 5.26, p = 0.02, \eta_p^2 = 0.03, 90\% \text{ CI } [0.002, 0.081]$) which was qualified by a significant time by stimulus by behavior interaction effect ($F(1.74, 305.59) = 3.26, p = 0.047, \eta_p^2 = .02, 90\% \text{ CI } [0.0002, 0.0473]$). Planned contrasts indicated for participants with risky or non-problematic gaming (see Fig. 4c) a significant increase in arousal ratings of the CS^G ($p < 0.001, 95\% \text{ CI } [-1.846, 0.600]$) which was not observed for the CS^S ($p = 0.79, 95\% \text{ CI } [-0.723, 0.528]$). Participants with risky or non-problematic shopping (see Fig. 4d) reported a significant increase in arousal ratings of the CS^S ($p = 0.04, 95\% \text{ CI } [-1.195, 0.035]$) and a decrease of pleasantness ratings of the CS^G, which was however only approaching significance ($p = 0.095, 95\% \text{ CI } [-1.062, 0.085]$). For both groups, an increase in arousal ratings of the

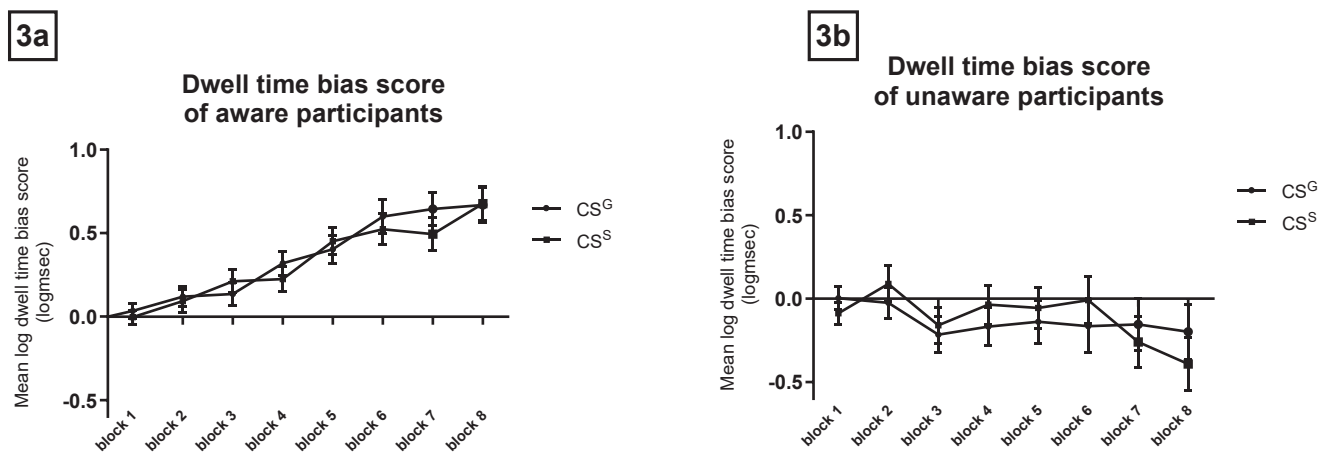


Fig. 3. Dwell time bias score (mean/SEM) to the CS^G and the CS^S for aware (3a) and unaware (3b) participants of the different groups; data from individuals with risky and non-problematic gaming and individuals with risky and non-problematic buying-shopping were collapsed; presented are difference scores to the control stimuli.

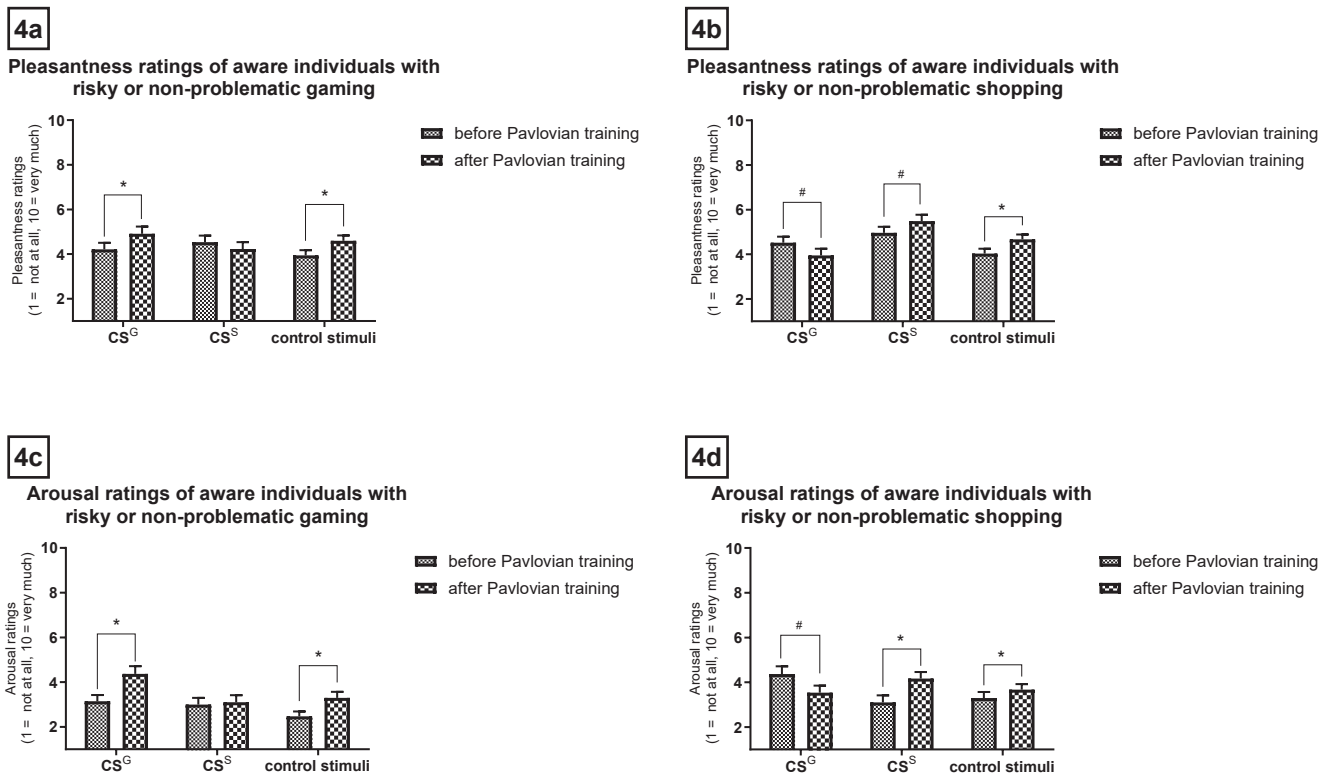


Fig. 4. Pleasantness and arousal ratings of the different experimental stimuli before and after Pavlovian training for aware individuals with risky and non-problematic gaming or risky and non-problematic buying-shopping, * $p < 0.05$, # $p < 0.10$.

Table 4

Results of the stepwise hierarchical linear regression analysis to predict the magnitude of the conditioned pleasantness response towards a gaming-related outcome (CS^G) compared to a shopping-related outcome (CS^S) after the final block of Pavlovian training.

Variables and steps	Magnitude of conditioned pleasantness response								
	Step 1			Step 2			Step 3		
	β (95 % CI)	T	P	β (95 % CI)	T	P	β (95 % CI)	T	P
Age	.043 (.102,.188)	0.58	0.565	.005 (.134,.144)	0.08	0.940	.003 (.136,.142)	0.04	0.971
Gender	-.155 (-.451,.141)	-2.11	0.036	.135 (.423,.153)	1.88	0.062	.007 (.330,.344)	0.08	0.934
Extraversion (BFI 2)				.019 (.132,.170)	0.26	0.799	.083 (.078,.244)	1.03	0.303
Narcissism (D4)				.038 (.120,.196)	0.48	0.633	.028 (.130,.186)	0.35	0.726
Material values endorsement (MVS)				-.270 (-.423, -.117)	-3.51	<0.001	-.207 (-.374, -.040)	-2.48	0.014
Attentional impulsivity (BIS 15)				.245 (.102,.388)	3.39	<0.001	.233 (.092,.374)	3.24	0.001
Experience of hedonism (EGS)							.018 (.184,.220)	0.18	0.861
Gratification of needs (EGS)							.011 (.218,.240)	0.10	0.921
Compensation of needs (ECS)							.126 (.142,.394)	1.34	0.344
Compensation of stress (ECS)							.147 (.398,.104)	1.18	0.238
Cue reactivity							.090 (.253,.073)	1.07	0.285
Symptom severity gaming (ACSID 11)							.230 (.062,.398)	2.72	0.007
Symptom severity buying-shopping (ACSID 11)							.117 (.299,.065)	1.29	0.197
R ²	.025		0.104	.134		<0.001	.199		<0.001

Note. β is the standardized regression coefficient. Control variables were entered in the first step. Personality variables were entered in the second step. In the final step, variables related to gaming and buying-shopping were entered. Significant effects are highlighted in bold. ^ = not significant after FDR correction

control stimuli was observed ($ps \leq 0.006$). After Pavlovian training, participants with risky or non-problematic gaming rated the CS^G as significantly more arousing than the CS^S ($p = 0.004$, 95 % CI [0.328, 2.217]) and the control stimuli ($p < 0.001$, 95 % CI [0.388, 1.761]). For participants with risky or non-problematic shopping these differences were not significant ($p \geq 0.23$).

3.3.3. Prediction of the magnitude of the conditioned emotional responses

Regarding the prediction of the magnitude of conditioned emotional

responses, results from the linear multiple hierarchical regression analyses are presented in Table 4 for pleasantness and Table 5 for arousal ratings.

3.3.3.1. Pleasantness. In the initial step, the model did not achieve significance ($R^2 = .025$, $F(2, 181) = 2.33$, $p = 0.100$). Subsequent entering of personality variables in the second block significantly improved the model ($\Delta R^2 = .106$, $p < 0.001$), resulting in overall significance ($R^2 = .131$, $F(4, 177) = 4.46$, $p < 0.001$). Adding the variables

Table 5

Results of the stepwise hierarchical linear regression analysis to predict the magnitude of the conditioned arousal response towards a gaming-related outcome (CS^G) compared to a shopping-related outcome (CS^S) after the final block of Pavlovian training.

Variables and steps	Magnitude of conditioned arousal response								
	Step 1			Step 2			Step 3		
	β (95 % CI)	T	P	β (95 % CI)	T	P	β (95 % CI)	T	P
Age	.047 (.099,.193)	0.63	0.531	.011 (.127,.149)	0.15	0.878	.009 (.128,.146)	0.13	0.900
Gender	.075 (.373,.223)	1.01	0.316	.055 (.198,.088)	0.76	0.450	.101 (.229,.431)	1.22	0.225
Extraversion (BFI 2)				.054 (.098,.206)	0.71	0.476	.100 (.056,.256)	1.27	0.205
Narcissism (D4)				.058 (.103,.219)	0.72	0.470	.072 (.083,.227)	0.92	0.360
Material values endorsement (MVS)				.283 (.436, .130)	3.66	<0.001	-.246 (-.409, -.083)	-3.00	0.003
Attentional impulsivity (BIS 15)				.267 (.122,.412)	3.68	<0.001	.259 (.121,.397)	3.67	<0.001
Experience of hedonism (EGS)							.140 (.057,.337)	1.42	0.159
Gratification of needs (EGS)							.118 (.342,.106)	1.07	0.288
Compensation of needs (ECS)							.254 (.003,.511)	1.95	0.053
Compensation of stress (ECS)							-.338 (-.591, -.085)	-2.78	0.006
Cue reactivity							.037 (.122,.196)	0.46	0.650
Symptom severity gaming (ACSID 11)							.219 (.055,.383)	2.64	0.009
Symptom severity buying-shopping (ACSID 11)							-.228 (-.402, -.054)	-2.56	0.011
R ²	.007		0.524	.128		<0.001	.228		<0.001

Note. β is the standardized regression coefficient. Control variables were entered in the first step. Personality variables were entered in the second step. In the final step, variables related to gaming and buying-shopping were entered. Significant effects are highlighted in bold.

related to gaming and buying-shopping in the third block did not significantly improve the model, although the increase approached significance ($\Delta R^2 = .067, p = 0.054$). The final model remained significant ($R^2 = .198, F(7, 170) = 3.24, p < 0.001$).

Attentional impulsivity ($\beta = .233, 95\% \text{ CI } [.092, .374]$) and symptom severity of problematic gaming ($\beta = .230, 95\% \text{ CI } [.062, .398]$) emerged as significant predictors for a relatively higher magnitude of the conditioned pleasantness response towards the gaming-associated stimulus as indicated by positive regression coefficients, while materialistic values endorsement ($\beta = -.207, 95\% \text{ CI } [-.374, .040]$) significantly predicted a relatively higher magnitude of the conditioned pleasantness response towards the shopping-associated stimulus as indicated by a negative regression coefficient (see Fig. 5). However, after the FDR correction, only attentional impulsivity ($p = 0.001$) and symptom severity of gaming ($p = 0.007$) remained significant.

3.3.3.2. Arousal. In the initial step, the model did not achieve significance ($R^2 = .007, F(2, 181) = 0.64, p = 0.527$). Subsequent entering of personality variables in the second block significantly improved the model ($\Delta R^2 = .121, p < 0.001$), resulting in overall significance ($R^2 = .128, F(4, 177) = 4.34, p < 0.001$). When the variables related to gaming and buying-shopping were entered in the third block, the model further improved significantly ($\Delta R^2 = .098, p = .005$).

Attentional impulsivity ($\beta = .259, 95\% \text{ CI } [.121, .397]$) and symptom severity of problematic gaming ($\beta = 0.219, 95\% \text{ CI } [.055, .383]$) emerged as significant predictors for a relatively higher magnitude of the conditioned arousal response towards the gaming-associated stimulus as indicated by positive regression coefficients, while materialistic values endorsement ($\beta = -.246, 95\% \text{ CI } [-.409, .083]$), compensation of stress ($\beta = -.338, 95\% \text{ CI } [-.591, .085]$), and symptom severity of problematic buying-shopping ($\beta = -.228, 95\% \text{ CI } [-.402, .054]$) significantly predicted a relatively higher magnitude of the conditioned arousal response towards the shopping-associated stimulus as indicated by negative regression coefficients (see Fig. 6). All predictors remained significant after the FDR correction.

4. Discussion

Given the important role attributed to processes of Pavlovian conditioning regarding the development and maintenance of addictive

behavior, the aim of the present study was to investigate whether individual differences identified as risk factors for the development of gaming disorder and/or compulsive buying-shopping disorder facilitate the acquisition of conditioned appetitive responses related to either gaming or buying-shopping. We administered a Pavlovian training with abstract stimuli and stimuli related to gaming or buying-shopping to individuals with risky gaming or buying-shopping as well as participants with non-problematic application use. We then analyzed factors affecting the awareness of the experimental contingencies and the speed of acquisition of awareness (as indicated by expectancy ratings) and the magnitude of the conditioned emotional responses (as indicated by subjective ratings on pleasantness and arousal of the abstract conditioned stimuli). Based on the current literature, we hypothesized that cognitive abilities, certain personality features, experiences of gratification and compensation as specific use motives as well as the severity of problematic gaming or buying-shopping would emerge as significant predictors.

Our results first of all demonstrated that as Pavlovian training progressed, participants awareness of the experimental contingencies increased as indicated by higher expectancy ratings of gaming-related pictures when the CS^G was presented compared to the CS^S and higher expectancy ratings of buying-shopping-related pictures when the CS^S was presented compared to the CS^G. These outcomes are in line with our previous findings [6] and underline the validity of the Pavlovian training to assess the development of learning processes. Extending our previous findings, using an eyetracking system we now also demonstrated that in parallel an attentional bias for the CS^G and CS^S developed as indicated by dwell times, however only in participants aware of the experimental contingencies. Interestingly though, the severity of problematic gaming/buying-shopping did only marginally affect the acquisition of awareness of the experimental contingencies as indicated by a stimulus by block by group interaction effect that only approached significance. This finding was supported by results from the regression analysis on acquisition of awareness in which severity of problematic behavior did not emerge as significant predictor. On the contrary, higher symptom severity of problematic gaming emerged as one of the most reliable predictors for a slower acquisition of awareness. Individuals with gaming disorder have been shown to exhibit cognitive deficits (e.g., [54-56]) which could mediate this effect. In line with these assumptions, results of the regression analysis revealed that awareness of the

Prediction of the magnitude of the conditioned pleasantness response

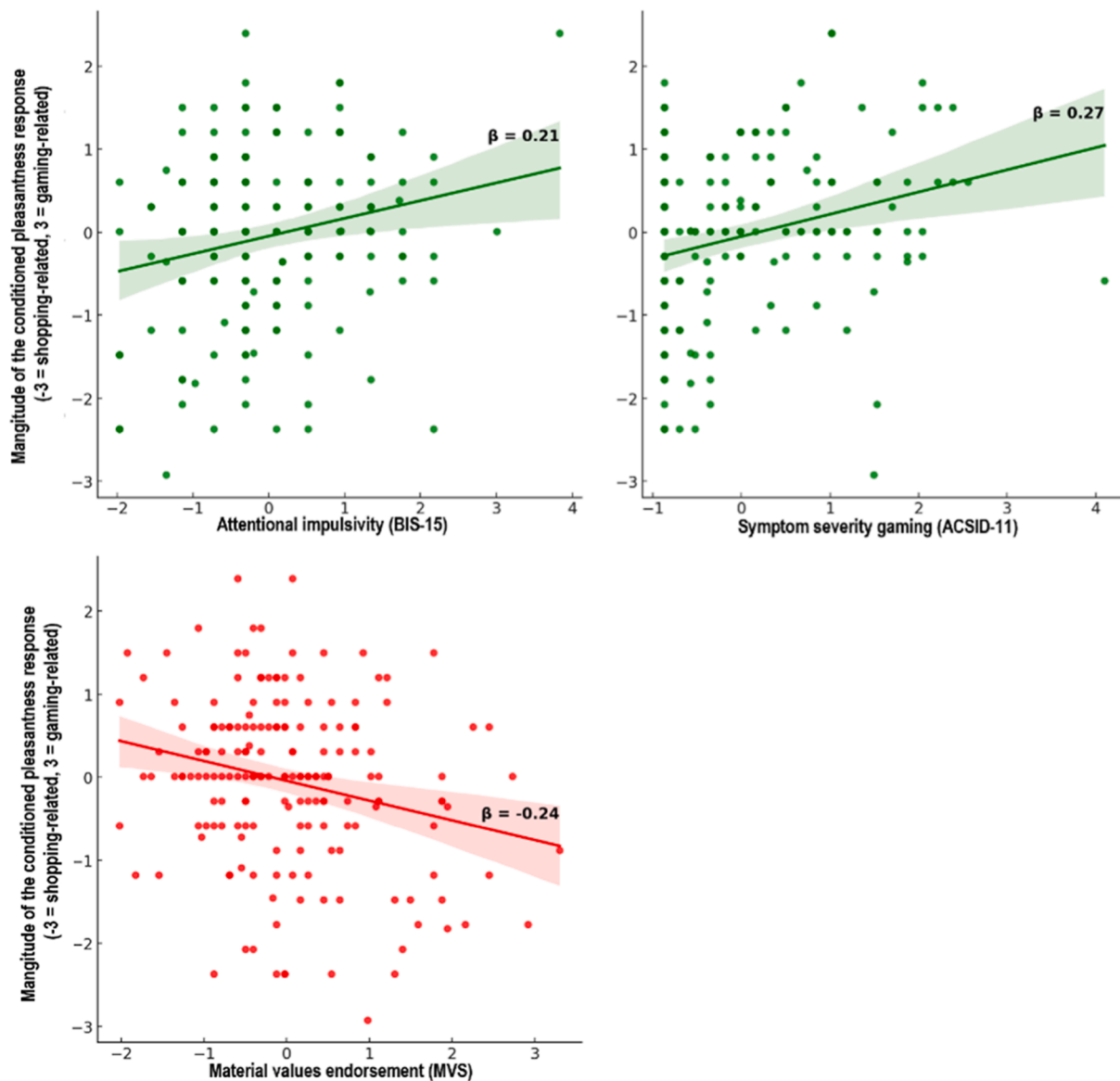


Fig. 5. Hierarchical multiple linear regression analysis of the conditioned pleasantness response difference scores by individual characteristics, presented in separate panels for each predictor. Scatter plots depict the relationship between the conditioned pleasantness response and significant predictors. Green regression lines represent positive correlations, where higher predictor values are associated with greater pleasantness ratings for the gaming-associated stimulus (CS^G). Red regression lines indicate negative correlations, where higher predictor values are linked to greater pleasantness ratings for the buying-shopping-associated stimulus (CS^S). Confidence intervals around the regression lines provide an estimate of the uncertainty in the predictions. Only significant predictors are depicted for clarity (please note, that material values endorsement was not significant after the FDR correction anymore).

experimental contingencies was predicted solely by lower levels of cognitive impairment. No further personality characteristics, variables related to gaming or buying-shopping, or severity of problematic Internet behavior emerged as significant predictors. Participants who made more perseverative errors on the MCST were significantly less likely to become aware of the experimental contingencies. This suggests that individuals who struggle with perseveration—continuing to make the same mistake despite feedback—might have more difficulty in learning or recognizing patterns that lead to awareness of the contingencies in the experiment. Thus, awareness of the experimental contingencies may rely more on general cognitive abilities such as problem-solving, rather than on previous experiences of gratification or compensation from using the application or an enhanced incentive

salience of application-related stimuli as indicated by cue reactivity. However, it should be acknowledged, that these findings may be due to the inclusion of individuals with risky use of gaming or buying-shopping applications fulfilling less than five DSM-5 criteria for gaming disorder/compulsive buying-shopping disorder according to inclusion/exclusion criteria for the present study. Different findings may be observed when including participants with clinically relevant, pathological application use.

Our results further indicated that participants of the gaming groups, irrespective of whether they reported non-problematic or risky use, acquired a clearer differentiation between the CS^G and CS^S compared to the buying-shopping groups. This was also reflected in awareness rates at the end of Pavlovian training. While in the entire sample 64.31 % of

Prediction of the magnitude of the conditioned arousal response

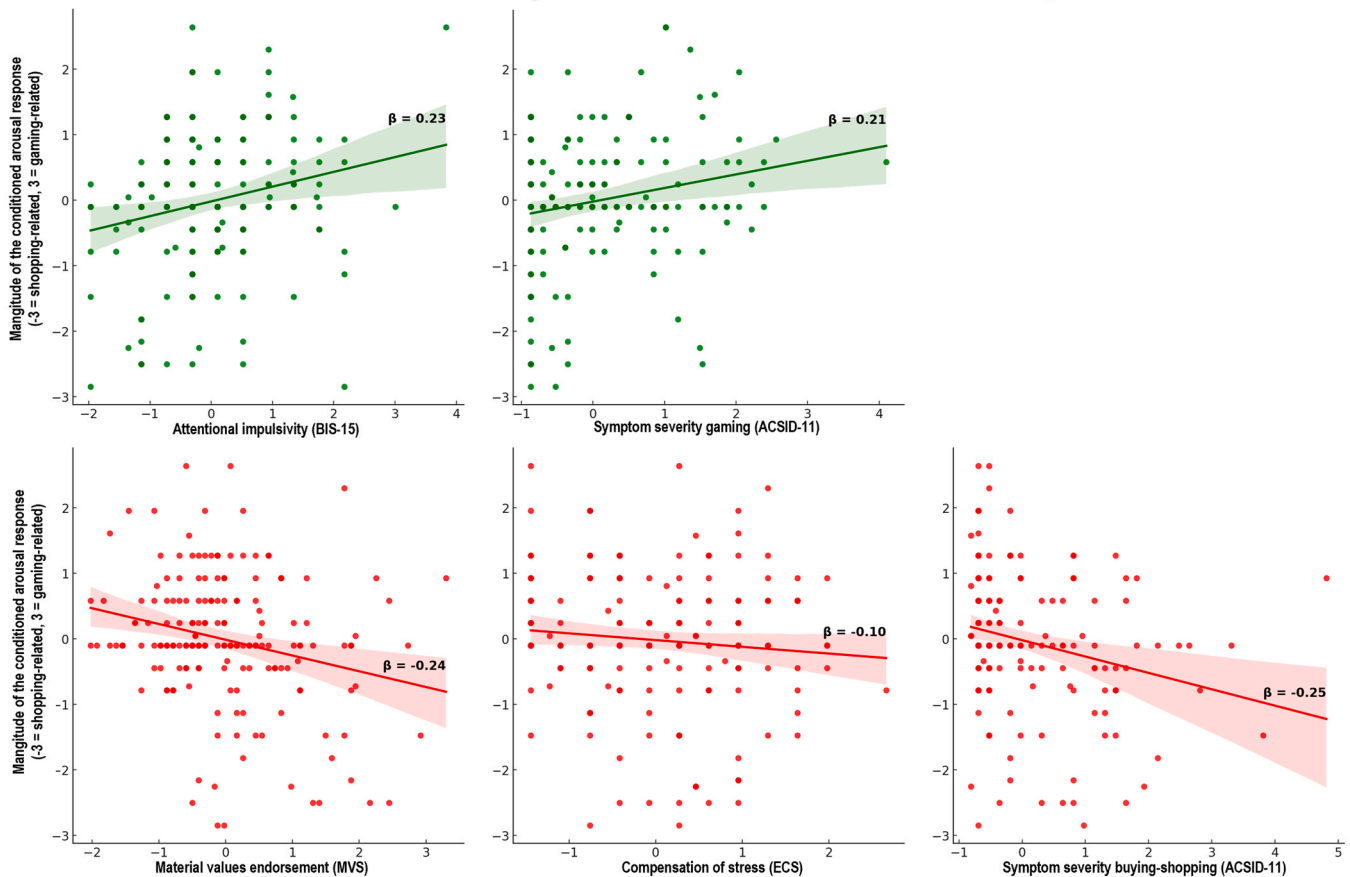


Fig. 6. Hierarchical multiple linear regression analysis of the conditioned arousal response difference scores by individual characteristics, presented in separate panels for each predictor. Scatter plots depict the relationship between the conditioned arousal response and significant predictors. Green regression lines represent positive correlations, where higher predictor values are associated with greater arousal ratings for the gaming-associated stimulus (CS^G). Red regression lines indicate negative correlations, where higher predictor values are linked to greater arousal ratings for the buying-shopping-associated stimulus (CS^S). Confidence intervals around the regression lines provide an estimate of the uncertainty in the predictions. Only significant predictors are depicted for clarity.

participants were coded as aware of the experimental contingencies, this percentage was significantly higher in the gaming compared to the buying-shopping group. These findings suggest that the gaming group, including both individuals with non-problematic and risky gaming behavior, and the buying-shopping group, similarly including individuals with non-problematic and risky buying-shopping behavior, may differ in important characteristics that makes the gaming group more prone to acquire awareness of the experimental contingencies than the buying-shopping group.

Regarding the emotional evaluation of the stimuli and thus appetitive conditioning our findings indicated that in participants aware of the experimental contingencies, pleasantness and arousal ratings of the different conditioned stimuli changed through Pavlovian training dependent on whether participants were individuals with risky/non-problematic gaming or risky/non-problematic buying-shopping. Thus, individuals with risky/non-problematic gaming rated the CS^G as significantly more pleasant and arousing after Pavlovian training compared to before Pavlovian training, while individuals with risky/non-problematic buying-shopping rated the CS^S as more pleasant (though this increase slightly failed to achieve significance) and arousing. These findings suggest the acquisition of differential conditioned responses. Interestingly, significant increases in pleasantness and arousal ratings were also observed for the control stimuli. These findings are not without precedence. One plausible explanation is the temporal and spatial pairing due to the experimental procedure. Since the control stimuli were consistently presented alongside the CS^G and CS^S ,

participants likely formed associative links due to their frequent co-occurrence, leading to conditioning of the control stimuli through their close temporal proximity to the CSs and US. Additionally, generalization is a plausible factor in this context [57]. Given that all four stimuli were abstract geometrical figures, participants may have generalized their conditioned responses from the CS^G and CS^S to the control stimuli. However, the observed increase in pleasantness and arousal ratings for the control stimuli does not undermine the present study's findings since the primary focus was on comparing predictors of conditioned responses specific to gaming versus compulsive buying-shopping. However, future studies, particularly those examining a single disorder, should implement different control conditions to avoid such generalization effects and ensure clearer differentiation between conditioned and control stimuli.

Regarding the conditioned emotional responses, several individual characteristics were identified as significant predictors. Specifically, for gaming, higher attentional impulsivity, and symptom severity of problematic gaming emerged as significant predictors for both the conditioned pleasantness and arousal responses. Individuals with higher attentional impulsivity may have an increased sensitivity to immediate rewards [58,59], and heightened attentional impulsivity has been found in individuals with gaming disorder [54]. Gaming is often designed to provide rapid and frequent rewards, such as leveling up, earning points, or achieving in-game goals. The gaming experience may therefore be more appealing and emotionally engaging for impulsive individuals, leading to stronger conditioned emotional responses toward

gaming-associated stimuli. Although further research is needed to confirm these findings, our results suggest that these characteristics make individuals more vulnerable to developing problematic behavior by fostering the acquisition of gaming-associated conditioned responses.

Regarding buying-shopping, higher material values endorsement initially emerged as significant predictor for the conditioned pleasantness response. However, after applying the False Discovery Rate correction, this personality trait was not significant anymore. This discrepancy suggests that while material values endorsement might have potential predictive validity, its significance for the conditioned pleasantness response should be interpreted with caution. In contrast, for the conditioned arousal response, higher material values endorsement, compensation of stress, and symptom severity of problematic buying-shopping remained significant predictors even after the FDR correction. While previous studies demonstrated that materialistic value orientation traits and specific buying-shopping motives are associated with problematic buying-shopping (e.g. [16,22]), our findings expand previous knowledge by demonstrating that these variables are associated with the acquisition of stronger buying-shopping-related conditioned responses. In addition, the observation that the severity of problematic application use is associated with the acquisition of stronger conditioned responses suggests a vicious cycle. When individuals have frequent problematic application use, they may already be more sensitized to rewards associated with the application use. This heightened sensitivity could amplify their conditioned emotional responses because their reward system is more attuned to stimuli associated with application use (e.g., [1]). As outlined in the I-PACE model and also demonstrated in previous research [4,60], cue reactivity is an important mechanism contributing to the development of problematic behavior. Cue reactivity is based on the assumption that cues repeatedly associated with application use acquire incentive properties, leading to stronger conditioned responses and further problematic behavior. However, it is interesting to note that cue reactivity itself was not a significant predictor in our model. This could be due to our sample characteristics, as we included participants with risky, but not pathological, behavior. Although cue reactivity is expected to be heightened in this group compared to individuals with non-problematic use [4,60], experiences of compensation may play a more significant role in strengthening conditioned responses at this early stage of the addiction process [3], at least in the context of problematic buying-shopping behavior, where compensation of stress emerged as a significant predictor.

Together, our findings highlight that distinct individual characteristics might be linked to stronger conditioned buying-shopping-associated responses compared to gaming-associated responses. In this regard, our findings also indicate that while certain individual characteristics may predispose individuals to addictive behaviors in general, there also appear to be specific characteristics associated with the development of specific Internet-use disorders. These findings support the conceptual differentiation of specific Internet-use disorders from a general Internet-use disorder [61]. However, it is important to note that our findings may not be applicable to other forms of specific Internet-use disorders, which could share common individual risk factors [62].

Our findings also underscore the possibility that awareness of the experimental contingencies and the acquisition of conditioned emotional response represent two distinct processes given that different predictors were identified. Most intriguingly, the severity of problematic behavior was associated with the acquisition of conditioned emotional responses, but not the acquisition of awareness. On the other hand, our findings support the assumption that explicit contingency knowledge is an important prerequisite for the acquisition of conditioned responses (e.g., [63]). The question of the automaticity of evaluative conditioning continues to be a subject of ongoing debate (see [64] for a review). For example, research by Lovibond and Shanks [65] has shown that while some forms of learning can occur without conscious awareness, explicit knowledge often enhances the strength and persistence of learned

associations. In contrast, research by Olson and Fazio [66] demonstrated that individuals could develop attitudes toward stimuli through evaluative conditioning without conscious awareness of the contingencies involved. This may suggest that although many forms of human conditioned behavior may depend upon explicit knowledge of the predictive contingency between stimuli, responses, and the reinforcer, this may not always be a necessary condition for the emotional evaluation of stimuli. Therefore, while our findings support the importance of explicit contingency awareness for conditioned responses in the context of problematic Internet use, it is essential to consider that learning can occur through both conscious and unconscious mechanisms. Future research should continue to explore these different pathways to better understand the conditions under which each type of learning predominates, which may have significant treatment implications. In general, an enhanced ability to detect and acquire stimulus-outcome associations could hold evolutionary advantages and may not be inherently problematic. Yet, in our current environment, where we are frequently exposed to reward-predicting stimuli, such as through media, a heightened sensitivity to learning these associations might indeed be a vulnerability factor for susceptible individuals [67].

4.1. Limitations

In the present study, 64.31 % of participants were coded as aware of the experimental contingencies, based on significantly higher expectancy ratings of the gaming-related outcome in CS^G trials compared to CS^S trials in the final block of Pavlovian training. Although this definition relies on previous research (e.g., [6,35]) and allows comparison to previous findings, we cannot exclude that different findings would have been observed with a different definition. For example, presenting the CS^G and the CS^S and asking participants whether a gaming- or shopping-related picture had followed this stimulus is a categorical and maybe a more rigorous measure of awareness of the stimulus-outcome association than asking “What picture do you expect? (1 = shopping, 5 = I don’t know, 9 = gaming)” when the CS^G or CS^S are presented as compound with the control stimuli on a trial-by-trial basis. The definition of awareness in the present study bears the risk that a significant difference emerges although only contingency knowledge for one of the stimulus was acquired (for example by providing mean expectancy ratings of 9 in CS^G trials and of 5 in CS^S trials). However, inspection of our data indicated that this did not occur. In addition, dwell time data also indicated that unaware participants showed a failure to learn. While future studies are warranted to assess systematically the pros and cons of different definitions of contingency knowledge, the use of the definition in the present study provides also important information. Thus, the percentage of 64.31 % of aware participants observed which is only a small increase compared to Vogel et al. [6] who found that 62 % were aware of the experimental contingencies. Given that in the present study the number of training blocks was doubled compared to Vogel et al. [6] this finding suggests that the number of training blocks is only of marginal relevance regarding the acquisition of awareness of experimental contingencies. While this stresses the role of individual characteristics, for example, cognitive flexibility, given the observed amount of variance explained by these variables in the present study, there might be also some further variables that may affect the learning process. Additionally, a similar argument applies to the regression model used for predicting the magnitude of the conditioned response. Although our models are statistically significant and explain 19.9 % of the variance in pleasantness and 22.8 % of the variance in arousal, a substantial portion of the variance remains unexplained. Thus, further aspects and individual characteristics should be investigated systematically in future research.

One such aspect that should be addressed in future research is gender. Thus, in the present study participants with risky use of gaming or buying-shopping applications differed significantly regarding gender with a significantly higher proportion of females in the group with risky buying-shopping. Although this reflects prevalence rates in the general

population and enhances generalizability of our findings, we cannot clearly disentangle possible effects of gender and type of behavioral addiction even though we recruited gender-matched control groups and entered these variables as covariates/control variables in all analyses. Thus, future studies are warranted to investigate systematically gender-specific differences regarding behavioral addictions.

However, one aspect that potentially limits the generalizability of our findings is the preselection criterion. As per our preregistered protocol, subjects who simultaneously fulfilled the risk criteria for both gaming disorder and buying-shopping disorder were excluded from the study. This exclusion criterion was implemented to isolate the effects of each behavior independently. However, by excluding individuals with comorbid risky gaming and buying-shopping behaviors, our results may not fully capture the broader spectrum of these disorders as they manifest in the general population. Future research should consider including participants with comorbid conditions to provide a more comprehensive understanding of how these disorders interact and impact one another.

While overall there was a lot of convergence between pleasantness and arousal in our results, there were also dissimilarities, such as for materialistic values endorsement and compensation of stress. This dissimilarity could reflect statistical issues. For example, materialistic values endorsement was initially significant as predictor for the conditioned pleasantness response, but this significance did not hold after applying the FDR correction. This could suggest that the effect is real but smaller in magnitude, and thus more susceptible to being deemed non-significant when controlling for multiple comparisons. However, from a theoretical point of view it is possible that the conditioning process itself differs for arousal and pleasantness. Arousal could be more susceptible to associative learning because it is a more fundamental physiological response, whereas pleasantness may require more complex cognitive associations that involve individual preferences and subjective interpretations. Therefore, it is important for future research to disentangle the effects of predictors on conditioning of both dimensions further.

Moreover, it is important for future research to assess the individual relevance of the gaming-related and shopping-related stimuli used as outcomes in the Pavlovian training and their appetitive nature. While the stimuli used in the present study were selected based on the highest ratings regarding craving, pleasantness and arousal as indicated in a pilot study, the ratings were rather in the neutral than appetitive range. Although we observed significant increases in pleasantness and arousal ratings of the abstract stimuli after Pavlovian training, these ratings were also rather in a neutral than appetitive range. We cannot exclude that different findings would have been observed with stimuli with a higher individual relevance (for example depicting a desired scenario instead of a mere application) which might induce higher craving and be rated as more appetitive. However, other studies with participants with risky use also reported craving ratings in response to addiction-related stimuli in a rather medium range (e.g. [4]). In 1999, Verheul and colleagues [68] suggested that there are different pathways leading to craving and that reward craving (i.e. craving for the rewarding effects of alcohol) should be differentiated from relief craving (i.e. craving for the reduction of negative feelings). As outlined in the I-PACE model [3], there may also be a shift from the experience of gratification to the experience of compensation in the development of addictive behavior. It is thus possible that addiction-related cues have appetitive properties for some individuals and aversive properties for others and it is important to consider these individual differences.

In addition, while we assessed awareness of the experimental contingencies and the magnitude of the conditioned response as two distinct mechanisms, regarding the magnitude of the conditioned response we relied on subjective ratings and eyetracking and did not assess, for example, physiological responses or functional magnetic resonance imaging (fMRI). Previous research has observed a dissociation of subjective ratings and physiological responses (e.g., [10,69]), and

Schweckendiek et al. [11] observed that neuroticism or extraversion were correlated with BOLD-responses and effective connectivity, though not subjective ratings. This suggests that incorporating psychophysiological measures like skin conductance responses or fMRI in future studies may potentially enhance the explained variance in analyses, thus refining the predictive accuracy of our model based on the variables already entered. This is especially important, as in the present study, although eyetracking data indicated the development of an attentional bias for both the CS^G and the CS^S, no reliable group or behavior specific differentiations were observed suggesting that other physiological measures may be more suitable. Finally, due to the nature of our learning paradigm, expectancy ratings and conditioned responses were compared between cues related to two specific online behaviors, namely gaming and buying-shopping. This allowed us to analyze behavior-specific characteristics in the acquisition of awareness and conditioned responses. It would be interesting for future research to replicate these findings using different conditioning procedures and stimuli.

5. Conclusion

Taken together, our results provide additional support for the I-PACE model by Brand et al. [3], as we were able to demonstrate associations between various vulnerability factors and cognitive as well as affective mechanisms, such as Pavlovian learning and appetitive conditioned responses. By showing that factors such as materialistic values endorsement, experiences of compensation or severity of problematic application use are linked to Pavlovian conditioning of emotional responses towards behavior-relevant stimuli, we not only support the theoretical framework but also shed light on potential pathways through which these factors may contribute to the development or maintenance of addictive behaviors. This insight is crucial for informing targeted interventions and prevention strategies aimed at addressing problematic behaviors associated with these vulnerability factors. After individuals with risky gaming or risky buying-shopping behavior have been identified via screening instruments, effective prevention and treatment strategies [70] should be augmented by tailored interventions based on the specific problematic behavior. For those with risky buying-shopping behavior, interventions should focus on exploring alternative values, drawing from approaches such as Acceptance and Commitment Therapy [71]. Additionally, those individuals could benefit from interventions aimed at enhancing coping strategies for stress (e.g., [72]). Conversely, interventions for individuals with risky gaming behavior should aim to develop strategies that help those individuals to retrain their attention, e.g. via cognitive bias modification [73,74] or via mindfulness training [75,76]. By implementing targeted interventions based on the nature of the risky behavior, individuals can effectively address underlying issues and work towards healthier behavioral patterns. Thus, our findings underscore the importance of considering both individual characteristics and underlying psychological mechanisms in understanding and addressing behavioral addictions. Future studies could implement for example longitudinal designs and utilize more sophisticated statistical methods, such as structural equation modeling, to better account for the complexity of interactions among predisposing variables, cognitive and affective mechanisms, as well as experiences of gratification and compensation (e.g., [24]). This, in turn, would further enhance our understanding of the addictive process.

Formatting of funding sources

The work of AS, TT, AM, MB, SS-L on this article was carried out in the context of the Research Unit ACSID, FOR2974, funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 411232260.

CRedit authorship contribution statement

Matthias Brand: Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Sabine Steins-Loeber:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Astrid Müller:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Frank Lörtsch:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Conceptualization. **Tobias A. Thomas:** Writing – review & editing, Investigation, Data curation. **Anna M. Schmid:** Writing – review & editing, Software, Investigation, Data curation.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used OpenAI's ChatGPT (August 2024 version) for language review. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data and analysis code will be made available on an open repository as part of the research group's (FOR 2974) centralized efforts in the near future.

Acknowledgements

The placeholder pictures of gaming and buying-shopping in Fig. 1 were purchased from Colourbox©.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.bbr.2024.115254.

References

- [1] K.C. Berridge, T.E. Robinson, Liking, wanting, and the incentive-sensitization theory of addiction, *Am. Psychol.* 71 (8) (2016) 670–679, <https://doi.org/10.1037/amp0000059>.
- [2] C. Lüscher, T.W. Robbins, B.J. Everitt, The transition to compulsion in addiction, *Nat. Rev. Neurosci.* 21 (5) (2020) 247–263, <https://doi.org/10.1038/s41583-020-0289-z>.
- [3] M. Brand, E. Wegmann, R. Stark, A. Müller, K. Wölfling, T.W. Robbins, M. Potenza, The Interaction of Person-Affect-Cognition-Execution (I-PACE) model for addictive behaviors: Update, generalization to addictive behaviors beyond internet-use disorders, and specification of the process character of addictive behaviors, *Neurosci. Biobehav. Rev.* 104 (2019) 1–10, <https://doi.org/10.1016/j.neubiorev.2019.06.032>.
- [4] M. Diers, S.M. Müller, L. Mallon, A.M. Schmid, T.A. Thomas, L. Klein, K. Krikova, R. Stark, E. Wegmann, S. Steins-Loeber, M. Brand, S. Antons, Cue-reactivity to distal cues in individuals at risk for gaming disorder, *Compr. Psychiatry* 125 (2023) 152399, <https://doi.org/10.1016/j.comppsy.2023.152399>.
- [5] T.A. Thomas, M. Joshi, P. Trotzke, S. Steins-Loeber, A. Müller, Cognitive Functions in Compulsive Buying-Shopping Disorder: A Systematic Review, *Curr. Behav. Neurosci. Rep.* 10 (1) (2023) 1–19, <https://doi.org/10.1007/s40473-023-00255-6>.
- [6] V. Vogel, I. Kollei, T. Duka, J. Snagowski, M. Brand, A. Müller, S. Loeber, Pavlovian-to-instrumental transfer: a new paradigm to assess pathological mechanisms with regard to the use of Internet applications, *Behav. Brain Res.* 347 (2018) 8–16, <https://doi.org/10.1016/j.bbr.2018.03.009>.
- [7] S. Loeber, T. Duka, Acute alcohol impairs conditioning of a behavioural reward-seeking response and inhibitory control processes-implications for addictive disorders: the acute effects of alcohol on inhibition, *Addiction* 104 (12) (2009) 2013–2022, <https://doi.org/10.1111/j.1360-0443.2009.02718.x>.
- [8] C. Ebrahimi, M. Garbusow, M. Sebold, K. Chen, M.N. Smolka, Q.J.M. Huys, U. S. Zimmermann, F. Schlagenhaut, A. Heinz, Elevated Amygdala responses during De Novo Pavlovian conditioning in alcohol use disorder are associated with pavlovian-to-instrumental transfer and relapse latency, *Biol. Psychiatry Glob. Open Sci.* 3 (4) (2023) 803–813, <https://doi.org/10.1016/j.bpsgos.2023.02.003>.
- [9] K.A. Fleming, R.U. Cofresí, B.D. Bartholow, Transfer of incentive salience from a first-order alcohol cue to a novel second-order alcohol cue among individuals at risk for alcohol use disorder: electrophysiological evidence, *Addiction* 116 (7) (2021) 1734–1746, <https://doi.org/10.1111/add.15380>.
- [10] T. Klucken, S. Wehrum-Osinsky, J. Schweckendiek, O. Kruse, R. Stark, Altered appetitive conditioning and neural connectivity in subjects with compulsive sexual behavior, *J. Sex. Med.* 13 (4) (2016) 627–636, <https://doi.org/10.1016/j.jsxm.2016.01.013>.
- [11] J. Schweckendiek, R. Stark, T. Klucken, Neuroticism and extraversion moderate neural responses and effective connectivity during appetitive conditioning, *Hum. Brain Mapp.* 37 (8) (2016) 2992–3002, <https://doi.org/10.1002/hbm.23221>.
- [12] A.M. Gervasi, L. La Marca, A. Costanzo, U. Pace, F. Guglielmucci, A. Schimmenti, Personality and internet gaming disorder: a systematic review of recent literature, *Curr. Addict. Rep.* 4 (3) (2017) 293–307, <https://doi.org/10.1007/s40429-017-0159-6>.
- [13] P. Koncz, Z. Demetrovics, Z.K. Takacs, M.D. Griffiths, T. Nagy, O. Király, The emerging evidence on the association between symptoms of ADHD and gaming disorder: a systematic review and meta-analysis, *Clin. Psychol. Rev.* 106 (2023) 102343, <https://doi.org/10.1016/j.cpr.2023.102343>.
- [14] L. Claes, A. Müller, K. Luyckx, Compulsive buying and hoarding as identity substitutes: the role of materialistic value endorsement and depression, *Compr. Psychiatry* 68 (2016) 65–71, <https://doi.org/10.1016/j.comppsy.2016.04.005>.
- [15] A. Müller, L. Claes, E. Georgiadou, M. Möllenkamp, E.M. Voth, R.J. Faber, J. E. Mitchell, M. De Zwaan, Is compulsive buying related to materialism, depression or temperament? Findings from a sample of treatment-seeking patients with CB, *Psychiatry Res.* 216 (1) (2014) 103–107, <https://doi.org/10.1016/j.psychres.2014.01.012>.
- [16] A. Müller, E. Georgiadou, A. Birlin, N.M. Laskowski, S. Jiménez-Murcia, F. Fernández-Aranda, T. Hillemecher, M. De Zwaan, M. Brand, S. Steins-Loeber, The relationship of shopping-related decisions with materialistic values endorsement, compulsive buying-shopping disorder symptoms and everyday moral decision making, *Int. J. Environ. Res. Public Health* 19 (7) (2022) 4376, <https://doi.org/10.3390/ijerph19074376>.
- [17] T.A. Thomas, A.M. Schmid, A. Kessler, O.T. Wolf, M. Brand, S. Steins-Loeber, A. Müller, Stress and compulsive buying-shopping disorder: a scoping review, *Compr. Psychiatry* 132 (2024) 152482, <https://doi.org/10.1016/j.comppsy.2024.152482>.
- [18] C. Bäcklund, P. Elbe, H.M. Gavelin, D.E. Sörman, J.K. Ljungberg, Gaming motivations and gaming disorder symptoms: a systematic review and meta-analysis, *J. Behav. Addict.* 11 (3) (2022) 667–688, <https://doi.org/10.1556/2006.2022.00053>.
- [19] A. Giardina, A. Schimmenti, V. Starcevic, D.L. King, M. Di Blasi, J. Billieux, Problematic gaming, social withdrawal, and Escapism: the compensatory-dissociative online gaming (C-DOG) model, *Comput. Hum. Behav.* 155 (2024) 108187, <https://doi.org/10.1016/j.chb.2024.108187>.
- [20] K. Kircaburun, Z. Demetrovics, M.D. Griffiths, O. Király, B. Kun, B. Tosuntaş, Trait emotional intelligence and internet gaming disorder among gamers: the mediating role of online gaming motives and moderating role of age groups, *Int. J. Ment. Health Addict.* 18 (5) (2020) 1446–1457, <https://doi.org/10.1007/s11469-019-00179-x>.
- [21] A. Müller, L. Claes, A. Birlin, E. Georgiadou, N.M. Laskowski, S. Steins-Loeber, M. Brand, M. De Zwaan, Associations of buying-shopping disorder symptoms with identity confusion, materialism, and socially undesirable personality features in a community sample, *Eur. Addict. Res.* 27 (2) (2021) 142–150, <https://doi.org/10.1159/000511078>.
- [22] M.M. Norberg, J. David, C. Crone, V. Kakar, C. Kwok, J. Olivier, J.R. Grisham, Determinants of object choice and object attachment: compensatory consumption in compulsive buying-shopping disorder and hoarding disorder, *J. Behav. Addict.* 9 (1) (2020) 153–162, <https://doi.org/10.1556/2006.8.2019.68>.
- [23] S.T. T'ng, K.H. Ho, K. Pau, Need frustration, gaming motives, and internet gaming disorder in mobile multiplayer online battle arena (MOBA) games: through the lens of self-determination theory, *Int. J. Ment. Health Addict.* 21 (6) (2023) 3821–3841, <https://doi.org/10.1007/s11469-022-00825-x>.
- [24] X. Xu, L. Gao, S. Lian, Q. Chen, Z. Zhou, How the Dark Triad associated with internet gaming disorder? The serial mediation of basic psychological needs satisfaction and negative coping styles, *Curr. Psychol.* 42 (34) (2023) 30138–30146, <https://doi.org/10.1007/s12144-022-03996-x>.
- [25] I. Tapia León, O. Kruse, R. Stark, T. Klucken, Relationship of sensation seeking with the neural correlates of appetitive conditioning, *Soc. Cogn. Affect. Neurosci.* 14 (7) (2019) 769–775, <https://doi.org/10.1093/scan/nsz046>.
- [26] M. Brand, Can internet use become addictive? *Science* 376 (6595) (2022) 798–799, <https://doi.org/10.1126/science.abn4189>.
- [27] WHO. (2024). ICD-11 for mortality and morbidity statistics (Version: 01/2024). <https://icd.who.int/en/>.
- [28] M.W. Stevens, D. Dorstyn, P.H. Delfabbro, D.L. King, Global prevalence of gaming disorder: a systematic review and meta-analysis, *Aust. N. Z. J. Psychiatry* 55 (6) (2021) 553–568, <https://doi.org/10.1177/0004867420962851>.
- [29] M. Brand, H.-J.ü Rumpf, Z. Demetrovics, A. Müller, R. Stark, D.L. King, A. E. Goudriaan, K. Mann, P. Trotzke, N.A. Fineberg, S.R. Chamberlain, S.W. Kraus,

- E. Wegmann, J. Billieux, M.N. Potenza, Which conditions should be considered as disorders in the International Classification of Diseases (ICD-11) designation of "other specified disorders due to addictive behaviors"? *J. Behav. Addict.* (2020) <https://doi.org/10.1556/2006.2020.00035>.
- [30] A. Maraz, M.D. Griffiths, Z. Demetrovics, The prevalence of compulsive buying: a meta-analysis, *Addiction* 111 (3) (2016) 408–419, <https://doi.org/10.1111/add.13223>.
- [31] M. Brand, A. Müller, R. Stark, S. Steins-Loeber, T. Klucken, C. Montag, M. Diers, O. T. Wolf, H.-J. Rumpf, K. Wölfling, E. Wegmann, Addiction Research Unit: Affective and cognitive mechanisms of specific Internet-use disorders, *Addict. Biol.* 13087 (2021), <https://doi.org/10.1111/adb.13087>.
- [32] R. Englert, M. Schedlowski, H. Engler, W. Rief, C. Büchel, U. Bingel, T. Spisak, ALLIAS: Anonymization/pseudonymization with LimeSurvey integration and II-factor authentication for scientific research, *SoftwareX* 24 (2023) 101522, <https://doi.org/10.1016/j.softx.2023.101522>.
- [33] Müller, K.W., & Wölfling, K. (2018). AICA-SKI:IBS. Strukturiertes klinisches Interview zu Internetbezogenen Störungen [AICA-SKI:IBS. Structured clinical interview for internet-use disorders]. https://www.fv-medienabhaengigkeit.de/fileadmin/images/Dateien/AICA-SKI_IBS/Handbuch_AICA-SKI_IBS.pdf.
- [34] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*, American Psychiatric Association, 2013.
- [35] L. Hogarth, A. Dickinson, S.B. Hutton, N. Elbers, T. Duka, Drug expectancy is necessary for stimulus control of human attention, instrumental drug-seeking behaviour and subjective pleasure, *Psychopharmacology* 185 (4) (2006) 495–504, <https://doi.org/10.1007/s00213-005-0287-x>.
- [36] S.M. Müller, E. Wegmann, A. Oelker, R. Stark, A. Müller, C. Montag, K. Wölfling, H.-J. Rumpf, M. Brand, Assessment of Criteria for Specific Internet-use Disorders (ACSID-11): introduction of a new screening instrument capturing ICD-11 criteria for gaming disorder and other potential Internet-use disorders, *J. Behav. Addict.* (2022), <https://doi.org/10.1556/2006.2022.00013>.
- [37] C.J. Soto, O.P. John, The next Big Five Inventory (BFI-2): Developing and assessing a hierarchical model with 15 facets to enhance bandwidth, fidelity, and predictive power, *J. Personal. Soc. Psychol.* 113 (1) (2017) 117–143, <https://doi.org/10.1037/pspp0000096>.
- [38] D. Danner, B. Rammstedt, M. Bluemke, C. Lechner, S. Berres, T. Knopf, C.J. Soto, O. P. John, Das Big Five Inventar 2: Validierung eines Persönlichkeitsinventars zur Erfassung von 5 Persönlichkeitsdomänen und 15 Facetten, *Diagnostica* 65 (3) (2019) 121–132, <https://doi.org/10.1026/0012-1924/a000218>.
- [39] A. Meule, C. Vögele, A. Kübler, Psychometrische Evaluation der deutschen Barratt Impulsiveness Scale – Kurzversion (BIS-15), *Diagnostica* 57 (3) (2011) 126–133, <https://doi.org/10.1026/0012-1924/a000042>.
- [40] M. Spinella, Normative data and a short form of the Barratt Impulsiveness Scale, *Int. J. Neurosci.* 117 (3) (2007) 359–368, <https://doi.org/10.1080/00207450600588881>.
- [41] E. Wegmann, S. Antons, M. Brand, The experience of gratification and compensation in addictive behaviors: how can these experiences be measured systematically within and across disorders due to addictive behaviors? *Compr. Psychiatry* 117 (2022) 152336 <https://doi.org/10.1016/j.comppsy.2022.152336>.
- [42] Horn, W. (1983). *Leistungsprüfungssystem L-P-S. Hogrefe*.
- [43] H.E. Nelson, A modified card sorting test sensitive to frontal lobe defects, *Cortex* 12 (4) (1976) 313–324, [https://doi.org/10.1016/S0010-9452\(76\)80035-4](https://doi.org/10.1016/S0010-9452(76)80035-4).
- [44] A. Müller, D.J.M. Smits, L. Claes, O. Gefeller, A. Hinz, M. De Zwaan, The German version of the material values scale [Text/html], *ISSN 1860-5214*, GMS Psycho-Soc.-Med. 10 (2013) *Doc05*, <https://doi.org/10.3205/PSM000095>.
- [45] M.L. Richins, The material values scale: measurement properties and development of a short form, *J. Consum. Res.* 31 (1) (2004) 209–219, <https://doi.org/10.1086/383436>.
- [46] P.K. Jonason, G.D. Webster, The dirty dozen: A concise measure of the dark triad, *Psychol. Assess.* 22 (2) (2010) 420–432, <https://doi.org/10.1037/a0019265>.
- [47] A.C.P. Küfner, M. Dufner, M.D. Back, Das Dreieckige Dutzend und die *Niederrichtigen* Neun: Kurzskaleten zur Erfassung von Narzissmus, Machiavellismus und Psychopathie, *Diagnostica* 61 (2) (2015) 76–91, <https://doi.org/10.1026/0012-1924/a000124>.
- [48] K. Petrowski, S. Paul, C. Albani, E. Brähler, Factor structure and psychometric properties of the trier inventory for chronic stress (TICS) in a representative german sample, *BMC Med. Res. Methodol.* 12 (1) (2012) 42, <https://doi.org/10.1186/1471-2288-12-42>.
- [49] P. Schulz, W. Schlotz, P. Becker, *Trierer Inventar zum chronischen Stress, Hogrefe, 2004*.
- [50] F. Faul, E. Erdfelder, A.-G. Lang, A. Buchner, G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences, *Behav. Res. Methods* 39 (2) (2007) 175–191, <https://doi.org/10.3758/BF03193146>.
- [51] K. Starcke, S. Antons, P. Trotzke, M. Brand, Cue-reactivity in behavioral addictions: a meta-analysis and methodological considerations, *J. Behav. Addict.* 7 (2) (2018) 227–238, <https://doi.org/10.1556/2006.7.2018.39>.
- [52] F. Faul, E. Erdfelder, A. Buchner, A.-G. Lang, Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses, *Behav. Res. Methods* 41 (4) (2009) 1149–1160, <https://doi.org/10.3758/BRM.41.4.1149>.
- [53] Y. Benjamini, Y. Hochberg, Controlling the false discovery rate: a practical and powerful approach to multiple testing, *J. R. Stat. Soc. Ser. B: Stat. Methodol.* 57 (1) (1995) 289–300, <https://doi.org/10.1111/j.2517-6161.1995.tb02031.x>.
- [54] S.M. Müller, S. Antons, M. Brand, Facets of impulsivity in gaming disorder: a narrative review, *Curr. Addict. Rep.* 10 (4) (2023) 737–748, <https://doi.org/10.1007/s40429-023-00522-2>.
- [55] S.M. Müller, S. Antons, E. Wegmann, K. Ioannidis, D.L. King, M.N. Potenza, S. R. Chamberlain, M. Brand, A systematic review and meta-analysis of risky decision-making in specific domains of problematic use of the internet: evidence across different decision-making tasks, *Neurosci. Biobehav. Rev.* 152 (2023) 105271, <https://doi.org/10.1016/j.neubiorev.2023.105271>.
- [56] Y. Yao, J. Zhang, X. Fang, L. Liu, M.N. Potenza, Reward-related decision-making deficits in internet gaming disorder: A systematic review and meta-analysis, *Addiction* 117 (1) (2022) 19–32, <https://doi.org/10.1111/add.15518>.
- [57] D. Hermans, F. Baeyens, B. Vervliet, Generalization of acquired emotional responses (S.), in: M.D. Robinson, E.R. Watkins, E. Harmon-Jones (Eds.), *Handbook of Cognition and Emotion*, The Guilford Press, 2013, pp. 117–134 (S.).
- [58] J.W. Buckholtz, M.T. Treadway, R.L. Cowan, N.D. Woodward, R. Li, M.S. Ansari, R. M. Baldwin, A.N. Schwartzman, E.S. Shelby, C.E. Smith, R.M. Kessler, D.H. Zald, Dopaminergic network differences in human impulsivity, 532–532, *Science* 329 (5991) (2010), <https://doi.org/10.1126/science.1185778>.
- [59] A. Weinstein, M. Lejoyeux, Neurobiological mechanisms underlying internet gaming disorder, *Dialog.- Clin. Neurosci.* 22 (2) (2020) 113–126, <https://doi.org/10.31887/DCNS.2020.22.2/aweinstein>.
- [60] P. Trotzke, K. Starcke, A. Pedersen, M. Brand, Dorsal and ventral striatum activity in individuals with buying-shopping disorder during cue-exposure: a functional magnetic resonance imaging study, *Addict. Biol.* 26 (6) (2021) e13073, <https://doi.org/10.1111/adb.13073>.
- [61] M. Brand, C. Laier, K.S. Young, Internet addiction: coping styles, expectancies, and treatment implications, *Front. Psychol.* 5 (2014), <https://doi.org/10.3389/fpsyg.2014.01256>.
- [62] C. Sindermann, R. Sariyska, B. Lachmann, M. Brand, C. Montag, Associations between the dark triad of personality and unspecified/specific forms of Internet-use disorder, *J. Behav. Addict.* 7 (4) (2018) 985–992, <https://doi.org/10.1556/2006.7.2018.114>.
- [63] L. Hogarth, A. Dickinson, S.B. Hutton, H. Bamborough, T. Duka, Contingency knowledge is necessary for learned motivated behaviour in humans: relevance for addictive behaviour, *Addiction* 101 (8) (2006) 1153–1166, <https://doi.org/10.1111/j.1360-0443.2006.01459.x>.
- [64] T. Moran, Y. Nudler, Y. Bar-Anan, Evaluative conditioning: past, present, and future, *Annu. Rev. Psychol.* 74 (2023) 245–269.
- [65] P.F. Lovibond, D.R. Shanks, The role of awareness in Pavlovian conditioning: empirical evidence and theoretical implications, *J. Exp. Psychol.: Anim. Behav. Process.* 28 (1) (2002) 3–26, <https://doi.org/10.1037/0097-7403.28.1.3>.
- [66] M.A. Olson, R.H. Fazio, Implicit attitude formation through classical conditioning, *Psychol. Sci.* 12 (5) (2001) 413–417, <https://doi.org/10.1111/1467-9280.00376>.
- [67] M.E. Bouton, Learning and the persistence of appetite: extinction and the motivation to eat and overeat, *Physiol. Behav.* 103 (1) (2011) 51–58, <https://doi.org/10.1016/j.physbeh.2010.11.025>.
- [68] R. Verheul, W. Van Den Brink, P. Geerlings, A three-pathway psychobiological model of craving for alcohol, *Alcohol. Alcohol.* 34 (2) (1999) 197–222, <https://doi.org/10.1093/alcalc/34.2.197>.
- [69] T. Klucken, J. Schweckendiek, C.J. Merz, K. Tabbert, B. Walter, S. Kagerer, D. Vaitl, R. Stark, Neural activations of the acquisition of conditioned sexual arousal: effects of contingency awareness and sex, *J. Sex. Med.* 6 (11) (2009) 3071–3085, <https://doi.org/10.1111/j.1743-6109.2009.01405.x>.
- [70] A. Müller, N.M. Laskowski, T.A. Thomas, S. Antons, N. Tahmassebi, S. Steins-Loeber, M. Brand, E. Georgiadou, Update on treatment studies for compulsive buying-shopping disorder: a systematic review, *J. Behav. Addict.* 12 (3) (2023) 631–651, <https://doi.org/10.1556/2006.2023.00033>.
- [71] S.C. Hayes, J. Lillis, Acceptance and commitment therapy, *American Psychological Association*, 2012, <https://doi.org/10.1037/17335-000>.
- [72] D. Meichenbaum, Stress inoculation training. In D. Meichenbaum. *The Evolution of Cognitive Behavior Therapy*, 1st ed., Routledge, 2017, pp. 101–124, <https://doi.org/10.4324/9781315748931-10>.
- [73] J.N. Vrijzen, B. Grafton, E.H.W. Koster, J. Lau, C.E. Wittekind, Y. Bar-Haim, E. S. Becker, M.A. Brotman, J. Joormann, A. Lazarov, C. MacLeod, V. Manning, J. W. Pettit, M. Rinck, E. Salemink, M.L. Woud, L.S. Hallion, R.W. Wiers, Towards implementation of cognitive bias modification in mental health care: state of the science, best practices, and ways forward, *Behav. Res. Ther.* 179 (2024) 104557, <https://doi.org/10.1016/j.brat.2024.104557>.
- [74] R.W. Wiers, T. Pan, P. Van Dessel, M. Rinck, J. Lindenmeyer, Approach-bias retraining and other training interventions as add-on in the treatment of AUD patients. *Current Topics in Behavioral Neurosciences*, Springer Berlin Heidelberg, 2023, <https://doi.org/10.1007/978-3-662-02321-2>.
- [75] A. Brandtner, S. Antons, D.L. King, M.N. Potenza, Y.-Y. Tang, G.R. Blycker, M. Brand, M. Liebherr, A preregistered, systematic review considering mindfulness-based interventions and neurofeedback for targeting affective and cognitive processes in behavioral addictions, *Clin. Psychol.: Sci. Pract.* 29 (4) (2022) 379–392, <https://doi.org/10.1037/cps0000075>.
- [76] M. Liebherr, A. Brandtner, M. Brand, Y. Tang, Digital mindfulness training and cognitive functions: a preregistered systematic review of neuropsychological findings, *Ann. N. Y. Acad. Sci.* 1532 (1) (2024), <https://doi.org/10.1111/nyas.15095>.