Thomas, Tobias A.; Schmid, Anna M.; Erdal, Nicolas K.; u. a.

Risky online buying-shopping behavior : The role of stress responsivity on the transfer from goal-directed behavior to stimulus-response habits

Date of secondary publication: 26.01.2026

Version of Record (Published Version), Article

Persistent identifier: urn:nbn:de:bvb:473-irb-112730x

Primary publication

Thomas, Tobias A.; Schmid, Anna M.; Erdal, Nicolas K.; u. a. (2025): Risky online buying-shopping behavior : The role of stress responsivity on the transfer from goal-directed behavior to stimulus-response habits, in: Journal of behavioral addictions, Budapest: Akadémiai Kiadó, Vol. 14, Nr. 3, pp. 1326–1342, doi: 10.1556/2006.2025.00062.

1828
AKADÉMIAI KIADÓ

Journal of Behavioral Addictions

14 (2025) 3, 1326–1342

DOI:
10.1556/2006.2025.00062

Risky online buying-shopping behavior: The role of stress responsivity on the transfer from goal-directed behavior to stimulus-response habits

TOBIAS A. THOMAS[1*], ANNA M. SCHMID[2], NICOLAS K. ERDAL[1], STEFAN BLÜMEL[2], SILKE M. MÜLLER[3,4,5], CHRISTIAN J. MERZ[6], OLIVER T. WOLF[6], MATTHIAS BRAND[3,4,5], SABINE STEINS-LOEBER[2] and ASTRID MÜLLER[1]

[1] Department of Psychosomatic Medicine and Psychotherapy, Hannover Medical School, Hanover, Germany

[2] Department of Clinical Psychology and Psychotherapy, Otto-Friedrich-University of Bamberg, Bamberg, Germany

[3] General Psychology: Cognition, Faculty of Computer Science, University of Duisburg-Essen, Germany

[4] Center for Behavioral Addiction Research (CeBAR), Center for Translational Neuro- and Behavioral Sciences, University Hospital Essen, University of Duisburg-Essen, Germany

[5] Erwin L. Hahn Institute for Magnetic Resonance Imaging, Essen, Germany

[6] Department of Cognitive Psychology, Institute of Cognitive Neuroscience, Ruhr University Bochum, Bochum, Germany

Received: October 8, 2024 • Revised manuscript received: February 18, 2025; May 7, 2025 • Accepted: July 19, 2025
Published online: September 3, 2025

FULL-LENGTH REPORT

ABSTRACT

Background and aim: There is a lack of research on the stress-related transfer from goal-directed behavior to stimulus-response habits in (early stages of) online buying-shopping disorder (BSD). This study investigated the Pavlovian-to-instrumental transfer (PIT) effect after reward devaluation (PIT-dev) as indicator of habitual behavior and its modulation by acute stress in individuals with risky (online) buying-shopping (r-BSh). *Methods:* Individuals with r-BSh ($n = 67$) and a control group ($n = 67$) underwent a PIT paradigm with devaluation procedure. A stress induction/control procedure was administered after the first part of the paradigm. Four salivary samples (alpha-amylase, sAA; cortisol, sCort) and subjective stress ratings were collected before/after stress induction. *Results:* Individuals with r-BSh showed higher sAA levels (after stress induction), but comparable sCort and subjective stress levels to the control group. The devaluation reduced, albeit not abolished, shopping-specific instrumental behaviors in both groups, particularly in neutral trials. There were no interaction effects of stress condition, group and devaluation on shopping-specific response choice in the preregistered analysis. sCort response significantly predicted PIT-dev as indicator for habitual behavior. Exploratory analyses showed that interactions of BSD symptom severity with subjective and sCort stress response predicted PIT-dev. *Discussion and conclusions:* The findings are mixed. They show some evidence for a stress-related shift to habitual shopping-specific behaviors in persons with higher symptom severity yet they do not match findings of other planned analyses. Further research is needed to clarify the role of stress in PIT effects and potentially habitual behaviors, which may have implications for prevention/early intervention.

*Corresponding author.
E-mail: Thomas.Tobias@mh-hannover.de

KEYWORDS

compulsive buying-shopping disorder, Pavlovian-to-instrumental transfer, habits, goal-directed behavior, stress, behavioral addictions

AKJournals

INTRODUCTION

The transfer from goal-directed to habitual behaviors respectively the dominance of habitual behaviors has been repeatedly linked to different forms of addictive, compulsive and impulsive behaviors (Brand, 2022; Gillan, Kosinski, Whelan, Phelps, & Daw, 2016; Voon et al., 2015). Habit formation is assumed to play an important role in the development and maintenance of addictive disorders (Everitt & Robbins, 2016), which can be measured using Pavlovian-to-instrumental transfer (PIT) paradigms with an outcome-devaluation phase (Garbusow et al., 2022). Models on substance use disorders postulate that in individuals with substance use disorders, habitual behaviors increase at the expense of goal-directed behaviors, which is generally supported in individuals with severe alcohol use disorder (Doñamayor et al., 2022; Heinz et al., 2019). It is yet to clarify if this phenomenon might be explained by deficits in the goal-directed system or a predominance of the habitual system or an interaction of both.

Studies carried out in behavioral addictions found that individuals with internet gaming disorder tend to rely on habitual systems in an instrumental learning task (Zhou et al., 2021) and individuals with gambling disorder showed reduced model-based responding (i.e., goal-directed control) in a two-step decision task (Wyckmans et al., 2019). The concept of habitual behaviors in the field of addictions is a controverse one as some authors argue that addiction would be rather due to goal-directed drug consumption and that evidence for habitual behavior would be less convincing (e.g., Hogarth, 2020).

Besides habitual behaviors, conditioning processes are assumed to play an important role in the development of addictions. Two experimental studies in behavioral addictions investigated the influence of conditioning processes on the development and maintenance of behavioral addictions by administering a PIT paradigm. This experimental approach provides information on the effect of reward-related stimuli that underwent previous Pavlovian conditioning on instrumental responding related to the same reward (i.e. specific PIT-effect). Qin et al. (2023) considered specific PIT effects in internet gaming disorder and found PIT effects to be related to symptom severity. Vogel et al. (2018) conducted the only study that, besides gaming behavior, also examined buying-shopping behavior in the context of a PIT paradigm. Only gaming, but not shopping symptom severity, and strength expectancy ratings (i.e., a measure of awareness of the experimental contingencies in the Pavlovian phase) predicted the respective PIT effect. The authors discussed this as a possible effect of the low level of shopping symptom severity observed in the convenience sample. The Pavlovian phase of this PIT paradigm involved pairing the formerly neutral stimuli with shopping-/gaming images instead of pairing them with rewarding outcomes. This procedure does work as well because addictive images also acquire rewarding properties and become themselves rewarding (e.g., Trotzke, Starcke, Pedersen, & Brand, 2021).

Another factor known to influence the development, maintenance and relapse of addiction is stress (Goeders, 2003; Sinha, 2001, 2008). Stress can be measured subjectively (e.g., by a visual analogue scale) or by biological markers (e.g., salivary cortisol, sCort, for the hypothalamic-pituitary-adrenal axis and alpha-amylase, sAA, for the sympathetic nervous system) (Laurent, Powers, & Granger, 2013). A blunted biological stress reaction was found in individuals with alcohol use disorder (Blaine & Sinha, 2017) and this stress reaction has been linked to the risk of relapse (Milivojevic & Sinha, 2018). Robust biological stress reactions however have been associated with resilience (Wemm & Sinha, 2019). In behavioral addictions, the evidence regarding stress reactivity is mixed (e.g., Kaess et al., 2017; van Timmeren, Piray, Goudriaan, & van Holst, 2023; Wemm, Cao, Han, & Wulfert, 2020; Wyckmans et al., 2022) and there is a lack of studies, particularly in BSD (Thomas et al., 2024). In a study involving a negative mood induction scenario, individuals with BSD tendencies showed stronger negative affect after the negative mood induction than individuals without BSD tendencies (Vogt, Hunger, Türpe, Pietrowsky, & Gerlach, 2014).

Importantly, stress influences cognition in a complex manner (e.g., Roozendaal, 2002; Schwabe, Joëls, Roozendaal, Wolf, & Oitzl, 2012). Of particular relevance in the relation between stress and addictive behaviors are trait impulsivity and inhibitory control: The I-PACE model for behavioral addictions (Brand et al., 2019) assumes an effect of cue-reactivity/craving on habitual behaviors that is moderated by general inhibitory control and mediated by stimulus-specific inhibitory control. However, the evidence regarding stimulus-specific inhibitory control is mixed (Antons, Müller, Neumann, Müller, & Steins-Loeber, 2023). Antons et al. (2023) discuss that reduced inhibitory control might be particularly relevant when persons are stressed or in persons with high levels of impulsivity. They recommend to investigate interactions between these variables in future research. Likewise, Li and Sinha (2008) have recommended exploring the connection of craving, distress and inhibitory control in future studies. Findings from original studies also indicate an interacting effect of stress with impulsivity on addictive behaviors (Fox, Keri, Peihua, & Rajita, 2010; Tang, Chua, & Wu, 2011). Stress may furthermore cause a shift from goal-directed to habitual behaviors (e.g., Schwabe, Dickinson, & Wolf, 2011; Schwabe & Wolf, 2009, 2010). Two studies investigated goal-directed and habitual behavior in behavioral addictions under conditions of stress. Using a two-Step Markov Task/multistep decision-making task, no effects of stress on goal-directed and habitual behavior in gambling disorder were found (van Timmeren et al., 2023; Wyckmans et al., 2022). Research on alcohol use disorder showed that stress experimentally induced with the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993) led to an increase in instrumental responding for alcohol-related rewards (McCaul, Wand, Weerts, & Xu, 2018). Research thus remains inconclusive until now regarding if stress might further foster habitual behaviors beyond the potentially already increased levels of habitual behavior in persons with (behavioral) addictions. Also, it remains unclear if acute stress that might impact persons with (behavioral) addictions differently than healthy controls also facilitates the transition to habitual behavior in persons with (behavioral) addiction stronger than in healthy persons. Regarding PIT mechanisms, Steins-Loeber et al. (2020) investigated a convenience sample (university students and general population) and found no effect of stress experimentally induced with the socially evaluated cold pressor test (Schwabe, Haddad, & Schachinger, 2008) on behavior in a PIT paradigm with tobacco and chocolate rewards.

Considering the ongoing habit debate in addictions and the lack of research on the effect of Pavlovian conditioned cues on instrumental responding, the interaction between goal-directed and habitual behaviors and the influence of acute stress on these processes in BSD, further research is warranted. The largest body on research on habitual behavior or the shift from goal-directed to habitual behavior under stress in (behavioral) addictions has been carried out in persons with a pathological form of the behavior or in a convenience sample. As indicated by the I-PACE model, habitual behavior is typically detected in the later stage of the addiction process (i.e., pathological form of behavior). To the best of our knowledge, studies on the early stage of the addiction process with persons at risk of an addiction are rather absent. Therefore, it remains unclear if habitual behavior already develops/exists in the early stage of an addiction (e.g., in individuals with risky shopping). The present study administered a PIT paradigm with a psychosocial stress induction to individuals with risky (online) buying-shopping (r-BSh) and a matched control group (CG). The PIT paradigm was complemented by an outcome devaluation phase (Hogarth, 2018) to disentangle habitual and goal-directed behaviors. Given the increase of e-commerce and problematic forms of online shopping (Müller, Joshi, & Thomas, 2022), the study focused on online r-BSh. Based on the above-mentioned theoretical grounds, the following was hypothesized:

H1.1 The specific PIT effect will be more pronounced in r-BSh than in CG.

H1.2 The magnitude of the specific PIT effect will be related to symptom severity of buying-shopping behavior and awareness of the experimental contingencies.

H2.1 Individuals with r-BSh will have a more pronounced subjective stress response than individuals in CG. Stress effects on sCort and sAA response will be explored without specific hypotheses due to a lack of previous research.

H2.2 The subjective stress response will be associated with an enhanced specific PIT effect. This effect will be moderated by trait impulsivity and deficits in inhibitory control.

H2.3 Devaluation of the reward outcomes will lead to a stronger decrease in instrumental responding for the rewards in CG compared to r-BSh. In r-BSh, but not CG, stress will reduce the devaluation effect.

METHODS

Participants

A power analysis (GPower version 3.1.9.2) was run to detect a medium effect of the stress induction compared to the control condition on the PIT effect with a desired power of 0.80. This approach was in parts based on previous research (e.g., Schwabe & Wolf, 2010) and considered four different groups (r-BSh, CG, risky gaming behavior, control group gaming). Previous research on the effect of stress on PIT effects/habitual behavior in the context of behavioral addictions was sparse and previous research differed by methodology used (e.g., Vogel et al., 2018). A meta-analysis on the effect of acute stress on executive functions generally supports assuming medium effect sizes and mostly reports necessary sample sizes comparable to our assumption (see below) to find medium effects (Shields, Sazma, & Yonelinas, 2016). Results regarding the gaming samples are reported elsewhere (Schmid et al., 2024) and the necessary sample size in total for all four groups was $N = 256$. The power analysis yielded a target sample size of $n = 64$ for each shopping group (r-BSh, CG). Sixty-seven individuals with r-BSh and 67 age- and gender-matched control participants (CG) were included. Recruitment took place at Hannover Medical School, Germany and Otto-Friedrich-University of Bamberg, Germany. Inclusion criteria were non-problematic use of online shopping for CG/subclinical use of online shopping for r-BSh, age ≥18 years and ≤65 years and sufficient German language skills (at native speaker level or comparable) for both groups. Exclusion criteria were learning or developmental disorders, certain psychopharmacological medication, and severe mental disorders. Furthermore, illnesses or use of medication known to influence the hypothalamic-pituitary-adrenal axis led to exclusion. Participants who displayed both r-BSh and risky gaming behavior were excluded due to the use of gaming-related pictures as control cues in the PIT paradigm. Participants assessed were part of the FOR2974 cohort, which was recruited as part of a multi-center DFG-funded addiction research unit (FOR2974) on affective and cognitive mechanisms of specific Internet-use disorders (Brand et al., 2021).

Procedure

Participant data was pseudonymized using ALIIAS: Anonymization/Pseudonymization with LimeSurvey Integration and two-factor Authentication for Scientific research (Englert et al., 2023). Participants were screened for inclusion/exclusion criteria and symptom severity of buying-shopping and gaming disorder. The laboratory procedure consisted of the FOR2974 core battery (Brand et al., 2021) (approx. 4 h) including a structured clinical interview for specific Internet use disorders based on AICA-SKI:IBS (Müller & Wölfling, 2018). The outcome of the clinical interview (0–1 criteria fulfilled = CG; 2–4 criteria fulfilled = r-BSh) conducted by trained staff (e.g., psychologists) decided on the group allocation. Afterwards, the PIT paradigm was performed.

An overview of the procedure can be derived from Fig. 1. The study was preregistered on Open Science Framework in November 2021 (Link https://osf.io/f27qw/?view_only=4bcea30152d54aab8d6c191e269cbe7d).

Material

Pavlovian-to-instrumental paradigm with stress induction and devaluation. A PIT paradigm was conducted that mainly followed the procedure described by Vogel et al. (2018). It consisted of three phases, the Pavlovian training phase, the instrumental training phase, and the transfer phase. In the Pavlovian training phase, formerly neutral stimuli were repeatedly associated with a gaming- or shopping image. After presenting two out of four stimuli (one being the conditioned stimulus for shopping (CS-shopping), one being the CS-gaming and two having no predictive value) simultaneously, participants should indicate whether they expected the presentation of a gaming or shopping image afterwards. Answers could be given on a 1–9 scale with 1 representing shopping and 9 representing gaming or vice versa which was counterbalanced. Participants' knowledge, which of the formerly neutral stimuli predicted a shopping and which a gaming image, represents awareness of the experimental contingencies. For awareness, the ratings in the last block of the Pavlovian training phase were particularly important as a significant difference in the expectancy ratings between trials containing the CS-shopping and trials containing the CS-gaming formed one aspect of awareness. Concretely, the expectancy rating was recoded to 1 = shopping and 9 = gaming as the anchors in the rating had been randomized during the experiments (so that some participants performed the rating with 1 representing shopping and others with 9 representing shopping). Afterwards, a repeated measures ANOVA was computed for every participant with trial type (factor levels: CS-shopping, CS-gaming) being the independent variable and expectancy rating being the dependent variable. If the difference was significant and expectancy rating values were lower for CS-shopping trials, this person fulfilled this aspect of awareness (Hogarth, Dickinson, Hutton, Elbers, & Duka, 2006). After the Pavlovian training phase, participants had to answer questions on which conditioned stimuli were followed by which images afterwards which reflects the second aspect of awareness. Participants were only coded as aware if they showed significant differences in their expectancy rating between CS-shopping and CS-gaming trials in the last block of the Pavlovian training and if they answered all questions about the contingencies right. In the instrumental training phase, participants were intermittently rewarded for shopping- or gaming-related instrumental behaviors with shopping/gaming coins that could, according to a cover story, be exchanged for a gaming/shopping voucher afterwards. Rewards were given in 50% of the trials in which participants showed an instrumental behavior following a variable quote. Participants were informed after every trial in the instrumental phase, whether or whether not they won a shopping/gaming coin. In the transfer phase, the effect of the previously conditioned stimuli on instrumental responding was assessed. Concretely, 1/3 of trials contained the presentation of the CS-shopping prior to the decision to perform the gaming- or shopping-related instrumental behavior, 1/3 contained the CS-gaming and 1/3 contained a neutral condition (presentation of a gray square). Showing stronger shopping-specific instrumental reactions after presentation of the CS-shopping compared to the shopping-specific instrumental reactions in the neutral condition was indicative of a PIT effect. This phase was conducted under extinction conditions, so that participants were not informed after each trial, but only after half and after all of the blocks, about their winnings. Gaming cues were used as control cues because the CS-gaming also underwent conditioning but might be perceived as less rewarding than CS-shopping for persons interested in shopping. This enabled us to compare the CS-shopping to the CS-gaming and thus to a stimulus being associated by conditioning with another potentially rewarding (non-problematic) internet activity. The procedure used partly differed from the one described by Vogel et al.

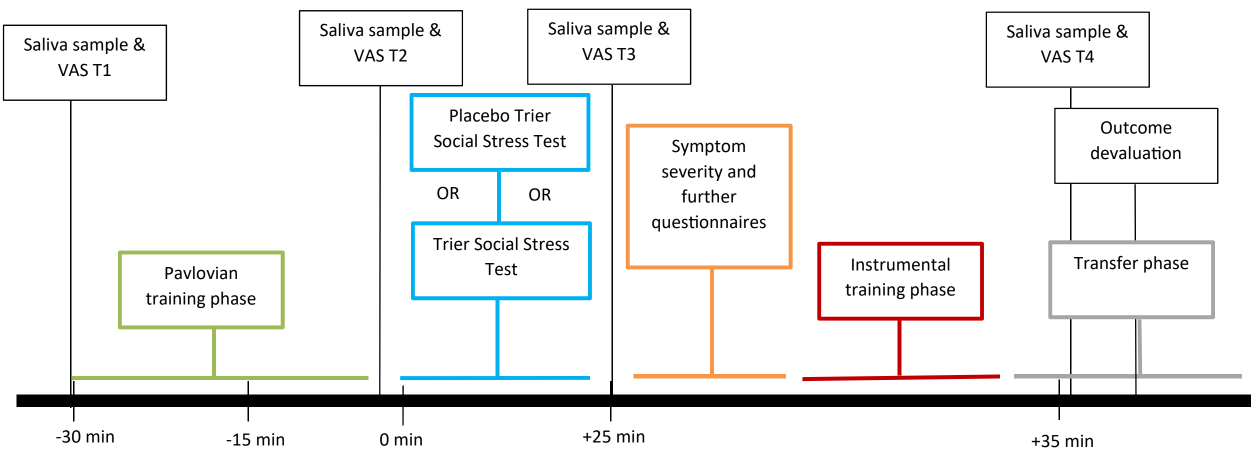

Fig. 1. Timeline of the Pavlovian-to-instrumental transfer paradigm, the stress induction procedure and the outcome devaluation *Notes*. The time points refer to stress onset. Saliva sample refers to cortisol and alpha-amylase samples as biological stress markers. VAS = Visual analogue scale.

(2018): The Pavlovian training phase consisted of eight blocks to offer more opportunity to learn the contingencies and was synchronized with eye tracking to capture time to first fixation of the stimuli and dwell time. These data were reported elsewhere (Lörsch et al., 2025). After the Pavlovian training phase, a modified TSST (Kirschbaum et al., 1993) or a friendly version (placebo-TSST; PTSST; Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009) was carried out to induce psychosocial stress. The TSST includes a preparation phase for a mock job interview (in which only personal qualities should be mentioned) taking place in front of a committee with two people wearing medical coats. Following the interview itself, a continuous algebra task is administered in front of the committee (for details on the original procedure see e.g., Labuschagne, Grace, Rendell, Terrett, & Heinrichs, 2019). The friendly version comprises a preparation phase for a talk on a positive memory (e.g., last book read) with no audience, the talk itself without a committee being present and a continuous algebra task with easier values and again without a committee. Participants were randomly allocated to either undergo the TSST or the PTSST so that $n = 67$ persons from both groups underwent the TSST (out of which $n = 34$ of r-BSh group) and $n = 67$ underwent the PTSST (out of which $n = 33$ of r-BSh group). The modifications of the TSST comprised necessary adaptations due to design (e.g., no resting period before or after the TSST) or circumstances during testing period (e.g., committee wore face masks). Further adaptations have been previously described or used by other authors (e.g., committee consisted of two persons, participants should only elaborate on personal qualities during interview phase, committee wore medical coats, algorithmic task was changed; Kudielka, Hellhammer, & Kirschbaum, 2007) or were not expected to influence the efficacy of the stress induction procedure (e.g., microphone and camera were set up, but not in operation, preparation time of 5 min). An outcome devaluation procedure was scheduled after half of the blocks of the transfer phase (see Fig. 2). Participants were told: 'Right now, you have reached the maximum of the shopping voucher. Earning more shopping points will not increase the money on the voucher.' The devaluation built upon the mechanism that, in goal-directed behavior, the shopping-related button should no longer be pressed if the desired outcome (i.e., higher shopping voucher) cannot be reached any more. Continued button presses might be indicative of habitual behaviors (Hogarth, 2020). Afterwards, participants were debriefed about the purpose of the TSST/PTSST and use of a cover story (i.e., vouchers did not exist).

Stress response measurement. Saliva samples were collected at four measurement points: Two before (approx. 30 min, approx. 5 min) and two after the onset of the TSST/PTSST (approx. +25 min, approx. +35 min) to assess sCort and sAA. Saliva samples were stored in a freezer (between 15 °C and 20 °C). They were analyzed at the biochemical lab of the departments of cognitive psychology and genetic psychology at Ruhr University Bochum. Inter- and

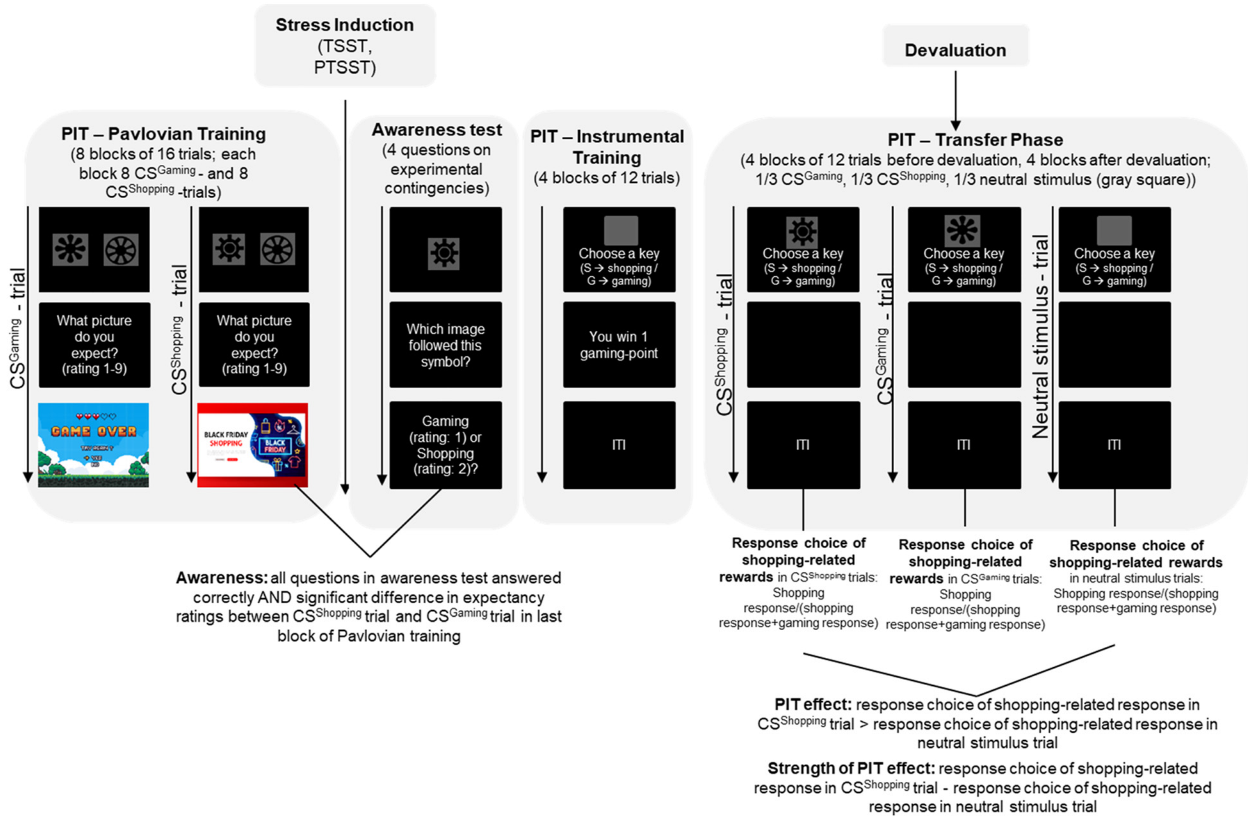

Fig. 2. Illustration of the Pavlovian-to-instrumental transfer paradigm

Notes. CS = conditioned stimulus; PIT = Pavlovian-to-instrumental transfer; TSST = Trier Social Stress Test; PTSST = placebo version of the Trier Social Stress Test; ITI = intertrial interval. © shopping & gaming picture: colourbox.

intraassay coefficients of variance were below 5%. Subjective stress was also assessed four times, immediately before/after the saliva samples by asking participants' agreement with the statement 'I feel stressed.' on a 1–100 visual analogue scale.

Clinical interview. The clinical interview *Assessment of internet and computer game addiction, Strukturiertes klinisches Interview zu Internetbezogenen Störungen* [Structured clinical interview on Internet-use disorders] (AICA-SKI IBS; Müller & Wölfling, 2018) was conducted. It is based on the DSM-5 criteria for gaming disorder (American Psychiatric Association, 2013) that were adapted for BSD.

Questionnaires. To measure symptom severity of online BSD and internet gaming disorder in accordance with the ICD-11 criteria for gaming disorder, the Assessment of Criteria for Specific Internet-use Disorders (ACSID-11; Müller, Wegmann et al., 2022; $\alpha_{shopping} = 0.91$, $\alpha_{gaming} = 0.83$) was used. Symptom severity of buying-shopping behavior (independently from the environment offline or online) was further assessed with the Pathological Buying Screener (Müller, Trotzke, Mitchell, Zwaan, & Brand, 2015, $\alpha = 0.91$). Additionally, the Internet Gaming Disorder Test (IGDT-10; Király et al., 2017, $\alpha_{gaming} = 0.76$) and an adapted version for shopping ($\alpha_{shopping} = 0.85$) was used.

Trait impulsivity was captured with the German 15-item version of the Barratt Impulsiveness Scale (Meule, Vögele, & Kübler, 2011), $\alpha = 0.80$. Habitual use of shopping applications was assessed with the Self Report Habit Index (Verplanken & Orbell, 2003) adapted for online shopping, $\alpha = 0.93$, and chronic stress with the stress screener (SSCS) of the Trier Inventory for Chronic Stress (TICS; Schulz & Schlotz, 1999), $\alpha = 0.87$.

Other behavioral tasks. To assess inhibitory control, a visual Go/No-Go task (Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013) with addiction-related distal target cues (e.g., log-in pages of shopping sites) and neutral stimuli (e.g., bureau material in a person's hands) as control cues was used. As outcome variable, the commission error index for shopping-stimuli as no-go stimuli was used.

Statistical analysis

Data regarding most main hypotheses were analyzed as mixed analyses of variance. For the preregistered hypothesis (H2.1) directed to stress reactivity, group (r-BSh vs. CG) and stress condition (TSST vs. PTSST) served as between-subjects factors and time (T1, T2, T3, T4) served as within-subjects factor. Dependent variables were sCort, sAA and subjective stress with one ANOVA per stress measure.

For further preregistered hypotheses (H1.1, H2.3) regarding the PIT and group-/condition-specific differences, a separate ANOVA was calculated in which stimulus category (CS-shopping vs. CS-gaming vs. neutral stimulus) and devaluation (before vs. after devaluation) served as repeated measures factors. Group (r-BSh vs. CG), awareness of the experimental contingencies (aware vs. unaware) and stress condition (TSST vs. PTSST) were between-subjects factors. Response choice of the shopping-related reward in % (choice of shopping-related reward/(choice of gaming-related reward + choice of shopping-related reward) was the dependent variable. This ANOVA was repeated for persons that were TSST responders/PTSST non-responders only.

Hierarchical regression analyses on the remaining preregistered hypotheses (H1.2, H2.2) included gender, awareness of the experimental contingencies and the magnitude of the PIT effect before the devaluation in the first step to predict the magnitude of the PIT effect after the devaluation. The magnitude of the PIT effect was calculated as the following difference value: response choice of shopping reward after presentation of CS-shopping – response choice of shopping reward in neutral condition (after presentation of gray square). In the second step, the severity of risky online buying-shopping behavior was added and the measures of stress response (sCort: difference T4-T2, subjective stress: T3-T2, sAA: T3-T2) were included in the third step. Inhibitory control and trait impulsivity were added in the fourth and the hypothesized moderating roles of trait impulsivity and inhibitory control (i.e., interactions with the measures of the stress response) in the last step. Regression analyses were run with both groups collapsed and variables were centralized by their mean (Cohen, Cohen, West, & Aiken, 2002). A second regression model was computed to exploratively assess possible interactions between stress responsivity and symptom severity. The model was identical to the previous model in steps one to three, but in step four interactions between measures of the stress response and symptom severity were added. There was no fifth step in this model. For the regression analyses, f^2 was calculated as effect size measure for multiple regressions and conventions by Cohen (1988) were followed for interpretation. IBM SPSS version 29 (statistical analysis etc.) and R (R Core Team, 2024; visualization of interactions) were used.

Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. The study was approved by the local ethics committees (Hannover Medical School: 9025_BO_K_2020; 17.04.2020; University Bamberg: 2019–12/33; 18.12.2019). All participants provided informed written consent before the study.

RESULTS

Sample description, results of questionnaires and clinical interview

There were no group differences regarding gender distribution (r-BSh: 79.1% women, CG: 77.6% women), $\chi^2(1) = 0.04$, $p = 0.834$, and education/school years (twelve or more years of schooling, r-BSh: 94.0%, CG: 95.5%), $\chi^2(1) = 0.15$, $p = 0.698$, age (r-BSh: 26.15 ± 8.90 years, CG: 26.12 ± 7.74 years), $|t|(132) = 0.02$, $p = 0.984$, and body mass index (r-BSh: 23.49 ± 3.67 kg/m^2, CG: 22.90 ± 2.60 kg/m^2), $|t|(131) = 1.07$, $p = 0.286$.

Individuals with r-BSh fulfilled more criteria in the clinical interview, had higher (online) BSD questionnaire values (Pathological Buying Screener, ACSID-11, and IGDT-10 shopping version), higher values for chronic stress (SSCS) and a higher extent of self-reported habits (Self Report Habit Index, see Table 1). Individuals with r-BSh however showed also higher symptom severity in gaming behavior as measured with the ACSID-11, but not in the IGDT-10. Problematic levels of gaming were ruled out by clinical interview.

Awareness of the experimental contingencies in the PIT paradigm was detected in 56.0% of the participants. No group differences could be found, $\chi^2(1) = 1.48$, $p = 0.223$.

Stress reactivity

An overview of the results of the mixed ANOVA for the respective stress measure can be found in Table 2. In total, 70.15% of the participants in the TSST condition were responders (mean sCort difference between T2, right before TSST as baseline, and T4, 35 min after stress onset, exceeded 1.5 nmol/l) in accordance with Miller, Plessow, Kirschbaum, and Stalder (2013), 93.94% of the participants in the PTSST condition were non-responders (mean sCort difference T4-T2 did not exceed 1.5 nmol/l).

For sCort, the significant main effects of time and condition were qualified by a time*condition interaction (see Table 2). sCort levels were higher in the TSST condition

Table 1. Descriptive statistics regarding questionnaires and clinical interview for the whole sample, individuals with non-problematic and risky use and mean comparisons between the two groups

	Descriptive statistics			Mean comparison				
	Whole sample	Individuals with non-problematic use	Individuals with risky use	*N* (for mean comparison)	|*t*|	*df*	*p*	|*d*|
AICA-SKI IBS (nr. of criteria)	1.62 ± 1.43	0.40 ± 0.49	2.85 ± 0.93	133	18.86	98.54	<0.001	3.29
PBS	26.40 ± 8.90	21.21 ± 6.06	31.67 ± 8.22	133	8.34	119.58	<0.001	1.45
IGDT-10 Shopping	0.69 ± 1.35	0.13 ± 0.39	1.26 ± 1.70	133	5.23	71.53	<0.001	0.91
IGDT-10 Gaming	0.13 ± 0.53	0.08 ± 0.28	0.18 ± 0.67	52[a]	0.65	50	0.520	0.18
ACSID-11 Shopping (frequency mean)	0.62 ± 0.58	0.34 ± 0.47	0.90 ± 0.54	133	6.41	127.98	<0.001	1.11
ACSID-11 Gaming (frequency mean)	0.18 ± 0.29	0.08 ± 0.13	0.27 ± 0.36	52[a]	2.63	34.98	0.013	0.69
SSCS	20.18 ± 8.20	18.04 ± 8.39	22.35 ± 7.46	133	3.13	131	0.002	0.54
SRHI Shopping	3.46 ± 0.96	4.01 ± 0.77	2.89 ± 0.80	133	8.24	131	<0.001	1.43

Notes. AICA-SKI IBS = Assessment of Internet and Computer Game Addiction, Strukturiertes klinisches Interview zu Internetbezogenen Störungen [Structured clinical interview on Internet-use disorders], ACSID-11 = Assessment of Criteria for Specific Internet-use Disorders, IGDT-10 = Internet Gaming Disorder Test, PBS = Pathological Buying Screener, SRHI = Self-Report Habit Index, SSCS = Screening-Skala zum chronischen Stress [Chronic Stress Screening Scale]. [a] out of which $n = 24$ individuals with non-problematic use, $n = 28$ with risky use. High SRHI values represent little extent of habitual behavior. Means and standard deviations are presented as descriptive statistics. Two-tailed *t*-tests were computed.

Table 2. Mixed analyses of variance for stress reactivity in the respective stress measure

	Cortisol (nmol/L)	Subjective stress (VAS)	Alpha-amylase (U/ml)
Time	**$F(1.49, 192.39) = 43.30$, $p < 0.001$, $\eta^2 = 0.25$**	**$F(2.45, 310.83) = 71.69$, $p < 0.001$, $\eta^2 = 0.36$**	**$F(1.53, 196.19) = 34.97$, $p < 0.001$, $\eta^2 = 0.22$**
Time*Group	$F(1.49, 192.39) = 0.65$, $p = 0.479$, $\eta^2 = 0.01$	$F(2.45, 310.83) = 0.66$, $p = 0.546$, $\eta^2 = 0.01$	**$F(1.53, 196.19) = 5.47$, $p = 0.009$, $\eta^2 = 0.04$**
Time*Condition	**$F(1.49, 192.39) = 45.20$, $p < 0.001$, $\eta^2 = 0.26$**	**$F(2.45, 310.83) = 40.80$, $p < 0.001$, $\eta^2 = 0.24$**	**$F(1.53, 196.19) = 12.78$, $p < 0.001$, $\eta^2 = 0.09$**
Time*Group*Condition	$F(1.49, 192.39) = 1.05$, $p = 0.334$, $\eta^2 = 0.01$	$F(2.45, 310.83) = 0.78$, $p = 0.482$, $\eta^2 = 0.01$	$F(1.53, 196.19) = 2.39$, $p = 0.108$, $\eta^2 = 0.02$
Group	$F(1, 129) = 0.76$, $p = 0.386$, $\eta^2 = 0.01$	$F(1, 127) = 3.18$, $p = 0.077$, $\eta^2 = 0.02$	**$F(1, 128) = 11.39$, $p < 0.001$, $\eta^2 = 0.08$**
Condition	**$F(1, 129) = 38.69$, $p < 0.001$, $\eta^2 = 0.23$**	**$F(1, 127) = 16.48$, $p < 0.001$, $\eta^2 = 0.12$**	$F(1, 128) = 0.91$, $p = 0.342$, $\eta^2 = 0.01$
Group*Condition	$F(1, 129) = 0.57$, $p = 0.451$, $\eta^2 = 0.00$	$F(1, 127) = 0.01$, $p = 0.924$, $\eta^2 = 0.00$	$F(1, 128) = 1.99$, $p = 0.161$, $\eta^2 = 0.02$

Notes. VAS = visual analogue scale. Significant effects were highlighted in bold. If assumptions of sphericity were violated, Greenhouse-Geisser corrections were performed. $N = 133$ for cortisol, $N = 131$ for subjective stress, $N = 132$ for alpha-amylase.

than in the PTSST condition at the third (mean difference ($|MD|$) = 1.82, SE = 0.33, $p < 0.001$) and fourth ($|MD|$ = 4.15, SE = 0.53, $p < 0.001$) measurement point. No main effect of group and no group*condition interaction were observed.

For subjective stress, the main effects of time and condition were further qualified by a time*condition interaction with higher subjective stress levels in the TSST condition at the third ($|MD|$ = 37.48, SE = 4.73, $p < 0.001$) and fourth ($|MD|$ = 9.56, SE = 3.90, p = 0.016) measurement point. Individuals with r-BSh showed a tendency towards more pronounced stress levels that did not yield significance. The group*condition interaction was not significant.

For sAA, a time*condition interaction with higher levels in the TSST condition at the third ($|MD|$: 88.23, SE: 32.19, p = 0.007) measurement point compared to the PTSST condition was found. Also, a time*group interaction showed higher sAA levels of r-BSh at all measurement points (T1: $|MD|$ = 40.25, SE = 16.80, p = 0.018, T2: $|MD|$ = 46.50, SE = 16.32, p = 0.005, T3: $|MD|$ = 108.38, SE = 32.19, p = 0.001, T4: $|MD|$ = 49.23, SE = 16.68, p = 0.004). Significant differences were found between T1 and T3 ($|MD|$ = 107.89, SE = 17.71, $p < 0.001$) and T2 and T3 ($|MD|$ = 113.24, SE = 17.96, $p < 0.001$) in r-BSh, but only between T2 and T3 in CG (T1-T3: $|MD|$ = 39.76, SE = 17.98, p = 0.173; T2-T3: $|MD|$ = 51.36, SE = 18.24, p = 0.034). Mean differences suggest a stronger sAA increase in r-BSh than CG. Significant main effects of time and group emerged. A group*condition interaction was not observed. For visualization of the results, see Fig. 3.

Results on devaluation effects

Analyses of the whole sample showed a main effect of stimulus and a main effect of devaluation on the choice of shopping reward in the transfer phase of the PIT paradigm before and after devaluation. The main effect of stimulus (choice of shopping-related reward after $CS_{Shopping}$ > neutral stimulus > CS_{Gaming}) and the main effect of devaluation (shopping-related reward chosen more often before devaluation than afterwards) were further qualified by interaction effects. For visualization of the results, see Fig. 4.

Two-way interactions (stimulus*awareness and devaluation*stimulus) could be observed as well as a devaluation*stimulus*awareness three-way interaction. This three-way interaction indicated that before devaluation, unaware participants did not differ in their instrumental behavior in response to the stimulus shown beforehand (all $ps \geq 0.052$) whereas aware participants did (all $ps < 0.001$). Aware participants chose the shopping-related reward most often after $CS_{Shopping}$ (M = 95.48, SE = 2.70) and more often after the neutral stimulus (M = 67.46, SE = 3.44) than after CS_{Gaming} (M = 18.20, SE = 4.08). After devaluation, unaware participants still did not differ in their instrumental response behavior depending on the stimulus shown beforehand (all $ps \geq 0.230$), but showed overall reduced responses (all $|MD| \geq 19.28$, all $ps < 0.001$). Aware participants also displayed reduced instrumental responses (all $|MD| > 13.66$, all $ps \leq 0.001$) which manifested in particularly strong decrease after the neutral stimulus

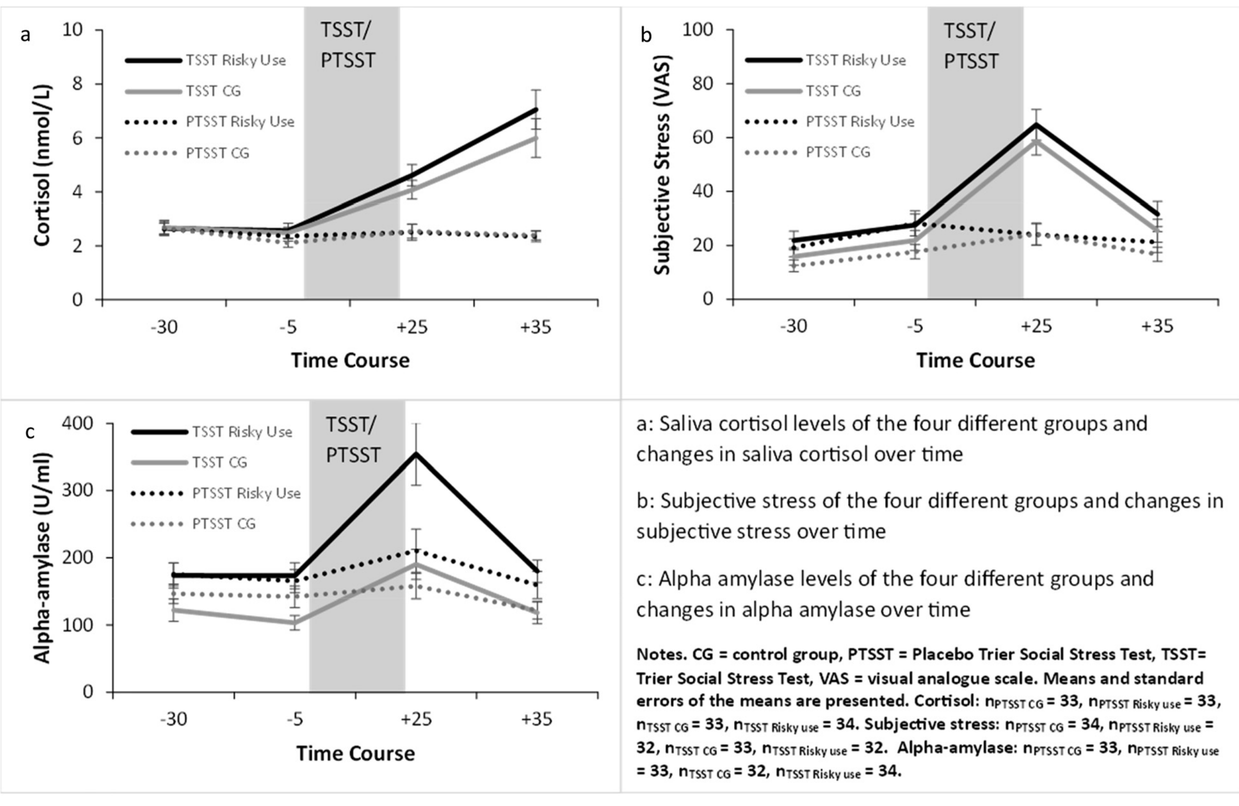

Fig. 3. Stress reactivity as measured by cortisol, alpha-amylase and subjective stress by group, condition, and measurement point

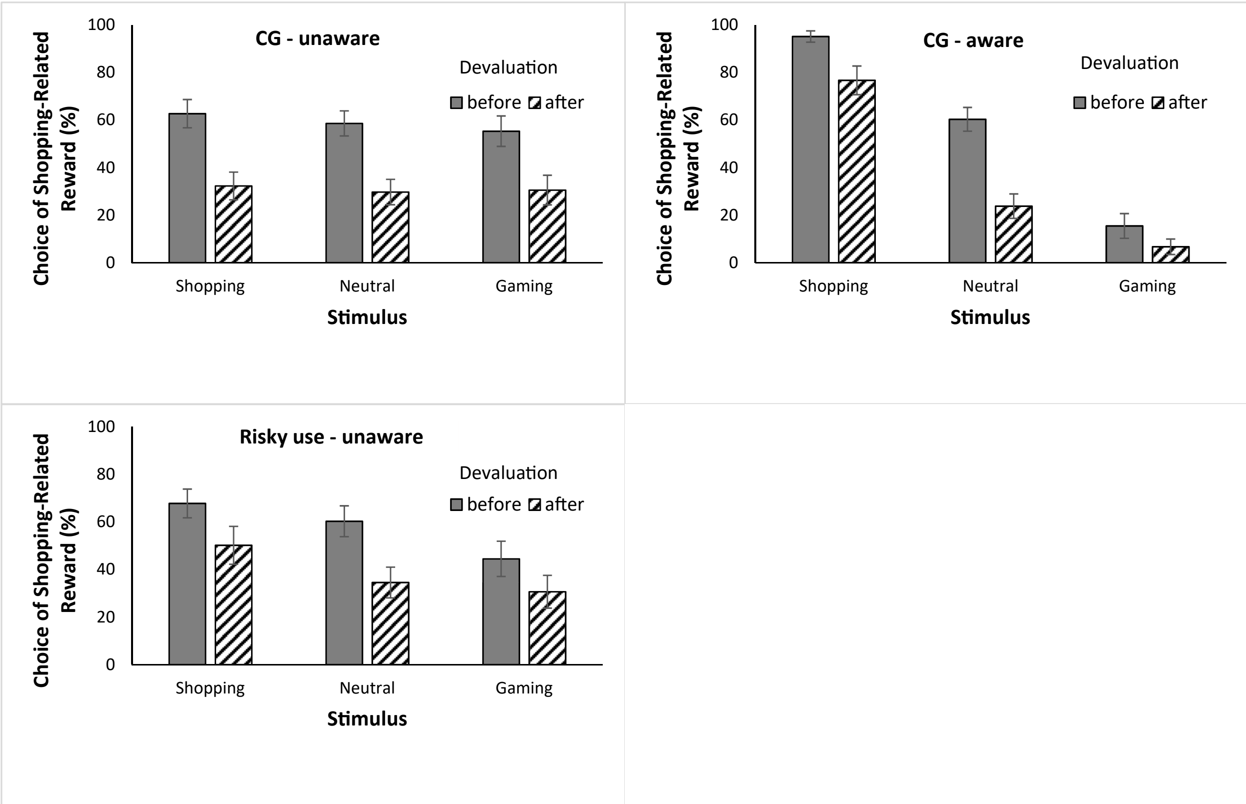

Fig. 4. Effect of the devaluation in the transfer phase of the PIT paradigm by group, stimulus and awareness

Notes. CG = control group (non-problematic use). The results 'before' refer to the four blocks of the transfer phase before the devaluation and the results 'after' refer to the four blocks of the transfer phase after the devaluation. Choice of the shopping-related reward refers to percentage of trials in which the shopping-related reward was chosen compared to all valid trials (trials in which either the gaming- or the shopping-related reward was chosen). Higher choice of shopping-related rewards after presentation of the shopping stimulus than after presentation of the neutral stimulus is indicative of a PIT effect. Potentially habitual behavior is to be reflected by little or no reductions in the choice of shopping-related rewards after the devaluation. Strong reductions or no choice of shopping-related rewards after devaluation would indicate goal-directed behavior. Means and standard errors of the means are presented. Sample size: $n_{CG - unaware} = 31$, $n_{CG - aware} = 34$, $n_{risky\ use - unaware} = 26$, $n_{risky\ use - aware} = 41$.

($|MD| > 47.10$, SE = 4.62, $p < 0.001$), but still reacted more strongly to $CS_{Shopping}$ than to the neutral stimulus and to the neutral stimulus than to CS_{Gaming} (all *p*s < 0.001). Taken together, aware participants showed stronger PIT effects that were even larger after devaluation (before devaluation: $M = 27.17$, $SD = 30.63$; after devaluation: $M = 50.12$, $SD = 39.42$) due to the decrease in instrumental responding after presentation of the neutral stimulus. There were no main effects of group, condition or awareness. Further significant interactions are not described in detail, as effect sizes were small and *p*-values surpassed significance level if corrected for multiple testing (see Table 3). Analyses only including TSST responders and PTSST non-responders led to comparable main results (see Table 3).

Regression analyses predicting magnitude of shopping PIT effect after devaluation

In the regression model, awareness, the magnitude of the shopping PIT effect before devaluation and sCort response emerged as significant predictors (see Table 4) for the magnitude of the shopping PIT effect after devaluation as criterion. Gender, symptom severity, sAA response, subjective stress response, inhibitory control, trait impulsivity, the interactions between trait impulsivity and sAA response/sCort response/subjective stress response and the interactions between inhibitory control and sAA response/sCort response/subjective stress response missed significance. Awareness and the PIT effect before devaluation showed medium-sized effects, the sCort stress response showed a small-sized effect and impulsivity showed a small-sized effect although not being significant. Remaining predictors showed no meaningful effect.

The finding of a main effect of sCort response led to additional, more fine-grained exploratory analyses to further investigate the effects of stress (sAA, sCort and subjective stress) and its potential interplay with symptom severity on the PIT effect after devaluation (see Table 5). Awareness, the PIT effect before devaluation, sCort response as well as the interactions between sCort response and symptom severity and between subjective stress response and symptom severity yielded significance. All other variables missed

Table 3. Mixed analysis of variance with stimulus, awareness and devaluation as repeated measures, group and condition as between-subjects factors and response choice of the shopping-related reward in the transfer phase as dependent variable

	Whole sample analysis (response choice)	TSST-responder analysis (response choice)
Devaluation	**$F(1.00, 124.00) = 85.55, p < 0.001, \eta^2 = 0.41$**	**$F(1.00, 100.00) = 64.13, p < 0.001, \eta^2 = 0.39$**
Devaluation*Group	$F(1.00, 124.00) = 0.26, p = 0.614, \eta^2 = 0.00$	$F(1.00, 100.00) = 0.00, p = 0.991, \eta^2 = 0.00$
Devaluation*Condition	$F(1.00, 124.00) = 0.02, p = 0.888, \eta^2 = 0.00$	$F(1.00, 100.00) = 0.15, p = 0.703, \eta^2 = 0.00$
Devaluation*Awareness	$F(1.00, 124.00) = 0.77, p = 0.383, \eta^2 = 0.01$	$F(1.00, 100.00) = 0.10, p = 0.750, \eta^2 = 0.00$
Devaluation*Group*Condition	$F(1.00, 124.00) = 0.09, p = 0.766, \eta^2 = 0.00$	$F(1.00, 100.00) = 0.11, p = 0.736, \eta^2 = 0.00$
Devaluation*Group*Awareness	$F(1.00, 124.00) = 4.49, p = 0.036, \eta^2 = 0.04$[a]	$F(1.00, 100.00) = 4.44, p = 0.038, \eta^2 = 0.04$[a]
Devaluation*Condition*Awareness	$F(1.00, 124.00) = 1.09, p = 0.298, \eta^2 = 0.01$	$F(1.00, 100.00) = 0.04, p = 0.845, \eta^2 = 0.00$
Devaluation*Group*Condition *Awareness	$F(1.00, 124.00) = 0.93, p = 0.338, \eta^2 = 0.01$	$F(1.00, 100.00) = 0.81, p = 0.371, \eta^2 = 0.01$
Stimulus	**$F(1.57, 194.15) = 90.20, p < 0.001, \eta^2 = 0.42$**	**$F(1.57, 156.57) = 75.01, p < 0.001, \eta^2 = 0.43$**
Stimulus*Group	$F(1.57, 194.15) = 0.59, p = 0.517, \eta^2 = 0.01$	$F(1.57, 156.57) = 1.01, p = 0.351, \eta^2 = 0.01$
Stimulus*Condition	$F(1.57, 194.15) = 2.29, p = 0.116, \eta^2 = 0.02$	$F(1.57, 156.57) = 1.71, p = 0.190, \eta^2 = 0.02$
Stimulus*Awareness	**$F(1.57, 194.15) = 43.65, p < 0.001, \eta^2 = 0.26$**	**$F(1.57, 156.57) = 41.18, p < 0.001, \eta^2 = 0.29$**
Stimulus*Group*Condition	$F(1.57, 194.15) = 0.03, p = 0.944, \eta^2 = 0.00$	$F(1.57, 156.57) = 0.06, p = 0.905, \eta^2 = 0.00$
Stimulus*Group*Awareness	$F(1.57, 194.15) = 1.91, p = 0.160, \eta^2 = 0.02$	$F(1.57, 156.57) = 2.21, p = 0.125, \eta^2 = 0.02$
Stimulus*Condition*Awareness	$F(1.57, 194.15) = 0.38, p = 0.634, \eta^2 = 0.00$	$F(1.57, 156.57) = 0.14, p = 0.817, \eta^2 = 0.00$
Stimulus*Group*Condition *Awareness	$F(1.57, 194.15) = 0.50, p = 0.561, \eta^2 = 0.00$	$F(1.57, 156.57) = 0.67, p = 0.478, \eta^2 = 0.01$
Devaluation*Stimulus	**$F(2.00, 248.00) = 18.44, p < 0.001, \eta^2 = 0.13$**	**$F(2.00, 200.00) = 16.55, p < 0.001, \eta^2 = 0.14$**
Devaluation*Stimulus*Group	$F(2.00, 248.00) = 1.45, p = 0.236, \eta^2 = 0.01$	$F(2.00, 200.00) = 1.24, p = 0.292, \eta^2 = 0.01$
Devaluation*Stimulus*Condition	$F(2.00, 248.00) = 0.01, p = 0.987, \eta^2 = 0.00$	$F(2.00, 200.00) = 0.04, p = 0.962, \eta^2 = 0.00$
Devaluation*Stimulus*Awareness	**$F(2.00, 248.00) = 7.67, p < 0.001, \eta^2 = 0.06$**	$F(2.00, 200.00) = 5.15, p = 0.007, \eta^2 = 0.05$[a]
Devaluation*Stimulus*Group *Condition	$F(2.00, 248.00) = 0.56, p = 0.571, \eta^2 = 0.01$	$F(2.00, 200.00) = 0.18, p = 0.834, \eta^2 = 0.00$
Devaluation*Stimulus*Group *Awareness	$F(2.00, 248.00) = 0.10, p = 0.903, \eta^2 = 0.00$	$F(2.00, 200.00) = 0.01, p = 0.993, \eta^2 = 0.00$
Devaluation*Stimulus*Condition *Awareness	$F(2.00, 248.00) = 4.70, p = 0.010, \eta^2 = 0.04$[a]	$F(2.00, 200.00) = 2.93, p = 0.056, \eta^2 = 0.03$
Devaluation*Stimulus*Group *Condition*Awareness	$F(2.00, 248.00) = 0.99, p = 0.373, \eta^2 = 0.01$	$F(2.00, 200.00) = 0.84, p = 0.433, \eta^2 = 0.01$
Group	$F(1,124) = 0.33, p = 0.569, \eta^2 = 0.00$	$F(1,100) = 1.02, p = 0.315, \eta^2 = 0.01$
Condition	$F(1,124) = 1.81, p = 0.181, \eta^2 = 0.01$	$F(1,100) = 0.49, p = 0.487, \eta^2 = 0.01$
Awareness	$F(1,124) = 0.02, p = 0.889, \eta^2 = 0.00$	$F(1,100) = 0.12, p = 0.728, \eta^2 = 0.00$
Group*Condition	$F(1,124) = 0.61, p = 0.437, \eta^2 = 0.01$	$F(1,100) = 0.77, p = 0.382, \eta^2 = 0.01$
Group*Awareness	$F(1,124) = 0.70, p = 0.403, \eta^2 = 0.01$	$F(1,100) = 1.64, p = 0.204, \eta^2 = 0.02$
Condition*Awareness	$F(1,124) = 0.14, p = 0.713, \eta^2 = 0.00$	$F(1,100) = 0.07, p = 0.791, \eta^2 = 0.00$
Group*Condition*Awareness	$F(1,124) = 0.59, p = 0.445, \eta^2 = 0.01$	$F(1,100) = 0.34, p = 0.560\ \eta^2 = 0.00$

Notes. If assumptions of sphericity were violated, Greenhouse-Geisser corrections were performed. α-level was set to 0.0016 due to Bonferroni correction for multiple testing (0.05/31). $N = 132$ for whole sample, $N = 108$ for TSST-responder analysis. [a] This test would have been significant on 0.05 α-level, but was not on the corrected α-level. Significant effects were highlighted in bold.

significance. The inclusion of the interactions of the stress variables with symptom severity ameliorated the predictive ability of the model by 6%. A closer inspection of the interactions revealed that persons with high symptom severity and a high sCort response showed highest PIT effects after devaluation when compared to persons with high symptom severity, but low sCort response (see Fig. 5). Differences between persons with low symptom severity and high sCort response and persons with low symptom severity and low sCort response were not that striking. Comparable patterns can be observed in the interaction involving symptom severity and subjective stress response. Effects of awareness and the PIT effect before devaluation were medium, sCort stress response and the interactions of symptom severity with sCort stress response respectively subjective stress response were small. Remaining predictors showed no meaningful effect.

DISCUSSION AND CONCLUSIONS

The TSST proved to successfully induce stress regarding subjective as well as biological measures with 70.15% of the participants in the TSST condition being classified as cortisol responders. Preregistered analyses indicated no group differences in sCort and subjective stress response (H2.1 not supported), however, participants with r-BSh had higher sAA baseline levels and a stronger increase in sAA levels than those in the CG. In both groups, shopping-specific instrumental reactions were reduced by the devaluation but

Table 4. Hierarchical moderated regression analyses with inhibitory control and trait impulsivity as potential moderators on the effect of stress response on the magnitude of shopping PIT effect after devaluation as dependent variable

Table 4a. Significance of predictors in the final model (after step 5)

		ß	*t*	*p*	f^2
Step 1	Gender	0.02	0.25	0.802	0.00
	Awareness	**0.36**	**4.24**	**<0.001**	**0.16**
	PIT effect before devaluation	**0.34**	**4.07**	**<0.001**	**0.15**
Step 2	Symptom severity buying-shopping	0.00	0.04	0.970	0.00
Step 3	Amylase stress response	0.02	0.25	0.803	0.00
	Cortisol stress response	**0.20**	**2.05**	**0.043**	**0.04**
	Subjective stress response	0.04	0.47	0.642	0.00
Step 4	Inhibitory control	0.00	0.02	0.982	0.00
	Impulsivity	0.11	1.37	0.172	0.02
Step 5	Amylase stress response*Inhibitory control	0.05	0.47	0.637	0.00
	Cortisol stress response*Inhibitory control	0.00	0.04	0.972	0.00
	Subjective stress response*Inhibitory control	0.01	0.07	0.944	0.00
	Amylase stress response*Impulsivity	0.05	0.55	0.584	0.00
	Cortisol stress response*Impulsivity	0.06	0.73	0.468	0.00
	Subjective stress response*Impulsivity	0.04	0.42	0.676	0.00

Notes. Subjective stress response refers to the difference value between the subjective stress ratings (visual analogue scale) at T3 and T2 (T3-T2). Cortisol stress response refers to the difference value between the different cortisol concentrations at T4 and T2 (T4-T2). Alpha-amylase stress response refers to the difference value between the different alpha-amylase concentrations at T3 and T2 (T3-T2). $N = 127$. Test statistics refer to the last step (step 5) with all predictors included. Step 1 etc. only refers to the stage in which the predictor was entered. $f^2 = 0.02$: small effect size, $f^2 = 0.15$: medium effect size, $f^2 = 0.35$: large effect size. Significant effects were highlighted in bold.

Table 4b. Explained variance of the models and increment in explained variance by step

	R^2	ΔR^2	Sign. in F
Step 1	**0.33**	**0.33**	**< 0.001**
Step 2	0.33	0.00	0.787
Step 3	0.35	0.02	0.281
Step 4	0.36	0.01	0.418
Step 5	0.37	0.01	0.961

Significant effects were highlighted in bold.

Table 5. Hierarchical moderated regression analyses with stress response as potential moderator on the effect of symptom severity on the magnitude of shopping PIT effect after devaluation as dependent variable

Table 5a. Significance of predictors in the final model (after step 4)

		ß	*t*	*p*	f^2
Step 1	Gender	0.01	0.14	0.893	0.00
	Awareness	**0.37**	**4.84**	**< 0.001**	**0.20**
	PIT effect before devaluation	**0.38**	**4.92**	**< 0.001**	**0.21**
Step 2	Symptom severity buying-shopping	0.02	0.30	0.768	0.00
Step 3	Amylase stress response	0.04	0.38	0.707	0.00
	Cortisol stress response	**0.16**	**1.99**	**0.049**	**0.03**
	Subjective stress response	0.09	1.11	0.270	0.01
Step 4	Amylase stress response*Symptom severity	0.12	1.20	0.231	0.01
	Cortisol stress response*Symptom severity	**0.18**	**2.22**	**0.028**	**0.04**
	Subjective stress response*Symptom severity	**0.18**	**2.29**	**0.024**	**0.04**

Notes. Subjective stress response refers to the difference value between the subjective stress ratings (visual analogue scale) at T3 and T2 (T3-T2). Cortisol stress response refers to the difference value between the cortisol concentrations at T4 and T2 (T4-T2). Alpha-amylase stress response refers to the difference value between the alpha-amylase concentrations at T3 and T2 (T3-T2). $N = 129$. Test statistics refer to the last step (step 4) with all predictors included. Step 1 etc. only refers to the stage in which the predictor was entered. $f^2 = 0.02$: small effect size, $f^2 = 0.15$: medium effect size, $f^2 = 0.35$: large effect size. Significant effects were highlighted in bold.

Table 5b. Explained variance of the model and increment in explained variance by step

	R^2	ΔR^2	Sign. in F
Step 1	**0.33**	**0.33**	**< 0.001**
Step 2	0.33	0.00	0.795
Step 3	0.35	0.02	0.281
Step 4	**0.41**	**0.06**	**0.007**

Significant effects were highlighted in bold.

still existed. Reductions mainly affected the neutral condition whereas shopping-specific instrumental reactions still occurred frequently after CS-shopping. This is likely the reason why the PIT effect even increased in aware persons after devaluation. It seems as if participants still tended to more or less reliably show the shopping-specific instrumental reaction after CS-shopping despite the devaluation meaning reward-absentness. Although the general reduction in shopping-specific instrumental behavior after devaluation could be viewed as indicator of goal-directedness (Hogarth, 2020), the remaining influence of the CS-shopping on the shopping-specific instrumental behavior after the devaluation could speak in favor of potential habitual processes being involved.

Of particular further interest is the lack of differences between stress conditions (H2.3 not supported). No

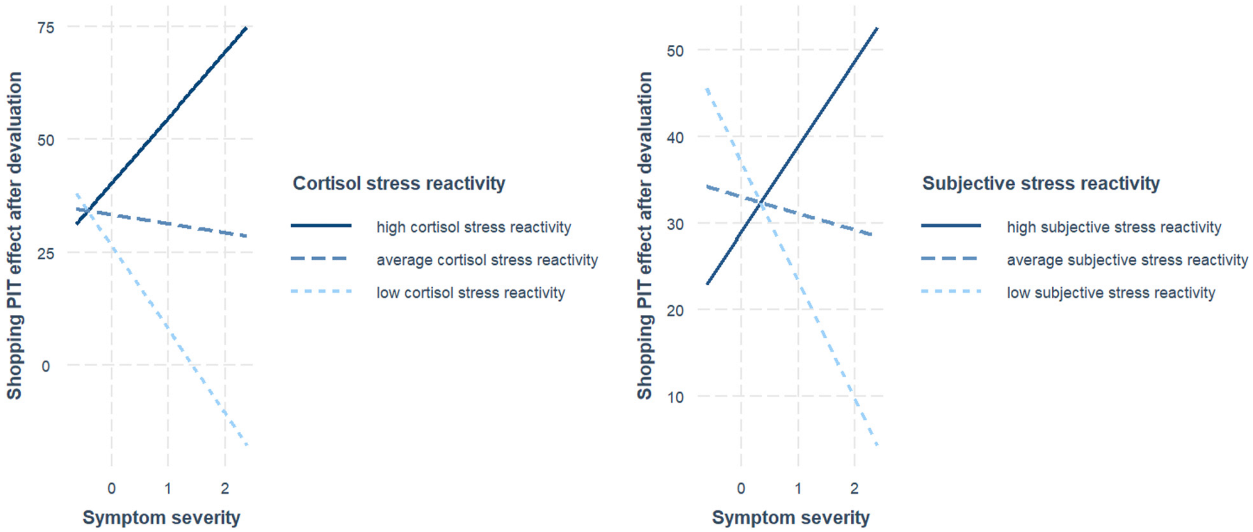

Fig. 5. Moderation of cortisol stress response (left figure) respectivley subjective stress response (right figure) on the impact of symptom severity on the magnitude of the shopping PIT effect after devaluation

Notes. For the purpose of illustrating this moderation, simple slopes were derived. Note that the values "low/high" represent the value of one standard deviation below the mean (=low) and a value of one standard deviation above the mean (=high) of the moderator (cortisol as left figure respectively subjective stress response as right figure). Average refers to the mean of the moderator. Subjective stress response refers to the difference value between the subjective stress ratings (visual analogue scale) at T3 and T2 (T3-T2). Cortisol stress response refers to the difference value between the different cortisol concentrations at T4 and T2 (T4-T2). PIT effect after devaluation: Response choice of shopping-related rewards in presence of $CS_{shopping}$ - response choice of shopping-related rewards in presence of the neutral stimulus in the blocks of the transfer phase after devaluation. Symptom severity and stress reactivity are centralized.

differences in the PIT effect between the groups emerged (H1.1 not supported). In addition, regression analyses showed that the PIT effect after devaluation was not predicted by symptom severity, but by the PIT effect before devaluation and awareness (H1.2 partly supported). No moderations of trait impulsivity or inhibitory control were found (H2.2 not supported). Still, the sCort response predicted the PIT effect after devaluation suggesting some influence of stress on potentially habitual behavior. Taken together, the above-mentioned preregistered main analysis showed that the response choice of shopping-specific behavior in the transfer phase is neither subject to group/symptom severity (risky use of online buying-shopping behavior vs. unproblematic use) nor to stress condition (stress induction vs. placebo procedure). Furthermore, the PIT effect after devaluation as indicator of potentially habitual behavior was not predicted by interactions of different measures of the stress response with inhibitory control or trait impulsivity but by sCort response solely. So, most preregistered analysis did not show the results as hypothesized. An additional exploratory analysis revealed that a symptom severity* stress response interaction (in sCort and subjective stress) predicted the PIT effect after devaluation demonstrating a more complex pattern. Thus, the PIT effect after devaluation (i.e., potentially habitual behavior) was high if symptom severity and stress responsivity were high. Although these findings suggest potentially habitual behavior in persons with high stress response and high symptom severity, they do not match the before-mentioned analyses on response choice in which no effects of devaluation, group and stress condition were found. These seemingly contradictory findings most importantly underline the need for further research and particularly of replication of the above-reported findings and extension to persons with pathological buying-shopping behaviors.

This study extends the body of evidence regarding PIT mechanisms and habitual behaviors in BSD. Preregistered and exploratory analyses are somewhat diverging in their main findings which might be due to the fact that the ANOVA captures group and stress condition as dichotomous variables which neglects the variance within the groups. A strength of the regression is that it considers this by incorporating continuous predictors. Also, the dependent variables differed across the analyses. In the ANOVA, shopping-specific response choice was the dependent variable, whereas the regression used the PIT effect after devaluation - a direct measure of potentially habitual shopping-specific behavior – as dependent variable. If the results in the regressions could be replicated, the finding of potentially higher habitual behavior in individuals with higher symptom severity and elevated stress responsiveness would suggest that once individuals have developed risky use patterns a vicious cycle could develop in which individual stress responses further contribute to the habitual use of the buying-shopping applications. These findings are in line with central assumptions of the I-PACE model (Brand et al., 2019), in which interactions of cognitive and affective responses are assumed to contribute to the development and maintenance of problematic behaviors. Concretely, the I-PACE model assumes that internal/external triggers such as acute stress are supposed to induce cue-reactivity and craving which leads to potentially shopping-specific habitual behavior in (online) CBSD (Brand et al., 2019). The relation between stress, cue-reactivity/craving and habitual behaviors should be a subject for future research. If the exploratory findings can be replicated, the results of our study might also indicate a potential transition from reward-oriented to more habitual behaviors, particularly when the motivation to reduce stress might additionally be involved, which would fit with theoretical considerations (Brand, 2022; Everitt & Robbins, 2016). Our findings, if further replicated, might also complement important contributions by Schwabe et al. (2011). They postulated that the shift from goal-directed to habitual behavior under stress may contribute to addiction. The prediction of the PIT effect after devaluation as indicator for habitual behavior by sCort response which was part of the preregistered analyses aligns well with the findings by Schwabe and Wolf (2009, 2010) who found a shift from goal-directed to habitual behavior under conditions of stress. Empirical contributions regarding PIT mechanisms in BSD are sparse so that findings of this study are embedded into studies on other behavioral addictions. Qin et al. (2023) found a direct association of symptom severity of gaming and the PIT effect, which was not observed in the present study. However, mechanisms may also be specific for different addictive behaviors and Vogel et al. (2018) already reported a direct association of the PIT-effect with symptom severity of gaming, but not shopping. This is consistent with the present findings. Unlike Wyckmans et al. (2019), who reported general reduced goal-directed behavior in individuals with gambling disorder, our study yielded mixed findings including no effect of devaluation, stress condition and group on shopping-specific response choice, but an interaction of symptom severity and sCort response on habitual behavior. At the same time, results partly align with the findings of other studies that investigated gambling disorder (van Timmeren et al., 2023; Wyckmans et al., 2022). The lack of an interaction between devaluation, stress condition and group on shopping-specific response choice resembles findings by van Timmeren et al. (2023) and Wyckmans et al. (2022) who did not find an effect of stress on goal-directed vs. habitual decision making in gambling disorder. However, exploratory analyses in our study showed an impact of stress response together with symptom severity on potentially habitual behavior which differs from the main findings by van Timmeren et al. (2023) and Wyckmans et al. (2022), but also from the findings on shopping-specific response choice in our study. The sample, tasks and stress procedures from the above-mentioned studies differed however from the ones applied in our study.

Previous findings regarding stress reactivity in behavioral addictions have yielded mixed results (e.g., Kaess et al., 2017; van Timmeren et al., 2023; Wemm et al., 2020; Wyckmans et al., 2022). The few studies that reported differences in stress responses pointed towards a blunted cortisol stress reaction in individuals with gaming/gambling disorder (Kaess et al., 2017; Wemm et al., 2020). In contrast, our current study however showed increased levels of sAA in individuals with risky buying-shopping and no differences in sCort and subjective stress. One explanation might include differences between r-BSh and pathological forms of BSD or other behavioral addictions that previous studies investigated.

Limitations and strengths

Some limitations have to be considered for proper interpretation of the results. The sample included individuals with r-BSh, so that no conclusions regarding pathological buying-shopping behavior are possible. Future research should consider person with pathological (online) buying-shopping behavior as well as persons with risky use in order to replicate the above-mentioned findings, if possible, and to investigate potential differences between early and later stage of this behavioral addiction. When integrating the study's results into the existing body of research in the field of (behavioral) addictions one should acknowledge that it is not yet clear if habitual behaviors and the impact of stress are comparable across different behavioral addictions. Nevertheless, theoretical models and research concerning behavioral addictions/internet-use disorders postulate comparability of the mechanisms involved in these addictions (Brand et al., 2019; Mestre-Bach, Steward, Jiménez-Murcia, & Fernández-Aranda, 2017). It is further yet to prove if risky behavior (i.e., early stage of a manifest behavioral addiction) involves the same influence of habitual behaviors or stress but to an intermediate extent. Research does not clearly indicate if habitual behavior linearly increases over the course of an addiction. Likewise, it remains unclear if it is less pronounced in persons with risky use compared to pathological use. The same concerns stress responsivity as it is not yet known if it increases from unproblematic to risky use, but decreases from risky to pathological use. The definition of r-BSh was challenging as previous literature focused on pathological use or used convenience samples. The assumed threshold of 2–4 criteria for r-BSh was not empirically derived. Data concerning self-control abilities however supports the group allocation as persons with risky and unproblematic use were distinct groups with regard to self-control abilities (Müller et al., 2025). Furthermore, participants conducted the PIT paradigm after an extensive core battery (Brand et al., 2021) of approximately four hours, which might have caused exhaustion effects.

The present study has several strengths. It is the first study that used a well-defined sample with r-BSh classified by clinical interview. To our knowledge, our study is the second (published) study that uses buying-shopping as target behavior in a PIT paradigm and the first that used a devaluation procedure in combination with the PIT paradigm. Generally, there are very few studies on the shift from goal-directed to habitual behavior in behavioral addictions. The devaluation procedure allows dissociation of goal-directed behavior from habitual behavior and was the first time applied to BSD. Also, the present study used a standardized procedure for experimental stress induction which has not been done in BSD research yet (for review see Thomas et al., 2024).

Clinical implications

If further studies are able to replicate these findings and to extend it to people with pathological buying-shopping behaviors, stress coping could be included into therapy, e.g., via psychoeducation (Bhattacharjee et al., 2011; Li et al., 2022), self-observation to detect risky situations, stress management/coping strategies (Linardatou, Parios, Varvogli, Chrousos, & Darviri, 2014; Wölfling et al., 2019) and to ameliorate relapse prevention (Kapetanovic et al., 2023). In the future, PIT mechanisms could be used to better understand treatment outcome as has been done in substance use disorder (Chen et al., 2023; Sekutowicz et al., 2019). The PIT effect itself might also be tackled by approach avoidance trainings (Rosenthal, Chen, Beck, & Romanczuk-Seiferth, 2023) or cognitive bias modification trainings (Chen et al., 2022). Becoming aware of automatic processes could be another relevant part of therapy to be able to counteract habitual behaviors by goal-directed reactions.

CONCLUSIONS

This study provided mixed evidence for a shift from goal-directed to habitual behavior under conditions of stress in persons with risky online buying-shopping behavior. Most preregistered analyses did not show effects in line with the hypotheses. Still, an effect of sCort response on potentially habitual behavior was found. More fine-grained and exploratory analyses showed that the PIT effect after devaluation as potentially habitual behavior was predicted by increased symptom severity of online shopping together with stress responsivity (sCort and subjective stress). The exploratory findings are tentative. If these findings can be replicated, PIT effects and presumably also habitual behaviors might be considered addiction mechanisms that commence even in an early stage of addictive behaviors or risky use respectively, which would highlight the need for prevention strategies/early interventions.

Funding sources: The work of all authors except CJM on this article was carried out in the context of the Research Unit ‘Affective and cognitive mechanisms of specific Internet-use disorders’, FOR2974, funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 411232260.

Authors' contribution: Study concept and design: AM, SSL, MB, OTW, AMS, TAT, SB; Data curation and recruiting participants: TAT, AMS, NE, SB; Preparation of the data: SMM, AMS, TAT; Analysis and interpretation of data: TAT, AMS, SSL, AM; Obtained funding: SSL, AM, MB; Study supervision: AM, SSL; Supervision of salivary sample analysis: CJM; writing – original draft: TAT; writing – review and editing: AM, SSL, AMS, MB, SMM, CJM, SB, OTW, NE. All authors had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflict of interest: The authors declare no conflict of interest. AM, CJM, OTW, SSL and MB have performed grant reviews for research-funding agencies and/or have edited journals and journal sections and/or have given academic lectures in clinical or scientific venues, and/or have generated book chapters for publishers of mental health texts. AM and MB are board members of the International Society for the Studies of Behavioral Addictions. MB is associate editor and AM is editorial board member of the Journal of Behavioral Addictions.

Acknowledgements: We thank Damla Burgac, Tobias Eggert, Ferdinand Gut, Felix Heublein, Eltje Ihle, Jarl Möhring, Insa Prünte, Samuel Sander, Katja Tilk, Antonia Wild, and Zoe Wörner for their support with the TSST. We thank all members of the Research Unit ‘Affective and cognitive mechanisms of specific Internet-use disorders’, FOR2974, for fruitful discussions on our findings and numerous forms of support (e.g., technical support during data collection).

REFERENCES

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596

Antons, S., Müller, S. M., Neumann, P., Müller, A., & Steins-Loeber, S. (2023). Stimuli-specific inhibitory control in disorders due to addictive behaviours: A review of current evidence and discussion of methodological challenges. *Current Addiction Reports*, *10*(4), 749–769. https://doi.org/10.1007/s40429-023-00517-z

Bhattacharjee, D., Rai, A. K., Singh, N. K., Kumar, P., Munda, S. K., & Das, B. (2011). Psychoeducation: A measure to strengthen psychiatric treatment. *Delhi Psychiatry Journal*, *14*(1), 33–39.

Blaine, S. K., & Sinha, R. (2017). Alcohol, stress, and glucocorticoids: From risk to dependence and relapse in alcohol use disorders. *Neuropharmacology*, *122*, 136–147. https://doi.org/10.1016/j.neuropharm.2017.01.037

Brand, M. (2022). Can internet use become addictive? *Science*, *376*(6595), 798–799. https://doi.org/10.1126/science.abn4189

Brand, M., Müller, A., Stark, R., Steins-Loeber, S., Klucken, T., Montag, C., … Wegmann, E. (2021). Addiction research unit: Affective and cognitive mechanisms of specific Internet-use disorders. *Addiction Biology*, *26*(6), e13087. https://doi.org/10.1111/adb.13087

Brand, M., Wegmann, E., Stark, R., Müller, A., Wölfling, K., Robbins, T. W., & Potenza, M. N. (2019). 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. *Neuroscience and Biobehavioral Reviews*, *104*, 1–10. https://doi.org/10.1016/j.neubiorev.2019.06.032

Chen, K., Garbusow, M., Sebold, M., Zech, H. G., Zimmermann, U., & Heinz, A. (2022). Automatic approach behaviors in alcohol dependence: Does a cognitive bias modification training affect

Pavlovian-to-instrumental transfer effects? *Neuropsychobiology*, *81*(5), 387–402. https://doi.org/10.1159/000526805
Chen, K., Schlagenhauf, F., Sebold, M., Kuitunen-Paul, S., Chen, H., Huys, Q. J., … Garbusow, M. (2023). The association of non–drug-related pavlovian-to-instrumental transfer effect in nucleus accumbens with relapse in alcohol dependence: A replication. *Biological Psychiatry*, *93*(6), 558–565. https://doi.org/10.1016/j.biopsych.2022.09.017
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2002). *Applied multiple regression/correlation analysis for the behavioral sciences*. Routledge. https://doi.org/10.4324/9780203774441
Doñamayor, N., Ebrahimi, C., Arndt, V. A., Weiss, F., Schlagenhauf, F., & Endrass, T. (2022). Goal-directed and habitual control in human substance use: State of the art and future directions. *Neuropsychobiology*, *81*(5), 403–417. https://doi.org/10.1159/000527663
Englert, R., Schedlowski, M., Engler, H., Rief, W., Büchel, C., Bingel, U., & Spisak, T. (2023). ALIIAS: Anonymization/pseudonymization with LimeSurvey integration and II-factor authentication for scientific research. *SoftwareX*, *24*, 101522. https://doi.org/10.1016/j.softx.2023.101522
Everitt, B. J., & Robbins, T. W. (2016). Drug addiction: Updating actions to habits to compulsions ten years on. *Annual Review of Psychology*, *67*, 23–50. https://doi.org/10.1146/annurev-psych-122414-033457
Fox, H. C., Keri, L. , B., Peihua, G., & Rajita, S. (2010). Interactive effects of cumulative stress and impulsivity on alcohol consumption. *Alcoholism: Clinical and Experimental Research*, *34*(8), 1376–1385. https://doi.org/10.1111/j.1530-0277.2010.01221.x
Garbusow, M., Ebrahimi, C., Riemerschmid, C., Daldrup, L., Rothkirch, M., Chen, K., … Rapp, M. A. (2022). Pavlovian-to-instrumental transfer across mental disorders: A review. *Neuropsychobiology*, *81*(5), 418–437. https://doi.org/10.1159/000525579
Gillan, C. M., Kosinski, M., Whelan, R., Phelps, E. A., & Daw, N. D. (2016). Characterizing a psychiatric symptom dimension related to deficits in goal-directed control. *ELife*, *5*, e11305. https://doi.org/10.7554/eLife.11305
Goeders, N. E. (2003). The impact of stress on addiction. *European Neuropsychopharmacology*, *13*(6), 435–441. https://doi.org/10.1016/j.euroneuro.2003.08.004
Heinz, A., Beck, A., Halil, M. G., Pilhatsch, M., Smolka, M. N., & Liu, S. (2019). Addiction as learned behavior patterns. *Journal of Clinical Medicine*, *8*(8), 1086. https://doi.org/10.3390/jcm8081086
Het, S., Rohleder, N., Schoofs, D., Kirschbaum, C., & Wolf, O. T. (2009). Neuroendocrine and psychometric evaluation of a placebo version of the 'trier social stress test'. *Psychoneuroendocrinology*, *34*(7), 1075–1086. https://doi.org/10.1016/j.psyneuen.2009.02.008
Hogarth, L. (2018). A critical review of habit theory of drug dependence. In B. Verplanken (Ed.), *The psychology of habit: Theory, mechanisms, change, and contexts* (pp. 325–341). Springer. https://doi.org/10.1007/978-3-319-97529-0_18.
Hogarth, L. (2020). Addiction is driven by excessive goal-directed drug choice under negative affect: Translational critique of habit and compulsion theory. *Neuropsychopharmacology*, *45*(5), 720–735. https://doi.org/10.1038/s41386-020-0600-8
Hogarth, L., Dickinson, A., Hutton, S. B., Elbers, N., & Duka, T. (2006). Drug expectancy is necessary for stimulus control of human attention, instrumental drug-seeking behaviour and subjective pleasure. *Psychopharmacology*, *185*, 495–504. https://doi.org/10.1007/s00213-005-0287-x
Kaess, M., Parzer, P., Mehl, L., Weil, L., Strittmatter, E., Resch, F., & Koenig, J. (2017). Stress vulnerability in male youth with Internet gaming disorder. *Psychoneuroendocrinology*, *77*, 244–251. https://doi.org/10.1016/j.psyneuen.2017.01.008
Kapetanovic, S., Gurdal, S., Einarsson, I., Werner, M., André, F., Håkansson, A., & Claesdotter-Knutsson, E. (2023). Relapse prevention therapy for problem gaming or Internet gaming disorder in Swedish child and youth psychiatric clinics: Protocol for a randomized controlled trial. *JMIR Research Protocols*, *12*, e44318. https://doi.org/10.2196/44318
Király, O., Sleczka, P., Pontes, H. M., Urbán, R., Griffiths, M. D., & Demetrovics, Z. (2017). Validation of the ten-item Internet Gaming Disorder Test (IGDT-10) and evaluation of the nine DSM-5 Internet gaming disorder criteria. *Addictive Behaviors*, *64*, 253–260. https://doi.org/10.1016/j.addbeh.2015.11.005
Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, *28*(1–2), 76–81. https://doi.org/10.1159/000119004
Kudielka, B. M., Hellhammer, D. H., & Kirschbaum, C. (2007). Ten years of research with the trier social stress test–revisited. In E. Harmon-Jones, & P. Winkielman (Eds.), *Social neuroscience: Integrating biological and psychological explanations of social behavior* (pp. 56–83). The Guilford Press.
Labuschagne, I., Grace, C., Rendell, P., Terrett, G., & Heinrichs, M. (2019). An introductory guide to conducting the trier social stress test. *Neuroscience and Biobehavioral Reviews*, *107*, 686–695. https://doi.org/10.1016/j.neubiorev.2019.09.032
Laurent, H. K., Powers, S. I., & Granger, D. A. (2013). Refining the multisystem view of the stress response: Coordination among cortisol, alpha-amylase, and subjective stress in response to relationship conflict. *Physiology & Behavior*, *119*, 52–60. https://doi.org/10.1016/j.physbeh.2013.05.019
Li, H., Gan, X., Li, X., Zhou, T., Jin, X., & Zhu, C. (2022). Diathesis stress or differential susceptibility? Testing the relationship between stressful life events, neuroticism, and internet gaming disorder among Chinese adolescents. *Plos One*, *17*(1), e0263079. https://doi.org/10.1371/journal.pone.0263079
Li, C. S. R., & Sinha, R. (2008). Inhibitory control and emotional stress regulation: Neuroimaging evidence for frontal–limbic dysfunction in psycho-stimulant addiction. *Neuroscience and Biobehavioral Reviews*, *32*(3), 581–597. https://doi.org/10.1016/j.neubiorev.2007.10.003
Linardatou, C., Parios, A., Varvogli, L., Chrousos, G., & Darviri, C. (2014). An 8-week stress management program in pathological gamblers: A pilot randomized controlled trial. *Journal of Psychiatric Research*, *56*, 137–143. https://doi.org/10.1016/j.jpsychires.2014.05.013
Loeber, S., Grosshans, M., Herpertz, S., Kiefer, F., & Herpertz, S. C. (2013). Hunger modulates behavioral disinhibition and

attention allocation to food-associated cues in normal-weight controls. *Appetite*, *71*, 32–39. https://doi.org/10.1016/j.appet.2013.07.008

Lörsch, F., Schmid, A. M., Thomas, T. A., Brand, M., Müller, A., & Steins-Loeber, S. (2025). The effect of individual differences on Pavlovian conditioning in specific Internet-use disorders. *Behavioural Brain Research*, *476*, 115254. https://doi.org/10.1016/j.bbr.2024.115254

McCaul, M. E., Wand, G. S., Weerts, E. M., & Xu, X. (2018). A paradigm for examining stress effects on alcohol-motivated behaviors in participants with alcohol use disorder. *Addiction Biology*, *23*(2), 836–845. https://doi.org/10.1111/adb.12511

Mestre-Bach, G., Steward, T., Jiménez-Murcia, S., & Fernández-Aranda, F. (2017). Differences and similarities between compulsive buying and other addictive behaviors. *Current Addiction Reports*, *4*, 228–236. https://doi.org/10.1007/s40429-017-0153-z

Meule, A., Vögele, C., & Kübler, A. (2011). Psychometrische Evaluation der deutschen Barratt Impulsiveness Scale – Kurzversion (BIS-15). [Psychometric evaluation of the German Barratt Impulsiveness Scale – Short Version (BIS-15)]. *Diagnostica*, *57*(3), 126–133. https://doi.org/10.1026/0012-1924/a000042

Milivojevic, V., & Sinha, R. (2018). Central and peripheral biomarkers of stress response for addiction risk and relapse vulnerability. *Trends in Molecular Medicine*, *24*(2), 173–186. https://doi.org/10.1016/j.molmed.2017.12.010

Miller, R., Plessow, F., Kirschbaum, C., & Stalder, T. (2013). Classification criteria for distinguishing cortisol responders from nonresponders to psychosocial stress: Evaluation of salivary cortisol pulse detection in panel designs. *Psychosomatic Medicine*, *75*(9), 832–840. https://doi.org/10.1097/PSY.0000000000000002

Müller, S. M., Antons, S., Schmid, A. M., Thomas, T. A., Kessling, A., Joshi, M., … Brand, M. (2025). Self-control abilities in specific types of problematic usage of the Internet: Findings from clinically validated samples with neurocognitive tasks. *American Journal of Psychiatry*, *182*(7), 660–670. https://doi.org/10.1176/appi.ajp.20240486

Müller, A., Joshi, M., & Thomas, T. A. (2022). Excessive shopping on the internet: Recent trends in compulsive buying-shopping disorder. *Current Opinion in Behavioral Sciences*, *44*, 101116. https://doi.org/10.1016/j.cobeha.2022.101116

Müller, A., Trotzke, P., Mitchell, J. E., Zwaan, M. de, & Brand, M. (2015). The Pathological Buying Screener: Development and psychometric properties of a new screening instrument for the assessment of pathological buying symptoms. *Plos One*, *10*(10), e0141094. https://doi.org/10.1371/journal.pone.0141094

Müller, K. W., & Wölfling, K. (2018). *AICA-SKI:IBS. Strukturiertes klinisches Interview zu internetbezogenen Störungen. Benutzerhandbuch.* [Structured clinical interview on Internet-use disorders. User manual]. https://www.fv-medienabhaengigkeit.de/fileadmin/images/Dateien/AICA-SKI_IBS/Handbuch_AICA-SKI_IBS.pdf.

Müller, S. M., Wegmann, E., Oelker, A., Stark, R., Müller, A., Montag, C., … Brand, M. (2022). 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. *Journal of Behavioral Addictions*, *11*(2), 427–450. https://doi.org/10.1556/2006.2022.00013

Qin, C., Feng, S., Chen, Y., Liao, X., Cheng, X., Tian, M., … Lei, W. (2023). Enhanced Pavlovian-to-instrumental transfer in Internet gaming disorder. *Journal of Behavioral Addictions*, *12*(2), 471–479. https://doi.org/10.1556/2006.2023.00023

R Core Team (2024). *R: A language and environment for statistical computing*. https://www.R-project.org/.

Roozendaal, B. (2002). Stress and memory: Opposing effects of glucocorticoids on memory consolidation and memory retrieval. *Neurobiology of Learning and Memory*, *78*(3), 578–595. https://doi.org/10.1006/nlme.2002.4080

Rosenthal, A., Chen, K., Beck, A., & Romanczuk-Seiferth, N. (2023). Modifying pavlovian-to-instrumental transfer by approach avoidance training in healthy subjects: A proof of concept study. *Scientific Reports*, *13*(1), 10074. https://doi.org/10.1038/s41598-023-37083-3

Schmid, A. M., Thomas, T. A., Blümel, S., Erdal, N. K., Müller, S. M., Merz, C. J., … Steins-Loeber, S. (2024). Transfer from goal-directed behavior to stimulus-response habits and its modulation by acute stress in individuals with risky gaming behavior. *Scientific Reports*, *14*(1), 26015. https://doi.org/10.1038/s41598-024-73899-3

Schulz, P., & Schlotz, W. (1999). Trierer Inventar zur Erfassung von chronischem Stress (TICS): Skalenkonstruktion, teststatistische Überprüfung und Validierung der Skala Arbeitsüberlastung. [The Trier Inventory for the Assessment of Chronic Stress (TICS). Scale construction, statistical testing, and validation of the scale work overload]. *Diagnostica*, *45*(1), 8–19. https://doi.org/10.1026//0012-1924.45.1.8

Schwabe, L., Dickinson, A., & Wolf, O. T. (2011). Stress, habits, and drug addiction: A psychoneuroendocrinological perspective. *Experimental and Clinical Psychopharmacology*, *19*(1), 53–63. https://doi.org/10.1037/a0022212

Schwabe, L., Haddad, L., & Schachinger, H. (2008). HPA axis activation by a socially evaluated cold-pressor test. *Psychoneuroendocrinology*, *33*(6), 890–895. https://doi.org/10.1016/j.psyneuen.2008.03.001

Schwabe, L., Joëls, M., Roozendaal, B., Wolf, O. T., & Oitzl, M. S. (2012). Stress effects on memory: An update and integration. *Neuroscience and Biobehavioral Reviews*, *36*(7), 1740–1749. https://doi.org/10.1016/j.neubiorev.2011.07.002

Schwabe, L., & Wolf, O. T. (2009). Stress prompts habit behavior in humans. *The Journal of Neuroscience*, *29*(22), 7191–7198. https://doi.org/10.1523/JNEUROSCI.0979-09.2009

Schwabe, L., & Wolf, O. T. (2010). Socially evaluated cold pressor stress after instrumental learning favors habits over goal-directed action. *Psychoneuroendocrinology*, *35*(7), 977–986. https://doi.org/10.1016/j.psyneuen.2009.12.010

Sekutowicz, M., Guggenmos, M., Kuitunen-Paul, S., Garbusow, M., Sebold, M., Pelz, P., … Schmack, K. (2019). Neural response patterns during Pavlovian-to-instrumental transfer predict alcohol relapse and young adult drinking. *Biological Psychiatry*, *86*(11), 857–863. https://doi.org/10.1016/j.biopsych.2019.06.028

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience and Biobehavioral Reviews*, *68*, 651–668. https://doi.org/10.1016/j.neubiorev.2016.06.038

Sinha, R. (2001). How does stress increase risk of drug abuse and relapse? *Psychopharmacology*, *158*(4), 343–359. https://doi.org/10.1007/s002130100917

Sinha, R. (2008). Chronic stress, drug use, and vulnerability to addiction. *Annals of the New York Academy of Sciences*, *1141*, 105–130. https://doi.org/10.1196/annals.1441.030

Steins-Loeber, S., Lörsch, F., van der Velde, C., Müller, A., Brand, M., Duka, T., & Wolf, O. T. (2020). Does acute stress influence the pavlovian-to-instrumental transfer effect? Implications for substance use disorders. *Psychopharmacology*, *237*(8), 2305–2316. https://doi.org/10.1007/s00213-020-05534-8

Tang, C. S. K., Chua, Z., & Wu, A. (2011). Impulsivity, life stress, refusal efficacy, and problem gambling among Chinese: Testing the diathesis-stress-coping model. *International Journal of Stress Management*, *18*(3), 263. https://psycnet.apa.org/doi/10.1037/a0023812.

Thomas, T. A., Schmid, A. M., Kessling, A., Wolf, O. T., Brand, M., Steins-Loeber, S., & Müller, A. (2024). Stress and compulsive buying-shopping disorder: A scoping review. *Comprehensive Psychiatry*, *132*, 152482. https://doi.org/10.1016/j.comppsych.2024.152482

Trotzke, P., Starcke, K., Pedersen, A., & Brand, M. (2021). Dorsal and ventral striatum activity in individuals with buying-shopping disorder during cue-exposure: A functional magnetic resonance imaging study. *Addiction Biology*, *26*(6), e13073. https://doi.org/10.1111/adb.13073

van Timmeren, T., Piray, P., Goudriaan, A. E., & van Holst, R. J. (2023). Goal-directed and habitual decision making under stress in gambling disorder: An fMRI study. *Addictive Behaviors*, *140*, 107628. https://doi.org/10.1016/j.addbeh.2023.107628

Verplanken, B., & Orbell, S. (2003). Reflections on past behavior: A self-report index of habit strength. *Journal of Applied Social Psychology*, *33*(6), 1313–1330. https://doi.org/10.1111/j.1559-1816.2003.tb01951.x

Vogel, V., Kollei, I., Duka, T., Snagowski, J., Brand, M., Müller, A., & Loeber, S. (2018). Pavlovian-to-instrumental transfer: A new paradigm to assess pathological mechanisms with regard to the use of internet applications. *Behavioural Brain Research*, *347*, 8–16. https://doi.org/10.1016/j.bbr.2018.03.009

Vogt, S., Hunger, A., Türpe, T., Pietrowsky, R., & Gerlach, A. L. (2014). Effects of mood induction on consumers with vs. without compulsive buying propensity: An experimental study. *Psychiatry Research*, *220*(1–2), 342–347. https://doi.org/10.1016/j.psychres.2014.06.014

Voon, V., Derbyshire, K., Rück, C., Irvine, M. A., Worbe, Y., Enander, J., … Bullmore, E. T. (2015). Disorders of compulsivity: A common bias towards learning habits. *Molecular Psychiatry*, *20*(3), 345–352. https://doi.org/10.1038/mp.2014.44

Wemm, S. E., Cao, Z., Han, L., & Wulfert, E. (2020). Stress responding and stress-related changes in cue reactivity in heavy smokers, problem gamblers, and healthy controls. *Addiction Biology*, *25*(2), e12687. https://doi.org/10.1111/adb.12687

Wemm, S. E., & Sinha, R. (2019). Drug-induced stress responses and addiction risk and relapse. *Neurobiology of Stress*, *10*, 100148. https://doi.org/10.1016/j.ynstr.2019.100148

Wölfling, K., Müller, K. W., Dreier, M., Ruckes, C., Deuster, O., Batra, A., & Beutel, M. E. (2019). Efficacy of short-term treatment of internet and computer game addiction: A randomized clinical trial. *JAMA Psychiatry*, *76*(10), 1018–1025. https://doi.org/10.1001/jamapsychiatry.2019.1676

Wyckmans, F., Banerjee, N., Saeremans, M., Otto, R., Kornreich, C., Vanderijst, L., … Noël, X. (2022). The modulation of acute stress on model-free and model-based reinforcement learning in gambling disorder. *Journal of Behavioral Addictions*, *11*(3), 831–844. https://doi.org/10.1556/2006.2022.00059

Wyckmans, F., Otto, A. R., Sebold, M., Daw, N., Bechara, A., Saeremans, M., … Noël, X. (2019). Reduced model-based decision-making in gambling disorder. *Scientific Reports*, *9*(1), 19625. https://doi.org/10.1038/s41598-019-56161-z

Zhou, W., Zheng, H., Wang, M., Zheng, Y., Chen, S., Wang, M.-J., & Dong, G.-H. (2021). The imbalance between goal-directed and habitual systems in Internet gaming disorder: Results from the disturbed thalamocortical communications. *Journal of Psychiatric Research*, *134*, 121–128. https://doi.org/10.1016/j.jpsychires.2020.12.058