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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

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Highlights

- Addictive behaviors are linked to cue-reactivity and craving
- Addictive behaviors are associated with diminished inhibitory control
- Habitual behaviors are developed in the process of addictive behaviors
- An imbalance between fronto-striatal circuits contributes to addictive behaviors

Abstract

We propose an updated version of the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, which we argue to be valid for several types of addictive behaviors, such as gambling, gaming, buying-shopping, and compulsive sexual behavior disorders. Based on recent empirical findings and theoretical considerations, we argue that addictive behaviors develop as a consequence of the interactions between predisposing variables, affective and cognitive responses to specific stimuli, and executive functions, such as inhibitory control and decision-making. In the process of addictive behaviors, the associations between cue-reactivity/ craving and diminished inhibitory control contribute to the development of habitual behaviors. An imbalance between structures of fronto-striatal circuits, particularly between ventral striatum, amygdala, and dorsolateral prefrontal areas, may be particularly relevant to early stages and the dorsal striatum to later stages of addictive processes. The I-PACE model may provide a theoretical foundation for future studies on addictive behaviors and clinical practice. Future studies should investigate common and unique mechanisms involved in addictive, obsessive-compulsive-related, impulse-control, and substance-use disorders.

Keywords: Behavioral addictions, gaming disorder, gambling disorder, problematic pornography use, buying-shopping disorder, cue-reactivity, inhibitory control

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1. Introduction

The Interaction of Person-Affect-Cognition-Execution (I-PACE) model of specific Internet-use disorders was published more than two years ago (Brand, Young, Laier, Wölfling, & Potenza, 2016). One aim was to describe the psychological and neurobiological processes underlying the development and maintenance of an addictive use of specific Internet applications, such as those used when gaming, gambling, viewing pornography, buying-shopping, and social-networking. Since the publication of the I-PACE model, it has been cited relatively frequently by researchers globally not only for gaming disorder (e.g., Deleuze et al., 2017; Dieter et al., 2017; Dong, Wang, Wang, Du, & Potenza, 2019; Kaess et al., 2017; Lee, Lee, Namkoong, & Jung, 2018; Lee, Namkoong, Lee, & Jung, 2018; Li et al., 2018; Paulus, Ohmann, von Gontard, & Popow, 2018; Sariyska, Lachmann, Markett, Reuter, & Montag, 2017), but also for gambling disorder (e.g., Ioannidis, Hook, Wickham, Grant, & Chamberlain, 2019; Starcke, Antons, Trotzke, & Brand, 2018), compulsive sexual behavior disorder including problematic pornography use (e.g., Carnes & Love, 2017; Strahler, Kruse, Wehrum-Osinsky, Klucken, & Stark, 2018; Wéry, Deleuze, Canale, & Billieux, 2018), buying-shopping disorder (e.g., Lam & Lam, 2017; Vogel et al., 2018), excessive use of communication applications (e.g., Dempsey, O'Brien, Tiarniyu, & Elhai, 2019; Elhai, Tiarniyu, & Weeks, 2018; Kircaburun & Griffiths, 2018; Montag et al., 2018; Rothen et al., 2018), unspecified Internet-use disorder (e.g., Carbonell, Chamarro, Oberst, Rodrigo, & Prades, 2018; Emelin, Rasskazova, & Tkhostov, 2017; Ioannidis, Hook, Goudriaan, et al., 2019; Lachmann et al., 2018; Vargas et al., 2019; N. Zhou et al., 2018), and for other addictive behaviors including substance-use disorders (F. Zhou et al., 2018). The eleventh edition of the International Classification of Diseases (ICD-11), as recently being released (World-Health-Organization, 2019), focuses on the disorder itself (e.g. gambling disorder) without referring to the medium of the disorder, for

example gaming disorder instead of Internet-gaming disorder in the fifth edition of the Diagnostic and Statistical Manual (DSM-5) (APA, 2013). In the ICD-11, the environment of the behavior may subsequently be specified as predominantly offline or predominantly online for gambling and gaming disorders. Consequently, a model explaining the underlying processes of the problematic behavior should be valid for both online and offline environment and for a combination of offline and online behaviors as well. We continue proposing that the behavior itself is the core element to consider and the environment (online versus offline) may be typically secondary but may contribute importantly to the expression of specific addictive behaviors and common variance across these behaviors (Baggio et al., 2018). We suggest an updated version of the I-PACE model, which we hypothesize will be valid not only for specific Internet-use disorders, but also for other types of addictive behaviors. This updated I-PACE model concentrates on the individual psychological and neurobiological mechanisms of addictive behaviors. Media-specific aspects and other environmental factors related to the behavior that likely accelerate or decrease the development of an addictive behavior could then be defined and described for specific versions of the model. Figure 1 summarizes the proposed differentiation between medium/ environmental aspects, individuals' reactions, and behavioral and neurobiological factors involved in addictive behaviors.

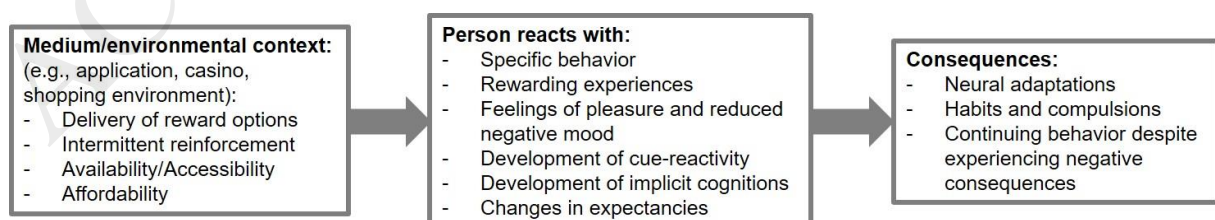


Figure 1: Differentiating environmental aspects, individual reactions of the person, and consequences of repeated specific behaviors over time. The revised I-PACE model concentrates on the person's reactions and consequences involved in developing addictive behaviors.

In addition, we aim at specifying more explicitly the process character of the model by differentiating two sub-models, one for the mechanisms involved in the early stages and one for the mechanisms involved in the later stages of the addiction process. We do not repeat the detailed discussion of all the components included in the I-PACE model (cf. Brand, Young, et al., 2016). Instead, we mainly concentrate on the most recent articles, in particular meta-analyses and systematic reviews that inspired the I-PACE update.

2. The updated I-PACE model of addictive behaviors

The revision of the I-PACE model includes three main steps. First, we focus on predisposing variables, which have been considered as being involved in different types of addictive behaviors (gambling disorders, gaming disorder, and others) and differentiate them from more behavior-specific predisposing variables. Second, we define more precisely the inner circle of the addiction process in the I-PACE model with respect to recent findings. Third, we differentiate between early and later stages of the process in order to illustrate explicitly potentially different roles of moderating and mediating variables depending upon the stage of addiction. The revised I-PACE model of addictive behaviors is shown in Figure 2. Figure 2A shows the interactions between variables that are considered particularly important in early stages of addictive behaviors. Figure 2B illustrates the interactions of variables in later stages of addictive processes.

2.1. The P-component of the I-PACE model

The P-component represents person's core characteristics likely involved in the addiction process as predisposing variables (see discussion in Brand, Young, et al.,

2016). The general predisposing variables (left side in the upper box of the model) may contribute importantly to all types of addictive behaviors (e.g., gambling disorder, gaming disorder, buying-shopping disorder, pornography-viewing disorder/hypersexual behavior). The list of these potentially predisposing variables is not exhaustive. It only summarizes variables for which relatively broad evidence exists, including from meta-analyses, even though the evidence may differ in strength for the different types of addictive behaviors. Data suggest a significant genetic contribution to gambling disorder (Lobo, 2016; Potenza, 2017, 2018; Xuan et al., 2017) and unspecified internet-use disorder (Hahn, Reuter, Spinath, & Montag, 2017). Furthermore, negative early childhood experiences have been reported as vulnerability factors for gambling disorder (Roberts et al., 2017) and gaming disorder (Schneider, King, & Delfabbro, 2017), findings consistent with recent theoretical considerations of the role of attachment in addictive behaviors (Alvarez-Monjaras, Mayes, Potenza, & Rutherford, 2018). Psychopathological correlates, in particular depression and social anxiety, have been reported repeatedly for gambling (Dowling et al., 2017), gaming (Männikkö, Ruotsalainen, Miettunen, Pontes, & Kääriäinen, 2017), unspecified internet-use (Ho et al., 2014), and buying-shopping (Müller et al., 2019) disorders, and other behavioral addictions (Starcevic & Khazaal, 2017). Temperamental features, such as high impulsivity, have also been associated with gambling (Dowling et al., 2017), gaming (Gervasi et al., 2017; Kuss, Pontes, & Griffiths, 2018; Ryu et al., 2018), and unspecified internet-use (Kayaş et al., 2016) disorders, as has dysfunctional coping styles with gaming disorder (Schneider, King, & Delfabbro, 2018). In the I-PACE model, we use general terms (e.g., psychopathology, temperamental features including, for example, impulsivity) that may be specified further with respect to specific addictive behaviors. The behavior-specific predisposing variables (right side of the upper box in the model, Figures 2A and 2B) are considered characteristic for the different specific

addictive behaviors. For example, individuals with higher novelty-seeking may be more likely to develop gambling disorder (Del Pino-Gutiérrez et al., 2017). Individuals with higher aggressiveness and narcissistic personality traits may be more prone to develop gaming disorder (Gervasi et al., 2017). Individuals with high trait sexual motivation may be more likely to develop hypersexual behavior or pornography-use disorder (Stark et al., 2017), and individuals with high materialistic values may be particularly prone to developing buying-shopping disorder (Claes, Müller, & Luyckx, 2016; Müller et al., 2014).

2.2. The inner circle: The affect (A-), cognition (C-), and execution (E-) components of the I-PACE model

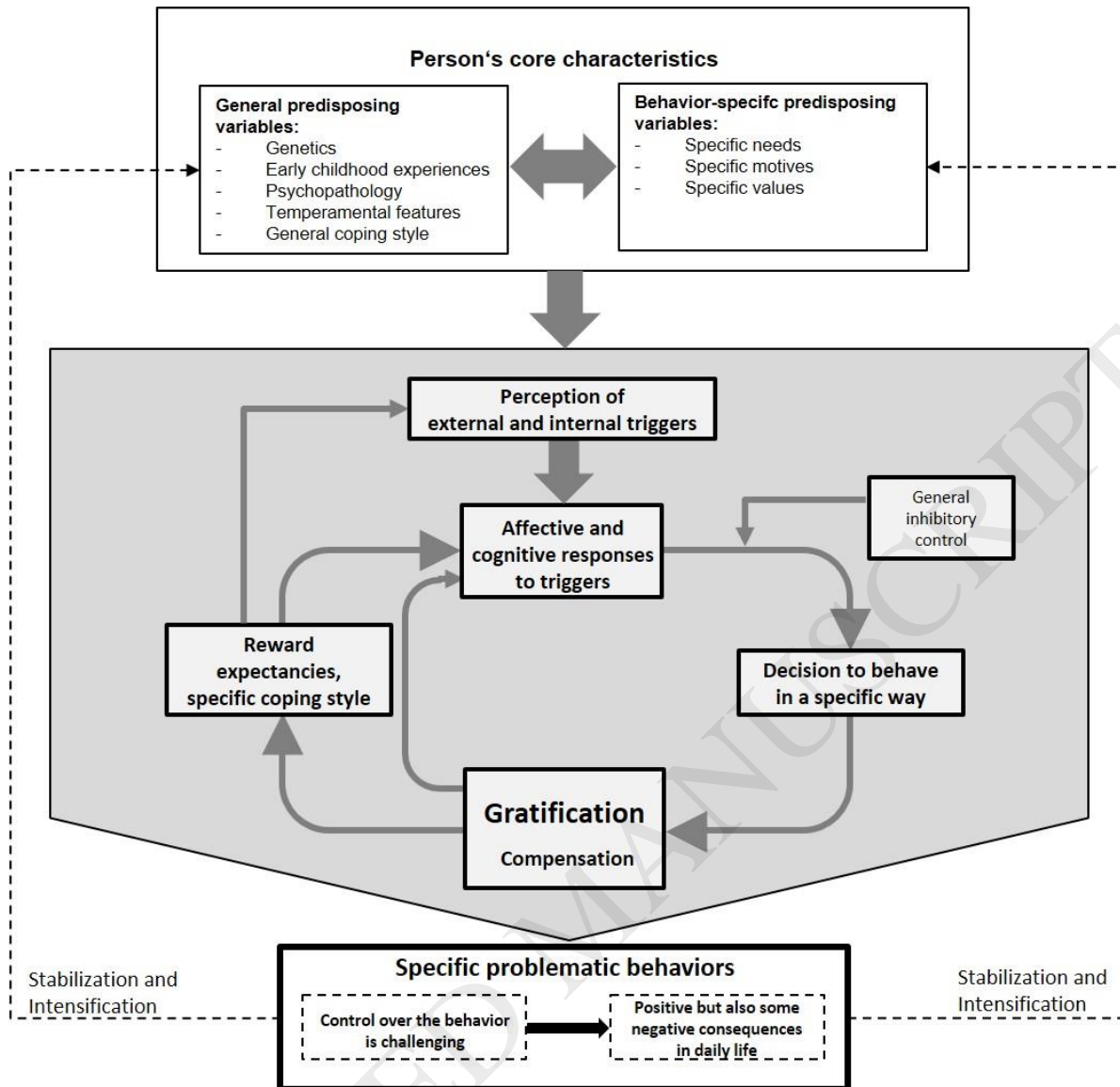
One main idea of the inner circle of the I-PACE model is that the development of a problematic and addictive behavior occurs only in interactions between individuals' predisposing variables and certain aspects that specific situations deliver. The interactions result in experiences of gratification and compensation that are associated with specific behaviors. In the early stages (Figure 2A), individuals may perceive external (e.g., confrontation with behavior-related stimuli) or internal triggers (e.g., negative or very positive moods) in specific situations. The perceptions may result in affective and cognitive responses, such as increased attention to these stimuli and urges to behave in specific ways; e.g. urges to play online games or view pornography (Starcke et al., 2018).

The affective and cognitive responses lead to decisions to behave in specific ways. The decision to engage in a specific behavior may be guided by two interactive systems: an impulsive/ reactive system, which is mainly based on associative learning (classical and operant conditioning), and a reflective/ deliberative system, which is mainly linked to reasoning and executive functions (Kahneman, 2003; Schiebener &

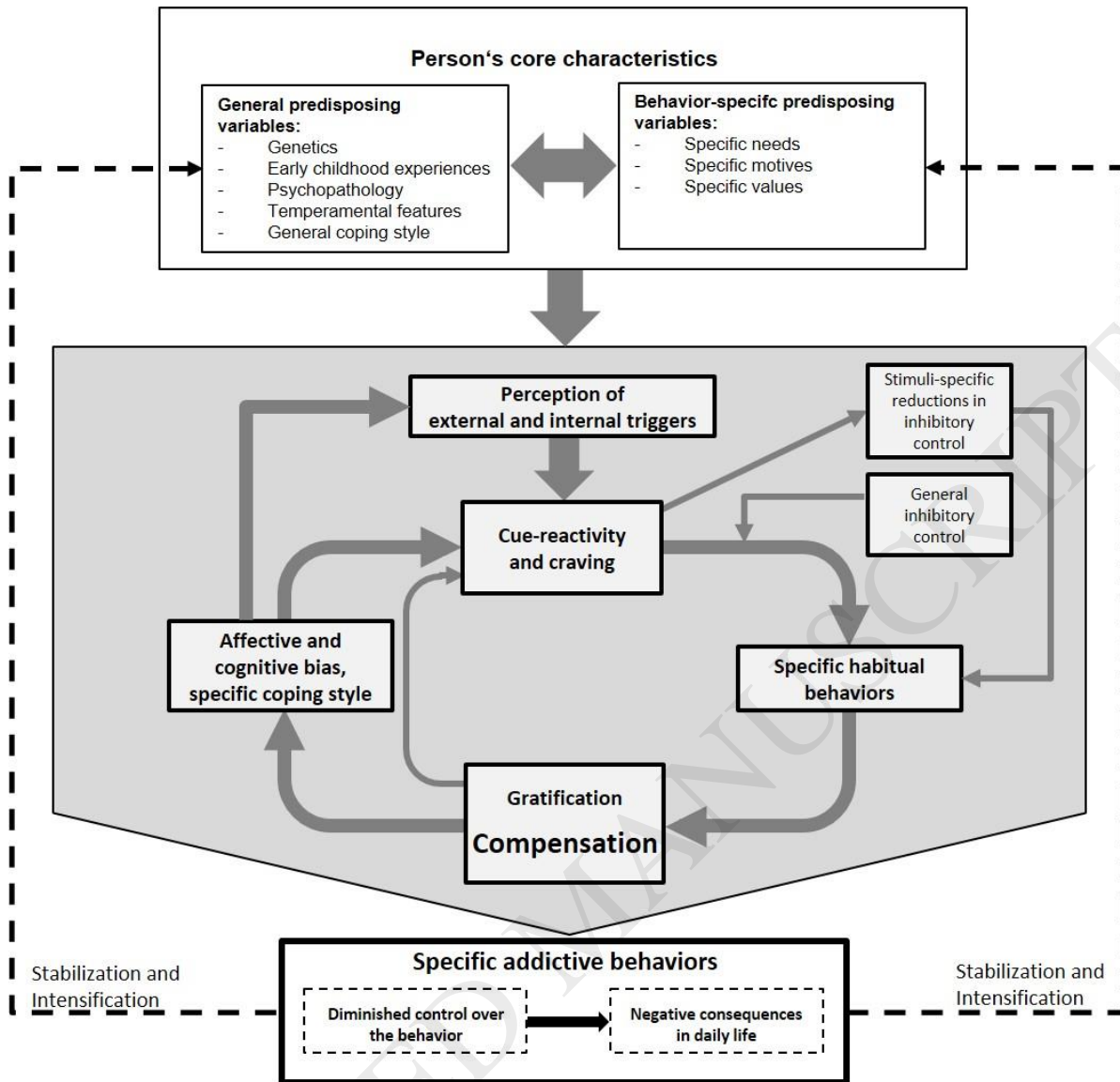
Brand, 2015; Strack & Deutsch, 2004). In individuals with addictions, behavior is considered to depend increasingly on impulsive/ reactive neural systems, including limbic structures (Noël, van der Linden, & Bechara, 2006). Prefrontal-cortex-related inhibitory control over urges and desires may decrease during the addiction process (Bechara, 2005; Volkow & Morales, 2015). Combining these theoretical perspectives, we propose that relationships between affective and cognitive responses to external or internal triggers and decisions to engage in specific behaviors are moderated by the level of general inhibitory control (in contrast to mood-specific or stimulus-specific inhibitory control) and self-regulation/ self-directedness (Hahn et al., 2017), at least in the early stages of addictive behaviors. The meta-analysis by Meng, Deng, Wang, Guo, and Li (2015) illustrates that prefrontal dysfunctions are associated with gaming disorder, indicating the potential conflict between reward-anticipation and self-regulation systems, including conflicts involved in the delaying of gratification (Volkow & Baler, 2015). Regarding a general inhibitory control, Yao et al. (2017) report functional and structural brain alterations in gaming disorder that are linked to reductions in executive functioning. Specific behaviors (e.g. playing an online game, gambling in a casino, buying items) may lead to feelings of gratification or relief from negative moods (Laier & Brand, 2017). These experiences subsequently change the subjective reward expectancies that are associated with the specific behaviors. They may also modify the individual coping style. For example, if individuals learn that playing online games is effective in generating good feelings or avoiding negative emotional states, they may generalize the expectancy that playing online games is helpful for dealing with emotions in daily life (Kuss et al., 2018; Laier, Wegmann, & Brand, 2018). The changes of expectancies and coping styles may increase the likelihood of responding with urge feelings or feelings of desire in subsequent situations when being confronted with external or internal triggers. This interaction of craving

experiences and expectancies has been demonstrated by individuals with higher symptom severity of an addictive use of internet-communication services (Wegmann, Ostendorf, & Brand, 2018). Over time, these associations between affective and cognitive responses, decisions to behave in specific ways, experiences of gratification and compensation and behavior-specific expectancies may become stronger. Consequently, control over the behaviors by general inhibitory mechanisms may become more difficult, and decisions to behave in specific ways may be guided more dominantly by impulsive/ reactive responses to triggers. Mechanisms proposed to be involved in later stages of addictive behaviors are summarized in Figure 2B.

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A: Early stages



B: Later stages

Figure 2: The revised I-PACE model for addictive behaviors. Figure A shows early stages of the development of addictive behaviors. Figure B illustrates later stages of the process and factors contributing to the maintenance of addictive behaviors. Bolder arrows indicate stronger connections/accelerated mechanisms.

In later stages of the addiction process, although the shift may be gradual, the aforementioned associations may become increasingly strong, resulting in habitual behaviors that may feel automatic in certain situations. Cue-reactivity and craving may evolve from affective and cognitive responses over time as a consequence of conditioning processes (Starcke et al., 2018). Previous research highlights the important role of sensitivities towards addiction-related stimuli and activations in neural reward systems involving the ventral and dorsal striatum and other limbic structures in addictive behaviors (Fauth-Bühler & Mann, 2017; Fauth-Bühler, Mann, & Potenza, 2017; Luijten, Schellekens, Kuhn, Machielse, & Sescousse, 2017; Palaus, Marron, Viejo-Sobera, & Redolar-Ripoll, 2017). Subjective expectancies may evolve into affective and cognitive biases, which may include biased or seemingly automatic attention to the respective behavior-related stimuli and triggers (Jeromin, Nyenhuis, & Barke, 2016). We propose that compensatory effects become stronger over gratifying effects in later stages of the addiction process (cf. Brand, Young, et al., 2016). In addition to the moderating effects of general inhibitory control on relationships between cue-reactivity/craving and the habitual behaviors, we propose that stimuli-specific inhibitory control may act as a mediator in the later stages of addictive processes (Everitt & Robbins, 2016). Several researchers have emphasized impairments in inhibitory control and executive functions in gambling disorder (Ioannidis, Hook, Wickham, et al., 2019; van Timmeren, Daams, van Holst, & Goudriaan, 2018), gaming disorder (Argyriou, Davison, & Lee, 2017; Kuss et al., 2018; Yao et al., 2017), and unspecified internet-use disorders (Ioannidis, Hook, Goudriaan, et al., 2019). We propose, however, that although the general inhibitory control may also decrease during addictive processes, the development of diminished specific stimulus-related inhibitory control is crucially involved in habitual behaviors in later stages of addictive behaviors. We propose that if cue-reactivity and craving have been developed as

responses to external or internal triggers, this may lead to reductions in controlling desire when being confronted with addictive stimuli, which may then increase the likelihood of behaving habitually (Piazza & Deroche-Gamonet, 2013).

3. Neurobiological mechanisms

3.1. Neuroscientific theories of addiction integrated in the inner circle of the I-PACE model

Several neuroscientific theories and models explaining addictive behaviors have been integrated in the theoretical framework of the inner circle of the I-PACE model (Brand, Young, et al., 2016). Direct links can be seen to the *Impaired Response Inhibition and Salience Attribution (I-RISA)* model (Goldstein & Volkow, 2011), *Incentive-Sensitization* (Robinson & Berridge, 2008), *Reward Deficiency Syndrome* (Blum et al., 1996) models and theories, and in dual-process approaches of addiction (Bechara, 2005; Everitt & Robbins, 2005, 2016) and ideas of imbalance between goal-directed behaviors and habits (Robbins, Vaghi, & Banca, 2019). We also refer to aspects of more specific theoretical models integrating neuroscientific considerations of gambling disorder (Blaszczynski & Nower, 2002; Goudriaan, Oosterlaan, Beurs, & van den Brink, 2004) and gaming disorder (Dong & Potenza, 2014; Wei, Zhang, Turel, Bechara, & He, 2017). Combining these theories, we consider the progression of an imbalance between increasing incentive-oriented urges and desires on the one hand and decreasing situation-specific inhibitory control over these urges and desires on the other hand as important for the development and maintenance of addictive behaviors. Increasing incentive sensitization, as a result of conditioning processes (Berridge, Robinson, & Aldridge, 2009), may associate with attentional bias and cue-reactivity in later stages of addiction processes. Individuals with reward deficiencies may be particularly prone to developing incentive sensitization (Blum, Gardner, Oscar-Berman,

& Gold, 2012). Incentive salience may promote cue-reactivity and craving, which may contribute to engagement in addictive behaviors.

Reductions in executive functions have considered both as vulnerability factors and consequences of addictive behaviors including substance-use disorders (Volkow, Wang, Fowler, & Tomasi, 2012). In behavioral addictions, such as gambling and gaming disorders, one may argue that executive reductions constitute vulnerability factors and do not develop as a consequence of the addictive behavior, because no direct substance-related neurotoxic effects on the brain are involved. Consistent with this notion, we propose that a diminished level of general inhibitory control is a vulnerability factor for the addictive behavior and acts as a moderating variable of the relationship between affective responses to certain triggering stimuli (e.g., stress or negative moods) and decisions to engage in specific behaviors (see Figure 2A). In addition, however, we argue that beyond this moderating effect of executive functions as a vulnerability factor of addictions, situation-specific inhibitory control (when being confronted with addiction-related stimuli) may decrease over time as a consequence of addictive behaviors, although – in contrast to substance-use disorders – no direct neurotoxic effects on the brain are involved in behavioral addictions. Reductions in stimuli-specific inhibitory control may develop based on cue-reactivity and craving and be accompanied by functional brain changes in addiction-related circuits (Ersche et al., 2012; Koob & Volkow, 2010; Volkow & Morales, 2015; Volkow et al., 2012). Thus, in later stages of addictive behaviors (Figure 2B), stimuli-specific inhibitory control processes may be influenced by craving and urges related to encountering addiction-related stimuli, which may then make it more likely that an individual will behave habitually or seemingly automatically (Everitt & Robbins, 2005, 2013, 2016).

3.2. Neural correlates of the main processes within the inner circle of the I-PACE model

The aforementioned proposed imbalance between limbic/ reward-oriented brain circuits and prefrontal control in behavioral addictions has been reviewed relatively extensively for gambling disorder (Clark et al., 2013; Goudriaan, Yücel, & van Holst, 2014; Potenza, 2013; van Holst, van den Brink, Veltman, & Goudriaan, 2010) and gaming disorder (Kuss et al., 2018; Weinstein, 2017; Weinstein, Livny, & Weizman, 2017), including in meta-analyses (Meng et al., 2015). Although less extensively, there also exist neuroimaging studies of compulsive sexual behaviors, including problematic pornography use (e.g., Brand, Snagowski, Laier, & Maderwald, 2016; Gola et al., 2017; Klucken, Wehrum-Osinsky, Schweckendiek, Kruse, & Stark, 2016; Schmidt et al., 2017; Voon et al., 2014), which have been examined in recent reviews (Kraus, Voon, & Potenza, 2016; Stark, Klucken, Potenza, Brand, & Strahler, 2018). Scientific studies of neural correlates of buying-shopping disorder are relatively scarce. There are, however, some studies from consumer psychology perspectives (e.g., Raab, Elger, Neuner, & Weber, 2011) and studies using electrophysiological measures to investigate neurobiological mechanisms of buying-shopping disorder (Trotzke, Starcke, Pedersen, & Brand, 2014) which have been reviewed recently (Kyrios et al., 2018; Trotzke, Brand, & Starcke, 2017). Although not yet recognized as a clinical condition, there are also recent publications on structural and functional neuroimaging findings of poorly controlled and problematic use of social networks sites and other internet-communication applications (e.g., Dieter et al., 2017; He, Turel, & Bechara, 2017; Lemenager et al., 2016; Montag et al., 2017; Montag et al., 2018; Turel & Qahri-Saremi, 2016), which have been reviewed by Wegmann, Mueller, Ostendorf, and Brand (2018).

There is significant variability across neuroimaging studies of addictive behaviors regarding the types of behavioral addictions, the techniques used (e.g., structural/functional magnetic resonance imaging [s/fMRI], positron emission tomography [PET]), the psychological constructs or processes of interest, the experimental tasks used to measure specific functions, the samples included (convenient samples with individuals showing different degrees of symptoms versus clinically diagnosed individuals or treatment-seeking patients), and the diagnostic procedures used. Nevertheless, when drawing conclusions from the studies, meta-analyses and reviews (see, for example, citations above), there is first evidence for hyperactive involvement of limbic structures, including the amygdala and the ventral striatum, and hypoactive prefrontal-striatal circuits involved in cognitive control over the behaviors. There are, however, some caveats, for example hypoactive engagement of reward circuitry during the anticipatory phase of monetary processing (Balodis & Potenza, 2015), with some researchers proposing differences relating to the processing of addictive cues (hyperactive reward responding) and non-addictive rewarding cues (relatively hypoactive reward responding) (Limbrick-Oldfield, van Holst, & Clark, 2013). The insula may be a mediator between the two systems (limbic and prefrontal-striatal), representing the somatic states linked to craving and the desire to behave specifically (see discussion in Namkung, Kim, & Sawa, 2017; Wei et al., 2017). The main structures that have been identified as potential brain correlates of addictive behaviors are summarized in Figure 3.

In the recent meta-analysis of cue-reactivity-related brain activity in fMRI-studies with samples of patients with behavioral addictions compared to control subjects (Starcke et al., 2018), the dorsal striatum (caudate nucleus) was more active in individuals with addictions compared to those without and in individuals with addictions when contrasting the addiction-related condition with the neutral condition in the cue-

reactivity tasks. The findings may reflect shifts from involvement of the ventral striatum in early stages of behavioral addictions when being confronted with addiction-related stimuli to involvement of the dorsal striatum in later stages of the disorder, when the behavior becomes more habitual (Everitt & Robbins, 2013, 2016; Zhou et al., 2019). The brain structures and circuits that likely underlie addictive behaviors and shifts from early to later stages of addiction processes are illustrated schematically in Figure 3.

Widespread connections among fronto-striatal structures have been examined using resting-state fMRI investigations with healthy subjects and have been shown to be involved in behavioral flexibility (Morris et al., 2016). These circuits are also broadly consistent with functional networks involved in emotion regulation (Öner, 2018). Changes in connectivity between specific structures involved in fronto-striatal circuits (e.g., connectivity between amygdala and medial PFC) appear important in explaining emotion dysregulation in substance-use disorders (Koob, 2015; Wilcox, Pommy, & Adinoff, 2016). The connectivity of networks involved in cognitive control (fronto-parietal circuits and medial frontal areas) and in reward processing (including subcortical and limbic structures) has also been shown to predict abstinence in cocaine-use disorder after treatment (Yip, Scheinost, Potenza, & Carroll, 2019). A stronger separation of the two networks involved in executive control and in reward sensitivity has been proposed to underlie behavioral flexibility and decreased compulsivity, which may explain better therapeutic outcomes (Yip et al., 2019).

In summary, we propose that an imbalance in circuits underlying behavioral flexibility and emotion/urge regulation relate to main aspects of addictive behaviors. The pathways include dopaminergic projections from the ventral tegmental area and substantia nigra to prefrontal areas, the ventral striatum, and anterior cingulate gyrus as well as serotonergic projections from raphé nuclei to prefrontal areas (mainly orbitofrontal regions) (Everitt & Robbins, 2005; Volkow et al., 2012; Volkow, Wang,

Tomasi, & Baler, 2013). The interconnections between striatal structures, thalamus, and prefrontal areas depend largely upon glutamate and gamma-aminobutyric acid (GABA) (Naaijen, Lythgoe, Amiri, Buitelaar, & Glennon, 2015), and the neurochemical systems involved in fronto-striatal loops act in concerted and cross-regulatory fashions (Gleich et al., 2015). Neurochemical correlates of addictions have been discussed intensively elsewhere, and many studies emphasize the important role of dopamine in substance-use disorders (Herman & Roberto, 2015; Pascoli et al., 2018; Volkow, Koob, & McLellan, 2016). The findings concerning dopamine in behavioral addictions are, however, less robust (Potenza, 2018).

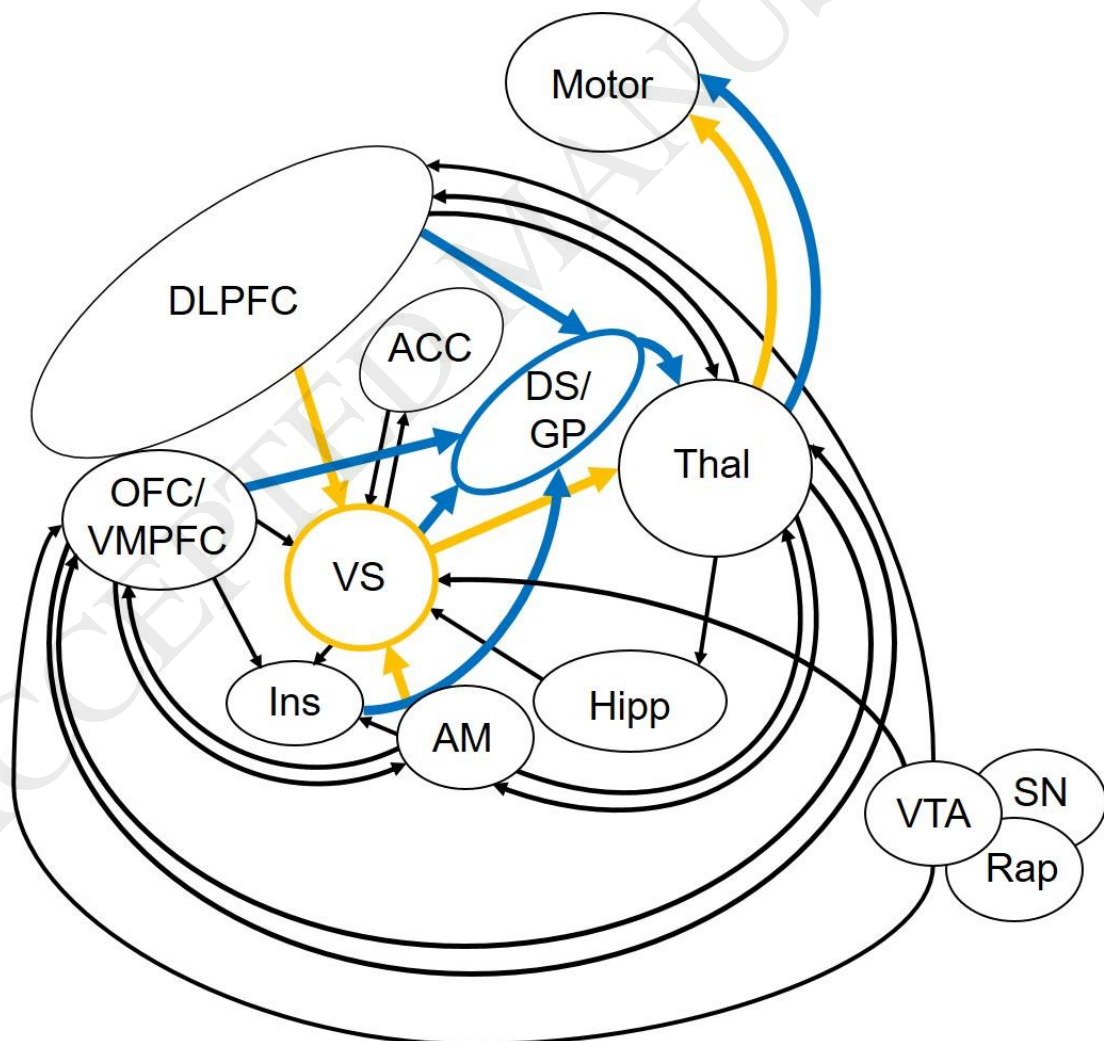


Figure 3: Brain circuits potentially underlying addictive behaviors. Orange arrows represent main circuitry proposed to be involved in early stages of addictive processes. Blue arrows indicate the additional involvement of the dorsal striatum and related structures in later stages of addiction processes, when behaviors become more habitual. ACC = anterior cingulate cortex, AM = amygdala, DLPFC = dorsolateral prefrontal cortex, DS = dorsal striatum, GP = globus pallidus, Hipp = hippocampus, Ins = insula, Motor = motor cortex and associated regions for executing behaviors, OFC = orbitofrontal cortex, Rap = serotonergic raphé nuclei, SN = substantia nigra, Thal = thalamus, VMPFC = ventromedial prefrontal cortex, VS = ventral striatum, VTA = dopaminergic ventral tegmental area.

Although a meaningful number of studies on neural correlates of behavioral addictions have been published in recent years, there remain limitations that should be mentioned. First, most studies have been published on gambling disorder and gaming disorder (see comments above). Less evidence exists for other behavioral addictions including compulsive sexual behaviors including problematic pornography use, buying-shopping disorder, and other potential phenomena that are not yet recognized as clinical conditions, such as problematic use of social-network sites. In particular, studies that systematically investigate neural correlates of specific psychological functions (e.g., craving, inhibitory control) across specific types of behavioral addictions are missing. Studies investigating stages of addiction processes or symptom severity as predictors or moderating variables of neural activity and potential structural brain abnormalities are important to better understand mechanisms underlying the progression of addictive behaviors. Consistent with this, longitudinal studies on brain correlates of addictive behaviors that test specific hypotheses are missing. Investigating the potential shift from activity of the ventral to the dorsal striatum as response to addiction-related cues across types of behavioral addictions and across different stages of addiction, using both cross-sectional and longitudinal designs, would help to understand better the nature of addictive behaviors. Such studies are

necessary to disentangle potential shifts from craving to compulsion and from expecting gratification to expecting relief from negative states when encountering addiction-related stimuli in different stages of behavioral addictions, which in turn should help in optimizing treatments. Studies comparing different types of addictive behaviors and different stages of addiction processes including prospective longitudinal studies could also investigate hypothesized involvement of reductions in inhibitory control as a vulnerability factor and/ or as a consequence of the addictive behaviors, and one that may mediate links between affective responses and habitual/ compulsive behaviors (see discussion in Everitt & Robbins, 2016).

4. Conclusion and future directions

The updated I-PACE model is a theoretical approach for describing the process of addictive behaviors by combining psychological and neuroscientific theories of substance-use disorders and behavioral addictions. We consider disorders due to addictive behaviors being the consequence of interactions between core characteristics of a person and several moderating and mediating variables, which may be dynamic and develop over time as a consequence of engagement in specific behaviors. We propose that the I-PACE model of addictive behaviors may be useful for psychological and neuroscientific research because it permits formation and testing of clear hypotheses regarding interaction effects of specific variables in explaining variance in symptom severity of behavioral addictions. The model may also inspire clinical practice (cf. King et al., 2017; Potenza, 2017) by defining and investigating possible mediating variables that may represent important targets for treatment (e.g., expectancies, affective and cognitive responses to triggers). The updated I-PACE model also offers the possibility of deriving hypotheses on the stages of addictive processes (both during progression and recovery), for example by arguing that

reductions of specific inhibitory-control accelerate in later stages in the progression of addiction processes. It is important to note, however, that we consider theoretical models as being dynamic. The validity of specific hypotheses, combined in a theoretical framework, should be evaluated empirically, and theoretical models should be updated by considering recent scientific findings from different perspectives.

What is important to keep in mind is that the theoretical model proposed is based on different degrees of scientific evidence with respect to addictive behaviors. As mentioned in the previous sections, the involvement of specific psychological mechanisms and neurobiological processes is relatively well studied in gambling disorder and gaming disorder and less intensively investigated in other types of behaviors that potentially become addictive, for example pornography use, buying-shopping and social-networking. Furthermore, for some aspects and mechanisms proposed in the updated I-PACE model, different levels of evidence exist. For executive functions and inhibitory control, a relatively large number of studies has used experimental paradigms and has examined particular aspects of executive functioning in different types of addictive behaviors. On the other hand, for cue-reactivity and craving in specific addictive behaviors, some studies applied a correlational design, which makes interpretations of causality and the time of development of cue-reactivity and craving in the addiction process difficult to define (Zilberman, Lavidor, Yadid, & Rassovsky, 2019). Considering these limitations it is important to emphasize that the model proposed is a theoretical model that summarizes the current state-of-the-art of behavioral addiction research and aims at inspiring theory-based future studies.

Another issue that is important to consider is that personality and temperament features are rather vague predictors for specific addictive behaviors, given that these variables are involved in many psychopathologies and often explain only a mild-to-

moderate proportion of symptoms across different disorders (Zilberman, Yadid, Efratim, Neumark, & Rassevsky, 2018).

We would also like to comment on the current debate with respect to classifying buying-shopping disorder and pornography-use disorder as impulse-control disorders or as behavioral addictions. The ICD-11 includes problematic pornography use as one facet of compulsive sexual behavior disorder within the category of impulse-control disorders. Buying-shopping disorder is listed as an example for other specified impulse-control disorders in the ICD-11 coding tool (World-Health-Organization, 2019). Many researchers, however, argue that both types of disorders would be better classified as addictive behaviors (Potenza, Higuchi, & Brand, 2018).

One challenge for future research and theory building involves identifying and disentangling potential commonalities and differences between disorders due to addictive behaviors and other mental disorders, such as obsessive-compulsive-related and impulse-control disorders, which may relate to behavioral addictions on psychological and neurobiological levels (Chamberlain et al., 2016; Fineberg et al., 2013; Fineberg et al., 2018; Robbins et al., 2019). For example, inhibitory control and reward processing have also been proposed to be important in obsessive-compulsive-related and impulse-control disorders, such as discussed in skin-picking disorder and trichotillomania, which have also been related to functioning of fronto-striatal brain circuits (Chamberlain et al., 2008). Dysfunctions of fronto-striatal loops may, however, be involved in multiple other mental health disorders as well (Mitelman, 2019). Nonetheless, the fact that fronto-striatal loops are involved in different mental disorders does not necessarily mean that the psychological processes related to the clinical phenotypes of disorders are the same. First, fronto-striatal loops are differently defined and analyzed across studies. Future studies should examine more closely specific contributions of structures currently broadly defined within fronto-striatal loops to

certain specific psychological processes underlying specific problematic behaviors. Second, the general involvement of inhibitory control and reward processing does not mean that the psychological processes are comparable across disorders, although there may be some overlap of impulsivity/compulsivity and addictive behaviors (e.g., Chamberlain, Ioannidis, & Grant, 2018). It is important to define more precisely the factors underlying the temporal progression of motivations for people to engage excessively in specific behaviors. For example, in addictive behaviors, it may be that core motivations to engage in gaming or gambling, at least at early stages, involve reward anticipation. In later stages, avoidance of negative feelings is likely additionally involved. In obsessive-compulsive-related disorders, it may be that the core drive at early stages involves avoidance of negative feelings or anxiety. Later, the behavior itself may potentially be experienced as rewarding because it may help relieve stress. In other words, the general involvement of specific neurocognitive functions may not entirely explain a disorder. The same idea potentially applies to neural mechanisms. It may be the case that in disorders due to addictive behaviors, the ventral striatum contributes importantly at early stages of the disorder, with respect to cue-reactivity and craving. In later stages, the dorsal striatum may become more involved and relate to habitual and compulsive aspects of addictive disorders. In contrast, the dorsal striatum is likely involved in obsessive-compulsive-related disorders and impulse-control disorders, such as trichotillomania, from early stages (Isobe et al., 2018; van den Heuvel et al., 2016).

In future studies, it seems important to investigate processes and interactions of different neurocognitive functions in different types of addictive behaviors in order to achieve a better understanding of the underlying natures of behavioral phenomena. The I-PACE model may be used for defining and clarifying specific hypotheses in researching these phenomena. It is important to examine hypothesized processes in

addictive behaviors and compare them with other mental disorders, such as obsessive-compulsive-related and impulse-control disorders to understand whether the underlying processes involved are different or similar. In this process, data generated should help clarify the extent to which different terms may be currently employed for describing similar mechanisms across disorders. In this manner, the updated version of the I-PACE model provides a theoretical framework that should help address major questions relating to addictive, obsessive-compulsive, impulse-control and other disorders, including those relating to internet use, which may become increasingly relevant over time given changes in the digital technology environment.

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References

- Alvarez-Monjaras, M., Mayes, L. C., Potenza, M. N., & Rutherford, H. J. V. (2018). A developmental model of addictions: Integrating neurobiological and psychodynamic theories through the lens of attachment. *Attachment & Human Development, 1*, 1-22. doi:10.1080/14616734.2018.1498113
- APA. (2013). *Diagnostic and Statistical Manual of Mental Disorders 5th Edition*. Washington DC: APA.
- Argyriou, E., Davison, C. B., & Lee, T. T. C. (2017). Response inhibition and Internet Gaming Disorder: A meta-analysis. *Addictive Behaviors, 71*, 54-60. doi:10.1016/j.addbeh.2017.02.026
- Baggio, S., Starcevic, V., Studer, J., Simon, O., Gainsbury, S. M., Gmel, G., & Billieux, J. (2018). Technology-mediated addictive behaviors constitute a spectrum of related yet distinct conditions: A network perspective. *Psychology of Addictive Behaviors, 32*, 564-572. doi:10.1037/adb0000379
- Balodis, I. M., & Potenza, M. N. (2015). Anticipatory reward processing in addicted populations: A focus on the monetary incentive delay task. *Biological Psychiatry, 77*, 434-444. doi:10.1016/j.biopsych.2014.08.020
- Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nature Neuroscience, 8*, 1458-1463. doi:10.1038/nn1584
- Berridge, K. C., Robinson, T. E., & Aldridge, J. W. (2009). Dissecting components of reward: 'Liking', 'wanting', and learning. *Current Opinions in Pharmacology, 9*, 65-73. doi:10.1016/j.coph.2008.12.014
- Blaszczyński, A., & Nower, L. (2002). Apathways model of problem and pathological gambling. *Addiction, 97*, 487-499.
- Blum, K., Gardner, E., Oscar-Berman, M., & Gold, M. (2012). "Liking" and "wanting" linked to Reward Deficiency Syndrome (RDS): Hypothesizing differential responsivity in brain reward circuitry. *Current Pharmaceutical Design, 18*, 113-138. doi:10.2174/138161212798919110
- Blum, K., Sheridan, P. J., Wood, R. C., Braverman, E. R., Chen, T. J., Cull, J. G., & Comings, D. E. (1996). The D2 dopamine receptor gene as a determinant of reward deficiency syndrome. *Journal of the Royal Society of Medicine, 89*, 396-400.
- 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. doi: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. doi:10.1016/j.neubiorev.2016.08.033
- Carbonell, X., Chamarro, A., Oberst, U., Rodrigo, B., & Prades, M. (2018). Problematic use of the internet and smartphones in university students: 2006–2017. *International Journal of Environmental Research and Public Health, 15*, E475. doi:10.3390/ijerph15030475
- Carnes, S., & Love, T. (2017). Separating models obscures the scientific underpinnings of sex addiction as a disorder. *Archives of Sexual Behavior, 46*, 2253-2256. doi:10.1007/s10508-017-1072-8
- Chamberlain, S. R., Ioannidis, K., & Grant, J. E. (2018). The impact of comorbid impulsive/compulsive disorders in problematic Internet use. *Journal of Behavioral Addictions, 7*, 269-275. doi:10.1556/2006.7.2018.30
- Chamberlain, S. R., Lochner, C., Stein, D. J., Goudriaan, A. E., van Holst, R. J., Zohar, J., & Grant, J. E. (2016). Behavioural addiction - A rising tide? *European Neuropsychopharmacology, 26*, 841-855. doi:10.1016/j.euroneuro.2015.08.013
- Chamberlain, S. R., Menzies, L., Hampshire, A., Suckling, J., Fineberg, N. A., del Campo, N., . . . Sahakian, B. J. (2008). Orbitofrontal dysfunction in patients with obsessive-compulsive disorder and their unaffected relatives. *Science, 321*, 421-422. doi:10.1126/science.1154433

- Claes, L., Müller, A., & Luyckx, K. (2016). Compulsive buying and hoarding as identity substitutes: The role of materialistic value endorsement and depression. *Comprehensive Psychiatry*, *68*, 65-71. doi:10.1016/j.comppsy.2016.04.005
- Clark, L., Averbeck, B., Payer, D., Sescousse, G., Winstanley, C. A., & Xue, G. (2013). Pathological choice: The neuroscience of gambling and gambling addiction. *Journal of Neuroscience*, *33*, 17617-17623. doi:10.1523/JNEUROSCI.3231-13.2013
- Del Pino-Gutiérrez, A., Jiménez-Murcia, S., Fernández-Aranda, F., Agüera, Z., Granero, R., Hakansson, A., . . . Menchón, J. M. (2017). The relevance of personality traits in impulsivity-related disorders: From substance use disorders and gambling disorder to bulimia nervosa. *Journal of Behavioral Addictions*, *6*, 396-405. doi:10.1556/2006.6.2017.051
- Deleuze, J., Nuyens, F., Rochat, L., Rothen, S., Maurage, P., & Billieux, J. (2017). Established risk factors for addiction fail to discriminate between healthy gamers and gamers endorsing DSM-5 Internet gaming disorder. *Journal of Behavioral Addictions*, *6*, 516-524. doi:10.1556/2006.6.2017.074
- Dempsey, A. E., O'Brien, K. D., Tiamiyu, M. F., & Elhai, J. D. (2019). Fear of missing out (FoMO) and rumination mediate relations between social anxiety and problematic Facebook use. *Addictive Behaviors Reports*, *9*, 100150. doi:10.1016/j.abrep.2018.100150
- Dieter, J., Hoffmann, S., Mier, D., Reinhard, I., Beutel, M., Vollstädt-Klein, S., . . . Leménager, T. (2017). The role of emotional inhibitory control in specific internet addiction – an fMRI study. *Behavioural Brain Research*, *324*, 1-14. doi:10.1016/j.bbr.2017.01.046
- Dong, G., & Potenza, M. N. (2014). A cognitive-behavioral model of Internet gaming disorder: Theoretical underpinnings and clinical implications. *Journal of Psychiatric Research*, *58*, 7-11. doi:10.1016/j.jpsychires.2014.07.005
- Dong, G., Wang, Z., Wang, Y., Du, X., & Potenza, M. N. (2019). Gender-related functional connectivity and craving during gaming and immediate abstinence during a mandatory break: Implications for development and progression of internet gaming disorder. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *88*, 1-10. doi:10.1016/j.pnpbp.2018.04.009
- Dowling, N. A., Merkouris, S. S., Greenwood, C. J., Oldenhof, E., Toumbourou, J. W., & Youssef, G. J. (2017). Early risk and protective factors for problem gambling: A systematic review and meta-analysis of longitudinal studies. *Clinical Psychology Review*, *51*, 109-124. doi:10.1016/j.cpr.2016.10.008
- Elhai, J. D., Tiamiyu, M., & Weeks, J. (2018). Depression and social anxiety in relation to problematic smartphone use: The prominent role of rumination. *Internet Research*, *28*, 315-332. doi:10.1108/IntR-01-2017-0019
- Emelin, V. A., Rasskazova, E. I., & Tkhostov, A. S. (2017). Technology-related transformations of imaginary body boundaries: Psychopathology of the everyday excessive Internet and mobile phone use. *Psychology in Russia: State of the Art*, *10*, 177-189. doi:10.11621/pir.2017.0312
- Ersche, K. D., Jones, P. S., Williams, G. B., Turton, A. J., Robbins, T. W., & Bullmore, E. T. (2012). Abnormal brain structure implicated in stimulant drug addiction. *Science*, *335*, 601-604. doi:10.1126/science.1214463
- Everitt, B. J., & Robbins, T. W. (2005). Neural systems of reinforcement for drug addiction: From actions to habits to compulsion. *Nature Neuroscience*, *8*, 1481-1489. doi:10.1038/nn1579
- Everitt, B. J., & Robbins, T. W. (2013). From the ventral to the dorsal striatum: Devolving views of their roles in drug addiction. *Neuroscience and Biobehavioral Reviews*, *37*, 1946-1954. doi:10.1016/j.neubiorev.2013.02.010
- 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. doi:10.1146/annurev-psych-122414-033457
- Fauth-Bühler, M., & Mann, K. (2017). Neurobiological correlates of internet gaming disorder: Similarities to pathological gambling. *Addictive Behaviors*, *64*, 349-356. doi:10.1016/j.addbeh.2015.11.004

- Fauth-Bühler, M., Mann, K., & Potenza, M. N. (2017). Pathological gambling: A review of the neurobiological evidence relevant for its classification as an addictive disorder. *Addiction Biology*, *22*, 885-897. doi:10.1111/adb.12378
- Fineberg, N. A., Baldwin, D. S., Menchon, J. M., Denys, D., Grünblatt, E., Pallanti, S., . . . ObsessiveCompulsiveandRelatedDisordersResearchNetwork. (2013). Manifesto for a European research network into obsessive-compulsive and related disorders. *European Neuropsychopharmacology*, *23*, 561-568. doi:10.1016/j.euroneuro.2012.06.006
- Fineberg, N. A., Demetrovics, Z., Stein, D. J., Ioannidis, K., Potenza, M. N., Grünblatt, E., . . . Chamberlain, S. R. (2018). Manifesto for a European research network into Problematic Usage of the Internet. *European Neuropsychopharmacology*, *11*, 1232-1246. doi:10.1016/j.euroneuro.2018.08.004
- Gervasi, A. M., La Marca, L., Costanzo, A., Pace, U., Guglielmucci, F., & Schimmenti, A. (2017). Personality and Internet gaming disorder: A systematic review of recent literature. *Current Addiction Reports*, *4*, 293-307. doi:10.1007/s40429-017-0159-6
- Gleich, T., Deserno, L., Lorenz, R. C., Boehme, R., Pankow, A., Buchert, R., . . . Gallinat, J. (2015). Prefrontal and striatal glutamate differently relate to striatal dopamine: Potential regulatory mechanisms of striatal presynaptic dopamine function? *Journal of Neuroscience*, *35*, 9615-9621. doi:10.1523/JNEUROSCI.0329-15.2015
- 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*, 2021-2031. doi:10.1038/npp.2017.78
- Goldstein, R. Z., & Volkow, N. D. (2011). Dysfunction of the prefrontal cortex in addiction: Neuroimaging findings and clinical implications. *Nature Reviews Neuroscience*, *12*, 652-669. doi:10.1038/nrn3119
- Goudriaan, A. E., Oosterlaan, J., Beurs, E., & van den Brink, W. (2004). Pathological gambling: A comprehensive review of biobehavioral findings. *Neuroscience and Biobehavioral Reviews*, *28*, 123-141. doi:10.1016/j.neubiorev.2004.03.001
- Goudriaan, A. E., Yücel, M., & van Holst, R. J. (2014). Getting a grip on problem gambling: What can neuroscience tell us? *Frontiers in Behavioral Neuroscience*, *8*, 141. doi:10.3389/fnbeh.2014.00141
- Hahn, E., Reuter, M., Spinath, F. M., & Montag, C. (2017). Internet addiction and its facets: The role of genetics and the relation to self-directedness. *Addictive Behaviors*, *65*, 137-146. doi:10.1016/j.addbeh.2016.10.018
- He, Q., Turel, O., & Bechara, A. (2017). Brain anatomy alterations associated with Social Networking Site (SNS) addiction. *Scientific Reports*, *23*(7), 45064. doi:10.1038/srep45064
- Herman, M. A., & Roberto, M. (2015). The addicted brain: Understanding the neurophysiological mechanisms of addictive disorders. *Frontiers in Integrative Neuroscience*, *9*, 18. doi:10.3389/fnint.2015.00018
- Ho, R. C., Zhang, M. W. B., Tsang, T. Y., Toh, A. H., Pan, F., Lu, Y., . . . Mak, K.-K. (2014). The association between internet addiction and psychiatric co-morbidity: A meta-analysis. *BMC Psychiatry*, *14*, 183. doi:10.1186/1471-244X-14-183
- Ioannidis, K., Hook, R., Goudriaan, A. E., Vlies, S., Fineberg, N. A., Grant, J. E., & Chamberlain, S. R. (2019). Cognitive deficits in problematic Internet use: A meta-analysis of 40 studies. *The British Journal of Psychiatry*, [EPub ahead of print]. doi:10.1192/bjp.2019.3
- Ioannidis, K., Hook, R., Wickham, K., Grant, J. E., & Chamberlain, S. R. (2019). Impulsivity in gambling disorder and problem gambling: A meta-analysis. *Neuropsychopharmacology*, [EPub ahead of print]. doi:10.1038/s41386-019-0393-9
- Isobe, M., Redden, S. A., Keuthen, N. J., Stein, D. J., Lochner, C., Grant, J. E., & Chamberlain, S. R. (2018). Striatal abnormalities in trichotillomania: A multi-site MRI analysis. *NeuroImage: Clinical*, *17*, 893-898. doi:10.1016/j.nicl.2017.12.031

- Jeromin, F., Nyenhuis, N., & Barke, A. (2016). Attentional bias in excessive Internet gamers: Experimental investigations using an addiction Stroop and a visual probe. *Journal of Behavioral Addictions, 5*, 32-40.
- 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. doi:10.1016/j.psyneuen.2017.01.008
- Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist, 58*, 697-720. doi:10.1037/0003-066X.58.9.697
- Kayış, A. R., Satici, S. A., Yılmaz, M. F., Şimşek, D., Ceyhan, E., & Bakioğlu, F. (2016). Big five-personality trait and internet addiction: A meta-analytic review. *Computers in Human Behavior, 63*, 35-40. doi:10.1016/j.chb.2016.05.012
- King, D. L., Delfabbro, P. H., Wu, A. M. S., Doh, Y. Y., Kuss, D. J., Pallesen, S., . . . Sakuma, H. (2017). Treatment of Internet gaming disorder: An international systematic review and CONSORT evaluation. *Clinical Psychology Review, 54*, 123-133. doi:10.1016/j.cpr.2017.04.002
- Kircaburun, K., & Griffiths, M. D. (2018). Instagram addiction and the Big Five of personality: The mediating role of self-liking. *Journal of Behavioral Addictions, 7*, 158-170. doi:10.1556/2006.7.2018.15
- Klucken, T., Wehrum-Osinsky, S., Schweckendiek, J., Kruse, O., & Stark, R. (2016). Altered appetitive conditioning and neural connectivity in subjects with compulsive sexual behavior. *Journal of Sexual Medicine, 13*, 627-636. doi:10.1016/j.jsxm.2016.01.013
- Koob, G. F. (2015). The dark side of emotion: The addiction perspective. *European Journal of Pharmacology, 753*, 73-87. doi:10.1016/j.ejphar.2014.11.044
- Koob, G. F., & Volkow, N. D. (2010). Neurocircuitry of addiction. *Neuropsychopharmacology, 35*, 217-238.
- Kraus, S. W., Voon, V., & Potenza, M. N. (2016). Should compulsive sexual behavior be considered an addiction? *Addiction, 111*, 2097-2106. doi:10.1111/add.13297
- Kuss, D. J., Pontes, H. M., & Griffiths, M. D. (2018). Neurobiological correlates in Internet gaming disorder: A systematic literature review. *Frontiers in Psychiatry, 9*, 166. doi:10.3389/fpsy.2018.00166
- Kyrios, M., Trotzke, P., Lawrence, L., Fassnacht, D., Ali, K., Laskowski, N. M., & Müller, A. (2018). Behavioral Neuroscience of Buying-Shopping Disorder: A Review. *Current Behavioral Neuroscience Reports, 5*, 263-270. doi:10.1007/s40473-018-0165-6.
- Lachmann, B., Sindermann, C., Sariyska, R. Y., Luo, R., Melchers, M. C., Becker, B., . . . Montag, C. (2018). The role of empathy and life satisfaction in internet and smartphone use disorder. *Frontiers in Psychology, 9*, 398. doi:10.3389/fpsyg.2018.00398
- Laier, C., & Brand, M. (2017). Mood changes after watching pornography on the Internet are linked to tendencies towards Internet-pornography-viewing disorder. *Addictive Behaviors Reports, 5*, 9-13. doi:10.1016/j.abrep.2016.11.003
- Laier, C., Wegmann, E., & Brand, M. (2018). Personality and cognition in gamers: Avoidance expectancies mediate the relationship between maladaptive personality traits and symptoms of Internet-gaming disorder. *Frontiers in Psychiatry, 9*, 1-8. doi:10.3389/fpsy.2018.00304
- Lam, L. T., & Lam, M. K. (2017). The association between financial literacy and problematic Internet shopping in a multinational sample. *Addictive Behaviors Reports, 6*, 123-127. doi:10.1016/j.abrep.2017.10.002
- Lee, D., Lee, J., Namkoong, K., & Jung, Y. C. (2018). Subregions of the anterior cingulate cortex form distinct functional connectivity patterns in young males with internet gaming disorder with comorbid depression. *Frontiers in Psychiatry, 9*, 1-9. doi:10.3389/fpsy.2018.00380
- Lee, D., Namkoong, K., Lee, J., & Jung, Y. C. (2018). Abnormal gray matter volume and impulsivity in young adults with Internet gaming disorder. *Addiction Biology, 23*, 1160-1167. doi:10.1111/adb.12552
- Lemenager, T., Dieter, J., Hill, H., Hoffmann, S., Reinhard, I., Beutel, M., . . . Mann, K. (2016). Exploring the neural basis of avatar identification in pathological Internet gamers and of self-reflection

- in pathological social network users. *Journal of Behavioral Addictions*, *5*, 485-499. doi:10.1556/2006.5.2016.048
- Li, W., Garland, E. L., O'Brien, J. E., Tronnier, C., McGovern, P., Anthony, B., & Howard, M. O. (2018). Mindfulness-oriented recovery enhancement for video game addiction in emerging adults: Preliminary findings from case reports. *International Journal of Mental Health and Addiction*, *16*, 928–945. doi:10.1007/s11469-017-9765-8
- Limbrick-Oldfield, E. H., van Holst, R. J., & Clark, L. (2013). Fronto-striatal dysregulation in drug addiction and pathological gambling: Consistent inconsistencies? *Neuroimage Clinical*, *2*, 385-393. doi:10.1016/j.nicl.2013.02.005
- Lobo, D. S. S. (2016). Genetic aspects of gambling disorders: Recent developments and future directions. *Current Behavioral Neuroscience Reports*, *3*, 58-66. doi:10.1007/s40473-016-0064-7
- Luijten, M., Schellekens, A. F., Kuhn, S., Machielse, M. W., & Sescousse, G. (2017). Disruption of reward processing in addiction: An image-based meta-analysis of functional magnetic resonance imaging studies. *JAMA Psychiatry*, *74*(4), 387-398. doi:10.1001/jamapsychiatry.2016.3084
- Männikkö, N., Ruotsalainen, H., Miettunen, J., Pontes, H. M., & Käriäinen, M. (2017). Problematic gaming behaviour and health-related outcomes: A systematic review and meta-analysis. *Journal of Health Psychology*. doi:10.1177/1359105317740414
- Meng, Y., Deng, W., Wang, H., Guo, W., & Li, T. (2015). The prefrontal dysfunction in individuals with Internet gaming disorder: A meta-analysis of functional magnetic resonance imaging studies. *Addiction Biology*, *20*, 799–808. doi:10.1111/adb.12154
- Mitelman, S. A. (2019). Transdiagnostic neuroimaging in psychiatry: A review. *Psychiatry Research*. doi:10.1016/j.psychres.2019.01.026
- Montag, C., Markowitz, A., Blaszkiewicz, K., Andone, I., Lachmann, B., Sariyska, R., . . . Markett, S. (2017). Facebook usage on smartphones and gray matter volume of the nucleus accumbens. *Behavioural Brain Research*, *329*, 221-228. doi:10.1016/j.bbr.2017.04.035
- Montag, C., Zhao, Z., Sindermann, C., Xu, L., Fu, M., Li, J., . . . Becker, B. (2018). Internet Communication Disorder and the structure of the human brain: Initial insights on WeChat addiction. *Scientific Reports*, *8*, 1–10. doi:10.1038/s41598-018-19904-y
- Morris, L. S., Kundu, P., Dowell, N., Mechelmans, D. J., Favre, P., Irvine, M. A., . . . Voon, V. (2016). Fronto-striatal organization: Defining functional and microstructural substrates of behavioural flexibility. *Cortex*, *74*, 118-133. . doi:10.1016/j.cortex.2015.11.004
- Müller, A., Brand, M., Claes, L., Demetrovics, Z., de Zwaan, M., Fernández-Aranda, F., . . . Kyrios, M. (2019). Buying-shopping disorder – Is there enough evidence to support its inclusion in ICD-11? *CNS Spectrums*, 1-6. doi:10.1017/S1092852918001323
- Müller, A., Claes, L., Georgiadou, E., Möllenkamp, M., Voth, E. M., Faber, R. J., . . . de Zwaan, M. (2014). Is compulsive buying related to materialism, depression or temperament? Findings from a sample of treatment-seeking patients with CB. *Psychiatry Research*, *216*, 103-107. doi:10.1016/j.psychres.2014.01.012
- Naaijen, J., Lythgoe, D. J., Amiri, H., Buitelaar, J. K., & Glennon, J. C. (2015). Fronto-striatal glutamatergic compounds in compulsive and impulsive syndromes: A review of magnetic resonance spectroscopy studies. *Neuroscience and Biobehavioral Reviews*, *52*, 74-88. doi:10.1016/j.neubiorev.2015.02.009
- Namkung, H., Kim, S. H., & Sawa, A. (2017). The insula: An underestimated brain area in clinical neuroscience, psychiatry, and neurology. *Trends in Neurosciences*, *40*, 200-207. doi:10.1016/j.tins.2017.02.002
- Noël, X., van der Linden, M., & Bechara, A. (2006). The neurocognitive mechanisms of decision-making, impulse control, and loss of willpower to resist drugs. *Psychiatry (Edgmont)*, *3*, 30-41.
- Öner, S. (2018). Neural substrates of cognitive emotion regulation: A brief review. *Psychiatry and Clinical Psychopharmacology*, *28*, 91-96. doi:10.1080/24750573.2017.1407563

- Palaus, M., Marron, E. M., Viejo-Sobera, R., & Redolar-Ripoll, D. (2017). Neural basis of video gaming: A systematic review. *Frontiers in Human Neuroscience*, *11*, 248. doi:10.3389/fnhum.2017.00248
- Pascoli, V., Hiver, A., Van Zessen, R., Loureiro, M., Achargui, R., Harada, M., . . . Lüscher, C. (2018). Stochastic synaptic plasticity underlying compulsion in a model of addiction. *Nature*, *564*, 366-371. doi:10.1038/s41586-018-0789-4
- Paulus, F. W., Ohmann, S., von Gontard, A., & Popow, C. (2018). Internet gaming disorder in children and adolescents: A systematic review. *Developmental Medicine and Child Neurology*, *60*, 645-659. doi:10.1111/dmcn.13754
- Piazza, P. V., & Deroche-Gamonet, V. (2013). A multistep general theory of transition to addiction. *Psychopharmacology*, *229*, 387-413.
- Potenza, M. N. (2013). Neurobiology of gambling behaviors. *Current Opinion in Neurobiology*, *23*, 660-667. doi:10.1016/j.conb.2013.03.004
- Potenza, M. N. (2017). Clinical neuropsychiatric considerations regarding nonsubstance or behavioral addictions. *Dialogues in Clinical Neuroscience*, *19*, 281-291.
- Potenza, M. N. (2018). Searching for replicable dopamine-related findings in gambling disorder. *Biological Psychiatry*, *83*, 984-986. doi:10.1016/j.biopsych.2018.04.011
- Potenza, M. N., Higuchi, S., & Brand, M. (2018). Call for research into a wider range of behavioural addictions. *Nature*, *555*, 30. doi:10.1038/d41586-018-02568-z
- Raab, G., Elger, C. E., Neuner, M., & Weber, B. (2011). A neurological study of compulsive buying behaviour. *Journal of Consumer Policy*, *34*, 401-413. doi:10.1007/s10603-011-9168-3
- Robbins, T. W., Vaghi, M. M., & Banca, P. (2019). Obsessive-compulsive disorder: Puzzles and prospects. *Neuron*, *102*, 27-47. doi:10.1016/j.neuron.2019.01.046
- Roberts, A., Sharman, S., Coid, J., Murphy, R., Bowden-Jones, H., Cowlshaw, S., & Landon, J. (2017). Gambling and negative life events in a nationally representative sample of UK men. *Addictive Behaviors*, *75*, 95-102. doi:10.1016/j.addbeh.2017.07.002
- Robinson, T. E., & Berridge, K. C. (2008). The incentive sensitization theory of addiction: Some current issues. *Philosophical Transactions of the Royal Society B*, *363*, 3137-3146. doi:10.1098/rstb.2008.0093
- Rothen, S., Briefer, J. F., Deleuze, J., Karila, L., Andreassen, C. S., Achab, S., . . . Billieux, J. (2018). Disentangling the role of users' preferences and impulsivity traits in problematic Facebook use. *PloS One*, *13*, 1-13. doi:10.1371/journal.pone.0201971
- Ryu, H., Lee, J. Y., Choi, A., Park, S., Kim, D. J., & Choi, J. S. (2018). The relationship between impulsivity and Internet gaming disorder in young adults: Mediating effects of interpersonal relationships and depression. *International Journal of Environmental Research and Public Health*, *15*(3), 1-11. doi:10.3390/ijerph15030458
- Sariyska, R., Lachmann, B., Markett, S., Reuter, M., & Montag, C. (2017). Individual differences in implicit learning abilities and impulsive behavior in the context of Internet addiction and Internet Gaming Disorder under the consideration of gender. *Addictive Behaviors Reports*, *5*, 19-28. doi:10.1016/j.abrep.2017.02.002
- Schiebener, J., & Brand, M. (2015). Decision making under objective risk conditions - a review of cognitive and emotional correlates, strategies, feedback processing, and external influences. *Neuropsychology Review*, *25*, 171-198.
- Schmidt, C., Morris, L. S., Kvamme, T. L., Hall, P., Birchard, T., & Voon, V. (2017). Compulsive sexual behavior: Prefrontal and limbic volume and interactions. *Human Brain Mapping*, *38*, 1182-1190. doi:10.1002/hbm.23447
- Schneider, L. A., King, D. L., & Delfabbro, P. H. (2017). Family factors in adolescent problematic Internet gaming: A systematic review. *Journal of Behavioral Addictions*, *6*(3), 321-333. doi:10.1556/2006.6.2017.035
- Schneider, L. A., King, D. L., & Delfabbro, P. H. (2018). Maladaptive coping styles in adolescents with Internet gaming disorder symptoms. *International Journal of Mental Health and Addiction*, *16*(4), 905-916. doi:10.1007/s11469-017-9756-9

- Starcevic, V., & Khazaal, Y. (2017). Relationship between behavioural addictions and psychiatric disorder: What is known and what is yet to be learned. *Frontiers in Psychiatry, 8*(53). doi:10.3389/fpsy.2017.00053
- Starcke, K., Antons, S., Trotzke, P., & Brand, M. (2018). Cue-reactivity in behavioral addictions: A meta-analysis and methodological considerations. *Journal of Behavioral Addictions, 7*, 227-238. doi:10.1556/2006.7.2018.39
- 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*, 218–231. doi:10.1007/s40473-018-0162-9
- Stark, R., Kruse, O., Wehrum-Osinsky, S., Snagowski, J., Brand, M., Walter, B., & Klucken, T. (2017). Predictors for (problematic) use of Internet sexually explicit material: Role of trait sexual motivation and implicit approach tendencies towards sexual explicit material. *Sexual Addiction & Compulsivity, 24*, 180-202.
- Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*, 220-247. doi:10.1207/s15327957pspr0803_1
- 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. doi:10.1016/j.neuroimage.2018.04.072
- Trotzke, P., Brand, M., & Starcke, K. (2017). Cue-reactivity, craving, and decision making in buying disorder: A review of the current knowledge and future directions. *Current Addiction Reports, 4*, 246-253. doi:10.1007/s40429-017-0155-x
- Trotzke, P., Starcke, K., Pedersen, A., & Brand, M. (2014). Cue-induced craving in pathological buying: Empirical evidence and clinical implications. *Psychosomatic Medicine, 76*, 694-700.
- Turel, O., & Qahri-Saremi, H. (2016). Problematic use of Social Networking Sites: Antecedents and consequence from a dual system theory perspective. *Journal of Management Information Systems, 33*, 1087-1116.
- van den Heuvel, O. A., van Wingen, G., Soriano-Mas, C., Alonso, P., Chamberlain, S. R., Nakamae, T., . . . Veltman, D. J. (2016). Brain circuitry of compulsivity. *European Neuropsychopharmacology, 26*, 810-827. doi:10.1016/j.euroneuro.2015.12.005
- van Holst, R. J., van den Brink, W., Veltman, D. J., & Goudriaan, A. E. (2010). Why gamblers fail to win: A review of cognitive and neuroimaging findings in pathological gambling. *Neuroscience and Biobehavioral Reviews, 34*, 87-107. doi:10.1016/j.neubiorev.2009.07.007
- van Timmeren, T., Daams, J. G., van Holst, R. J., & Goudriaan, A. E. (2018). Compulsivity-related neurocognitive performance deficits in gambling disorder: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews, 84*, 204-217. doi:10.1016/j.neubiorev.2017.11.022
- Vargas, T., Maloney, J., Gupta, T., Damme, K. S. F., Kelley, N. J., & Mittal, V. A. (2019). Measuring facets of reward sensitivity, inhibition, and impulse control in individuals with problematic Internet use. *Psychiatry Research, 275*, 351-358. doi:10.1016/j.psychres.2019.03.032
- 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. doi:10.1016/j.bbr.2018.03.009
- Volkow, N. D., & Baler, R. D. (2015). NOW vs LATER brain circuits: Implications for obesity and addiction. *Trends in Neurosciences, 38*, 345-352. doi:10.1016/j.tins.2015.04.002
- Volkow, N. D., Koob, G. F., & McLellan, A. T. (2016). Neurobiologic advances from the brain disease model of addiction. *New England Journal of Medicine, 374*, 363-371. doi:10.1056/NEJMra1511480
- Volkow, N. D., & Morales, M. (2015). The brain on drugs: From reward to addiction. *Cell, 162*, 712-725. doi:10.1016/j.cell.2015.07.046

- Volkow, N. D., Wang, G. J., Fowler, J. S., & Tomasi, D. (2012). Addiction circuitry in the human brain. *Annual Review of Pharmacology and Toxicology*, *52*, 321-336. doi:10.1146/annurev-pharmtox-010611-134625
- Volkow, N. D., Wang, G. J., Tomasi, D., & Baler, R. D. (2013). Unbalanced neuronal circuits in addiction. *Current Opinion in Neurobiology*, *23*, 639-648. doi:10.1016/j.conb.2013.01.002
- 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*, e102419. doi:10.1371/journal.pone.0102419
- Wegmann, E., Mueller, S., Ostendorf, S., & Brand, M. (2018). Highlighting Internet-communication disorder as further Internet-use disorder when considering neuroimaging studies. *Current Behavioral Neuroscience Reports*, *5*, 295-301. doi:10.1007/s40473-018-0164-7
- Wegmann, E., Ostendorf, S., & Brand, M. (2018). Is it beneficial to use Internet-communication for escaping from boredom? Boredom proneness interacts with cue-induced craving and avoidance expectancies in explaining symptoms of Internet-communication disorder. *PLoS One*, *13*(4), e0195742. doi:10.1371/journal.pone.0195742
- Wei, L., Zhang, S., Turel, O., Bechara, A., & He, Q. (2017). A tripartite neurocognitive model of Internet Gaming Disorder. *Frontiers in Psychiatry*, *8*(285). doi:10.3389/fpsy.2017.00285
- Weinstein, A. M. (2017). An update overview on brain imaging studies of Internet gaming disorder. *Frontiers in Psychiatry*, *8*, 185. doi:10.3389/fpsy.2017.00185
- Weinstein, A. M., Livny, A., & Weizman, A. (2017). New developments in brain research of internet and gaming disorder. *Neuroscience and Biobehavioral Reviews*, *75*, 314-330. doi:10.1016/j.neubiorev.2017.01.040.
- Wéry, A., Deleuze, J., Canale, N., & Billieux, J. (2018). Emotionally laden impulsivity interacts with affect in predicting addictive use of online sexual activity in men. *Comprehensive Psychiatry*, *80*, 192-201. doi:10.1016/j.comppsy.2017.10.004
- Wilcox, C. E., Pommy, J. M., & Adinoff, B. (2016). Neural circuitry of impaired emotion regulation in substance use disorders. *American Journal of Psychiatry*, *173*, 344-361. doi:10.1176/appi.ajp.2015.15060710
- World-Health-Organization. (2019). ICD-11 for Mortality and Morbidity Statistics. Retrieved from <https://icd.who.int/en/>
- Xuan, Y.-H., Li, S., Tao, R., Chen, J., Rao, L.-L., Wang, X. T., & Zheng, R. (2017). Genetic and environmental influences on gambling: A meta-analysis of twin studies. *Frontiers in Psychology*, *8*, 2121-2121. doi:10.3389/fpsyg.2017.02121
- Yao, Y. W., Liu, L., Ma, S. S., Shi, X. H., Zhou, N., Zhang, J. T., & Potenza, M. N. (2017). Functional and structural neural alterations in Internet gaming disorder: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews*, *83*, 313-324. doi:10.1016/j.neubiorev.2017.10.029
- Yip, S. W., Scheinost, D., Potenza, M. N., & Carroll, K. M. (2019). Connectome-based prediction of cocaine abstinence. *American Journal of Psychiatry*. doi:10.1176/appi.ajp.2018.17101147
- Zhou, F., Zimmermann, K., Xin, F., Scheele, D., Dau, W., Banger, M., . . . Becker, B. (2018). Shifted balance of dorsal versus ventral striatal communication with frontal reward and regulatory regions in cannabis-dependent males. *Human Brain Mapping*, *39*, 5062-5073. doi:10.1002/hbm.24345
- Zhou, N., Cao, H., Li, X., Zhang, J., Yao, Y., Geng, X., . . . Fang, X. (2018). Internet addiction, problematic internet use, nonproblematic internet use among Chinese adolescents: Individual, parental, peer, and sociodemographic correlates. *Psychology of Addictive Behaviors*, *32*, 365-372. doi:10.1037/adb0000358
- Zhou, X., Zimmermann, K., Xin, F., Derck, R., Sassmannshausen, A., Scheele, D., . . . Becker, B. (2019). Cue-reactivity in the ventral striatum characterizes heavy cannabis use, whereas reactivity in the dorsal striatum mediates dependent use. *bioRxiv*. doi:10.1101/516385

- Zilberman, N., Lavidor, M., Yadid, G., & Rassovsky, Y. (2019). Qualitative review and quantitative effect size meta-analyses in brain regions identified by cue-reactivity addiction studies. *Neuropsychology, 33*, 319-334. doi:10.1037/neu0000526. Review. PubMed PMID: 30816782.
- Zilberman, N., Yadid, G., Efratim, Y., Neumark, Y., & Rassovsky, Y. (2018). Personality profiles of substance and behavioral addictions. *Addictive Behaviors, 82*, 174-181. doi:10.1016/j.addbeh.2018.03.007. Epub 2018 Mar 6. PubMed PMID: 29547799.

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