

Pulling for Pleasure? Erotic Approach-Bias Associated With Porn Use, Not Problems

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ABSTRACT

Background and Objectives: Addictive behaviors are gaining recognition in the clinical community, leading to more attention for the effects of problematic porn use. As many addictive behaviors are characterized by automatically activated approach-tendencies for disorder-relevant stimuli, we tested whether such tendencies are also present for erotic images and whether these are related to problematic porn use.

Methods: Measuring approach-bias for erotic photographs, sixty-two healthy heterosexual and bisexual men completed both a relevant-feature and an irrelevant-feature approach-avoidance task (AAT). Half of participants operated a joystick as response device, the other half a keyboard. We recorded participants' number of weekly porn-viewing sessions and symptoms of problematic porn use.

Results: The irrelevant-feature AAT produced unreliable results and was not analyzed further. In the relevant-feature AAT, participants had an overall approach-bias towards erotic stimuli. Porn use frequency, but not problematic porn use, was associated with with greater erotic approach-bias. This relationship was stronger when measured with a joystick than with a keyboard.

Limitations: Our design did not allow to test the causal direction of the relationship between porn use and approach-bias, and our results cannot be generalized to women, non-heterosexual men, and clinical populations.

Conclusions: Similar to other addictive behaviors and substances, we found a positive relation between porn use and approach-bias. Future studies using the relevant-feature AAT will likely benefit from using the joystick rather than the keyboard.

Keywords: AAT; approach-avoidance; behavioral addiction; embodied cognition; pornography; problematic sexual behavior

1. Introduction

It has recently been recognized that addictive behaviors need not always involve a substance. For instance, the DSM-5 now classifies gambling disorder as a behavioral addiction, and the rising popularity of the internet has made excessive videogaming relevant enough for internet gaming disorder to be listed as a condition for further study (American Psychiatric Association, 2013). Problematic internet porn use, the most common form of internet sex addiction (Griffiths, 2012), has not yet been recognized as an addictive behavior in the DSM-5, and it is instead recognized in the ICD-11 as a form of compulsive sexual behavior disorder within the category of impulse control disorders (World Health Organization, 2018).

An overwhelming majority of young men consumes pornographic materials (Carroll et al., 2008), and estimates of the prevalence of problematic porn use range from 1.7% (Ballester-Arnal, Castro Calvo, Gil-Llario, & Gil-Julia, 2017) to 13% (Ross, Mansson, & Daneback, 2012). But when does porn use become problematic? Some users feel they have no control over their behavior, consuming more than they intended and continuing to use despite experiencing social, personal, or occupational hazards (Kor et al., 2014; Ross et al., 2012), such as relational conflict and breakup or divorce (Cooper, Delmonico, Griffin-Shelley, &

Mathy, 2004; Schneider, 2003), social isolation, loss of self-esteem, reduced job performance and job loss (Schneider, 2000), worry, guilt and shame (Twohig, Crosby, & Cox, 2009), and physical pain and erectile dysfunction (Twohig et al., 2009; Wéry & Billieux, 2016).

Individuals displaying problematic porn use can also experience cravings persistently and in inappropriate contexts (Griffiths, 2012), display an attentional bias towards erotic cues (Mechelmans et al., 2014; although this is not always found: Strahler, Kruse, Wehrum-Osinsky, Klucken, & Stark, 2018), and show increased neural responses to cues for erotic material (Brand, Snagowski, Laier, & Maderwald, 2016; Gola et al., 2017; Seok & Sohn, 2015; Voon et al., 2014), despite experiencing no heightened pleasure from actually consuming porn (Gola et al., 2017; for an overview, see Stark, Klucken, Potenza, Brand, & Strahler, 2018; Voon et al., 2014). These findings are consistent with the incentive-sensitization theory of addiction (Robinson & Berridge, 1993), which posits that addiction involves excessive amplification of psychological “wanting”, without a complementary increase of “liking”.

1.2. Approach-bias and addiction

In the present study, we set out to investigate what drives some individuals to continue using porn despite experiencing negative consequences. An automatically activated action tendency to approach reward-related cues, also known as approach-bias, can draw people to contexts and cues that increase craving and facilitate relapse. Approach-bias has been measured using the Approach-Avoidance Task (AAT), in which participants move a reward cue towards or away from themselves, and the Stimulus-Response Compatibility task (SRC), where participants move a manikin towards or away from a reward cue. Approach-bias for addictive cues has been found in heavy drinkers (AAT: Wiers, Rinck, Kordts, Houben, & Strack, 2010; SRC: Mogg, Bradley, Field, & De Houwer, 2003), and heavy users of cannabis (AAT: Cousijn, Goudriaan, & Wiers, 2011; SRC: Field, Eastwood, Bradley, & Mogg, 2006)

and tobacco (AAT: C. E. Wiers, Kuhn, Javadi, et al., 2013; SRC: Bradley, Field, Mogg, & De Houwer, 2004). More recently, approach-bias has been found in those exhibiting addictive behaviors without substance involvement, such as excessive videogaming (Rabinovitz & Nagar, 2015) and gambling (Boffo et al., 2018).

When it comes to problematic porn use, studies on approach-bias have only recently started to emerge. Using the AAT, Hofmann, Friese, and Gschwendner (2009) found that men have an overall approach-bias for erotic stimuli, compared to modern art pictures. Snagowski and Brand (2015) confirmed and extended these results, finding that problematic craving and social problems predicts an avoidance-bias in some people but an approach-bias in others, whereas individuals without problematic cravings and social problems experience no strong approach or avoidance-biases towards erotic stimuli. This finding is at odds with most studies on approach and avoidance in addiction, which report a positive linear association between approach-bias and symptoms of problematic substance use (Christiansen, Cole, Goudie, & Field, 2012; Kersbergen, Woud, & Field, 2015; R. W. Wiers et al., 2010). Kersbergen and colleagues (2015), for example, report a positive relationship between hazardous drinking behavior and approach bias on both the AAT and SRC. More in line with this general literature are the findings of Sklenarik et al. (2019) that approach-bias for erotic stimuli correlates with loss of control over porn use but not with problematic porn use more broadly, and the findings of Stark et al. (2017) that approach-bias for erotic stimuli correlates positively with frequency of porn use and severity of problematic porn use. The latter study also revealed, however, that approach-bias scores do not contribute over and above trait sexual motivation to the prediction of problematic porn use.

1.3. The current study

In the current study we addressed the relationship between approach-bias and porn use more comprehensively, by examining relationships between various operationalizations of

both. There are many ways to define (problematic) porn use, multiple variants of the AAT, and multiple response devices that can be used. If we want to know whether approach-bias relates to problematic porn use, our answer to the question depends, in part, on how we define our methods. In the current study, we attempted to minimize the issue of inflated researcher degrees of freedom by reporting the effects of multiple operationalizations of each aforementioned construct.

There are different variants of the AAT. The relevant-feature AAT requires participants to approach or avoid, depending on the addiction-relevant features of the stimulus. In our study, we instructed participants to approach erotic stimuli and avoid non-erotic stimuli during one block, and we instructed them to avoid erotic stimuli and approach non-erotic stimuli during another block. In the irrelevant-feature AAT, participants are instructed to approach or avoid stimuli depending on a feature that is addiction-irrelevant, such as image format or tilt (Wiers et al., 2010). In our study, participants were instructed to approach or avoid stimuli depending on the hair colour of the women in the picture. In both task variants, approach-bias is operationalized as the RT difference between approaching and avoiding erotic images, relative to the RT difference between approaching and avoiding non-erotic stimuli. Relevant-feature and irrelevant-feature approach-bias scores are often uncorrelated, indicating they measure different constructs (R. W. Wiers, Gladwin, & Rinck, 2013). The relevant-feature AAT is typically found to be more reliable, and relates more strongly to measures of problematic behavior (e.g. Kersbergen et al., 2015). In our study, participants completed both a relevant-feature AAT and an irrelevant-feature AAT.

Apart from feature relevance, responses to the AAT can be made with a joystick (e.g. Rinck & Becker, 2007) or with a keyboard (e.g. Peeters et al., 2012), among others. As far as we know, no studies have directly compared the reliability and validity of these two response devices for the AAT so far. Early accounts theorized that approach and avoidance responses

respectively facilitate arm flexion and extension (Chen & Bargh, 1999), and thus considered arm movements crucial for approach-bias measurement. However, more recent accounts (van Dantzig, Pecher, & Zwaan, 2008) found that affective word approach-bias was evoked by a visual zoom effect, regardless of the presence of arm movement. Keyboard and joystick versions of the AAT should thus be largely similar, provided that zoom is included in both; in our study, half of participants responded with the keyboard, and the other half with the joystick.

To measure determinants and consequences of porn use, we recorded participants' total weekly porn use, self-perceived problematic symptoms, and craving. We expected that (a) approach-bias scores on the relevant-feature AAT would be more reliable than approach-bias scores on the irrelevant-feature AAT, that (b) approach-biases for erotic stimuli would be related to indices of problematic porn use and frequency of porn use, and that (c) the pattern of results would not be influenced by the choice of response device.

2. Method

2.1. Participants

Sixty-three adult males ($M_{\text{age}} = 24.47$, $SD = 6.42$) participated. Participants with odd participant numbers were assigned to the joystick group and participants with even participant numbers were assigned to the keyboard group. Data of one participant was lost due to a computer crash. Of the remaining participants, 58 were heterosexual and 4 were bisexual. Participants were recruited in and around the University of Amsterdam campus using flyers, posters, and the university's participant recruitment system, and they were told the study was about viewing erotic pictures. Groups did not differ significantly on problematic porn use symptoms, last week's porn use, age, or relational status, as compared with t -tests and χ^2 tests, all $ps > .05$. Participants had an average PPUS score of 11.40 ($SD = 10.64$, $min = 0$, $max = 52$) and viewed porn 3.52 times per week on average ($SD = 2.79$, $min = 0$, $max = 13$), each

session lasting an average of 19.03 minutes ($SD = 14.28$, $min = 0$, $max = 90$) for a total of 62.58 minutes per week on average ($SD = 62.90$, $min = 0$, $max = 300$).

2.2. Questionnaires

The Problematic Pornography Use Inventory (PPUS) was used to measure problematic porn use (Kor et al., 2014). This questionnaire consists of 12 items with a six-point Likert scale. The scale is reliable (α in the current study = .92), and valid, predicting psychopathological symptoms, lack of self esteem, attachment insecurity, hypersexuality, internet addiction, and motivation for pornography use (Kor et al., 2014).

The frequency and intensity of porn use was measured by asking how many times participants used porn on each day of the week preceding the study, and for how long during each session.

Other questionnaires were administered, but not used in the current study; these are described in the Supplementary Materials.

2.3. Materials

For the AAT, pictures of 40 blonde nude models, 40 brown-haired nude models, 40 blonde clothed models and 40 brown-haired clothed models were downloaded from the internet and resized to 1024×768 pixels. We excluded pictures featuring more than one individual, dark skin color, ambiguous hair color or lack of visible hair to avoid confusion and to ensure that other features of the image did not give away the correct response.

2.4. Approach-avoidance task

In each trial of the AAT, a single picture was presented in the center of the screen. Participants were instructed to approach or avoid these pictures by respectively pressing the downward or upward arrow keys (keyboard group), or by moving the joystick backward or forward (joystick group). Responses were accompanied by a zoom effect: stimuli became larger upon approach and shrank upon avoidance (Rinck & Becker, 2007). Participants

completed 8 blocks of 40 trials each, in fixed order. We chose not to counterbalance block order, as we suspected that relevant-feature trials may influence subsequent irrelevant-feature trials more strongly than vice-versa, causing imbalanced carryover effects: nudity is a more salient stimulus feature than hair color, and may thus be harder to ignore than hair color if the participant had previously been instructed to respond to it. Block 1 was preceded by 12 practice trials, and all other blocks by 8. Errors during practice trials were signalled with a large red cross; during test trials error feedback was not shown. In block 1 participants approached nudes and avoided dressed models, in block 2 the reverse instruction was given. These blocks constituted the first half of the relevant-feature AAT. In block 3, participants approached blonde-haired models (irrespective of clothing) and avoided brown-haired models, and the opposite responses were required in block 4. These blocks constituted the first half of the irrelevant-feature AAT. For these blocks, we opted to use hair color as the response-determining feature, as paying attention to hair color requires active processing of the content of the pictures, similar to manipulations of camera perspective (Neimeijer, Roefs, Glashouwer, Jonker, & de Jong, 2019; Neimeijer, Roefs, Ostafin, & de Jong, 2017) and unlike manipulations of image tilt and image frame color. The instructions for block 1 to 4 were repeated for blocks 5 to 8. All pictures were shown once during the first half of the task and once during the second half in semi-random order, with no more than 2 same-category stimuli appearing consecutively, and with 10 of each category appearing in each block. RT was operationalized as the time from stimulus onset until initiation of response.

2.5. Procedure

Participants provided written informed consent and performed the AAT. They then completed all questionnaires described above, after which they were compensated and debriefed. The entire procedure was approved by the ethical committee of the University of Amsterdam (ref. number 2017-DP-7952).

2.6. Analysis

2.6.1. Trial and participant exclusion. Incorrect responses were excluded, as were RTs below 200ms and above 2000ms; this led to the exclusion of 1729 (8.6%) trials. After this, RTs deviating more than 3 SDs from the participant's mean were also excluded; this led to the exclusion of 352 (1.75%) trials. Lastly, participants were entirely excluded from either the relevant-feature or irrelevant-feature AAT if more than 15% of their trials had been excluded due to errors or outliers, as this is an indication they did not adhere to, or did not understand task instructions, and their RTs are thus less likely to represent an underlying approach-bias. We excluded 2 participants from the relevant-feature AAT and 7 from the irrelevant-feature AAT due to excessive errors; and 1 participant was excluded from both tasks due to excessive outliers. This led to a final sample size of 59 for the relevant-feature AAT and 54 for the irrelevant-feature AAT.

2.6.2. Reliability methodology. Bootstrapped split-half reliability values were computed using the AATtools package (Kahveci, 2019) for R (R Core Team, 2019). To compute bootstrapped split-half reliability, we randomly split trials into two sets, calculated approach-bias scores for each half using the mean double-difference algorithm ($[\text{push erotic} - \text{pull erotic}] - [\text{push control} - \text{pull control}]$), and computed the correlation between the two sets of approach-bias scores. This process was iterated 1000 times, after which the average of these correlation values was computed to arrive at a final reliability score. As is customary, split-half reliability scores were corrected for reduced test length using the Spearman-Brown prediction formula (Spearman, 1910).

2.6.3. Multilevel methodology. Hypotheses were examined with multilevel analysis using the statistical modelling package lme4 (Bates, Mächler, Bolker, & Walker, 2015) for R (R Core Team, 2019). For all multilevel analyses, all relevant fixed trial-level variables were also modelled as random effects grouped under subject (following the advice of Barr, Levy,

Scheepers, & Tily, 2013). Additionally, we also modelled random intercepts per stimulus in every analysis. The statistical significance of the highest-order term was assessed by comparing a model with this term to a model without this term using a Wald chi-square test. All data and analysis scripts of the current study are freely available at this study's Open Science Framework repository (see section "Data availability statement").

3. Results

3.1. Reliability

The relevant-feature AAT was reliable, $r_{SB}(57) = .66, p < .001$, but the irrelevant-feature AAT was not, $r_{SB}(52) = -.11, p = .425$. Due to the unreliability of the irrelevant-feature task, it was omitted from further analyses. The reliability of the joystick relevant-feature AAT, $r_{SB}(27) = .76, p < .001$, and the keyboard relevant-feature AAT, $r_{SB}(28) = .52, p = .001$, did not differ significantly, $z = 1.50, p = .226$.

3.2. Bias

To examine whether an overall approach-bias towards erotic stimuli was present, we fitted a multilevel model predicting log RT with fixed and random main effects and interactions for Movement (0 = avoid; 1 = approach) and StimulusType (0 = clothed; 1 = erotic), as well as random intercepts per stimulus, as displayed in lme4 Equation 1. A Movement \times StimulusType interaction could be demonstrated, $\chi^2(1) = 7.71, p = .006$. Participants approached stimuli faster than they avoided them, and this approach advantage was stronger for erotic stimuli than for clothed model pictures. In other words, there was an approach-bias for erotic stimuli.

$$(1) \quad \log RT \sim \text{Movement} * \text{StimulusType} + (\text{Movement} * \text{StimulusType} / \text{Subject}) + (1 / \text{Stimulus})$$

3.3. Influence of porn use frequency and problematic porn use symptoms

We examined the effect of problematic porn use symptoms and porn use frequency in two separate models, as the two scales were correlated, $r(60) = .56, p < .001$. Their effect on approach-bias was assessed by predicting log RT with fixed and random effects for Movement and StimulusType and their interaction, fixed effects for porn use frequency (SessionsPerWeek) or problematic porn use symptoms (PPUS) and its interactions with the other variables, and random intercepts per stimulus, as displayed in lme4 Equation 2. SessionsPerWeek moderated the magnitude of approach-bias, $\chi^2(1) = 5.01, p = .025$. PPUS did not, $\chi^2(1) = .55, p = .815$. Participants who used more porn also had a stronger approach-bias towards erotic stimuli. Stronger symptoms of problematic porn use, however, did not similarly translate to a stronger approach-bias.

$$(2) \quad \log RT \sim \text{Movement} * \text{StimulusType} * \text{Scale} + (\text{Movement} * \text{StimulusType} / \text{Subject}) + (1 / \text{Stimulus})$$

We compared the model with problematic porn use symptoms to the model with porn use frequency to examine which one explains the most variance. Porn use frequency explained more variance in RTs than problematic porn use symptoms did, $\chi^2(0) = 2.76, p < .001$.

Following Sklenarik et al. (2019), we identified 5 participants with a PPUS score of 28 or higher and classified them as problematic porn users. We compared the performance of problematic and non-problematic porn users on the AAT with a multilevel model following lme4 Equation 2, using group classification in place of the Scale variable. There was no demonstrable difference between problematic and non-problematic porn users on the interaction between Movement and StimulusType, indicating no difference in approach-bias, $\chi^2(1) = .51, p = .473$. If anything, problematic porn users' average approach-bias was lower (6 ms) than that of non-problematic porn users (49 ms), as computed with a mean double

difference score. There was no significant difference either when only erotic stimuli were examined, as was done by Sklenarik et al., $\chi^2(1) = .53, p = .465$.

3.4. Effect of response device

To examine whether the overall approach bias to erotic stimuli was different for the AAT variants with different response devices, we added response device as a third fixed term interacting with the other fixed terms from lme4 Equation 1, as displayed in lme4 Equation 3. Overall approach-bias did not differ for the joystick and keyboard tasks, $\chi^2(1) = 2.66, p = .103$.

$$(3) \quad \log RT \sim \text{Movement} * \text{StimulusType} * \text{ResponseDevice} + (\text{Movement} * \text{StimulusType} / \text{Subject}) + (1 / \text{Stimulus})$$

Next, we examined whether the moderating effect of porn use frequency on approach-bias differed between response devices, by adding a fixed effect and interactions for response device to the aforementioned model, as displayed in lme4 Equation 4. Response device did moderate the relationship between porn use frequency and approach-bias $\chi^2(1) = 6.18, p = .013$. Follow-up tests revealed that porn use frequency had a three-way interaction with Movement and Stimulustype in the joystick condition, $\chi^2(1) = 7.05, p = .008$, but not in the keyboard condition, $\chi^2(1) = 0, p = .975$, as can be seen in Figure 1. More porn use predicted more approach-bias for erotic stimuli, but only when this approach-bias was measured with a joystick.

$$(4) \quad \log RT \sim \text{Movement} * \text{StimulusType} * \text{Scale} * \text{ResponseDevice} + (\text{Movement} * \text{StimulusType} / \text{Subject}) + (1 / \text{Stimulus})$$

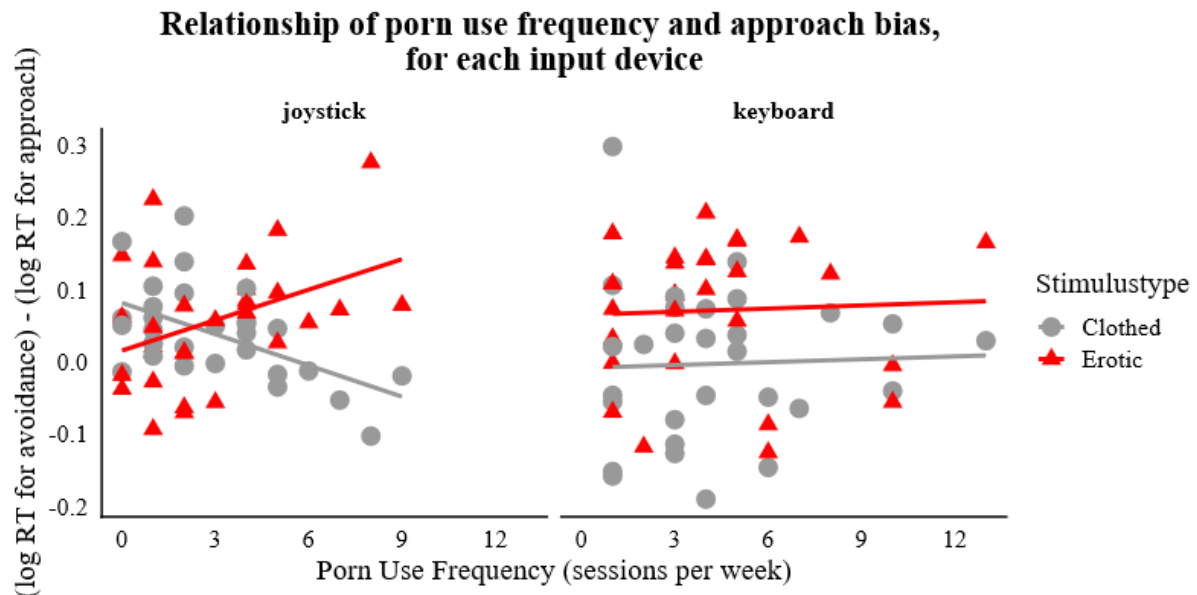


Figure 1. There is a differing linear effect of porn use frequency on approach-bias for erotic and clothed model stimuli, but only for the joystick-AAT. Points represent the ‘approach advantage’ for clothed (grey) or erotic (red) stimuli, and the lines represent the average trend of this approach advantage for lower and higher values of porn use frequency.

4. Discussion

Our main findings can be summarized as follows: we found an overall approach-bias for erotic stimuli (replicating Hofmann et al., 2009) that was larger than the approach-bias for non-erotic photographs of women. This bias was associated with higher porn use frequency, but not with self-reported symptoms of problematic porn use. We further found that porn use frequency only predicted relevant-feature approach-bias when the latter was measured with real pull and push movements using a joystick. Lastly, we found that the relevant-feature AAT was reasonably reliable, but the irrelevant-feature AAT was not. We will discuss each of these findings in the following paragraphs.

4.1. Approach bias relates to porn use but not to related problems

The association of approach-bias with quantity of porn use but not with *problematic* porn use symptoms contrasts with the findings of a number of studies: Snagowski and Brand (2015) reported a curvilinear association between approach-bias and problematic cravings and social problems, but no link between approach-bias and actual porn use; Stark et al. (2017) demonstrated a link between measures of problematic porn use and erotic approach-bias; Sklenarik et al. (2019) found a link between approach-bias and loss of control over porn use. In particular, our sample had a similar number of problematic porn users as Sklenarik et al. (2019), but while they found that problematic porn users had an approach-bias twice as large as non-problematic porn users, we found no such difference. However, our findings are in line with a study from the gambling literature, finding that gambling approach-bias was similarly related to frequency, but not with self-reported problems (Boffo et al., 2018). Taken together, these findings suggest that approach-bias does not have a simple relationship with symptoms of problematic use in the behavioral addiction domain. Why might this be the case?

One possibility is that the link between frequency of use and problems is stronger in substance addictions than in non-substance addictions, as substances physically harm the individual more when they are used more (Rehm et al., 2013), which is not necessarily the case for behavioral addictions, where the harm is more dependent on situational factors and cultural beliefs. Frequent porn use is typically considered less harmful than other behavioral and substance addictions – one study did not find a relationship between the amount of porn use and level of experienced problems (Twohig et al., 2009); and the harm that it causes is not commonly known or seen by the environment. The literature suggests frequent porn use relates to reduced relationship satisfaction and erectile dysfunction, but these are not problematic when the individual is not in a (sexual) relationship (Muise, Milhausen, Cole, & Graham, 2013; Wéry & Billieux, 2016). For these reasons, only a subset of porn users would feel a need to reduce their porn use, and find out that they are unable to do so. Those who do

report problematic porn use tend to have negative associations with the behavior, for example for social or religious reasons (Gola, Lewczuk, & Skorko, 2016). Problematic porn use is therefore not merely a function of the frequency of porn use, but likely also of the individual's relationship status, beliefs about porn, and motivation to quit. This crucial role of external factors also exists in gambling, where affluent and financially disadvantaged individuals could spend the same amount of money, but only the poor are harmed. In substance abuse, in contrast, the substance itself causes harm to the individual regardless of their situation (Rehm et al., 2013), leading to a more consistent association between quantity of use, problematic use symptoms, and implicit biases.

As approach-bias is theorized to play a role in the decision to use porn (Brand, Young, Laier, Wölfling, & Potenza, 2016), it may thus only play a role in problematic porn use when excessive porn use is the cause of the experienced problems, which is often but not always the case, for example when a patient engages in digital sexual activities at normal intervals but is unable to reduce their use despite negative effects due to the nature of the specific activity or due to contextual factors. To shed light on this complex relationship between the quantity of use, the self-perceived problematic nature of the behavior, and the harm due to use, further research is required in clinical populations, where a stronger co-occurrence of highly frequent porn use and experienced negative effects is likely.

4.2. Reliability of AAT variants and validity of response devices

Our second set of findings relates to the assessment of approach-biases in addiction: we assessed the influence of different response devices on AAT results, as well as the reliability of the relevant-feature and irrelevant-feature AAT. Our results are consistent with previous studies showing the irrelevant-feature AAT is unreliable (Kersbergen et al., 2015) and there is an overall approach-bias for positively valenced stimuli, regardless of response device (van Dantzig et al., 2008). However, we found that approach-bias as measured with the

joystick relates more strongly to the *frequency* of porn use. This has implications future research: physical approach or avoid movement may be necessary to reveal approach-biases that are related to behavior. As far as we know there are no keyboard-AAT studies relating approach-bias scores to the frequency of use; studies using keyboard-AATs have only been able to distinguish drug from nondrug cues and users from non-users, for whom drug cues may not have any affective value (e.g. Peeters et al., 2012). In line with the original embodied conceptualization of approach bias (Chen & Bargh, 1999), our results suggest that future AAT studies will likely produce more behaviorally relevant results when physical movement is required to respond.

4.3. Directions for future research

Our results open up new avenues for future research. In other addictions, approach-bias has been successfully modified to reduce frequency of use and improve treatment outcomes (Boffo et al., 2019; Kakoschke, Kemps, & Tiggemann, 2017; R. W. Wiers, Boffo, & Field, 2018). The current study demonstrates a link between approach-bias and porn use, but does not inform us about the causal direction of this relationship. Further research is needed to demonstrate whether experimentally reducing this approach-bias also reduces porn use. This could be of benefit to problematic porn users who experience a loss of control over their porn use and are thus unable to reduce it through only explicit mechanisms. Additionally, further research is needed to demonstrate whether these results generalize to individuals of other genders and sexualities as well.

4.4. Conclusion

In conclusion, our findings reveal a general approach-bias for erotic stimuli in men, which is elevated in those who consume more erotic content in daily life. Our study also highlights that use-related approach-bias may be preferentially measured with a joystick.

Understanding the relationship between approach-bias, actual use, and addiction symptoms will be important in understanding and successfully treating behavioral addictions.

5. Declarations

Data availability statement

All data and analysis scripts of this study, as well as supplementary materials and additional analyses, are available at this study's Open Science Framework repository:

<https://osf.io/6h2rj/>

Conflict of Interest Statement

Sercan Kahveci, Bram Van Bockstaele, Jens Blechert, and Reinout Wiers declare that they have no conflict of interest.

Authorship statement

The authors contributed the following efforts to the manuscript. Sercan Kahveci: conceptualization, methodology, investigation, formal analysis, data curation, writing of original draft, review & editing. Bram van Bockstaele: conceptualization, resources, review & editing, supervision. Jens Blechert: review & editing. Reinout Wiers: conceptualization, resources, review & editing, supervision.

Acknowledgements

The authors would like to thank Anu Hiekkaranta, Šimon Kucharský, and Ágnes Hoffmann for their help with participant recruitment, as well as Nicole Y.L. Oei for her contribution to the design of the experiment. Sercan Kahveci was supported by the Doctoral College "Imaging the Mind" (FWF; W1233-B).

6. References

- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). <https://doi.org/10.1176/appi.books.9780890425596>
- Ballester-Arnal, R., Castro Calvo, J., Gil-Llario, M. D., & Gil-Julia, B. (2017). Cybersex Addiction: A Study on Spanish College Students. *Journal of Sex & Marital Therapy*, 43(6), 567–585. <https://doi.org/10.1080/0092623X.2016.1208700>
- Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278. <https://doi.org/10.1016/j.jml.2012.11.001>
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using {lme4}. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Boffo, M., Smits, R., Salmon, J. P., Cowie, M. E., de Jong, D. T. H. A., Salemink, E., ... Wiers, R. W. (2018). Luck, come here! Automatic approach tendencies toward gambling cues in moderate- to high-risk gamblers. *Addiction*, 113(2), 289–298. <https://doi.org/10.1111/add.14071>
- Boffo, M., Zerhouni, O., Gronau, Q. F., van Beek, R. J. J., Nikolaou, K., Marsman, M., & Wiers, R. W. (2019). Cognitive Bias Modification for Behavior Change in Alcohol and Smoking Addiction: Bayesian Meta-Analysis of Individual Participant Data. *Neuropsychology Review*, 29(1), 52–78. <https://doi.org/10.1007/s11065-018-9386-4>
- Bradley, B., Field, M., Mogg, K., & De Houwer, J. (2004). Attentional and evaluative biases for smoking cues in nicotine dependence: component processes of biases in visual orienting. *Behavioural Pharmacology*, 15(1), 29–36. <https://doi.org/10.1097/00008877-200402000-00004>
- Brand, M., Snagowski, J., Laier, C., & Maderwald, S. (2016). Ventral striatum activity when

watching preferred pornographic pictures is correlated with symptoms of Internet pornography addiction. *NeuroImage*, 129, 224–232.

<https://doi.org/10.1016/j.neuroimage.2016.01.033>

Brand, M., Young, K. S., Laier, C., Wölfling, K., & Potenza, M. N. (2016). Integrating psychological and neurobiological considerations regarding the development and maintenance of specific Internet-use disorders: An Interaction of Person-Affect-Cognition-Execution (I-PACE) model. *Neuroscience and Biobehavioral Reviews*, 71, 252–266. <https://doi.org/10.1016/j.neubiorev.2016.08.033>

Carroll, J. S., Padilla-Walker, L. M., Nelson, L. J., Olson, C. D., McNamara Barry, C., & Madsen, S. D. (2008). Generation XXX: Pornography Acceptance and Use Among Emerging Adults. *Journal of Adolescent Research*, 23(1), 6–30.
<https://doi.org/10.1177/0743558407306348>

Chen, M., & Bargh, J. A. (1999). Consequences of Automatic Evaluation: Immediate Behavioral Predispositions to Approach or Avoid the Stimulus. *Personality and Social Psychology Bulletin*, 25(2), 215–224. <https://doi.org/10.1177/0146167299025002007>

Christiansen, P., Cole, J. C., Goudie, A. J., & Field, M. (2012). Components of behavioural impulsivity and automatic cue approach predict unique variance in hazardous drinking. *Psychopharmacology*, 219(2), 501–510. <https://doi.org/10.1007/s00213-011-2396-z>

Cooper, A. L., Delmonico, D. L., Griffin-Shelley, E., & Mathy, R. M. (2004). Online sexual activity: An examination of potentially problematic behaviors. *Sexual Addiction & Compulsivity*, 11(3), 129–143.

Cousijn, J., Goudriaan, A. E., & Wiers, R. W. (2011). Reaching out towards cannabis: approach-bias in heavy cannabis users predicts changes in cannabis use. *Addiction*, 106(9), 1667–1674. <https://doi.org/10.1111/j.1360-0443.2011.03475.x>

Field, M., Eastwood, B., Bradley, B. P., & Mogg, K. (2006). Selective processing of cannabis

- cues in regular cannabis users. *Drug and Alcohol Dependence*, 85(1), 75–82.
<https://doi.org/10.1016/j.drugalcdep.2006.03.018>
- Gola, M., Lewczuk, K., & Skorko, M. (2016). What Matters: Quantity or Quality of Pornography Use? Psychological and Behavioral Factors of Seeking Treatment for Problematic Pornography Use. *The Journal of Sexual Medicine*, 13(5), 815–824.
<https://doi.org/10.1016/j.jsxm.2016.02.169>
- Gola, M., Wordecha, M., Sescousse, G., Lew-Starowicz, M., Kossowski, B., Wypych, M., ... Marchewka, A. (2017). Can Pornography be Addictive? An fMRI Study of Men Seeking Treatment for Problematic Pornography Use. *Neuropsychopharmacology*, 42(10), 2021–2031. <https://doi.org/10.1038/npp.2017.78>
- Griffiths, M. D. (2012). Internet sex addiction: A review of empirical research. *Addiction Research & Theory*, 20(2), 111–124. <https://doi.org/10.3109/16066359.2011.588351>
- Hofmann, W., Friese, M., & Gschwendner, T. (2009). Men on the “pull”: automatic approach-avoidance tendencies and sexual interest behavior. *Social Psychology*, 40(2), 73–78. <https://doi.org/10.1027/1864-9335.40.2.73>
- Kahveci, S. (2019). *AATtools: Tools for Analyzing the Approach-Avoidance Task*. Retrieved from <https://github.com/Spiritspeak/AATtools>
- Kakoschke, N., Kemps, E., & Tiggemann, M. (2017). Approach bias modification training and consumption: A review of the literature. *Addictive Behaviors*, 64, 21–28.
<https://doi.org/10.1016/j.addbeh.2016.08.007>
- Kersbergen, I., Woud, M. L., & Field, M. (2015). The validity of different measures of automatic alcohol action tendencies. *Psychology of Addictive Behaviors*, 29(1), 225–230.
<https://doi.org/10.1037/adb0000009>
- Kor, A., Zilcha-Mano, S., Fogel, Y. A., Mikulincer, M., Reid, R. C., & Potenza, M. N. (2014). Psychometric development of the Problematic Pornography Use Scale. *Addictive*

- Behaviors*, 39(5), 861–868. <https://doi.org/10.1016/j.addbeh.2014.01.027>
- Mechelmans, D. J., Irvine, M., Banca, P., Porter, L., Mitchell, S., Mole, T. B., ... Voon, V. (2014). Enhanced Attentional Bias towards Sexually Explicit Cues in Individuals with and without Compulsive Sexual Behaviours. *PLOS ONE*, 9(8), e105476. <https://doi.org/10.1371/journal.pone.0105476>
- Mogg, K., Bradley, B. P., Field, M., & De Houwer, J. (2003). Eye movements to smoking-related pictures in smokers: relationship between attentional biases and implicit and explicit measures of stimulus valence. *Addiction*, 98(6), 825–836. <https://doi.org/10.1046/j.1360-0443.2003.00392.x>
- Muise, A., Milhausen, R. R., Cole, S. L., & Graham, C. (2013). Sexual Compulsivity in Heterosexual Married Adults: The Role of Sexual Excitation and Sexual Inhibition in Individuals not Considered “High-Risk.” *Sexual Addiction & Compulsivity*, 20(3), 192–209. <https://doi.org/10.1080/10720162.2013.786661>
- Neimeijer, R. A. M., Roefs, A., Glashouwer, K. A., Jonker, N. C., & de Jong, P. J. (2019). Reduced automatic approach tendencies towards task-relevant and task-irrelevant food pictures in Anorexia Nervosa. *Journal of Behavior Therapy and Experimental Psychiatry*, 65, 101496. <https://doi.org/10.1016/j.jbtep.2019.101496>
- Neimeijer, R. A. M., Roefs, A., Ostafin, B. D., & de Jong, P. J. (2017). Automatic Approach Tendencies toward High and Low Caloric Food in Restrained Eaters: Influence of Task-Relevance and Mood . *Frontiers in Psychology* , Vol. 8, p. 525. Retrieved from <https://www.frontiersin.org/article/10.3389/fpsyg.2017.00525>
- Peeters, M., Wiers, R. W., Monshouwer, K., van de Schoot, R., Janssen, T., & Vollebergh, W. A. M. (2012). Automatic processes in at-risk adolescents: the role of alcohol-approach tendencies and response inhibition in drinking behavior. *Addiction*, 107(11), 1939–1946. <https://doi.org/10.1111/j.1360-0443.2012.03948.x>

- R Core Team. (2019). *R: A Language and Environment for Statistical Computing*. Retrieved from <https://www.r-project.org/>
- Rabinovitz, S., & Nagar, M. (2015). Possible End to an Endless Quest? Cognitive Bias Modification for Excessive Multiplayer Online Gamers. *Cyberpsychology, Behavior and Social Networking*, 18(10), 581–587. <https://doi.org/10.1089/cyber.2015.0173>
- Rehm, J., Marmet, S., Anderson, P., Gual, A., Kraus, L., Nutt, D. J., ... Gmel, G. (2013). Defining substance use disorders: Do we really need more than heavy use? *Alcohol and Alcoholism*, 48(6), 633–640. <https://doi.org/10.1093/alcalc/agt127>
- Rinck, M., & Becker, E. S. (2007). Approach and avoidance in fear of spiders. *Journal of Behavior Therapy and Experimental Psychiatry*, 38(2), 105–120. <https://doi.org/10.1016/j.jbtep.2006.10.001>
- Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Research. Brain Research Reviews*, 18(3), 247–291. [https://doi.org/10.1016/0165-0173\(93\)90013-p](https://doi.org/10.1016/0165-0173(93)90013-p)
- Ross, M. W., Mansson, S.-A., & Daneback, K. (2012). Prevalence, severity, and correlates of problematic sexual Internet use in Swedish men and women. *Archives of Sexual Behavior*, 41(2), 459–466. <https://doi.org/10.1007/s10508-011-9762-0>
- Schneider, J. (2000). A qualitative study of cybersex participants: Gender differences, recovery issues, and implications for therapists. *Sexual Addiction & Compulsivity: The Journal of Treatment and Prevention*, 7(4), 249–278.
- Schneider, J. (2003). The impact of compulsive cybersex behaviours on the family. *Sexual and Relationship Therapy*, 18(3), 329–354.
- Seok, J.-W., & Sohn, J.-H. (2015). Neural Substrates of Sexual Desire in Individuals with Problematic Hypersexual Behavior. *Frontiers in Behavioral Neuroscience*, 9, 321. <https://doi.org/10.3389/fnbeh.2015.00321>

Sklenarik, S., Potenza, M. N., Gola, M., Kor, A., Kraus, S. W., & Astur, R. S. (2019).

Approach bias for erotic stimuli in heterosexual male college students who use pornography. *Journal of Behavioral Addictions*, 8(2), 234–241.

Snagowski, J., & Brand, M. (2015). Symptoms of cybersex addiction can be linked to both approaching and avoiding pornographic stimuli: results from an analog sample of regular cybersex users. *Frontiers in Psychology*, 6, 653.

<https://doi.org/10.3389/fpsyg.2015.00653>

Spearman, C. (1910). Correlation Calculated From Faulty Data. *British Journal of Psychology*, 1904-1920, 3(3), 271–295. <https://doi.org/10.1111/j.2044-8295.1910.tb00206.x>

Stark, R., Klucken, T., Potenza, M. N., Brand, M., & Strahler, J. (2018). A Current Understanding of the Behavioral Neuroscience of Compulsive Sexual Behavior Disorder and Problematic Pornography Use. *Current Behavioral Neuroscience Reports*, 5(4), 218–231. <https://doi.org/10.1007/s40473-018-0162-9>

Stark, R., Kruse, O., Snagowski, J., Brand, M., Walter, B., Klucken, T., & Wehrum-Osinsky, S. (2017). Predictors for (Problematic) Use of Internet Sexually Explicit Material: Role of Trait Sexual Motivation and Implicit Approach Tendencies Towards Sexually Explicit Material. *Sexual Addiction & Compulsivity*, 24(3), 180–202.

<https://doi.org/10.1080/10720162.2017.1329042>

Strahler, J., Kruse, O., Wehrum-Osinsky, S., Klucken, T., & Stark, R. (2018). Neural correlates of gender differences in distractibility by sexual stimuli. *NeuroImage*, 176, 499–509. <https://doi.org/10.1016/j.neuroimage.2018.04.072>

Twohig, M. P., Crosby, J. M., & Cox, J. M. (2009). Viewing Internet pornography: For whom is it problematic, how, and why? *Sexual Addiction & Compulsivity*, 16(4), 253–266.

van Dantzig, S., Pecher, D., & Zwaan, R. A. (2008). Approach and avoidance as action

effects. *Quarterly Journal of Experimental Psychology*, 61(9), 1298–1306.

<https://doi.org/10.1080/17470210802027987>

Voon, V., Mole, T. B., Banca, P., Porter, L., Morris, L., Mitchell, S., ... Irvine, M. (2014).

Neural Correlates of Sexual Cue Reactivity in Individuals with and without Compulsive Sexual Behaviours. *PLoS ONE*, 9(7), e102419.

<https://doi.org/10.1371/journal.pone.0102419>

Wéry, A., & Billieux, J. (2016). Online sexual activities: An exploratory study of problematic and non-problematic usage patterns in a sample of men. *Computers in Human Behavior*, 56, 257–266. <https://doi.org/10.1016/J.CHB.2015.11.046>

Wiers, C. E., Kuhn, S., Javadi, A. H., Korucuoglu, O., Wiers, R. W., Walter, H., ...

Bermppohl, F. (2013). Automatic approach bias towards smoking cues is present in smokers but not in ex-smokers. *Psychopharmacology*, 229(1), 187–197.

<https://doi.org/10.1007/s00213-013-3098-5>

Wiers, R. W., Boffo, M., & Field, M. (2018). What's in a Trial? On the Importance of Distinguishing Between Experimental Lab Studies and Randomized Controlled Trials: The Case of Cognitive Bias Modification and Alcohol Use Disorders. *Journal of Studies on Alcohol and Drugs*, 79(3), 333–343.

Wiers, R. W., Gladwin, T. E., & Rinck, M. (2013). Should we train alcohol-dependent patients to avoid alcohol? *Frontiers in Psychiatry*, 4, 33.

<https://doi.org/10.3389/fpsy.2013.00033>

Wiers, R. W., Rinck, M., Kordts, R., Houben, K., & Strack, F. (2010). Retraining automatic action-tendencies to approach alcohol in hazardous drinkers. *Addiction*, 105(2), 279–287. <https://doi.org/10.1111/j.1360-0443.2009.02775.x>

World Health Organization. (2018). *International classification of diseases for mortality and morbidity statistics* (11th ed.). Retrieved from <https://icd.who.int/browse11/l-m/en>

SUPPLEMENTARY MATERIALS

Additional administered questionnaires

Besides the questionnaires mentioned in the Methods section, the following measures were administered during the test session, to be discussed in a future publication.

The Sexual Inhibition and Sexual Excitation scales (Janssen, Vorst, Finn, & Bancroft, 2002) consist of 44 items. The constituent scales are Sexual Excitability (SES, $\alpha = .80$), Sexual Inhibition due to performance concerns (SIS1, $\alpha = .76$) and Sexual Inhibition due to consequences of sex (SIS2, $\alpha = .73$).

Participants rated their attitude on porn on a -100 to 100 visual analogue scale. They also indicated whether they expect positive and negative effects of porn use on a 22-item questionnaire based on Wiers, van Woerden, Smulders and de Jong (2002). Positive expectations include reduction of anxiety and feeling ecstatic, whereas negative expectations include feeling dirty and estranged from oneself. Reliability was excellent for positive ($\alpha = .88$) and negative expectancies ($\alpha = .83$).

The Pornography Craving Questionnaire (Kraus & Rosenberg, 2014) measures craving at the moment of administration, and consists of twelve items answered on a seven-point Likert scale and has good reliability in this study, $\alpha = .85$.

Erectile dysfunction was assessed using the International Index of Erectile Function (Rosen et al., 1997), consisting of 15 items answered on five- and six-point scales. The literature reports excellent internal consistency ($\alpha = .91$) and construct validity.

Religiosity was measured by enquiring the frequency of visits to places of worship, the frequency of prayer, and self-rated intensity of belief.

Descriptive statistics for these variables are displayed in Table S.1; correlations between variables are displayed in Table S.2.

Table S.1; Means, standard deviations, and range for all self-report variables.

	Min.	Max.	<i>M</i>	<i>SD</i>
Age	18	57	24.47	6.42
PPUS	0	52	11.40	10.64
Pre-AAT PCQ	4	51	19.65	11.00
Post-AAT PCQ	2	59	29.55	15.74
Δ PCQ	-10	42	9.90	12.09
SES	15	47	33.29	6.53
SIS1	3	27	15.85	5.62
SIS2	3	26	16.35	4.67
Erectile Function	4	32	22.19	6.13
Porn sessions per week	0	13	3.52	2.79
Minutes per week viewing porn	0	300	62.58	62.91
Daily electronic device use	2	12	6.52	2.84
Daily internet use	1	12	5.98	2.67
Attitude towards porn	-75	100	41.65	33.92
Positive expectancy	-89.71	69.07	0	33.61
Negative expectancy	-59.44	74.21	0	34.75
Religiosity	0	14	1.79	2.75

Note: PPUS = Problematic Porn Use Inventory; PCQ = Porn Craving Questionnaire;

SES = Sexual Excitability Scale; SIS1= Sexual Inhibition Due To Performance Concerns;

SIS2= Sexual Inhibition Due To Performance Consequences. Erectile Function scores were computed by excluding items relating to sex, as 30 out of 62 participants had not recently had sex.

Table S.2; Correlations between self-report variables.

	<i>n</i>	1	2	3	4	5	6	7	8	9	10	11
1. PPUS	60											
2. Pre-test PCQ	62	.41 [†]										
3. SES	62	.22	.41 [†]									
4. SIS1	62	.44 [†]	.22	-.01								
5. SIS2	62	.10	.18	.06	.03							
6. Erectile function	62	-.12	.03	-.07	-.24	-.18						
7. Porn Sessions per Week	61	.42 [†]	.21	.12	.24	.08	-.30 [*]					
8. Daily internet use	62	.17	.02	-.05	.01	.03	.07	.06				
9. Attitude towards porn	61	.05	.25 [*]	.33 [†]	-.15	.07	.12	.23	.05			
10. Positive Expectancy	62	.23	.49 [†]	.45 [†]	-.04	.17	.09	.21	-.05	.44 [†]		
11. Negative Expectancy	62	.44 [†]	.06	.19	.34 [†]	.05	-.07	.11	.03	-.01	.34 [†]	
12. Religiosity	61	.08	.23	.13	-.06	.22	-.10	0	.20	.10	.13	.04

Note: PPUS = Problematic Porn Use Inventory; PCQ = Porn Craving Questionnaire;

SES = Sexual Excitability Scale; SIS1= Sexual Inhibition Due To Performance Concerns;

SIS2= Sexual Inhibition Due To Performance Consequences. Erectile Function scores were

computed by excluding items relating to sex, as 30 out of 62 participants had not recently had

*sex. * = $p < .05$; [†] = $p < .01$. Scores deviating more than 3 SD from the mean were removed*

before calculating correlation coefficients.