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Cue-reactivity to distal cues in individuals at risk for gaming disorder

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ABSTRACT

Background: Gaming disorder (GD) is a disorder due to addictive behaviors (ICD-11). Cue-reactivity and craving are relevant mechanisms in the development and maintenance of addictive behaviors. When confronted with cues showing in-game content (proximal cues) individuals with higher symptom severity show increased cue-reactivity. Based on conditioning and addiction theories on incentive sensitization, cue-reactivity responses may generalize to more distal cues, e.g. when individuals at risk of developing a GD are confronted with a starting page of an online game. In cue-reactivity paradigms so far, only proximal gaming cues have been used.
Methods: We investigated the effect of distal gaming cues compared to gaming-unrelated control cues on cue-reactivity and craving in 88 individuals with non-problematic use of online games (nPGU) and 69 individuals at risk for GD (rGD). The distal cues showed the use of an electronic device (e.g., desktop PC or smartphone) whose screen showed starting pages of either games (target cues), shopping- or pornography sites (control cues) from a first-person perspective.
Findings: We found significantly higher urge and arousal ratings as well as longer viewing times for gaming-related compared to gaming-unrelated control cues in rGD compared to nPGU. Valence ratings did not differ between groups.
Interpretation: The results demonstrate that already distal gaming-specific cues lead to cue-reactivity and craving in rGD. This finding indicates that based on conditioning processes, cue-reactivity and craving develop during the course of GD and generalize to cues that are only moderately related to the specific gaming activity.

1. Introduction

Gaming disorder (GD) refers to the addictive use of (online) games and has been identified as clinically relevant entity classified within the category of 'disorders due to addictive behaviors' in the eleventh revision of the International Classification of Diseases [1]. Disorders due to addictive behaviors, such as GD and gambling disorder, share similarities with substance-use disorders. In both, substance and behavioral addiction research, cue-reactivity and craving are considered core mechanisms that contribute to the development and maintenance of addictive behaviors [2–5].

In the Interaction of Person-Affect-Cognition-Execution (I-PACE) model [6] cue-reactivity and craving are considered processes of the so-called inner circle, which represents affective and cognitive mechanisms. Cue-reactivity results from conditioning processes that occur when individuals frequently engage in a specific behavior that is

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perceived as rewarding [7,8]. Due to associative learning, previously neutral stimuli become associated with the specific behavior and the experienced reward and act as conditioned stimuli. Cue-reactivity describes the automatic physiological, emotional, and cognitive responses towards these conditioned stimuli [6,9,10]. In addictive behaviors, one response pattern resulting from cue-reactivity can be craving, which is described as urges to use a substance or to engage in a specific behavior that are difficult to resist [7,11]. During the course of addictive disorders and based on reinforcing mechanisms, cue-reactivity responses may become more frequent or occur more reliably. In particular, individuals vulnerable for developing an addictive behavior may be more prone to develop cue-reactivity and craving (e.g., due to dysfunctions within the dopaminergic reward system [12–14]) resulting in higher engagement in the behavior. Cue-reactivity and craving have been associated with diminished control over behavioral engagement [15,16], reduced treatment outcomes and increased risk of relapses [15,17,18]. On a neural level, the striatum as part of the mesolimbic reward system is involved in the process of cue-reactivity and craving. It seems that the ventral striatum is involved in cue-reactivity, especially in early stages of addictive behaviors, and that the dorsal striatum is probably additionally involved in later stages [2,10]. These changes in neural process may represent the shift from reward-driven behaviors to compulsive behaviors [19–23].

Previous studies on substance-use disorders have shown that not only proximal stimuli showing the substance (e.g., images showing alcoholic beverages) but also stimuli that are more distal to the behavior engagement (e.g., stimuli from the broader environment, like the entrance to a pub) can become conditioned cues [24]. Distal cues are less closely associated with the behavior as they might only be present for a short time or they might not always be present when engaging in the behavior. They could also be less explicit or related to the reward than proximal cues. However, these more unspecific cues may frequently occur in the natural environment like a keyboard, or might be relevant particularly before an individual is confronted with proximal/more explicit stimuli (e.g., starting pages of games). Proximal and distal stimuli can be conceptualized on a continuum from stimuli showing explicitly the rewarding content (proximal stimuli) to stimuli showing content that is less frequently or intensively associated with the rewarding content (distal stimuli). It can be assumed that conditioning processes with more proximal stimuli compared to more distal stimuli may appear faster and may result in more reliable cue-outcome associations, while cue-outcome associations for distal cues may develop more slowly. However, the development of cue-reactivity towards more distal cues can be catalyzed if individuals are highly sensitive to these cue-outcome associations (incentive sensitization) [13,14]. Therefore, it is highly relevant to better understand if such more distal cues indicating a potential starting point for a specific behavior can also trigger cue-reactivity and craving responses in gaming disorder and other addictive behaviors.

In behavioral addiction research, cue-reactivity and cue-triggered craving responses have been consistently identified as relevant mechanisms in GD [25–28], gambling disorder [29–32], compulsive sexual behaviors [33,34], problematic pornography use [35], compulsive buying-shopping disorder [36,37], and problematic social network use [38–41].

In GD, so far only proximal cues (showing game-related content) have been investigated that were either game specific (League of Legends, StarCraft, World of Warcraft) [26,42–57], individualized for the specific game preference [27,58–61], or they showed game-related contents but were not matched to the games participants were familiar with or individualized to the participants [28,49,62,63]. To our knowledge, there are no studies investigating more distal gaming cues (e.g., starting pages of online games). A better understanding of cue-reactivity mechanisms including the responses towards more distal cues might be important for the understanding of the underlying processes of the development and maintenance of GD and the treatment of patients, especially when it comes to real life situations in which patients are exposed to stimuli related to their problematic behavior before engaging in gaming. In addition, the use of more distal cues may have the advantage to differentiate between mechanisms of reward experience and cue-reactivity as the stimuli do not show the explicit rewarding content [c.f. 64].

In the study presented here, we focus on individuals at risk for GD (rGD). This group of individuals can be assumed to represent the early stages of the addiction circle where cue-reactivity and craving are assumed to develop [6]. Comparing individuals with rGD and those with non-problematic use of online games (nPGU) may provide insights into early processes of addiction and may help understand if already in these early stages cue-reactivity and craving to more distal cues could take place. We hypothesize higher subjective craving reactions within a cue-reactivity paradigm using distal cues in individuals with rGD compared to individuals with nPGU.

2. Material and methods

2.1. Participants and clinical assessment

Participants were recruited from the general population at a) the Department of Clinical Psychology and Psychotherapy, Otto-Friedrich University of Bamberg, b) the Department of Psychosomatic Medicine and Psychotherapy, Hannover Medical School, c) Psychotherapy and Systems Neuroscience, Justus Liebig University Giessen, and d) the Department of Psychosomatic Medicine and Psychotherapy, LWL University Hospital, Ruhr University Bochum as part of a larger ongoing project [65]. A structured clinical interview and a screening instrument ('Assessment of Criteria for Specific Internet-use Disorders', ACSID-11, see chapter 2.2 for detailed description) were used to identify groups of nPGU and rGD. The study procedures were carried out in accordance with the Declaration of Helsinki. The Institutional Review Boards of the Otto-Friedrich University of Bamberg (2019–12/33; 18.12.2019), Hannover Medical School (9025_BO_K_2020; 17.04.2020), Justus Liebig University Giessen (2019–0033; 06.02.2020), and the Medical Faculty of the Ruhr University Bochum (19–6759; 26.11.2019) approved the study. All subjects were informed about the study and all provided informed consent.

We included 88 nPGU (age: 24.71 ± 4.0 years, 9 women, 1 other) and 69 rGD (age: 24.48 ± 5.1 years, 4 women). Age ($t(154) = 0.323$, $p = .747$) and sex ($\chi 2(2) = 1.832$, $p = .400$) were not different between the groups. Symptom scores of the clinical interview (nPGU: 0.3 ± 0.4, rGD: 3.2 ± 1.1, ($t(155) = -21.637$, $p < .001$)), ASCID-11 scores (nPGU: 0.2 ± 0.5, rGD: 0.9 ± 1.1, ($t(151) = -5.483$, $p < .001$)), as well as the mean daily use time of gaming (nPGU: 109 ± 83 min/day, rGD: 221 ± 116 min/day, ($t(154) = -7.053$, $p < .001$)) were significantly different between groups with higher values in the rGD compared to the nPGU (see next section for detailed description of assignment to groups and symptom scores).

2.2. Psychometric assessment

Participants underwent a structured diagnostic clinical interview assessing the diagnostic criteria (DSM-5) for GD (based on [66]). Criteria were: (1) preoccupation, prioritization, craving; (2) loss of interest on other behaviors than gaming; (3) unsuccessful attempts of abstinence, loss of control; (4) game engagement despite experiencing negative consequences; (5) tolerance; (6) symptoms of withdrawal; (7) emotion regulation; (8) hiding, deception; (9) loss of important relations or future perspectives. For the current analysis focusing on nPGU and rGD, participants with values of 0–1 were allocated in the non-problematic group, and participants with values of 2–4 in the risky group. Participants with a value of 5 or above 5 were excluded.

For a dimensional approach we also used the 11-item 'Assessment of

Criteria for Specific Internet-use Disorders' (ACSID-11) based on the ICD-11 diagnostic criteria for GD, which measures five behavioral addictions with the same set of items ensuring comparability between different specific Internet-use disorders [67]. Each item is answered on two 4-point Likert scales (frequency: "never" to "often" and intensity: "not intense" to "intense"). The scores are dichotomized with the final sum score reflecting the number of fulfilled criteria (possible range: 0–4).

For the assessment of craving we used the 'Craving Assessment Scale for Behavioral Addictions' (CASBA) with respect to gaming and pornography or shopping [68,69]. The CASBA consists of nine items assessing reward craving (e.g., "Gaming now, would give me satisfaction"), relief craving (e.g., "Gaming now, would make me less stressed."), and obsessive craving (e.g., "Gaming now, is the most urgent thing I want to do."). All items are rated on a 5-point Likert scale (1 "completely disagree" to 5 "completely agree") resulting in a sum-score of 9–45. The CASBA has been used in previous studies for gaming, pornography, and online-shopping [68–71].

2.3. Experimental paradigm: cue-reactivity and craving assessment

The cue-reactivity paradigm included visual stimuli (pictures) of Internet applications, which were presented with the Presentation software (Neurobehavioral Systems Inc., Berkley, CA, USA). The pornographic stimuli have been used in a preliminary study [72]. Distal cues were pictures showing, from a first-person perspective, a person (male or female depending on the gender of the participant) using a mobile (Tablet, Mobile Phone) or non-mobile (Desktop PC, Laptop) device on which an Internet site was called up. The Internet sites for the gaming cues (target cues) showed log-in pages or starting-pages of web-representations of twelve games (i.e., Overwatch, Minecraft, League of Legends, Battlefield V, Counter Strike Global Offensive, Call of Duty, Grand Theft Auto V, Player Unknown's Battlegrounds, Dota 2, Fortnite, World of Warcraft, Hearthstone). For non-gaming related control cues, images from log-in pages or starting pages of pornography or shopping sites were used (see supplementary for list of contents). Accordingly, in contrast to proximal cues, the used distal cues did not include explicit gaming or pornography/shopping content (see Fig. 1). Before starting the cue-reactivity task, participants were asked to choose two of the four devices, based on the devices they usually use (or would preferably use) for gaming. As the study was a part of a larger study on multiple sites with different control groups, for one group of participants' pornography-related distal cues were used as control cues ($n = 58$), and for the other group, shopping-related distal cues ($n = 99$) were used as control cues. The cues were presented in four blocks each consisting of twelve pictures of one category in the following order: (1) gaming (2) shopping/pornography (3) gaming (4) shopping/pornography (see Fig. 1).

The paradigm involved craving measures at three different levels: (1) Picture level: Each picture was evaluated with respect to valence, arousal, and urge to use the specific application shown at the picture i.e., games or shopping sites/pornography (as a measure for craving) on a 5-point Likert scale from 1 'no urge at all' to 5 'very strong urge', as has been done in previous studies (e.g., [73,74]). (2) Block level: As baseline before the experiment and after each block consisting of twelve pictures (twelve gaming related pictures or twelve control pictures i.e., shopping or pornography), participants were asked to indicate their current overall craving with respect to both target behavior (i.e., gaming) and control behavior (i.e., pornography or shopping) in randomized order on a visual analogue scale (VAS) ranging from 0 'no urge at all' to 10 'very strong urge respectively. The two craving ratings (craving to game, craving to shop/use pornography) for the two blocks on the same picture category were averaged resulting in a mean 'post gaming' craving rating and mean 'post control' condition craving rating for each picture category (gaming and shopping/pornography). (3) Task level: Before the cue-reactivity paradigm and directly after the cue-reactivity paradigm, the participants were asked to answer the questions of the CASBA with respect to gaming (CASBA_gaming).

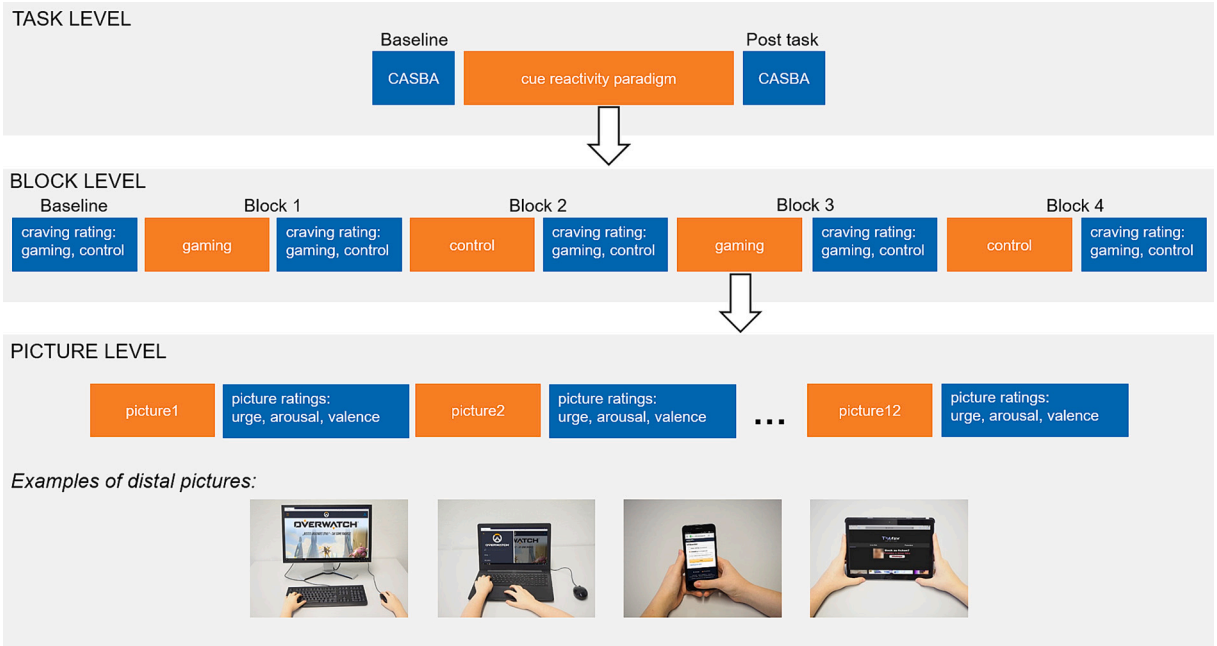

Fig. 1. Experimental paradigm: the paradigm involved cue-reactivity and craving measures at three different levels: (1) task level: before the cue-reactivity paradigm and directly after the cue-reactivity paradigm, the participants were asked to answer the questions of the CASBA with respect to gaming (2) block level: as baseline before the experiment and after each block consisting of twelve pictures, participants were asked to indicate their current overall craving with respect to both gaming and control (pornography or shopping) (3) picture level: each picture was evaluated with respect to valence, arousal, and urge to use the specific application shown at the picture. Additionally, examples of distal cues used in the cue-reactivity paradigm were shown. Starting pages of online games, pornographic sites and shopping sites are depicted on the four possible devices (Desktop PC, Laptop, Tablet, Mobile Phone).

2.4. Data analysis

Age and clinical questionnaire scores were compared between groups with *t*-tests for independent samples; sex distributions were compared with the chi^2 test.

At picture level, the urge to use the specific application, arousal, and valence of the cues, as well as the viewing times were compared with a repeated measures ANOVA with group (nPGU, rGD) as between subject factor and cue type (gaming, control) as within subject factor.

At block level, baseline craving and the mean of the urge gaming or control ratings after each block of the cue-reactivity task were compared with a mixed ANOVA with group (nPGU, rGD) as between-subjects factor and behavior (gaming, control) as well as time (baseline, gaming blocks, control blocks) as within-subjects factor.

At task level, we compared the CASBA_gaming scores at baseline and after the experimental paradigm between the two groups using a mixed ANOVA with group (nPGU, rGD) as between-subjects factor and time (baseline, post task) as within-subjects factor.

As participants at different sites were confronted with different types of control stimuli (either shopping or pornography), the same analyses were repeated separately for each type of control cues (see supplemental material).

The level of significance was set at $p < .05$. Partial η^2 is reported. Statistical analysis was conducted with IBM® SPSS® Statistics 27 (Chicago, IL, USA).

3. Results

3.1. Cue ratings and viewing time at picture level

For urge to use the specific application, we found a significant effect for cue type ($F(1, 155) = 17.342$; $p < .001$; $\eta^2 = 0.101$) with higher ratings for gaming compared to control cues (see Table 1), and a significant interaction of cue type x group ($F(1, 155) = 8.517$; $p = .004$; $\eta^2 = 0.052$), but no significant effect for group ($F(1, 155) = 3.147$; $p = .078$; $\eta^2 = 0.020$). Post-hoc pairwise comparisons revealed that only in rGD urge to game was higher when gaming cues were presented compared to the urge to shop or use pornography when control cues were presented ($t(68) = 4.519$; $p < .001$) (see Fig. 2a).

For arousal, we found significant effects of cue type ($F(1, 155) = 18.377$; $p < .001$; $\eta^2 = 0.106$) with higher ratings for gaming compared to control cues, of group ($F(1, 155) = 6.860$; $p = .010$; $\eta^2 = 0.042$) with higher ratings in rGD compared to nPGU, and of the interaction between cue type x group ($F(1, 155) = 6.302$; $p = .013$; $\eta^2 = 0.039$). Post-hoc tests revealed that only in rGD arousal was higher in gaming compared to control cues ($t(68) = 4.617$; $p < .001$).

For valence, we found a significant interaction of cue type x group ($F(1, 155) = 4.296$; $p = .040$; $\eta^2 = 0.027$), but no significant effect of cue type ($F(1, 155) = 2.535$; $p = .127$; $\eta^2 = 0.015$), or group ($F(1, 155) = 2.137$; $p = .146$; $\eta^2 = 0.014$).

For viewing time, we found a significant effect of cue type ($F(1, 155) = 28.688$; $p < .001$; $\eta^2 = 0.156$) with higher viewing times for gaming compared to control cues. However, there was no significant effect of group ($F(1, 155) = 3.239$; $p = .074$; $\eta^2 = 0.020$), or interaction of cue type x group ($F(1, 155) = 1.545$; $p = .216$; $\eta^2 = 0.010$). Post-hoc tests revealed that in both rGD ($t(68) = 5.685$; $p < .001$) and nPGU ($t(87) = 2.708$; $p = .008$) viewing time was higher for gaming cues compared to control cues (see Fig. 2b).

3.2. Craving ratings at block and task levels

At block level, for the craving ratings at baseline, post-control blocks and post-gaming blocks (averaged across the two blocks of the same image category) we found significant main effects of group ($F(1, 155) = 7.607$; $p = .007$; $\eta^2 = 0.047$) with higher craving ratings in rGD compared to nPGU, of behavior ($F(1, 155) = 92.143$; $p < .001$; $\eta^2 =$

Table 1
Descriptive data for individuals with non-problematic Gaming Use (nPGU) and individuals at risk for Gaming Disorder (rGD): Overall data and subgroups depending on the control cue (shopping/pornography).

	nPGU m ± std	rGD m ± std
Picture level		
Cue ratings [a]		
Gaming picture: gaming urge		
Overall	1.66 ± 0.58	1.99 ± 0.74
Shopping	1.65 ± 0.55	1.92 ± 0.71
Pornography	1.67 ± 0.62	2.18 ± 0.81
Control picture: control urge		
Overall	1.59 ± 0.73	1.58 ± 0.64
Shopping	1.55 ± 0.60	1.56 ± 0.55
Pornography	1.63 ± 0.87	1.63 ± 0.86
Gaming picture: arousal		
Overall	1.84 ± 0.67	2.24 ± 0.70
Shopping	1.86 ± 0.65	2.20 ± 0.68
Pornography	1.82 ± 0.70	2.35 ± 0.76
Control picture: arousal		
Overall	1.74 ± 0.75	1.87 ± 0.67
Shopping	1.76 ± 0.67	1.82 ± 0.62
Pornography	1.73 ± 0.85	2.01 ± 0.81
Gaming picture: valence		
Overall	2.82 ± 0.53	3.02 ± 0.53
Shopping	2.89 ± 0.43	3.05 ± 0.55
Pornography	2.73 ± 0.62	2.98 ± 0.48
Control picture: valence		
Overall	2.84 ± 0.62	2.86 ± 0.56
Shopping	3.03 ± 0.41	2.92 ± 0.53
Pornography	2.61 ± 0.74	2.72 ± 0.65
Gaming picture: viewing time in s		
Overall	2.52 ± 1.19	2.90 ± 1.00
Shopping	2.84 ± 1.30	3.07 ± 1.03
Pornography	2.14 ± 0.92	2.42 ± 0.76
Control picture: viewing time in s		
Overall	2.22 ± 1.11	2.42 ± 0.97
Shopping	2.21 ± 1.07	2.39 ± 1.02
Pornography	2.24 ± 1.16	2.50 ± 0.83
Block level		
Gaming craving [b]: baseline		
Overall	2.30 ± 2.02	3.91 ± 2.45
Shopping	2.29 ± 1.98	3.61 ± 2.50
Pornography	2.30 ± 2.09	4.78 ± 2.13
Gaming craving [b]: post gaming		
Overall	2.53 ± 2.24	4.38 ± 2.63
Shopping	2.54 ± 2.06	4.09 ± 2.75
Pornography	2.51 ± 2.46	5.19 ± 2.15
Gaming craving [b]: post control		
Overall	2.39 ± 2.20	3.91 ± 2.50
Shopping	2.41 ± 1.97	3.71 ± 2.63
Pornography	2.38 ± 2.47	4.50 ± 2.06
Control craving [b]: baseline		
Overall	1.28 ± 1.81	1.14 ± 1.64
Shopping	1.00 ± 1.49	1.08 ± 1.49
Pornography	1.63 ± 2.11	1.33 ± 2.03
Control craving [b]: post control		
Overall	1.82 ± 2.17	1.67 ± 1.95
Shopping	1.74 ± 1.84	1.58 ± 1.77
Pornography	1.93 ± 2.52	1.94 ± 2.42
Control craving [b]: post gaming		
Overall	1.45 ± 1.98	1.11 ± 1.57
Shopping	1.25 ± 1.59	1.08 ± 1.47
Pornography	1.70 ± 2.37	1.19 ± 1.87
Task level: CASBA_gaming		
Baseline	8.68 ± 5.93	16.01 ± 7.67
Shopping	9.23 ± 5.62	15.00 ± 7.50
Pornography	8.03 ± 6.28	18.89 ± 7.62
Post task	7.98 ± 6.37	15.55 ± 8.66
Shopping	8.38 ± 5.93	14.12 ± 8.40
Pornography	7.50 ± 6.90	19.61 ± 8.28

[a] 5-point Likert scale with the anchors no and very strong.
[b] rating on visual analogue scale between 0 = no urge and 10 = very strong urge to use application.

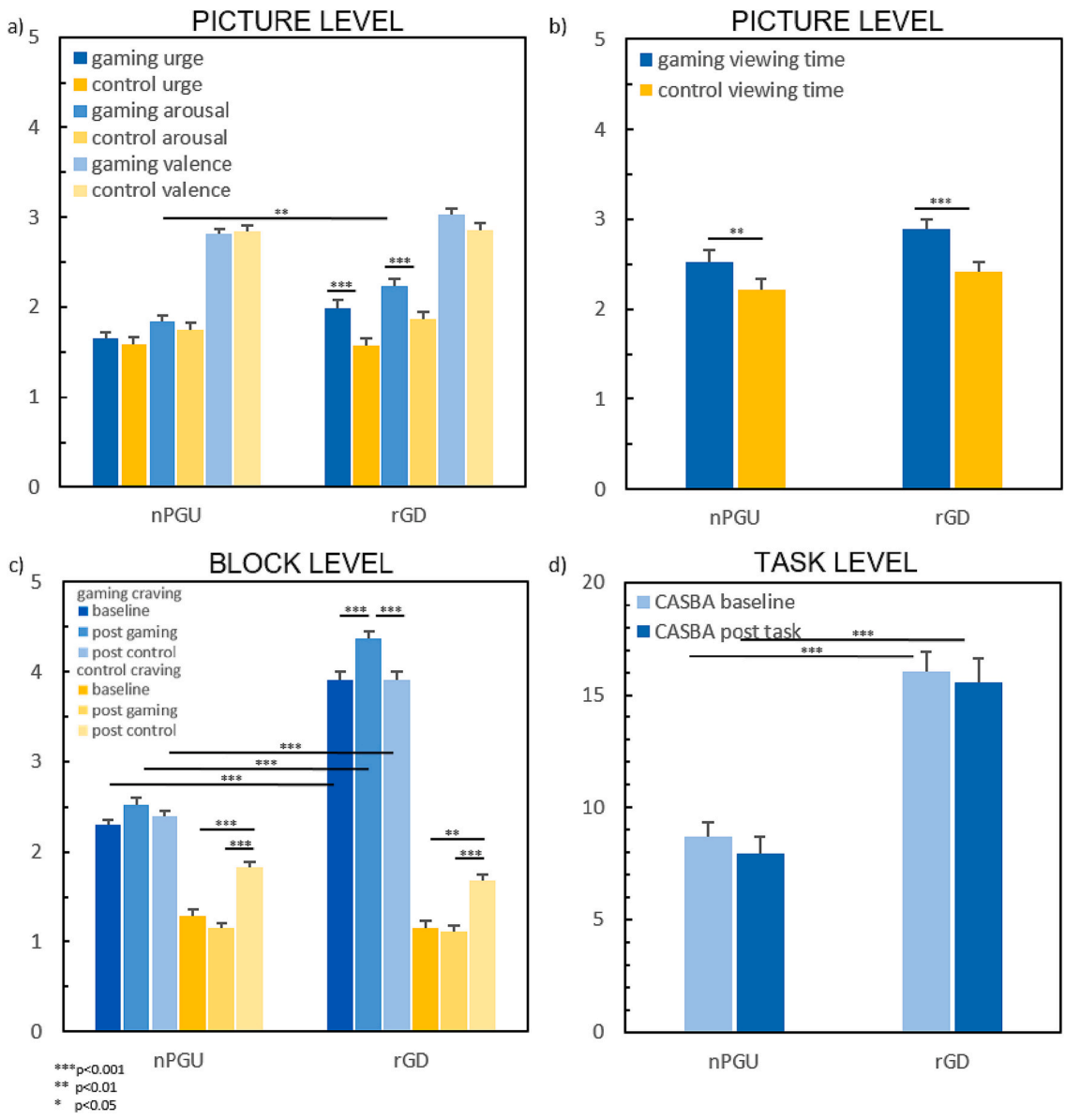

Fig. 2. Behavioral data for individuals with non-problematic Gaming Use (nPGU) and individuals at risk for Gaming Disorder (rGD): a) picture level: urge to use gaming, arousal, and valence ratings for gaming and control cues (5-point Likert scale with the anchors no and very strong), b) picture level: viewing times for target and control cues in s, c) block level: baseline and post task craving ratings for target and control cues (rating between 0 = no urge and 10 = very strong urge to use application), d) task level: CASBA_gaming baseline and post task ratings.

0.373) with higher craving ratings for gaming compared to control behavior, of time ($F(2,310) = 11.255$; $p \leq .001$; $\eta^2 = 0.068$) with higher craving ratings post-task compared to baseline. Furthermore, the interaction effects of behavior x group ($F(1, 155) = 24.383$; $p < .001$; $\eta^2 = 0.136$) and behavior x time ($F(2, 310) = 19.165$; $p < .001$; $\eta^2 = 0.110$) were significant. The interactions time x group ($F(2, 310) = 0.153$; $p = .858$; $\eta^2 = 0.001$) and the three-way interaction behavior x time x group ($F(2, 310) = 2.504$; $p = .083$; $\eta^2 = 0.016$) were not significant (see Fig. 2c). Post-hoc tests revealed that craving for gaming was higher in rGD compared to nPGU (baseline: $t(155) = -4.538$; $p < .001$; post-gaming blocks: $t(155) = -4.747$; $p < .001$; post-control blocks: $t(155) = -4.047$; $p < .001$). In nPGU, the craving ratings for the control behavior increased from baseline to control blocks ($t(87) = -4.125$; $p < .001$), and from gaming blocks to control blocks ($t(87) = -4.163$; $p < .001$). In rGD, the craving ratings for gaming behavior increased from baseline to gaming blocks ($t(68) = -2.688$; $p = .009$), and from control blocks to gaming blocks ($t(68) = 4.651$; $p < .001$). The craving rating for the control behavior increased from baseline to control blocks ($t(68) = -3.063$; $p = .003$), and from gaming blocks to control blocks ($t(68) = -6.087$; $p < .001$).

At task level, for the CASBA_gaming we found a significant main effect of group ($F(1, 155) = 46.322$; $p < .001$; $\eta^2 = 0.230$) with higher values for rGD compared to nPGU. Time (baseline and post-task; $F(1, 155) = 3.133$; $p = .079$; $\eta^2 = 0.020$) and the interaction of time x group ($F(1, 155) = 0.133$; $p = .716$; $\eta^2 = 0.001$) did not have significant effects (see Fig. 2d). Post-hoc tests revealed that ratings were higher in rGD compared to nPGU at both baseline ($t(155) = -6.758$; $p < .001$)) and post-task ratings ($t(155) = -6.314$; $p < .001$).

4. Discussion

In order to investigate if more distal gaming cues can trigger mechanisms of cue-reactivity and craving for gaming we used a classical cue-reactivity paradigm with blocks showing gaming-related distal cues and

blocks showing control cues related to other online behaviors (shopping, pornography). As hypothesized, individuals in early stages of GD (rGD group) indicated higher craving for gaming compared to individuals with unproblematic gaming (nPGU group). In addition, higher cue-reactivity responses towards distal cues were identified in individuals with rGD but not in the nPGU group. Increased cue-reactivity was indicated by (1) higher arousal ratings when gaming pictures were presented compared to control pictures showing other behaviors (shopping/use of pornography) in the rGD group compared to the control group, (2) higher cue-induced urges to game compared to cue-induced urges towards other behaviors in rGD group compared to control group, and (3) higher craving ratings after gaming blocks compared to control blocks, which was only shown by the rGD group and not by the control group. The CASBA scores did not differ at the task level, however, the task design with alternate order of gaming and control blocks might have prevented long lasting craving responses. Interestingly, both groups show increased craving for the control behavior after the control block, but only the rGD group shows increased craving for gaming after the gaming block. However, it should be noted, that all participants generally engage in the control behavior in their daily life and the amount of craving was much less in the control cues than in the gaming cues.

The results are consistent with previous studies on cue-reactivity towards proximal gaming cues (e.g., [26,28,49,56,59]). The findings of our study expand previous results by showing that cue-reactivity is already present in individuals in early stages of the addiction process and that besides proximal cues also more distal gaming-specific cues could elicit cue-reactivity.

4.1. Individuals in early stages of GD show increased cue-reactivity compared to the control group

It has been proposed within the I-PACE model that cue-reactivity and craving develop from early to later stages of the addictive disorders [6]. In previous studies, individuals with a pathological gaming behavior (i.e., meeting 5 or more criteria of the 9 DSM-5 criteria) have been in focus aiming to understand behavioral, affective, and neural mechanisms involved in later stages of the disorder (e.g., [45,46,75]). In the current study, we investigated individuals in early/ pre-stages of GD, focusing on the development of cue-reactivity and craving. The groups were defined based on the results of a comprehensive clinical interview addressing the DSM-5 criteria for GD. The at-risk group (rGD) fulfilled 2–4 of these criteria meaning that they experienced some problems related to gaming, but without having the full picture of GD. The findings indicate that already in this potential prodromal or transition phase, cue-reactivity and craving have been developed. Based on addiction theories these differences in cue-reactivity and craving in the early stages of GD compared to the control group can be explained with altered reward-learning mechanisms and an increased incentive sensitization of the dopaminergic reward system in early stages of GD [14,15,76,77]. In this early stage, cue-reactivity and craving may be especially driven by motivations to feel better (i.e., experience gratification or compensation) that are assumed to be processed via a neural pathway consisting of the ventral tegmental area, nucleus accumbens, ventromedial prefrontal cortex, also described as “feels better” pathway [19]. Theoretically one would assume that the neural processing of stimuli in individuals in early stages of GD compared to a healthy control group might especially appear in this “feels better” pathway. Interestingly, we found no significant main effects for valence ratings. A previous study with proximal gaming cues found differences between regular gamers and gaming naïve controls only for valence but not for arousal [55]. It might be possible that our distal cues are less effective in evoking the emotional component as they do not include the explicit rewarding content of the behavior. Another explanation might be that the strong emotional component is not yet fully developed in individuals with only risky behavior, but that it might be part of the later addiction stages exclusively. Accordingly, the question if the development of cue-reactivity in early stages of GD is also characterized by shifts in the quality and intensity and neural processing of craving needs to be investigated in future studies.

4.2. Cue-reactivity towards more distal cues

Compared to proximal gaming cues, where specific scenes of games are shown, our cues show starting pages of online games and are therefore much less detailed and do not include specific (rewarding) content of the games but rather a situation that might precede the actual use. Nevertheless, these cues were sufficient to elicit cue-reactivity and urge to use the application in rGD. Which might indicate that the development of cue-reactivity and craving also to distal cues might begin in early stages of the GD. In addition, different contents of cues might elicit different affective and cognitive responses, while proximal cues showing in-game scenes might elicit the experience of reward, more distal cues such as starting-pages might elicit the anticipation of reward, an increased arousal, or an urge to start gaming. However, future studies need to systematically investigate the differences between affective, cognitive, and physiological responses elicited by different types of cues (proximal-distal). A possible limitation is that the cues were not individualized. The distal cues showed starting pages of different games that were most frequently used in Germany at the time of study conception, however, they might not have represented the games that the participants prefer to game. The fact that those more distal and non-individualized pictures could nevertheless elicit cue-reactivity and craving in the rGD group indicates that cue-reactivity responses may – already in early stages of GD – be generalized to various gaming-related contents. One further cue-reactivity eliciting component of the more distal cue might have been that cues showed a situation from first-person perspective. This perspective could have triggered interoceptive processes which in turn might have stimulated desire thinking [78]. Craving experiences and desire thinking have been identified as two components in the development of behavioral addictions [78]. The cue-reactivity response to more distal cues showing starting pages from a first-person perspective may be stronger than only showing devices with black screens or other gaming related devices (e.g., joystick, keyboard), e.g., by eliciting affective and cognitive responses related to the beginning of a gaming session. Thus, when generating cues for cue-reactivity studies it has to be considered that not only the position of the cues on the continuum from proximal to distal but also the individualization and perspective might be important to consider.

4.3. Implications for the design of cue-reactivity studies

The results of the current study using more distal cues are indicative for the design of cue-reactivity studies. First, the more distal cues used in the current study, showing a device (computer, laptop, tablet, smartphone) with starting pages, can be easily adapted for further online activities (e.g., social network sites or gambling), like we did in our study for the control stimuli (pornography and compulsive buying-shopping). Accordingly, while the content of the images is specific, the quality is highly comparable across different types of online activities, which allows systematic investigations of cue-reactivity and craving in different online addictive behaviors (e.g., individuals with gaming disorder, online-shopping disorder, pornography-use disorder, and social networks use disorder) with control cues from the respective other type of online addictive behaviors. Second, more distal compared to proximal cues do not show the rewarding content of the specific online behavior. Therefore, mechanisms of cue-reactivity and reward experience (experience of gratification and compensation) can be distinguished. In the context of pornographic stimuli this issue has been discussed as distal cues with no explicit pornographic material circumvent the naturally reinforcing character of explicit sexual material, which may not function as a cue, but as a reward [64]. This is useful

knowledge for future designs of studies investigating problematic online pornography use and other types of problematic online behaviors. Third, to compare the intensity and quality of cue-reactivity in response to distal versus proximal cues could provide further interesting findings regarding the mechanisms contributing to the development and maintenance of addictive behaviors and could help to better understand differences related to the severity of dependence. The fact that we presented only distal cues in our study limits the interpretation of findings and hinders direct comparisons.

5. Conclusions

A cue-reactivity paradigm with more distal cues is suitable for measuring subjective cue-reactivity and craving responses in individuals at-risk for developing GD. Future studies could use this paradigm in clinical populations. Cue-reactivity appears to generalize to distal cues that indicate "the activity is about to start" and to already be present in individuals who are at-risk for GD but who do not (yet) show the severe symptomatology.

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Authors' contribution

MD, SMM, SSL, EW, MB, and SA: study concept and design; MD, MB, and SA: analysis and interpretation of data; MD: statistical analysis; SMM: data curation; MD, RS, EW, SSL, and MB: obtained funding; MD, RS, SSL, and MB: study supervision; LM, AMS, TAT, LK, KK: participant recruitment and data assessment; MD, SA and MB: wrote the article. 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. All authors discussed the results, commented on the manuscript and approved the final version of the manuscript.

The data supporting the findings of this study is available from the corresponding author, Martin Diers, upon request.

Contributions

Each author declares substantial contributions through the following:

(1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content,

Please indicate for each author the author contributions in the text field below. Signatures are not required.

MD, SMM, SSL, EW, MB, and SA: study concept and design; MD, MB, and SA: analysis and interpretation of data; MD: statistical analysis; SMM: data curation; MD, RS, EW, SSL, and MB: obtained funding; MD, RS, SSL, and MB: study supervision; LM, AMS, TAT, LK, KK: participant recruitment and data assessment; MD, SA and MB: wrote the article. 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. All authors discussed the results, commented on the manuscript and approved the final version of the manuscript.

Approval of the submitted version of the manuscript

Please check this box to confirm that all co-authors have read and approved the version of the manuscript that is submitted. Signatures are not required.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.comppsych.2023.152399.

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