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VIEWPOINT

# Current interpretations of the I-PACE model of behavioral addictions

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## ABSTRACT

*Background and aims:* The Interaction of Person-Affect-Cognition-Execution (I-PACE) model of behavioral addictions is used relatively often as a scientific framework to specify research hypotheses and to interpret empirical findings in behavioral addiction research. There are, however, controversial interpretations in the literature regarding some specific elements of the model, which may require a more precise definition of specific constructs and processes that are central to the I-PACE model. *Methods:* This is neither a comprehensive literature review nor a proposal for a new version of the I-PACE model. We aim to provide a selective, critical evaluation of some interpretations of the model and to include recent developments regarding addiction theories and controversial debates. *Results:* The role of gratification and compensation and therefore positive and negative reinforcement are specified. The concepts of cue-reactivity and craving are considered in the context of desire thinking and permissive beliefs. The relationships between impulsive, habitual, and compulsive behaviors in behavioral addictions are discussed. The effects of general self-control and situation-specific executive functions are elaborated. Punishment (in)sensitivity is discussed as a further important process potentially involved in behavioral addictions. These constructs and processes (through their interactions) are considered in the context of changes over time in the course of addictive behaviors. *Conclusion:* This viewpoint article aims to provide greater precision and clarity regarding some specific elements of the I-PACE model, which may help stimulate research and theory building and advance clinical care in the behavioral addiction field.

## KEYWORDS

theoretical considerations, reinforcement, cue-reactivity and craving, habitual and compulsive behaviors, self-control, punishment sensitivity

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## INTRODUCTION

Theories and theoretical models in clinical psychology and neuroscience may have great value for research and may help derive explicit hypotheses on mechanisms underlying clinical phenomena and disorders. In clinical practice, theoretical models may inform clinicians about features to consider in assessment and treatment, and they can be useful in psychoeducation (Brand & Potenza, 2021). At the same time, theory building and model development in any psychological field is often a strenuous and difficult endeavor, since the phenomena of interest are usually complex and nuanced, the psychological constructs need better validation and assessment procedures, and the causes of phenomena are difficult to identify (Eronen & Bringmann, 2021). These (and other) considerations are encountered in the context of theories and models which try to explain the development and maintenance of behavioral addictions.

Addictive behaviors are complex, multifactorial, highly dynamic phenomena, likely caused by variables ranging on a time scale from prenatal to very recent situational influences and across biological, psychological, social, and environmental factors. In addition, many psychological constructs within this field lack precision and specificity and most (if not all) can be measured only indirectly via self-reports or behavioral observations. These circumstances make theory building in behavioral addiction research a challenge, like in other areas of clinical psychology (Fried & Robinaugh, 2020), including in the context of mental disorders that are researched for many decades, such as depression (Fried, 2015). But what should we do? Should we give up for fear of not being able to fulfill the requirements of good theories? From our perspective, we should and must continue developing the theoretical frameworks for behavioral addictions, and we are optimistic that we are on a productive path. At the same time, we all should be mindful that our current theories and models within behavioral addiction research (or addiction research more broadly) are all not final, likely generic, and speculative at some points, and therefore may be considered most appropriately as preliminary suggestions as to which processes might contribute to behavioral addictions.

Despite these limitations, the existing models can and should be used, particularly to derive specific hypotheses and test them empirically. Testing the models should then result in further theoretical considerations to help improve the quality of the theoretical assumptions (Fried, 2020). Empirical testing of theories and models requires the genesis of testable predictions (Fried, 2020). This includes predictions based on interactions of variables, where theoretical models should be as precise, simple, and concrete as possible and only as complicated as necessary (Smaldino, 2020). This process also suggests that no theoretical model (neither within the addiction field nor in any other area of psychology) can represent the entire complexity of potential variables that might or might not have an impact on the (behavioral) phenomenon and which might or might not interact in explaining an individual case. Good theoretical models can only describe a specific part of the real world. It is the task of the modeler(s) to choose which parts seem to be more important to explain the phenomenon and should therefore be represented by the model. For example, a model of behavioral addictions could principally focus on (micro) neurobiological aspects (including genetics, neurotransmitters, neurons, brain circuits), on individual psychological processes and/or on environmental and societal factors (micro-, meso-, macro- levels). However, in order to follow the principle of parsimony in theory building and at the same time not to overlook anything important (Weger, 2020), the selection of topics to be included in the theoretical models (like all other aspects of theory building) should be continuously reflected upon, criticized and possibly modified (Smaldino, 2020). In this viewpoint article, we discuss three of the aforementioned requirements for good models: precise definition of constructs, selection of constructs, and precise definition of processes.

We will follow the rule of *attack your designed model* (Smaldino, 2020) and will particularly discuss the current version of the I-PACE (Interaction of Person-Affect-Cognition-Execution) model (Brand et al., 2019). While this model is used relatively often to specify research hypotheses and to interpret empirical findings in behavioral addiction research and related fields, thus helping to improve both research and theory in the behavioral addiction field, the rule of being as precise as possible may have not always been followed, possibly resulting in controversial interpretations. In this viewpoint article, we aim to provide greater precision and clarity regarding several specific elements of the I-PACE model. This may be helpful since the I-PACE model is used frequently to generate very specific hypotheses, for example in Jhone, Song, Lee, Yoon, and Bhang (2021), Liu, Gao, Liang, and Liu (2022), Wang, Elhai, Montag, Zhang, and Yang (2024), Tie et al. (2025) and Xu, Cao, Chen, Xu, and Zhou (2025), to mention a few examples. If a theoretical model is being used to generate specific hypotheses, the theoretical arguments summarized in the model should be as precise as possible. Therefore, we aimed to specify some mechanisms central to the I-PACE model in this article. This may also be helpful since the I-PACE model is rather complex and includes many terminologies and pathways that may benefit from more detailed descriptions or interpretations. In particular, the role of positive and negative reinforcement, cue-reactivity/craving and the relationship with desire thinking and permissive beliefs, habitual and/or compulsive behaviors in behavioral addictions and the role of self-control and executive functions will be discussed. In addition, as a new element that was not considered in the I-PACE model so far, we will discuss the potential role of punishment (in)sensitivity. These constructs and processes (through their interactions) will be considered in the context of changes over time in the course of addictive behaviors. This is neither a comprehensive literature review nor a proposal for a new version of the I-PACE model. Recent comprehensive reviews on the specific mechanisms as proposed in the I-PACE model exist

(e.g., Brandtner, Antons, Cornil, & Brand, 2021; Brandtner et al., 2022), as do reviews considering the validity of specific I-PACE features for certain behavioral addictions (e.g., Pickering & Norberg, 2023; Thomas, Joshi, Trotzke, Steins-Loeber, & Müller, 2023) and reviews on behavioral addictions more broadly (e.g., Brand et al., 2025). We aim to provide a selective, critical evaluation of some interpretations of the model (or specific parts of it) and to hopefully contribute to a more precise understanding of some of the specific assessments.

## EARLY VERSUS LATER STAGES AND RISKY VERSUS ADDICTIVE BEHAVIORS

The I-PACE model was intended to be an etiological model describing the development and maintenance of addictive behaviors. In this context, early stages mean the early phase of the addiction process, in which the behavior is no longer non-problematic, but the full picture of the addiction syndrome has not (yet) been reached. On a behavioral level, early stages mean something between non-problematic and disordered behaviors (e.g., meeting some but not all diagnostic requirements for the diagnosis of a disorder due to addictive behaviors) and may therefore be named "risky behavior" (which may be equivalent to hazardous behaviors; e.g., hazardous gambling and hazardous gaming as defined in the ICD-11). Later stages represent the behavioral addiction in terms of a diagnosis with symptoms severe enough that the criteria (e.g., ICD-11) are fulfilled to justify the diagnosis, including marked distress and/or significant impairments in important areas of functioning and fulfilling requirements for being a mental disorder (Stein et al., 2010). On a behavioral level, we therefore use the term addictive behavior for the later stages of the addiction process.

However, the development of an addiction is typically gradual, not categorical, and neither linear nor uni-directional. Nevertheless, we have differentiated between early and later stages in the I-PACE model to indicate the potential change in processes and because multiple additional stages of gradual changes are challenging to accurately depict in a figure. The categories "early" versus "later" stages are therefore auxiliary constructs to express the addiction process and the potentially associated gradual, non-linear and complex changes in affective and cognitive processes.

Even though the I-PACE model aims at describing the development of addictive behaviors and how interactions between affective and cognitive mechanisms may change over time during the development (and maintenance) of behavioral addictions, this does not mean that a (re)development in the other direction is not possible. The course of an addictive disorder can be highly variable with different individual trajectories of symptom severity over time. Individuals who have developed pathological/addictive behaviors may turn to risky behavior or recover (e.g., through therapy or spontaneously), indicating a transient nature of the problematic behavior in some cases (Konkolÿ Thege, Woodin, Hodgins, & Williams, 2015; López Fernández et al., 2024). There may be also a distinct subgroup of individuals with an episodic course, in which symptom-free phases alternate with phases of high symptom severity and even spontaneous regression of symptoms. Last but not least, considering transdiagnostic mechanisms in mental health, symptom shifts may occur. In other words, individuals recovering from one addictive behavior may be at increased risk of developing another addictive behavior based on the same transdiagnostic mechanisms (Wise, Robinson, & Gillan, 2023). Taken together, individuals with risky behaviors may develop addictive behaviors, but may also revert to non-problematic behaviors or may stay relatively stable regarding engagement in risky behaviors over a long period of time. We therefore suggest using early versus later stages when referring to the development of addictive behaviors, but to use risky versus addictive behaviors when describing the cross-sectional status of behaviors without specifying the direction of possible preceding transitions. Even though the I-PACE model is aimed at describing the development and maintenance of a disorder (behavioral addiction) and not the mechanisms underlying recreational/non-problematic behaviors (i.e., the I-PACE model starts with early stages/risky behaviors), we include aspects probably involved in non-problematic behaviors to contrast the mechanisms underlying risky and addictive behaviors. This is particularly important since most of the behaviors that can become addictive are integrally involved in daily life in most individuals (e.g., shopping, using social networks, having sex). Therefore, it is important to contrast risky and addictive behaviors in the context of behavioral addictions to non-problematic/recreational behaviors and not to complete abstinence. Following this approach, in non-dimensional but categorial research, i.e., when comparing groups of individuals with a pathological/addictive behavior to groups of individuals with risky or non-problematic behaviors, one method for defining the groups may be to use specific cut-off scores based on the number of the nine DSM-5 criteria met (e.g., those proposed for gaming disorder). For example, 0–1 criteria may define non-problematic behavior, 2–4 criteria may define risky behavior, and 5 and more criteria may define pathological behavior/addictive disorder. In a recent study (Müller et al., in press), this approach for defining these three groups was used and the number of criteria fulfilled was assessed by a structured diagnostic interview (see description of the study/results in the section on executive functions and self-control in this article). In addition to this approach, for specific research questions it may also be important to include participants who are abstinent or without engagement in the specific potentially addictive behavior, for example, individuals who do not gamble or do not use pornography. At the same time, for some behavioral addictions (e.g., buying-shopping in adults), a complete abstinence/non-use is so seldom that we still consider the comparison between risky/pathological use to non-problematic use central to a theoretical model on the etiology of addictive behaviors to better understand the mechanisms that may differentiate between "healthy/non-problematic" and "unhealthy/problematic" or "addictive" behaviors.

## POSITIVE AND NEGATIVE REINFORCEMENT IN BEHAVIORAL ADDICTIONS

Considerations of the involvement of positive and negative reinforcement in the course of addictions have a long-standing tradition in addiction theories (Koob, 2015; Koob & Volkow, 2010). In established multistage models of addictions (e.g., Berridge & Robinson, 2016; Everitt & Robbins, 2005, 2013, 2016; Koob, 2015; Koob et al., 2014; Robinson & Berridge, 1993; Volkow, Koob, & McLellan, 2016), it has been argued that typically positive reinforcement may be the main driving motivation in early stages (e.g., voluntary drug consumption), while negative reinforcement may be more strongly involved in later stages, e.g., in the "withdrawal/negative affect" phase (Koob & Volkow, 2010). Reinforcement may be defined as a process that increases the probability of performing a specific behavior if it has previously been rewarded (e.g., positive feelings or pleasure drive positive reinforcement) or if it has previously led to the removal or reduction of aversive stimuli or conditions (e.g., reduction of stress and negative mood drives negative reinforcement). In the I-PACE model, we use the terminology of "gratification" for describing positive experiences of the behavior (feelings of pleasure and reward during an activity, e.g., while gaming) and "compensation" for relieving negative feelings or aversive conditions (e.g., anxiety, dysphoria, stress) that are mitigated by performing the behavior. Consequently, gratification experiences are the bases for positive reinforcement and compensation is associated with the process of negative reinforcement. We have argued (consistently with many scholars within the addiction community; see citations above) that gratification and positive reinforcement are particularly relevant in early stages of developing addictive behaviors. Compensation and negative reinforcement have been considered particularly relevant within later stages, when symptoms of addictive behaviors (e.g., continuation despite negative consequences) have already been developed. In these later stages, individuals might experience a higher degree of negative feelings that might be elicited due to the negative consequences of the addictive behavior. This increase in negative consequences could explain the increase in compensation and these negative phases may be more intense at certain times (e.g., problems at work) and may be less pronounced in other phases (Koob, 2020). In previous discussions, this appeared as the assumption of a complete shift from gratification to compensation. However, more recent interpretations may say that the "shift" is not a complete shift but means that gratification is important at all stages and compensation may increase over time. This development does not occur from one moment to the next, but develops gradually over time, usually not linearly, but perhaps in waves. The waves reflect the hypothesis that the gradual development of compensation may be affected by other processes such as affective and cognitive mechanisms as well as the additional impact of gratification experiences. This multifactorial process sometimes leads to a stronger influence of compensatory experiences and sometimes to lesser, even if the relevance of compensation increases in the long term. Moreover, compensation feelings and negative reinforcement may play an important role even in the very early stages of addictive behaviors or even in casual behaviors, for example, when using games or pornography to cope with stress. Particularly at the beginning, the experience of compensation appears to be closely related to (maladaptive) coping strategies (e.g., Di Blasi et al., 2019; Kardefelt-Winther, 2014, 2017). However, at a conceptual level, a greater distinction should be made between the experience during the use itself (i.e., compensation) and the application of the behavior based on a specific motivation (i.e., coping strategies). Keeping in line with this distinction, we argue that even a behavior that may be motivated mainly by the anticipation of stress relief or other compensation effects, gratification can be experienced as well (e.g., experiences of pleasure and fun while using a game or sexual excitement while using pornography). This means that gratification (positive rewards) may be experienced simultaneously with stress relief and reduction of negative mood. Therefore, distinguishing between "pure" positive reinforcement and "pure" negative reinforcement may be difficult in real-life settings. In addition, even in later stages of addictive behaviors with a relatively high symptom severity and many problems in daily life resulting from the excessive behavior, the experience while performing the behavior may still be gratifying and pleasurable (Wegmann et al., 2025). For example, gaming can still be the most (or even only) rewarding activity of the day. Thus, both mechanisms are not mutually exclusive or completely independent of each other over the course of addiction.

In summary, as a more current interpretation of the I-PACE model, we suggest that both gratification and compensation may be considered involved in the entire addiction process but with relative dominance of gratification at the beginning (and also in casual and recreational use) and an (additional) stronger involvement of compensation in later stages of addictive behaviors (see Fig. 1B). We acknowledge that there may also be inter-individual differences regarding the dominance of positive or negative reinforcement (or even equal contributions) in the context of addictive behaviors now illustrated as waves. The combination of both positive and negative reinforcement in behavioral addictions has been summarized in a simplified manner as "feels better" pathway in (online) addictive behaviors (Brand, 2022). "Feels better" also comprises "less bad" and therefore stands for the combination of positive and negative reinforcement (see Fig. 1). However, this does not mean that the development of compulsive behaviors within behavioral addictions is equally associated with positive and negative reinforcement. We still argue that seemingly habitual and compulsive behaviors are driven by the expectation that only specific behaviors (e.g., using a game) can effectively help avoid or reduce negative mental conditions, which has been called "must-do" pathway of (online) addictive behaviors (Brand, 2022), based on earlier work (e.g., Everitt & Robbins, 2005, 2016). We now elaborate this aspect in the section on habitual and compulsive behaviors in behavioral addictions.

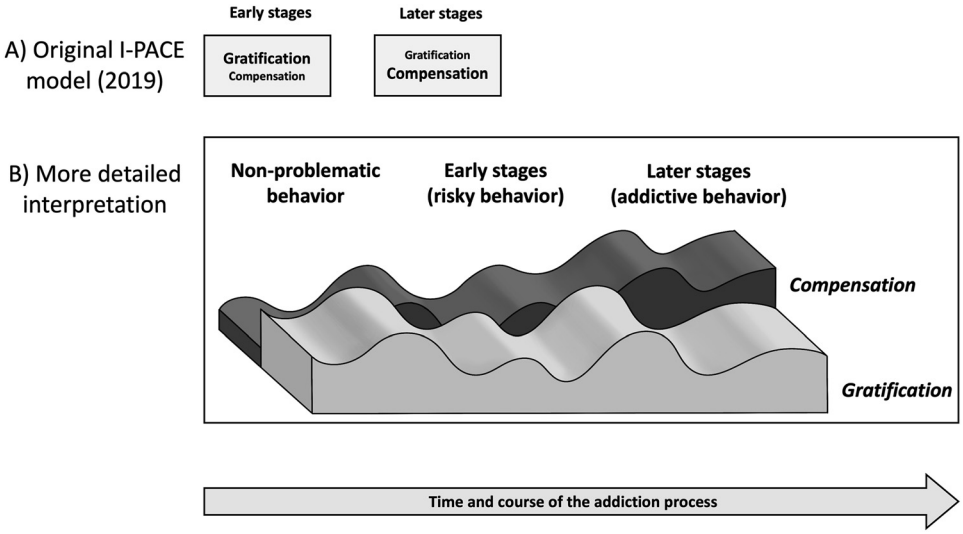


*Fig. 1.* Gratification and compensation related to the severity of addictive behaviors. We argue that both experiences of gratification and compensation while performing the specific behaviors are involved in all stages of behavioral addictions but may vary regarding their relative dominance. While gratification may stay relatively stable (within a range of involvement) compensation may increase over time. The waves indicate that in the course of addictive behaviors, there may be spontaneous (situation-specific) fluctuations of experiences of gratification and compensation and also indicate that over time, the involvement of gratification and compensation may develop non-linearly

## CUE-REACTIVITY, CRAVING, DESIRE THINKING, AND PERMISSIVE BELIEFS IN BEHAVIORAL ADDICTIONS

Desires drive individuals to seek out specific stimuli and activities in the environment and engage with them in ways that satisfy the desire in terms of offering immediate pleasure and/or provide relief from discomfort (Kavanagh, Andrade, & May, 2005). With a historical background tracing back to ancient Greek philosophy, desires may be likened to a wild horse that must be tamed by a rational and reflective rider controlling the horse's impulsive forces (Hofmann & Van Dillen, 2012). This conceptualization has persisted in the form of contemporary dual-process models of addiction suggesting that addictive behaviors arise from an imbalance between a hyperactive impulsive system that generates strong cravings in response to relevant cues (Robinson & Berridge, 1993), and a hypoactive reflective system that is less likely to inhibit those impulses and consider long-term consequences (Bechara, 2005).

Cue-reactivity is a learned response observed in individuals with addictive disorders that is expressed as an emotional, motivational, and physiological reaction in response to the confrontation with conditioned, addiction-relevant stimuli (Carter & Tiffany, 1999). The I-PACE model summarizes that individuals with non-problematic behaviors might simply be aware of behavior-specific cues (e.g., that controllers are generally associated with computer games), whereas individuals with risky behaviors might be attentionally sensitive towards such cues and significant cue-reactivity is generated by multiple reward-associated learning cycles throughout the later stages (see Fig. 2B) (Hyman, Malenka, & Nestler, 2006). Cues that are repeatedly present when the behavior is executed (e.g., external objects or internal states such as psychological distress) become associated with the behavior and elicit heightened conditioned responses in individuals with addictive behaviors (Starcke, Antons, Trotzke, & Brand, 2018). Whereas in the earlier stages, a desire for certain cues and related behaviors is experienced, empirical research suggests that individuals with addictive behaviors respond to such reward-associated cues with cue-induced craving (Noori, Cosa Linan, & Spanagel, 2016).

Craving describes a phenomenon where desires have become seemingly uncontrollable or irresistible and highly specific for a certain target, as in the case of addiction. Defined as "a strong desire for drugs" in the DSM-5, craving is significantly associated with relapse (Vafaie & Kober, 2022), making it a key driver of addictive behaviors and hence an important therapeutic target in addiction treatments. Amid controversy surrounding its phenotypical appearance, there is consensus that craving is multi-faceted and may include several (sub)dimensions. A distinction between reward and relief craving (Verheul, Van den Brink, & Geerlings, 1999) has been corroborated by observations in empirical studies (Glöckner-Rist, Lémenager, & Mann, 2013; Heinz et al., 2003). Due to neurobiological dysregulations (Koob, 2013), individuals in the later stages may seek substances/behaviors not for their pleasurable effects (reward craving) but to alleviate aversive states such as stress, anxiety, or withdrawal. This shift marks the dominance of relief craving, where individuals experience a release from discomfort rather than achieve euphoria. However, reward and relief cravings may also be experienced simultaneously but perhaps with relative dominance of reward craving in

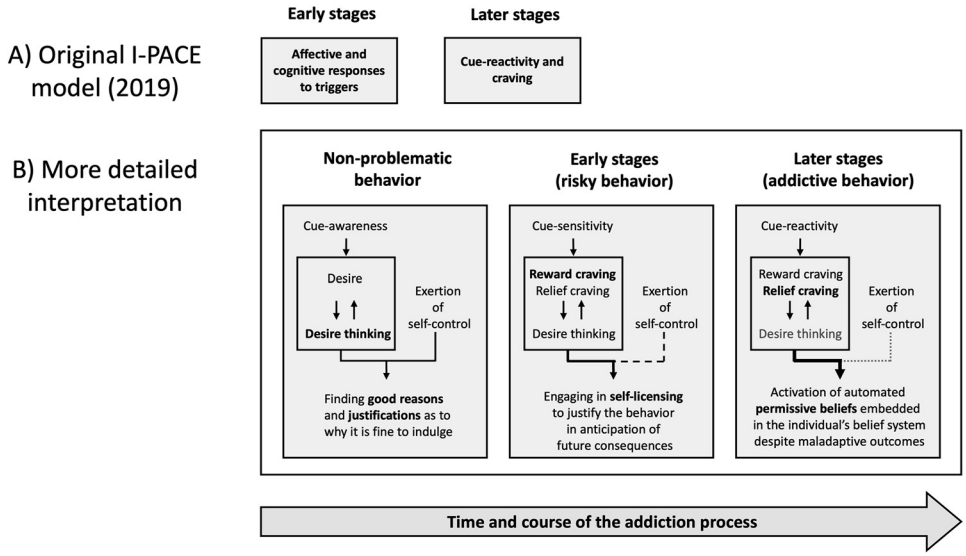


*Fig. 2.* Cue-awareness, cue-sensitivity, and cue-reactivity as well as desire thinking and craving in addictive behaviors

early stages/risky behaviors and relief craving in later stages/addictive behaviors. We have integrated these (sub)dimensions of craving into the current interpretations of the I-PACE model, now specifying how desires may develop into reward and relief cravings over time (see Fig. 2B). Theoretically, craving should also play a role in later stages of the addiction process or when severe symptoms are present, even if the behavior is presumably motivated by avoidance goals and compulsivity (see next section). This is probably because avoidance goals are particularly associated with relief craving. The relationship between craving and symptom severity is supported by a recent meta-analysis, which reports a pooled correlation for this relationship of 0.537 (López-Guerrero, Navas, Perales, Rivero, & Muela, 2023).

Until now, the I-PACE model was also lacking a clear specification of explicit processes involved in the development of desires and craving (see Fig. 2A). Thus, we integrated ideas on such reflective processes, appearing as "desire thinking" in related research (Mansueto et al., 2019). In contrast to craving, desire thinking is considered an inherent human faculty and pertains to the effortful elaboration of any desired target on an imaginal and verbal level (Caselli & Spada, 2010). This may lead to an escalation of craving, accompanied by more vivid imagery and more urgent thoughts on their realization. The Elaborated Intrusion Theory of Desire (EIT; Kavanagh et al., 2005) proposes that this faculty may be hijacked for the elaboration of addiction-specific thoughts and memories, making desire thinking a candidate mechanism for non-problematic, risky, and addictive stages of a behavior (see Fig. 2B). In an earlier publication, Brandtner et al. (2021) hypothesized how desire thinking may be positioned in the I-PACE model. We take up this suggestion and propose further that a decline in cognitive control and reflective processing could lead to a shift towards more automatic, seemingly habitual responses to addiction-related cues, potentially reducing the conscious engagement in desire thinking while simultaneously increasing the influence of reward and relief craving processes (see Fig. 2B).

Desiring to do something is prerequisite but not sufficient for behavioral engagement. Some individuals might experience a self-regulatory conflict where their short-term indulgence interferes with their long-term goals (de Witt Huberts, Evers, & De Ridder, 2012) just as individuals with addictive disorders may experience strong cravings in the setting of negative long-term consequences. To resolve this inner conflict, individuals may engage in self-licensing - a conscious reasoning process to gather justifiable excuses for indulgence, allowing for relevant efforts to self-control by choice (Miller & Effron, 2010). This understanding of a desire-related process challenges the traditional view in dual-process models which typically regards conscious reasoning as a characteristic of the thoughtful rider (i.e., the reflective system). In the case of self-licensing, these capacities appear to be hijacked in favor of the addictive behavior, resulting in the horse and rider effectively joining forces. However, this dynamic might change from earlier to later phases of an addiction. The I-PACE model incorporates considerations from and empirical tests of the Cognitive Model of Addiction (Beck, Wright, Newman, & Liese, 1993; Caselli et al., 2020) where craving and desire thinking are followed by the activation of facilitating or permissive beliefs (see Fig. 2B). Permissive beliefs refer to rather automated self-licensing processes that appear in the form of stable beliefs which have been implemented into the individual's beliefs system. Research shows that permissive beliefs are heightened in addiction-prone individuals (Brandtner, Müller, Behrens, Oelker, & Brand, 2024; Caselli et al., 2020) and highlights them as crucial therapeutic target in addictive disorders (Kim & Hodgins, 2018). Understanding permissive beliefs as an automated or semi-automated process also questions the necessity of a precedent self-regulatory conflict. There might be a point at which permissive beliefs are so habitually activated that they might be of a less reflective

nature than initially thought and could prevent a conflict from surfacing. Like all hypotheses within the I-PACE model, the speculation of earlier and later phases of self-licensing processes needs empirical testing with subsequent verification – or falsification.

## HABITUAL AND COMPULSIVE BEHAVIORS IN BEHAVIORAL ADDICTIONS

The idea that the addiction process is related to the transition from voluntary (goal-directed) drug consumption/behavioral engagement to habit formation and habitual consumption/compulsive behaviors has, like positive and negative reinforcement, a longstanding tradition in addiction research. Habitual behaviors in the addiction context means that (based on reinforcement processes) a strong association between a specific addiction-related stimulus (e.g., the sight of the drug) and a specific drug-seeking response (i.e., consumption) has been built. This may lead to (seemingly) automatic drug-seeking and/or drug-taking behaviors once being confronted with the specific stimulus without activating the value of the drug or a specific goal of the behavior and even if the drug-seeking behavior conflicts with specific (cognitive) goals (e.g., abstinence) (e.g., Berridge, Robinson, & Aldridge, 2009; Berridge & Robinson, 2016; Dickinson, Wood, & Smith, 2002; Doñamayor et al., 2021; Everitt, 2014; Everitt & Robbins, 2005, 2016; Robinson & Berridge, 1993). It has also been argued that internal states, such as stress and negative mood, may accelerate habitual behaviors in the context of addiction (Schwabe, Dickinson, & Wolf, 2011). Habit formation in addiction has been studied intensively in animals, and there are also some human studies, for example, using a Pavlovian-to-Instrumental-Transfer paradigm (cf. Cartoni, Balleine, & Baldassarre, 2016). However, results are mixed, in particular in studies with humans, and few studies have implemented devaluation procedures (e.g., by informing participants that the reward outcome is no longer available) which allows researchers to draw clearer conclusions about the habitual nature of the behavior (cf. Hogarth, 2020). Nowadays, roles of habit formation and habitual behaviors in addiction are debated, and some authors argue that even if the addictive behavior may seem habitual, it is still goal-directed (Hogarth, 2020; Hommel & Wiers, 2017). Thus, Hogarth (2020) argues that habitual behavior is still flexible and the experience of a reduced reward value is associated with decreased drug-seeking behavior. In contrast, compulsive behavior is characterized by a loss of flexibility of the behavior, which is not modified by experience of reduced value of the drug. This results, for example, in continued use despite the experience of negative consequences. Lüscher, Robbins, and Everitt (2020) differentiate between compulsive drug-seeking and compulsive drug-taking and argue that compulsive drug-seeking is associated with habitual tendencies, which may dominate goal-directed tendencies. The behavior itself, that is, compulsive drug-taking, may be more related to reduced executive control, so that the behavior is difficult to stop once started. However, even if compulsivity in drug addictions may be related to seemingly habitual drug-seeking, this does not necessarily mean that goals and goal-directed behaviors are completely diminished. Both drug-seeking behaviors and drug-taking behaviors may still be goal-directed, but the goals may change within the addiction process.

In the I-PACE model, we have used the term "habitual behaviors" when referring to later stages of behavioral addictions. We have also used "seemingly automatic" for these behaviors and aimed at distinguishing between cognitively controlled decisions to behave in a specific manner (early stages) and behavior that is more driven by external stimuli and internal triggers and is performed under less cognitive and inhibitory control and is therefore "seemingly" automatic/habitual. In the 2019 article on the updated I-PACE model (Brand et al., 2019) we did not include a definition of habitual behaviors or a discussion of whether we argue that the seemingly automatic/habitual behavior is still goal-directed (or not). From our perspective now, we should have 1) used the term "seemingly" before "habitual" more often, and 2) included a brief discussion of the way habit formation may contribute to the development of behavioral addictions. We are now elaborating on this point in this viewpoint article.

Consistent with Brand (2022), we argue that positive and negative reinforcement ("feels better") in combination with reduced self-control are driving paths in the manifestation of behavioral addictions. More likely based on negative reinforcement and compensation experiences, compulsive behaviors may develop (cf. Liu et al., 2024), which may be mainly performed to avoid anticipated negative consequences which may result from not performing the behavior. This, however, does not mean that the behavior is habitual in the classical definition and not goal-oriented. We consider habit formation as a general process in the context of rewarding behavior, which is not characteristic for a specific stage, but starts early on and may contribute to compulsive behaviors in later stages. Habit formation may be understood as building stimulus-response associations, and these associations may become stronger over time, based on response-reward outcomes. Nonetheless, this does not imply that stimulus-response associations automatically result in the behaviors. Habit formation may increase the likelihood that a specific behavior is executed in specific situations, but the behaviors likely remain goal-directed. Habit formation may contribute to seemingly automatic behaviors if specific goals are situation-specifically activated, for example, the goal to experience pleasure or the goal to avoid negative consequences of not behaving specifically. The goal activation is probably the result of cue-reactivity and reward/relief craving and the execution of the desired behavior may be accelerated based on habit formation in terms of a learned preparedness to respond specifically when being confronted with specific stimuli/situations. We argue that compulsive behaviors in the context of behavioral addictions remain goal-directed, but that specific goals related to avoiding or reducing negative feelings are activated more automatically

by external stimuli or internal triggers (e.g., stress, negative mood). Nevertheless, the behavior may be in so far relatively inflexible, as these often immediate specific goals (e.g., to reduce negative mood) are favored although negative consequences of the behavior are often experienced in the long run (e. g., loss of social contacts, depression). More details are included in Fig. 3. The potential relative dominance of anticipated/experienced positive/negative consequences of behaving or not behaving specifically is illustrated in Fig. 4.

Regarding habit formation and habitual behaviors, we have shown recently that stimuli associated with addiction-related rewards (e.g., gaming vouchers) trigger reward-related instrumental responding for these rewards not only in people with risky, but also non-problematic use (Schmid et al., 2024). The finding of a specific Pavlovian-to-instrumental transfer (PIT) effect in these individuals suggests that habit formation may represent an early process in addictions. In addition, in several studies (e.g., Schmid et al., 2024; Vogel et al., 2018), an association between the magnitude of the PIT effect and symptoms of gaming disorder was observed, suggesting that habit formation may contribute to the development of problematic behaviors. We also found that personality characteristics considered as potential risk factors for the development of addictive behaviors as well as symptom severity contribute to the speed of acquisition of awareness of experimental contingencies in the conditioning phase of the PIT paradigm (Lörsch et al., 2025), with awareness being related in turn to the magnitude of the PIT effect (Schmid et al., 2024). This further supports the idea of habit formation as a process contributing to problematic behaviors. However, longitudinal studies are needed to confirm empirically the predictive value of habit formation for developing addictive behaviors. Interestingly, Thomas et al. (under re-review) recently reported that regarding buying-shopping, the interaction of symptom severity and acute stress is associated with the strength of the specific PIT effect to shopping-related stimuli. This may be interpreted as a goal-directed habitual/compulsive behavior under acute stress with the aim of relief from negative feelings.

## GENERAL EXECUTIVE FUNCTIONS, SPECIFIC INHIBITORY CONTROL, AND SELF-CONTROL IN BEHAVIORAL ADDICTIONS

Executive functions, specifically (general versus stimuli-specific) inhibitory control as types of executive functions, are explicitly mentioned within the inner circle of the I-PACE model as a factor relevant to determining whether a specific behavior is executed in a given situation. In more current interpretations of the I-PACE model, we believe that executive functions may be underrepresented in two areas. First, while (stimulus-specific) inhibitory control may be the final intervening factor before engaging in specific behaviors, it is only one (albeit important) aspect of executive functions relevant to decision-making, (reduced) self-control, and the development of behavioral addictions. Instead of only inhibitory control, executive (control) functions should be considered part of the executive function boxes, ultimately interacting with affective and cognitive responses to triggers (early stages) and cue-reactivity and craving (later stages), leading to the decision to engage in the behavior or, in later stages, to seemingly habitual behaviors. Accordingly, rather than focusing solely on inhibitory control, the model should be expanded to address executive functions as a whole.

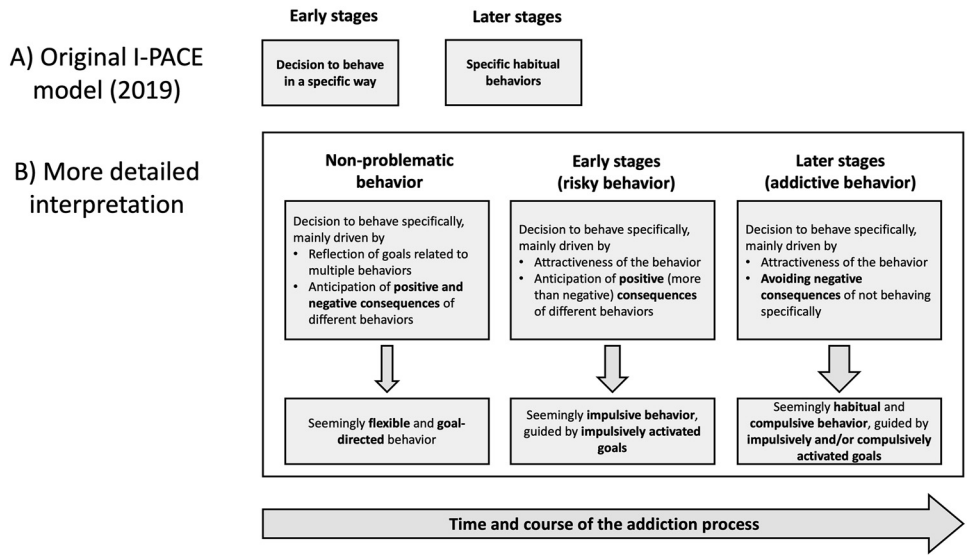


*Fig. 3.* Seemingly flexible, impulsive, habitual, and compulsive behaviors related to the severity of addictive behaviors. We argue that even in later stages, when habit formation may have contributed to more seemingly habitual and compulsive behaviors, these behaviors may still be considered goal-directed but that the situation-specific goals may change. In severe stages of behavioral addictions, beyond the attractiveness of the specific behaviors, an additional goal could be to avoid negative consequences that are anticipated from not behaving specifically (e.g., to avoid "withdrawal symptoms")

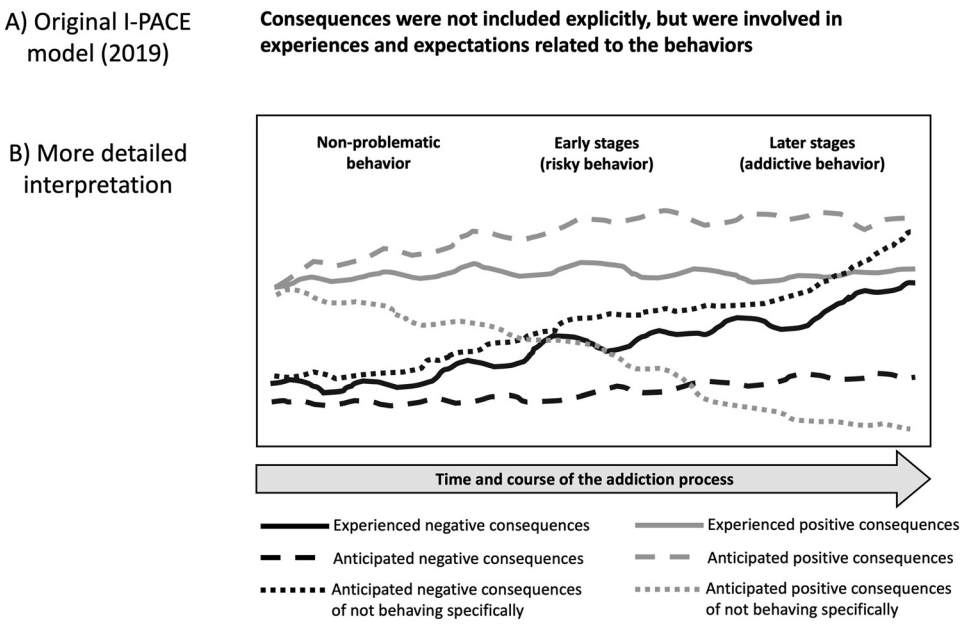


*Fig. 4.* Experienced and anticipated positive and negative consequences directly related to behavior execution (e.g. gaming) and anticipated positive and negative consequences directly related to not behaving specifically (e.g., not gaming). This figure is, however, rather speculative since no clear evidence is available on the potentially different mechanisms of positive/negative and experienced/anticipated consequences. The figure is motivated by theoretical considerations and by clinical observations. The experienced/anticipated consequences may vary substantially between individuals. However, given that this topic is very important in individual treatments, we have generated a figure as an example of how the consequences may relate to each other based on three individual observations with participants (with non-problematic, risky, and addictive behaviors). Note: Anticipated negative consequences of not behaving specifically (e.g., not gaming) may be related to anticipated withdrawal symptoms or negative mood. Anticipated positive consequences of not behaving specifically (e.g., not gaming) may also involve anticipated positive consequences related to other activities (e.g., engaging in sports)

Second, executive functions may influence processes at various points within the inner circle (e.g., they may impact affective and cognitive biases, as well as the relationship between the perception of triggers and cue-reactivity). Additionally, based on the cascade model of diminished self-control in addictive behaviors (Brand, 2022), we argue that reduced general executive functions can serve as a vulnerability factor in some individuals (i.e., lower self-control facilitates addictive behaviors while higher self-control tendencies are a protective factor against addictive behaviors). This influences the entire circle of the I-PACE model, while also potentially declining further in the addiction process as urges and desires intensify (lower inhibitory control as a 'consequence' of addictive behaviors). Thus, executive functions are relevant both as a general predisposing variable (i.e., general/"cool" executive functions) and as a situational factor (i.e., stimulus-related/"hot" executive functions) within the inner circle.

Reductions in both general and stimulus-specific executive functions in multiple (online) addictive behaviors have been demonstrated very recently (Müller et al., in press). The study analyzed data from a large-scale multi-center study in Germany (FOR2974), in which affective and cognitive mechanisms of online addictive behaviors were investigated. The study considered four specific types of problematic usage of the internet: gaming, buying-shopping, pornography use, and use of social networks. Across all types of internet use (aggregated samples) we included three groups (based on structured clinical interviews): pathological/addictive ($n$ = 284), risky ($n$ = 305), and non-problematic behaviors ($n$ = 424). We used multiple neurocognitive measures of executive functions and several self-report measures and found that the three groups differed significantly in both neurocognitive functions (decision-making, cognitive flexibility, interference susceptibility, and stimuli-specific inhibitory control) and self-reported self-directedness and impulsivity. The weakest performance on all tasks was observed in the group with addictive behaviors. The group with risky behaviors performed between the group of addictive and non-problematic behaviors on some but not all neurocognitive tasks and was between the two other groups on all self-report measures. Interestingly, the effects of group on all neurocognitive measures of self-control did not change when co-occurring conditions (depression, anxiety, obsessive-compulsive symptoms) were entered as co-variates. The effects were most robustly seen in buying-shopping and pornography use. The findings demonstrate that online addictive behaviors are associated with impairments in general executive functions, disadvantageous decision-making, and poor stimulus-specific inhibitory control that are particularly seen in later stages of addiction development. The findings complement meta-analyses indicating executive impairments in multiple behavioral addictions (Ioannidis, Hook, Goudriaan, et al., 2019; Ioannidis, Hook,

Wickham, Grant, & Chamberlain, 2019; Müller et al., 2023; Yao, Zhang, Fang, Liu, & Potenza, 2022) and show, for the first time, also effects when comparing addictive behaviors with risky, and non-problematic behaviors as determined by structured diagnostic interviews and using an extensive laboratory assessment of neurocognitive and self-report measures related to executive functions and self-control.

Within the inner circle of the I-PACE model, interactions between affective responses and executive functions related to engaging in addictive behavior are addressed. However, what is not yet explicitly considered is how other affective and cognitive processes and states, such as stress, may reduce executive functions, potentially becoming the decisive factor in allowing the impulse to engage in the specific behavior and to override the control processes of the reflective system (Bechara, 2005; Schwabe et al., 2011; Schwabe & Wolf, 2011). Thus, as stress levels increase in the later stages of behavioral addictions (e.g., due to severe negative consequences), the 'stop now' process (Brand, 2022) may become more impaired, giving free rein to impulses.

Again, reduced self-control over the behavior does not necessarily imply that the behavior is not goal-oriented – goals may change and may be selected more automatically, the ways to reach goals may become less flexible with reduced numbers of alternatives (Kruglanski et al., 2002), and reduced self-control may contribute to easier access to specific goals related to avoiding negative feelings resulting in seemingly habitual behaviors, which are nevertheless still goal-oriented (see Fig. 3).

Another factor to consider is that the situations themselves could change during the course of addiction, making executive control processes more relevant in later stages as compared to early stages. Some situations may be considered "strong" situations in which self-control and personality features more generally are usually less important, which was proposed in 1968 by Mischel (1968) and specified further 40 years later (Mischel, 2009). For example, if the traffic lights are red, you would stop your car without detailed reflection about what to do and you do not need strong self-control. In contrast, when the traffic lights are yellow, you may have to decide quickly whether to stop or not, which requires a balanced processing of activating and inhibitory signals and self-control over impulses. Using this example of a yellow traffic light, it has been argued by Volkow and Baler (2012) that diminished tendencies to stop impulsive responses to certain signals may be fundamentally involved in addictions. However, beyond the imbalance of impulses and self-control in ambiguous situations, it may also be that in the context of addictions, situations which were previously experienced as being strong become more ambiguous to the individual. For example, being at work may be experienced by most people as a strong situation that does not allow to shop online or to use pornography without requiring strong self-control. And it may be that within the course of addictive behaviors the perception of these situations may change or that meta-cognitive goals (e.g., "It is important for me to be perceived as a reliable worker") may change because the urge to take a drug or to behave specifically becomes stronger. If previously strong situations are perceived as more ambiguous and/or situation-specific, meta-cognitive goals may become less important compared to addictive behaviors, inhibitory control may become more important, but may often fail in individuals with addictions. In summary, the interaction between situation-specific features and self-control may be considered an additional aspect of decision-making in the context of addictive behaviors.

Taken together (see also Fig. 5) we argue that (1) inhibitory control is one important type of executive

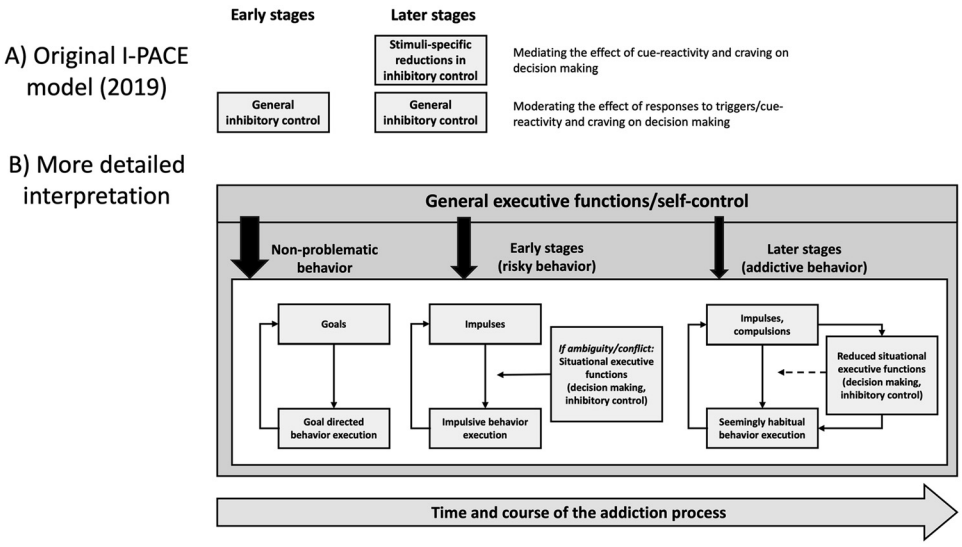


*Fig. 5.* Self-control and general and situation-specific executive functions in addictive behaviors. General executive functions may impact the complete inner circle (i.e. the affective and cognitive processes in specific situations), and specific executive functions may be directly linked to specific affective and cognitive processes

function, but that executive functions in general are involved in the development and maintenance of behavioral addictions, (2) reduced executive functions may be both causes and consequences of the development, (3) executive functions may be reduced due to situational factors such as acute stress, (4) changes in the situation may make executive functions especially relevant in later stages.

## PUNISHMENT (IN)SENSITIVITY IN BEHAVIORAL ADDICTIONS

The I-PACE model has focused on positive and negative reinforcement as main driving paths to behavioral addictions. Positive and negative punishment (in terms of negative consequences of the behavior) and why they may or may not influence the addictive behavior were not explicitly included in the interactions summarized in the I-PACE model. However, punishment sensitivity and/or insensitivity may be directly linked to positive and negative reinforcement mechanisms and may be therefore considered in more detailed interpretations of the reinforcement mechanisms.

Punishment sensitivity describes the adaptive suppression of a behavior in response to negative consequences (Jean-Richard-Dit-Bressel, Killcross, & McNally, 2018), and is a personal characteristic that differs markedly among the general population (Jean-Richard-Dit-Bressel et al., 2021). A generally decreased punishment sensitivity has been discussed as a vulnerability factor explaining why some individuals develop compulsive engagement in certain harmful behaviors (e.g., addictive behaviors) while others do not (Jean-Richard-dit-Bressel et al., 2023). Reduced punishment sensitivity can therefore contribute significantly to behavioral addictions. Although research on this topic in humans is scarce, it has been shown that people who smoke are generally less sensitive to punishment, as evidenced by reduced error-correction rates after punishment (Duehlmeyer & Hester, 2019). Similar findings are reported for individuals with opioid use disorder (Myers et al., 2017). Longitudinal or cross-sectional studies focusing on individuals at different points in the development of addictions are warranted to determine whether reduced punishment sensitivity is a factor that predates addiction, a consequence of addiction development, or both. Three (not mutually exclusive) reasons for the ineffectiveness of negative consequences are discussed: 1) a decreased aversiveness of negative consequences, 2) an overshadowing dominance of a concurrent reward, and 3) a deficit in instrumental punishment learning that impedes the establishment of an association between the behavior and the negative consequence (Jean-Richard-Dit-Bressel et al., 2018; Jean-Richard-dit-Bressel, Ma, Bradfield, Killcross, & McNally, 2019).

Negative consequences of addictive behaviors may be aversive experiences (e.g., feeling of shame and guilt or other negative affective states, bad grades at school) or the loss/reduction of positive experiences (e.g., reduced social support, lower productivity, fewer or less robust positive emotions or diminished pleasure). Moreover, negative consequences can occur in the short or long term. Immediately after the addictive behavior occurs, individuals often feel depressed and uncomfortable as they are not meeting their own standards for controlling their addictive behavior (Palazzolo & Bettman, 2020). Long-term negative consequences include job-related, academic, and social problems (Koós et al., 2021; Montag & Pontes, 2023). Although individuals with behavioral addictions report increasing negative consequences, they counterintuitively continue to engage in the behavior (Koós et al., 2021; Müller et al., 2015; Reid, Garos, & Fong, 2012).

The first reason for a decreased aversiveness of negative consequences may be increased habituation. Individuals may become accustomed to experiencing negative consequences as the addiction develops, such that a single negative consequence may lose its significance (McNally, Jean-Richard-dit-Bressel, Millan, & Lawrence, 2023). However, whether decreased aversiveness of negative consequences may be a vulnerability factor or whether this develops during the course of addictive behaviors, or both, remains debated.

An altered processing of rewards is a predominant line of argument in theories explaining the development of behavioral addictions (see section on positive and negative reinforcement). Seemingly blinded by the experienced reward, individuals with addictive behaviors may have difficulties recognizing or accepting the negative consequences (Field et al., 2020). The interaction between reinforcement experiences (or gratification and compensation) and a "myopia" for future negative consequences (Bechara, 2005) might be explained by temporal aspects. While the behavior may be perceived as highly rewarding at the time of performance and/or shortly thereafter, the rewarding effect may diminish after a certain time, when the negative consequences of the behavior appear. It is, however, still not clear why the (later) negative consequences do not have a strong effect on (changing) the addictive behavior.

One reason for this may be impairments in instrumental punishment learning which may contribute to reduced punishment sensitivity. Such impairments may emerge when individuals are unable to detect or encode the instrumental contingency between their actions and the negative consequences (Jean-Richard-Dit-Bressel et al., 2018). For instance, when individuals were asked about their knowledge regarding cues that indicated a potential negative consequence, those with a decreased punishment sensitivity were less able to detect this contingency than individuals with normal punishment sensitivity, especially if the punishment occurred infrequently (Jean-Richard-Dit-Bressel et al., 2021, 2023). At least in the early stages of addiction process, the negative consequences of addictive behaviors are often gradual and infrequent, which may explain why affected individuals rarely see the connection between their behavior and the negative consequences (McNally et al., 2023) and possibly why people with early symptoms may not seek help until they experience serious negative

consequences. Accordingly, some individuals may be unaware of or ambivalent regarding accepting the negative consequences of their behavior and thus fail to adjust their behavior (Jean-Richard-dit-Bressel et al., 2023).

Again, even though aspects of punishment (in)sensitivity were not explicitly mentioned in the I-PACE model, we suggest the following more detailed interpretation of reinforcement mechanisms of addictive behaviors that may interact with punishment (in)sensitivity and instrumental punishment learning. In general, the costs of a behavior are reflected in the negative consequences (punishment) and the loss of positive experiences (reward removal). In the case of unproblematic behavior, the weighing of benefits (gratification and compensation) and costs (punishment and reward removal) leads to balanced behavior. In the case of risky behaviors and even more so in the case of behavioral addictions, the behavior itself is driven more by the benefits than by the costs. In future studies, the interaction between positive/negative reinforcement and positive/negative punishment should be addressed in more detail in the context of behavioral addictions. Additionally, tendencies regarding punishment and reward sensitivity should be examined. We hope that the considerations of how (theoretically) punishment mechanisms may relate to addictive behaviors, may inspire future studies.

## CONCLUSION AND OUTLOOK

The role of gratification and compensation together with positive and negative reinforcement have been further specified. We argue that experiences of both gratification and compensation are involved in all stages of behavioral addictions but may vary regarding their relative dominance and may develop not linearly but in waves with spontaneous and situation-specific changes. The concepts of cue-reactivity and craving have been further considered in the context of desire thinking and permissive beliefs. The relationships between impulsive, habitual, and compulsive behaviors in behavioral addictions have also been further considered. We now argue that even in later stages, when habit formation may have contributed to more seemingly habitual and compulsive behaviors, these behaviors may still be considered goal-directed but that the situation-specific goals may have changed. The roles of self-control and general and situation-specific executive functions in addictive behaviors have been elaborated. General executive functions may impact the complete inner circle (i.e., the affective and cognitive processes in specific situations), and specific executive functions may be directly linked to situation-specific affective and cognitive processes and may be moderated by situational aspects like stress. Punishment sensitivity has been specified as an additional important process potentially involved in behavioral addictions. All of these constructs and processes (through their interactions) should be considered in the context of changes over time in the course of addictive behaviors.

There are still many open questions from both a theoretical and an empirical perspective. One question is whether the underlying processes and mechanisms (as proposed by the I-PACE model) differ between individuals showing risky behaviors for the first time in the early stages of addiction and those who report risky behaviors after recovering from addictive behaviors. In other words, do we expect similar affective and neurocognitive features (e.g., diminished inhibitory control/executive functioning) in individuals with risky behavior, regardless from which temporal perspective they have reached this stage (i.e., coming from the non-problematic or pathological domains)? In relation to the latter, are there differences regarding whether recovery was "natural" or therapy-induced? In the latter case, do specific therapies influence the considerations? Does long-term symptomatic remission result in favorable improvement of affective and cognitive processes as measured by self-report or in the laboratory by using computerized tasks and neuroimaging (and/or vice versa)? Empirical findings from other mental health areas suggest that this could be the case. Alcohol-specific attentional bias in patients with alcohol use disorder improves during alcohol abstinence (Escudero, Arias Horcajadas, & Orio, 2024). Neuroimaging studies of psychotherapy outcome in diverse clinical populations indicate differences in brain functions before versus after treatment (Bijanki et al., 2021; Stephenson et al., 2024). Following an experimental medicine approach (Field et al., 2021), it is also important to enhance our understanding of how the mechanisms and processes contributing to the development of problematic behavior can be targeted by interventions and whether these are associated with decreases in symptom severity. Even though there are also specific treatment studies of gaming disorder demonstrating, for example, that craving reduction techniques also modify the brain craving networks (Zhang et al., 2016) and that non-invasive neuromodulation techniques may be associated with performance in specific executive/decision-making tasks and symptom severity in gambling and gaming disorders (Stanković, Bjekić, & Filipović, 2023), large-scale longitudinal studies investigating multiple transitions from non-problematic to risky and to addictive behaviors and inverse transitions (natural and treatment-induced) from addictive behaviors to recovery are needed to better understand how changes in psychological and neurobiological mechanisms may be linked to changes in symptom severity.

In addition, the role of gender should be considered more intensively given that recent research demonstrates not only gender-specific prevalence rates of specific behavioral addictions (e.g., Stevens, Dorstyn, Delfabbro, & King, 2021; Zakiniaeiz & Potenza, 2018), but also gender-specific psychological and neurobiological mechanisms (Dong, Wang, Du, & Potenza, 2018; Müller et al., 2023). Future studies investigating potential gender-specific processes underlying behavioral addictions in males and females (and perhaps additional gender identities) may show whether gender (identity) is one of many other predisposing factors or

whether the theoretical models must be defined gender-specifically.

Furthermore, additional individual differences including cultural and personality-related aspects should be considered as the model evolves and becomes increasingly specified.

Despite the need for further research and further optimization of theory development, the more detailed interpretations of the I-PACE model may already be helpful for clinical practice. Using the more detailed interpretations, clinicians may ask more specific questions to better understand among people seeking treatment individual driving factors, for example regarding the interaction of experiences of gratification and compensation while performing the behavior. Clinicians may also consider more intensively how reward and/or relief craving may motivate engagement in addictive behaviors, and how permissive beliefs may conflict with self-control in everyday-life situations. This information may help guide treatment. For example, clinicians may consider mindfulness to reduce stress (if stress may be the prominent driving factor) or alternative behaviors that may deliver pleasure (if rewarding experiences may be the prominent driving factor). In addition, if an individual in treatment reports to behave in an automatic and habitual manner, it may be worthwhile considering incentive devaluation of the behavior in treatment. In cases where feelings of compulsion are prominent, it may be worthwhile to consider the goals of the individual in treatment may have that involve behaving specifically to avoid negative consequences. Given that the I-PACE model is already used in specific treatment programs (e.g., Stark et al., 2024), more detailed interpretations of the model and more detailed description of specific aspects may help therapists explain the model (or parts of it) more clearly in the context of psychoeducation. The additional details may also be helpful for people in treatment to better observe their behavior based on specific characteristics and to better recognize changes in behavior during therapy.

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All authors have performed grant reviews for research-funding agencies; have edited journals and journal sections; have given academic lectures in clinical or scientific venues; and have generated book chapters for publishers of mental health texts. MB, SA, and MNP serve as associate editors of the Journal of Behavioral Addictions.

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