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Biased Choice and Incentive Salience: Implications for Addiction

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Before we can make any choice, we must gather information from the environment about what our options are. This information-gathering process is critically mediated by attention, and our attention is, in turn, shaped by our previous experiences with—and learning about—stimuli and their consequences. In this review, we highlight studies demonstrating a rapid and automatic influence of reward learning on attentional capture and argue that these findings provide a human analog of sign-tracking behavior observed in nonhuman animals—wherein signals of reward gain incentive salience and become attractive targets for attention (and overt behavior) in their own right. We then consider the implications of this idea for understanding the drivers of cue-controlled behavior, with focus on addiction as a case in which choices with regard to reward-related stimuli can become injurious to health. We argue that motivated behavior in general—and addiction in particular—can be understood within a "biased competition" framework: Different options and outcomes compete for attentional priority as a function of top–down goals, bottom–up salience, and prior experience, and the winner of this competition becomes the target for subsequent outcome-directed and flexible behavior. Finally, we outline the implications of the biased-competition framework for cognitive, behavioral, and socioeconomic interventions for addiction.

Keywords: attention, reward learning, sign-tracking, addiction, habits

Our lives can be thought of as a series of choices. Some will have far-reaching consequences (should I move to a different country?), others are mundane (should I have fish or pasta for dinner?). Some will be labored, involving painstaking weighing-up of pros and cons, whereas others will be made in a flash. Indeed, much—and probably most—of the time, we may barely consider the consequences of our actions before making a choice, to the point where we may even not realize that we have made a choice at all. For example, while driving a well-practiced route, we may allow our mind to wander, even as our body continues to make turns in the appropriate places, speed up and slow down to avoid obstacles, and so on until we arrive at our destination. In fact, it could be argued that almost everything we do constitutes a choice—for instance, every time we move our eyes from one location to another, we have made a "choice" in the sense that we could have looked elsewhere.

Moreover, our choices are rarely (if ever) tightly circumscribed. When in the supermarket, we are confronted with thousands of possible items that we could purchase—or we could put aside the option of purchasing and do something else instead (leave the store, start a conversation, make a phone call, etc). Given the abundance of possible courses of action, and targets of those possible courses of action, we would rapidly become overwhelmed if it were not for the operation of information-processing mechanisms of attention that act to filter, prioritize and select choice alternatives to be passed to the decision-making system, and reject those to be ignored (Pearson et al., 2022). Consequently, if we are to understand and predict behavior, we need to understand the processes of attentional selection that promote actions directed at one option over another. In this review, we will consider this issue with a particular focus on recent research suggesting a critical role for learning mechanisms in the process of attentional selection and the influence this may have on choices relating to substance use in the context of addiction.

Top–Down Control, Bottom–Up Control, and Selection History

A traditional view of attentional control distinguishes between top–down control, driven by an observer's goals and intentions, and bottom–up control, driven by the physical features of stimuli in the environment (Itti & Koch, 2001; Luck et al., 2021; Yantis, 2000). For example, if Bob is searching an unfamiliar supermarket for strawberries, his top–down control would prioritize selection of red items, but bottom–up control might prioritize a brightly colored, flashing sign advertising detergent (even if he has no desire to buy detergent). More recently, this view has been expanded to include

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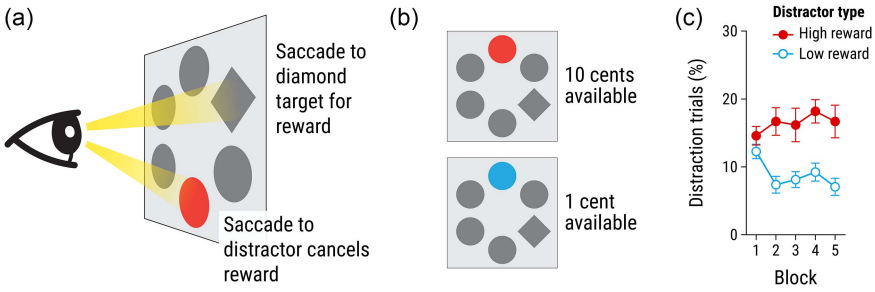
a third category of attentional control process, termed selection history, referring to persistent attentional biases deriving from experience with a stimulus, independent of the observer's goals and the physical features of that stimulus (Anderson et al., 2021; Awh et al., 2012; Theeuwes, 2019). In our supermarket example, Bob's attention might be involuntarily captured by the logo of his favorite beer—even though this is unrelated to his current goal (buying strawberries) and the logo is not particularly distinctive relative to other items in the display—as a result of his prior experience of enjoying that drink. And since we know that greater attention to an option translates into a greater likelihood of actively choosing that option (e.g., Armel et al., 2008; Krajbich, 2019; Krajbich et al., 2010), the implication is that this history-driven attentional bias may result in Bob buying beer even though he was originally looking for a healthy snack (Gluth et al., 2018).

Research has identified several experience-based influences that fall under the umbrella term of selection history, but the most studied—and most relevant in the context of addiction—is the finding that attentional prioritization is modulated by learning about the relationship between stimuli and rewards (for reviews, see Anderson, 2016a; Failing & Theeuwes, 2018; Le Pelley et al., 2016; Pearson et al., 2022; Watson, Pearson, Wiers, & Le Pelley, 2019). A growing literature has used various procedures to demonstrate that stimuli established (via learning) as signals of relatively large reward become more likely to capture attention than stimuli that signal smaller (or no) reward, independently of the observer's goals and the physical features of the stimuli involved: a finding termed value-modulated attentional capture (VMAC). Most studies of VMAC have examined spatial attention in the visual domain, using monetary rewards (e.g., Anderson et al., 2011; Hickey et al., 2010; Le Pelley et al., 2015; Mine & Saiki, 2015; Pearson et al., 2016; Theeuwes & Belopolsky, 2012), though other research has demonstrated VMAC using food or social rewards (e.g., Anderson, 2016b; Pool et al., 2014; Watson et al., 2021), in temporal attention (Le Pelley et al., 2017, 2019), and in the auditory domain (Anderson, 2016c).

To illustrate, we will consider a "one-phase" VMAC procedure developed by Le Pelley et al. (2015; see also Pearson et al., 2015, 2016). In this procedure, participants complete a visual search task in which, on each trial, their goal is to make a rapid eye movement (saccade) to a diamond-shaped target set among several circles (nontargets), to earn monetary reward (see Figure 1). One of the circles in the search display—termed the distractor—is colored either blue or orange (all other shapes are gray), and the color of this distractor signals whether a high reward (10 cents) or low reward (1 cent) is available for making a rapid saccade to the diamond target. However, participants are never required to attend to the distractor: They receive reward for looking at the diamond-shaped target (which is never colored), and the task is arranged so that if they ever do look at the distractor, the reward that would otherwise have been available on that trial is canceled. So the best strategy in this task—that would earn the largest reward—is to ignore colors altogether and simply look directly at the target on each trial. Nevertheless participants often look at the distractor, and the critical finding is that they are more likely to do so when the distractor appears in the high-reward color versus the low-reward color, even though this pattern is particularly counterproductive since it means that participants miss out on more of the high-value rewards than low-value rewards. Thus, learning about the relationship between colors and rewards renders the high-reward distractor more likely to capture attention in future—an effect that persists (for a time at least) even if rewards are now removed, or values of outcomes are changed (Watson et al., 2022; Watson, Pearson, Most, et al., 2019).

Figure 1

Illustration of the One-Phase Task for Demonstrating Value-Modulated Attentional Capture (Le Pelley et al., 2015)



Note. (a) On each trial, participants see a search display and must make an eye movement (saccade) to a diamond-shaped target among circles. One of the circles is colored; this color-singleton circle is termed the distractor. (b) The color of the distractor signals the magnitude of reward available for making a rapid saccade to the target. In this example, a red distractor signals availability of a high reward and a blue distractor signals low reward (in experiments, assignment of colors to rewards is counterbalanced across participants). If participants look at the distractor, the reward that would have been available on that trial is canceled. (c) Across trials of the task, participants are more likely to look at the distractor signaling high reward than the distractor signaling low reward, even though this pattern of behavior is counterproductive since it results in loss of more of the high-value rewards. Data are redrawn from "When Goals Conflict With Values: Counterproductive Attentional and Oculomotor Capture by Reward-Related Stimuli," by M. E. Le Pelley, D. Pearson, O. Griffiths, and T. Beesley, 2015, *Journal of Experimental Psychology: General*, *144*(1), 158–171 (Experiment 3, https://doi.org/10.1037/xge0000037). Copyright 2024 by the American Psychological Association. See the online article for the color version of this figure.

This influence of reward learning on attentional prioritization cannot be a consequence of top–down control (since participants' goal is to avoid looking at the distractors) or bottom–up control (since counterbalancing the assignment of colors to the roles of high- and low-reward distractors ensures that physical features are equivalent across participants), suggesting that the attentional priority of the high-reward distractor is augmented automatically via selection history.

Incentive Salience and Sign Tracking

The one-phase VMAC procedure is an interesting case because the critical reward relationships are Pavlovian in nature: Distractor colors signal the available reward but are not the instrumental stimuli that participants must respond to in order to earn that reward. At a broader level, this finding is thus consistent with the concept of incentive salience: the idea that signals of desirable outcomes become salient (and hence attention-grabbing) in their own right: "motivational magnets" that can come to elicit approach behavior (Berridge, 2000; Berridge & Robinson, 2003).

The idea of incentive salience is closely linked to observations of sign-tracking behavior in animals (e.g., Flagel et al., 2009; Hearst & Jenkins, 1974; for a review, see Colaizzi et al., 2020). For example, if rats are exposed to a Pavlovian contingency in which insertion of a lever into a conditioning chamber is repeatedly paired with delivery of food to a magazine, they will develop a conditioned response—but the form of this conditioned response differs between individuals. When the lever is inserted, some rats—known as goal-trackers—will approach the food magazine in anticipation of delivery of food. By contrast, other rats—sign-trackers—will approach the lever itself and grasp, lick or gnaw it, as though (by virtue of its status as a signal of food) the lever has taken on some of the appetitive properties of the food and hence become attractive in its own right: that is, the lever has acquired incentive salience. This behavior is observed even under an omission schedule in which lever interactions cancel food delivery (e.g., Atnip, 1977; Chang & Smith, 2016; Williams & Williams, 1969).

Notably, incentive salience has been proposed to play an important role in shaping motivated behavior, via its impact on attention (Berridge & Robinson, 2003, 2016; Pearson et al., 2022; Saunders & Robinson, 2013). On this hypothesis, the incentive salience of reward-associated cues increases the likelihood that they will be prioritized by attention, which in turn highlights these cues (and the associated reward) as potential targets of behavior. Recall the earlier example of Bob trying to buy strawberries in the supermarket: The incentive salience acquired by the logo of his favorite beer may render it a motivational magnet, consequently dominating other options as a potential target of choice. In effect, behavior becomes impulsive: A new potential target of behavior (beer) suggests itself automatically, and the intended strawberries are quickly forgotten now that this attractive alternative looms large. By contrast, another customer, Alice, may rarely drink beer and so the same logo would be much less salient to her—and hence less likely to suggest itself as a potential purchase.

The suggestion of a link between incentive salience and motivated behavior is supported by evidence from the animal literature demonstrating that rats classified as sign-trackers (i.e., rats who are more affected by incentive salience) are more likely to show evidence of "impulsive" behavior on measures of delay discounting, probabilistic choice, and ability to withhold responding in order to receive reward (e.g., Flagel et al., 2010; Tomie et al., 1998). Observations of sign-tracking are in line with the idea that incentive stimuli produce biases in attention that elicit "craving" and hence can invigorate reward-seeking behavior—and this idea has been of particular interest in the context of addiction (Field et al., 2009). Many addictive drugs produce potent neural reward signals (Dayan, 2009; Hyman, 2005), and so cues that are experienced to be associated with these drugs (packaging, logos, locations, smells, sounds, etc) may become imbued with incentive salience, becoming motivational magnets in their own right that elicit craving and consequently drug-seeking (Tomie et al., 2008, 2018; Tomie & Sharma, 2013).

There are clear parallels between VMAC and sign-tracking—observers approach a reward-signaling stimulus, even though doing so is counterproductive (and may lead to reward omission)—to the point where patterns of attentional prioritization in the VMAC task described earlier could be seen as a human analog of sign-tracking (see Colaizzi et al., 2020; Watson, Pearson, Wiers, & Le Pelley, 2019). Moreover, recent studies have demonstrated that these patterns of reward-conditioned attention can influence overt, motivated behavior in terms of shaping subsequent choices (Gluth et al., 2018, 2020; Le Pelley et al., 2023). And consistent with the idea of a relationship between sign-tracking and the behaviors implicated in addiction, research has demonstrated an association between laboratory measures of susceptibility to VMAC (using small, monetary rewards) and addiction-related behaviors. For example, studies have reported that VMAC was elevated among individuals in treatment for opioid addiction (Anderson et al., 2013) and was associated with severity of problematic alcohol use in a treatment-seeking sample of alcohol users (Watson et al., 2023). Other research has found that VMAC is related to illicit drug use (Albertella et al., 2017) and risky alcohol use (Albertella, Watson, et al., 2019) in nonclinical samples. In one particularly interesting study using a large sample ($N = 683$), behavior in a VMAC task conducted at baseline predicted likelihood of success in a subsequent 1-month voluntary alcohol abstinence challenge (Albertella et al., 2021). That is, participants who showed evidence of a greater impact of reward-signaling cues on their attention were less likely to succeed in remaining abstinent over the whole month. Finally, other work has reported associations between measures of VMAC and self-reported addiction and compulsivity symptoms, transdiagnostically (Albertella, Chamberlain, et al., 2020; Albertella, Le Pelley, et al., 2019, 2020).

Perspectives on Cue-Controlled Behavior: Habits Versus Biased Competition

We have argued above that a full account of motivated behavior must incorporate the critical role that selective attention plays in shaping the decisions and choices that we make, by influencing whether and how we encode and gather evidence about the various stimuli that could constitute targets of behavior. In particular, we have considered ways in which prior reward learning can modulate the incentive salience of stimuli, turning them into motivational magnets that can attract attention (and change behavior) independently of—and even contrary to—an observer's goals and intentions. This idea has the potential to offer an alternative perspective on the drivers of cue-controlled behavior to that which has characterized

much of the existing work in this area—particularly in the context of addiction.

Habits and Compulsion

A traditional and influential view of instrumental behavior distinguishes between goal-directed and habitual control of behavior (de Wit & Dickinson, 2009; Dickinson, 1985; Dickinson & Balleine, 1994; Heyes & Dickinson, 1990; Ouellette & Wood, 1998; Wood & Rünger, 2016). Goal-directed behaviors are willed and purposive actions that are targeted at attaining a specific, desired outcome. By contrast, actions that are repeated over and over can become habitual: stimulus-driven behavior patterns that are elicited automatically by the perception of particular "triggering stimuli," and which are not directed at achieving (currently desired) goals. That is, goal-directed behaviors are driven by the desire to obtain an outcome, whereas habits are not performed with the outcome in mind. To illustrate, imagine that Bob gets on his bike with the intention of going to a friend's house, but then finds that he has absent-mindedly cycled the well-rehearsed route to work instead. In this example of a so-called action slip, being on the bike elicits the overtrained behavior pattern (cycling to work) which is then run off automatically and mindlessly as a habit, even though the outcome it will achieve (being at work) is incompatible with current desires (visit friend).

Notably, it has been argued that addiction can be understood within this "dual-process" framework as reflecting a dominance of habit over goal-directed behavior (Dickinson et al., 2002; Everitt & Robbins, 2005, 2016; Ostlund & Balleine, 2008; Tiffany, 1990). On this account, drug seeking and drug use are viewed as cue-elicited behaviors that are no longer under goal-directed control and hence independent of current desire for the drug itself. For instance, consider a long-term smoker who is attempting to abstain and professes no current desire to smoke. The habit-based view argues that—by virtue of a long prior history of reinforcement—smoking-related cues may nevertheless automatically trigger responding: for example, the sight of a cigarette elicits the (automatic and mindless) response of lighting up and smoking. The strongest version of this account sees drug seeking as ultimately becoming a compulsion, where the stimulus–response association controlling behavior can no longer be modified by direct experience of the drug reinforcer (Everitt & Robbins, 2005, 2016; Ostlund & Balleine, 2008).

The dual-process view of instrumental action—and the habit theory of addiction in particular—has generated a huge body of research in animals and humans, with both empirical and modeling-based approaches being used to examine the underlying psychological and neural processes (for reviews, see Balleine & O'Doherty, 2010; Everitt & Robbins, 2016; Smith & Laiks, 2018). However, recent theorizing has challenged this view in the context of human behavior. At a general level, it has been questioned whether action slips rely on automatic, stimulus-driven behavior, or may instead reflect top–down, controlled action that is directed toward an inappropriately chosen outcome (Buabang et al., 2023; De Houwer et al., 2018; Köpetz et al., 2013; Kruglanski & Szumowska, 2020; Moors et al., 2017). Returning to an example provided earlier, if Bob were stopped midroute and asked where he was headed, he may say "To my office," before realizing that this is actually the wrong destination. Thus, it is possible that the inappropriate behavior may be under "goal-directed" control in the sense that it is controlled, and flexible, and directed toward achieving a particular outcome—the problem is that the wrong outcome has been selected (i.e., triggered by the bike-riding context).

Even if inflexible habits could have some limited effect on inconsequential everyday behaviors, it seems unlikely that drug stimuli could compulsively trigger "mindless" drug-seeking behavior, if drugs were not desired. Notably, recent reviews of the animal and human literature have found little empirical support for the habit model of addiction (Heather, 2017; Hogarth, 2018, 2020, 2022; Singer et al., 2018; Vandaele & Ahmed, 2021). Instead it has been argued that drug use remains goal-directed and indeed may reflect excessive goal-directed choice, with long-term users persisting in drug use because they attach greater value to the drug, that outweighs negative consequences (Hogarth, 2020)—consistent with the observation that craving consistently emerges as a factor leading to relapse, which suggests that users are focusing on their desire for the outcome at the time of use (e.g., Stohs et al., 2019; Watson et al., 2023; for review, see Sliedrecht et al., 2019). In line with this idea, evidence from animal studies that has been taken as consistent with the compulsivity account typically comes from procedures in which available choices are limited (see Hogarth, 2020); when alternative options are available, such as social rewards in rats (Venniro et al., 2018) or low-value monetary vouchers in humans (Hart et al., 2000), drug choice is substantially reduced or abandoned. Indeed, most people eventually quit addictions without treatment (Heyman, 2010, 2013), often due to legal concerns, economic pressures, and concern about respect from family members—"the correlates of quitting are the correlates of choice, not compulsion" (Heyman, 2013, p. 1). The idea that drug-seeking remains under goal-directed control should perhaps not be surprising: Procuring illicit drugs such as cocaine is typically not straightforward and may require flexible, novel, and ingenious behavior that does not have a history of reinforcement (Robinson & Berridge, 2003; Singer et al., 2018).

Biased Choice, Rather Than Loss of Choice

As described above, dual-process theories of instrumental action propose that habits reflect a situation in which the individual has lost control of their own behavior—where control has been ceded to the environment such that responses are directly elicited by (perception of) the stimuli themselves. By contrast, the ideas raised earlier in this article suggest an alternative framework for understanding motivated behavior as the outcome of a process of biased competition (Cushman & Morris, 2015; Field et al., 2020; Hommel & Wiers, 2017; Pearson et al., 2022; Wiers, van Gaal, et al., 2020; Wiers & Verschure, 2021). Earlier, we noted that the action taken in a given situation will be critically shaped by what the observer pays attention to in that situation—and what the observer pays attention to will in turn be influenced by a range of factors, including their (top–down) preexisting intentions, the (bottom–up) salience of stimuli in the environment, and their prior experiences with those stimuli (selection history). Hence, we can see these factors as modulating a competition between stimuli to be selected as targets of behavior. Returning to the supermarket example, depending on which factor exerts the greatest influence on a given occasion, attentional prioritization may ultimately favor strawberries (the preintended item), detergent (physically salient), or beer (reward-associated). On this account, once a target wins the competition for selection, it becomes the "goal" of subsequent goal-directed behavior: Flexible planning is then deployed to generate and implement an action sequence that will achieve that goal (cf. Cushman & Morris, 2015).

A critical feature of this account is that attention acts to select targets of behavior rather than actions, and hence the goal-directed nature of the resulting actions will be independent of how and why those targets were prioritized, for example, endogenously or exogenously (Hommel & Wiers, 2017).

The idea that prior experience can give rise to a rapid, fundamental, and automatic influence on attentional prioritization offers an alternative perspective on "habitual" behavior within this biased-competition framework. On this account, slips of action result from prioritization of inappropriate targets as a consequence of repeated prior selection of those targets: in effect, "habitual control of goal selection" (Cushman & Morris, 2015, p. 13817). When Bob sees his bike, his extensive prior experience may bias the competition such that the (inappropriate) outcome of cycling to work overcomes the (appropriate) goal of going to his friend's house. And from that point onward, Bob's behavior is directed at this outcome—in a flexible, planned way—unless and until something interrupts to cause him to reconsider the target of his behavior (e.g., a colleague stops him to ask where is going).

This framework applies equally to the case of addiction, where drug use is seen as the outcome of a biased choice process that results in selection of drug seeking or drug use as a behavioral goal (Field et al., 2020; Verschure & Wiers, 2022; Wiers, van Gaal, et al., 2020; Wiers & Verschure, 2021). And once again, this competition will be influenced by prior experience: Previous experience of reward will modulate the incentive salience of drug-related cues, in turn influencing the likelihood that they will receive attentional priority (Berridge & Robinson, 2016; Pearson et al., 2022; Robinson & Berridge, 2003). For example, consider a smoker who is attempting to quit, walking along a street where there is an advertisement showing the logo of their favorite brand of cigarettes. To the extent that this logo captures their attention (by virtue of its previous association with the rewarding consequences of smoking), it may prompt the goal of seeking cigarettes even despite a conflicting intention to abstain—as compared to the case of a nonsmoker for whom the logo has no prior reward association and so remains nonsalient. But even the "habitual" smoker will not lose control over their actions in this situation, and if sufficiently attractive options are available as potential alternative goals (e.g., social interaction, entertainment, exercise, etc), then they may avoid drug seeking altogether (Acuff et al., 2023).

Implications for Intervention

The compulsivity-based view of addiction falls under the dominant biomedical model which sees addiction as a consequence of a chronic and permanent change in brain chemistry. On this view, returning to a state of health requires biomedical intervention to interrupt aberrant processes and restore healthy functioning (Leshner, 1997; Volkow et al., 2016, 2019). By contrast, the biased-competition view offers an alternative perspective on addiction as a situation in which the machinery of choice has become skewed, resulting in actions that are ultimately detrimental to well-being. This approach moves away from the view of the person as a passive bystander and instead sees them as an active, choice-making agent (Verschure & Wiers, 2022; Wiers & Verschure, 2021).

In saying this, we should be clear that this account does not argue that the individual should be held fully responsible for addiction: Prior experience and life circumstances might produce situations in which drug use seems like the best available option. As an analogy, going to work each Monday morning is fundamentally a choice, but I may not feel that my financial circumstances are such that I have realistic alternatives. A corollary of this idea is that changing patterns of maladaptive choice may not be easy. But it does suggest that, if behavior change is the goal, then interventions should target the machinery and processes of choice.

One possibility that has been explored is to use training techniques in an attempt to strengthen individuals' top–down control over their cognition, with the idea that increasing executive functioning will decrease the automatic impacts of prior experience on attention and choice. For example, various forms of working memory training have been trialed in the context of addiction; however, while this training may impact other psychological functions (e.g., impulsivity), consistent evidence for an impact on relapse rates is lacking (Brooks et al., 2020; Wiers et al., 2023). This is perhaps unsurprising since this approach may be fighting an uphill battle: Studies of effects of reward on attention show that they are remarkably hard to overcome via top–down control. For example in the task shown in Figure 1, participants know that they will lose money if they look at the colored circle, but often cannot help themselves from doing so (Pearson et al., 2015; Pearson & Le Pelley, 2020, 2021; but see also Grégoire et al., 2022).

Rather than attempting to train general executive functions, an alternative approach has attempted to modify cognitive and attentional biases in the context of addiction-related stimuli, in an effort to retrain more automatic responses to these stimuli (in addition to any impact on top–down control). Despite some reported successes of this approach, particularly in the context of alcohol use disorder (e.g., Eberl et al., 2013; Rinck et al., 2018; for review, see Wiers et al., 2023), overall its effectiveness to date has been somewhat limited. For example, a meta-analysis of clinical trials in the context of alcohol and smoking yielded evidence for a small effect on relapse rate, but no effect on reduction of substance use (Boffo et al., 2019). Work in this area is still at an early stage (Boffo et al., 2019 noted very wide credible intervals for their effects), and it may be the case that existing training techniques have not yet been optimized. Indeed, this approach may run up against practical limitations: Any clinic-based intervention targeting automatic responses is likely to be minimal in scope—and hence may have limited impact—as compared to (potentially) years of prior experience of substance use.

Somewhat related to the idea of cognitive bias modification, interventions based on contingency management have attempted to retrain conditioned approach tendencies in the user's everyday life, by reinforcing avoidance: People are regularly monitored for drug use (e.g., via urine analysis) and incentives—typically money or vouchers—are provided only if abstinence is verified. From the perspective of the choice-based framework, the salient, short-term rewards offered under contingency management may act to reduce the relative value of drug use by increasing the value of alternative outcomes (abstinence). Meta-analysis indicates that contingency management is effective for promoting short-term abstinence (Benishek et al., 2014). The problem, however, is that once external incentivization is removed at the end of the program, the immediate value of abstinence falls and so relapse may occur: The same analysis found no detectable effect of contingency management (relative to treatment-as-usual control) at a 6-month follow-up (see also Benishek et al., 2014; Prendergast et al., 2006). Such findings have encouraged researchers to investigate strategies to maintain the effects of these interventions; for example, more recent work

suggests that combining contingency management with a group-based abstinence training program (including social reinforcement) may be more effective in maintaining lasting behavior change (van den Brand et al., 2018).

The problem faced by contingency management programs is that the reinforcement for abstinence is external (i.e., provided by the clinician), and hence difficult and expensive to maintain in the long term. An alternative approach to intervention is aimed at increasing the perceived value and availability of alternatives to drug use that exist in the user's everyday life and so can be sustained by the person themselves. For example, Wiers, Van Dessel, et al. (2020) recently proposed an "ABC" intervention that is targeted at the (individualized) choice level, identifying antecedents (As) that represent personalized risk situations (e.g., coming home after work), highlighting personally relevant alternative behaviors (Bs) that could compete for choice with the addictive behavior (e.g., going for a walk, rather than smoking), and underlining the consequences (Cs) of those choices (e.g., smoking is expensive and unhealthy; walking is free and healthy). Pilot findings using the ABC intervention have been encouraging (Van Dessel et al., 2023), but the effectiveness of this approach remains to be established in full, randomized controlled trials.

An alternative approach would operate at the structural and socioeconomic level, via manipulating the "choice architecture" (Thaler & Sunstein, 2008) of situations in which individuals are making decisions (Hogarth, 2022). For example, use of plain packaging could decrease the likelihood that smoking-related cues will capture attention and hence bias choices toward smoking goals (cf. Hogarth et al., 2015). Provision of alternative rewarding options could likewise bias the competition away from drug use—for example, education, social support, public libraries, sports facilities, and so forth. And finally, structural changes aimed at reducing stress states—such as improved housing and working conditions—could potentially reduce the perceived value of drug rewards (see Hogarth, 2022).

Conclusion

Influential accounts of motivated behavior have proposed that instances of seemingly self-defeating behavior reflect a loss of control to the environment, wherein responses are automatically and habitually triggered by stimuli as a result of prior experience. By focusing on the response, however, these accounts often neglect to consider the processes by which observers gather information from the environment in the first place and the ways in which this information-gathering process can itself influence subsequent behavior. In this article, we have considered the role of attention in shaping the prioritization of stimuli for further analysis and action and have highlighted the fundamental (and often automatic) influence of prior experience of reward on this prioritization process. These ideas give rise to an alternative framework for understanding motivated behavior—and addiction, in particular (Kopetz & Orehek, 2015)—as a biased competition between alternatives that constitute candidate targets for subsequent action.

We should be clear that the habit-based and biased-competition views are not mutually exclusive accounts of behavior. Given the substantial body of behavioral, neural, and modeling evidence in support of the idea of dissociable behavioral processes (particularly in animals), we would not wish to suggest abandoning this framework altogether. Likewise there may be (exceptional) cases in which drug use really is uncontrolled, stimulus-driven, and compulsive. However, we believe that a more nuanced consideration of the cognition of choice may provide a fuller understanding of the various facets of motivated behavior and highlights the potential for a range of interventions that fall outside the brain disease model of addiction.

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