Understanding attentional biases in severe alcohol use disorder: A combined behavioral and eye-tracking perspective.

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Abstract

Rationale: Severe alcohol use disorder (SAUD) is a psychiatric condition linked to cerebral and cognitive consequences. SAUD is notably characterized by an over-activation of the reflexive/reward system when confronted with alcohol-related cues. Such over-reactivity generates a preferential allocation of attentional resources towards these cues, labeled as attentional biases (AB). Theoretical assumptions have been made regarding the characteristics of AB and their underlying processes. While often considered as granted, these assumptions remain to be experimentally validated. *Aims*: We first identify the theoretical assumptions made by previous studies exploring the nature and role of AB. We then discuss the current evidence available to establish their validity. We finally propose research avenues to experimentally test them. *Methods*: Capitalizing on a narrative review of studies exploring AB in SAUD, the current limits of the behavioral measures used for their evaluation are highlighted, as well as the benefits derived from the use of eye-tracking measures to obtain a deeper understanding of their underlying processes. We describe the issues related to the theoretical proposals on AB and propose research avenues to test them. Four experimental axes are proposed, respectively related to the determination of: (1) the genuine nature of the mechanisms underlying AB; (2) their stability over the disease course; (3) their specificity to alcohol-related stimuli; and (4) their reflexive or controlled nature. *Conclusions*: This in-depth exploration of the available knowledge related to AB in SAUD, and of its key limitations, highlights the theoretical and clinical interest of our innovative experimental perspectives capitalizing on eye-tracking measures.

Keywords

Attention, alcohol, attentional bias, eye tracking, alcohol use disorders

Introduction

Severe alcohol use disorder (SAUD) is among the most prevalent psychiatric conditions (Rehm et al., 2013). The individual and societal burden of SAUD remains massive, notably because of the still limited efficiency presented by therapeutic settings: SAUD is associated with the widest treatment gap among psychiatric disorders, more than 75% of patients with SAUD not receiving any clinical support (Kohn et al., 2004). Moreover, even when SAUD is treated, the relapse rate is still beyond 60% one year after detoxification treatment (Maisto et al., 2018). This high relapse risk questions the efficiency of the current rehabilitation programs. There is thus an urgent need to improve this clinical efficiency, which could be achieved through the implementation of recent and empirically-grounded theoretical proposals related to SAUD.

According to dual-process models, decision-making relies on the interaction between the reflective system (underpinned by prefrontal areas and supervising rational behaviors) and the reflexive system (subtended by limbic regions and responsible for automatic approach behaviors; Mukherjee, 2010). These influential models postulate that the development and maintenance of SAUD would be due to the imbalance between systems, with an under-activation of the reflective system (leading to reduced inhibitory control and working memory) and an over-activation of the reflexive system, inducing craving and attentional biases (AB) towards alcohol-related stimuli (Bechara, 2005; Wiers et al., 2007). Beyond the dual-process models, most neuroscientific theories of addictive states underline the key role played by the over-activation of the reward system when confronted with substance-related stimuli. For example, according to the incentive-sensitization theory (Robinson & Berridge, 1993), the repetition of alcohol exposures sensitizes the dopaminergic system, enhancing the incentive-motivational properties of alcohol cues. Becoming more salient, these cues grab the consumer's attention and result in AB. Other neuroscientific models are presenting similar key assumptions, namely: (1) the presence of a reward/reflexive system; (2) the high sensitivity of this system to substance-related cues; (3) the identification of AB as an index of this system's over-activation.

Capitalizing on this theoretical background, several innovative proposals have emerged to improve SAUD treatment (Rolland et al., 2019). Neuropsychological rehabilitation programs have mostly been developed to rehabilitate the reflective system through cognitive remediation (Bates et al., 2013; Rupp et al., 2012), but studies have also attempted to directly modify AB (Schoenmakers et al., 2010). Such AB modification paradigms aim at countering the involuntary hijacking of attentional resources by alcohol-related stimuli, which leads to augmented salience of such stimuli, reflexive system's over-activation and *in fine* increases relapse risk (Cox et al., 2014). A recent systematic review pointed out the efficiency of these programs, attesting the major role of AB in addiction (Heitmann et al., 2018). Beyond this clinical usefulness, there is however a massive lack of knowledge about the processes underlying AB, which limits the development of more accurate paradigms to reduce it. The experimental results related to AB in SAUD still raise many theoretical, experimental, and clinical questions, mostly regarding the nature of AB and its role in the development and maintenance of SAUD.

The main aim of the present paper is to clarify the assumptions made by theoretical models regarding AB, as well as to discuss their experimental and clinical validity. This paper is a narrative review based on peer-reviewed studies exploring AB in patients with SAUD, identified in three databases (PsycInfo, PubMed, Scopus). Studies' selection also capitalized on recent systematic reviews on the topic (Maurage et al., 2020a;b)[1]. For the specific interest of

[1] The present paper capitalizes on the outcomes related to three recent systematic reviews conducted in our research group, namely Maurage et al. (2020a;b) for the eye-tracking studies in alcohol use disorders or acute alcohol consumption, and Bollen et al. (in preparation) for the behavioral studies on attentional bias in alcohol use disorders. These reviews were conducted following the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), and adhered to the associated 27-item checklist. Three databases were consulted (PsycInfo, Pubmed, Scopus). The search phrase combined attentional bias words (i.e. "bias*" AND “attention*”), eye-tracking words ("eye tracking" OR "eye-tracking" OR "eye movements" OR "visual

the current perspective paper, we focus on behavioral and eye-tracking findings that are relevant to address the main theoretical assumptions regarding AB. Based on this narrative review, the current limits of the behavioral measures traditionally used to investigate AB in SAUD are identified. Then, capitalizing on this identification, we propose to renew the paradigms exploring AB, through a combination of behavioral and eye-tracking measures, to deepen the exploration of the processes. A surge of interest has indeed recently emerged for eye-tracking in AB studies. This technique allows the detection of eye position and gaze direction, with a high temporal resolution, to infer links between eye movements and cognitive function such as attention (Popa et al., 2015). Several parameters can be measured, including fixations, saccades, pupillary diameter, and smooth-pursuit. It appears as a very promising tool, allowing to directly and precisely measure the consecutive steps involved in attentional processing and thus extending the understanding of the core processes of AB in SAUD. A research plan is finally proposed to address the main issues related to AB in SAUD, based on four experimental axes, respectively focused on the determination of (1) the genuine nature of the mechanisms underlying AB; (2) the stability of AB over the disease course; (3) the specificity of AB to alcohol-related stimuli; (4) the controlled or reflexive nature of AB.

Over-activation of the reflexive system: AB paradigm

Many neuroimaging studies have observed an over-activation of the reflexive system in SAUD when confronted with alcohol-related stimuli (e.g., Vollstädt-Klein et al., 2012). The available evidence regarding the behavioral counterpart of this over-activation is centrally obtained through self-reported craving or alcohol-related AB measures (Field & Cox, 2008).

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tracking" OR "gaze tracking") and a large range of alcohol-related terms (i.e. "alcoholism" OR "alcohol dependence" OR "alcohol use disorder" OR "binge drink*" OR "heavy drink*" OR "social drink*" OR "episodic drink*" OR "college drink*" OR "alcohol" OR "acute alcohol consumption"). The initial search related to these three papers respectively identified 1084, 995, 1013 papers, and the selection procedure ended in the inclusion of respectively 36 (Maurage et al., 2020a), 31 (Maurage et al., 2020b) and 93 (Bollen et al., In preparation) papers.

AB in SAUD are defined as the tendency to preferentially allocate one's attentional resources towards alcohol-related stimuli when such stimuli are presented in the environment. AB thus refers, in SAUD as well as in other addictive behaviors (e.g., Mogg et al., 2003), to the automatic capture of attention by substance-related rewarding stimuli, even when they are not relevant for the current task or not in line with present individual goals. These biases are most often considered as the result of associative learning from previous experiences, during which the individual was repeatedly confronted with the association between substance-related stimuli and beneficial outcomes (i.e., "reward history", e.g., Anderson, 2013; Marchner & Preuschhof, 2018). Among the variety of paradigms used to study AB in addictive disorders, the most commonly chosen tasks in experimental or clinical settings are the visual probe task and the addiction Stroop task.

In the visual probe task (Ehrman et al., 2002), two pictures, one representing an alcohol-related stimulus (e.g., alcoholic beverage bottle) and one a neutral stimulus (e.g., soft drink bottle), are displayed respectively on the left and right side of a computer screen. They are then replaced by a probe appearing at the location previously occupied by one of the pictures, and participants are instructed to process the probe as quickly and correctly as possible. Faster responses to probes appearing at the location previously occupied by the alcohol-related cue (compared to the neutral cue) reflect AB towards alcohol-related stimuli. In SAUD, findings from studies using the visual probe task are quite inconsistent. Some have found that patients with SAUD are faster to process probes replacing alcohol-related stimuli, suggesting the presence of AB towards alcohol cues (Loeber et al., 2009; Sinclair et al., 2016). However, other results have rather revealed an avoidance pattern as patients show longer reaction times for probes appearing replacing alcohol-related stimuli (Beraha et al., 2018; Townshend & Duka, 2007). In addition to this lack of coherence, the visual probe task shows very low internal reliability (Ataya et al., 2012). Moreover, inferring AB exclusively on reaction time measures raises concerns, as such measures only offer information about the location at which participants were focusing their attention at the specific time of probe onset, and do not say anything about the global stream and successive steps of visual or attentional processing (Field & Cox, 2008). This concern has been further reinforced by studies showing that when manipulating stimulus presentation's duration, the results obtained for short (e.g., 50-200ms) durations largely differed from those obtained with long (e.g., 500-2000ms) ones (Field et al., 2013). For example, Vollstädt-Klein et al. (2009) showed that patients with SAUD and light social drinkers both presented approach AB towards alcohol-related cues presented for 50ms, but that the reverse pattern (i.e., avoidance AB for alcohol-related stimuli) was observed for cues presented during 500ms. These findings underline the need to distinguish early (i.e., initial attentional orienting) and late (i.e., attention maintenance) processes related to AB. Nevertheless, such exploration of AB time course remains impossible through the unique use of reaction time measures.

In the addiction Stroop task (Cox et al., 2006), alcohol-related and neutral matched words are presented in different font colors, participants being asked to name as quickly as possible the color of the word. Slower responses to alcohol-related words compared to neutral ones index alcohol-related AB, assuming that the automatic allocation of increased attentional resources to the semantic processing of alcohol-related words slows down color naming (Field & Cox, 2008). Most studies found that patients with SAUD were slower to name the color of alcohol-related words, whereas control participants did not show such AB (Lusher et al., 2004). Nevertheless, this higher Stroop interference for alcohol-related words among patients with SAUD could result from their attempts to avoid processing these words rather than index AB *per se* (Klein, 2007). Here again, the mere reaction time measures previously used prevent from testing this alternative proposal. Thereby, although the crucial role of alcohol-related AB in the maintenance of SAUD is strongly suggested at clinical and theoretical levels, its evaluation is still facing important limits. Indeed, the behavioral measures do not allow distinguishing between different AB patterns (e.g., initial shifting, attentional engagement, attentional maintenance or disengagement, Stacy & Wiers, 2010).

Despite their limitations, such paradigms are now widely implemented to evaluate and rehabilitate AB in clinical settings (e.g., Heitmann et al., 2018). Lively debates regarding the effectiveness of AB modification paradigms (Cristea et al., 2016) lead us to suggest that the inconsistent results regarding AB evaluation and modification could be linked to the lack of understanding of their underlying mechanisms, leading to inappropriate measures and interventions.

The usefulness of eye-tracking measures

We propose that an efficient way to determine the genuine potential of AB paradigms for applied research and clinical implementation is to disentangle the processes involved in AB through innovative measuring tools. To do so, we suggest going beyond traditional behavioral measures, by using experimental paradigms (e.g., change-detection paradigms) which offer a more accurate exploration of the processes underlying AB, but also by using eye-tracking measures. As they allow detecting gaze direction and eye position throughout the task with a high temporal resolution, such measures provide important insights on AB time course (Popa et al., 2015). Whereas traditional behavioral results only offer an indirect AB measure (i.e., the final processing output), the eye-tracking technique directly and precisely measures the consecutive steps involved in attentional processing, deepening the understanding of the core mechanisms and processes (Armstrong & Olantunji, 2012).

Most studies using AB paradigms combined with eye-tracking measures have considered indexes like *first saccadic latency* (i.e., the time between stimulus onset and the onset of the first recorded saccade) and the *first area of interest visited* (i.e., the first zone of the stimulus to be targeted by a fixation) as reflecting an initial attentional capture that occurs quickly and early during a trial, while *dwell time* (i.e., overall fixation time on each area of interest) and the *number of fixations* (i.e., the number of times a fixation was made on this area) have been interpreted as indexing processes related to the controlled maintenance of attention. Eye-tracking indexes thus allow dissociating early processes (i.e., *first saccadic latency*, the *first area of interest visited*) from later ones (i.e., *dwell time, number of fixations*). The combination of eye-tracking methods with behavioral tasks offers the possibility to clarify the spatial and temporal dynamics of the reported bias, from the initial orientation to the later stages of attentional processing.

To date, studies using this technique in alcohol-related disorders are limited to non-clinical populations presenting low or heavy alcohol consumption (see Maurage et al., 2020a for a recent systematic review). While the number of studies is still low, their results clearly showed that indexes based on eye movements provided a more robust assessment of AB than reaction times, thus improving the internal reliability of traditional paradigms (Christiansen et al., 2015). Their findings also indicated the presence of attentional bias towards alcohol-related stimuli in subclinical populations, such as heavy drinkers, at the later and more controlled stages of information processing, as indexed by longer dwell time on alcohol cues (McAteer et al., 2015, 2018; Miller and Fillmore, 2010; Monem and Fillmore, 2017).

Key unsubstantiated assumptions regarding AB in SAUD

Beyond the many studies showing alcohol-related AB in patients with SAUD (see Field & Cox, 2008 for a review), some have also revealed a direct link between AB intensity and other SAUD symptoms. Indeed, stronger AB were observed in patients with SAUD who reported higher craving levels (Field et al., 2013), presented more severe alcohol-related problems (Jones et al., 2006), or relapsed over the 6-month follow-up period (Garland et al., 2012). While these results underline the major role played by AB in the emergence and persistence of SAUD, several theoretical and clinical assumptions currently made on the involved processes might have led to an over-interpretation of the actual data. Particularly, these results have led researchers to make strong inferences regarding AB characteristics. Namely, it is most often implicitly or explicitly considered that AB have to be considered as automatic and offering a specific index of the over-activation of the reflexive system when facing alcohol-related stimuli, as stable in time, as specific to alcohol-related stimuli, and as independent of any influence of reflective abilities. Given the current literature, we believe that these strong assumptions are premature. We thus challenge these four major theoretical assumptions and propose that they cannot be efficiently addressed using current behavioral measures:

(1) AB are related to automatic and attentional processes. Since AB are usually considered as an index of reflexive system's over-activation, giving rise to automatic and uncontrolled behaviors, their automatic nature has not been thoroughly tested in the literature. Moreover, in addition to the lack of consensus concerning the definition of automaticity (Moors & De Houwer, 2006), previous explorations were not designed to assert the automatic nature of AB, since behavioral measures are not suited to dissociate early automatic processing stages from later more controlled ones. Indeed, reaction times are only indexing the final output of all the successive stages involved in alcohol cues processing and thus cannot offer sufficient insight into AB time course. As described in the previous section, several studies have attempted to distinguish different levels of attentional processing through the manipulation of stimulus presentation's duration in the visual probe task (e.g., Vollstädt-Klein et al., 2009; Noël et al., 2006). Nevertheless, there is no consensus in the addiction literature regarding the timeframe required to shift or disengage attention from a single cue, as it highly depends on stimuli complexity. This prevents from drawing any clear-cut conclusion based on reaction time results. Furthermore, would AB indeed be automatic, its attentional specificity should also be

questioned, as low-level perceptual features of stimuli influence attention allocation. For example, Harrison and McCann (2014) showed that some salient visual properties (e.g., color) of neutral cues reduce the magnitude of AB towards alcohol cues in social drinkers. AB could thus also partly rely on perceptual differences between stimuli rather than on purely attentional processes.

(2) AB are stable. The consistency of AB through contexts and time is supposed to be a core characteristic of SAUD, and constitutes a pre-requisite for the clinical implementation of AB modification. Nevertheless, the stability of AB under context variations (e.g., withdrawal stage, mood, motivational state or craving) still needs to be experimentally addressed in SAUD. Results in student drinkers actually rather suggest that AB fluctuate alongside motivational state, as subjective craving (Bollen et al., 2020), mood induction procedure (Grant et al., 2007), stress (Field & Quigley, 2009) or alcohol-cue exposure (Ramirez et al., 2015) usually generate changes in AB magnitude. These findings led Field et al. (2016) to reconsider the predictions shared by most of the theoretical models regarding AB by underlining their overstatement of its stability. Hence, they propose a novel theoretical account of AB in addictive states, which claims that AB arise from momentary changes in appetitive and/or aversive motivational states. According to the valence [positive, negative or both (i.e., ambivalence)] of the evaluation of a substance-related cue, individuals may maintain their gaze on it or conversely ignore it, resulting in different AB patterns (Field et al., 2016). This could partly explain the inconsistencies in the aforementioned studies using the visual probe task, where patients with SAUD showed either an approach or avoidance pattern towards alcohol-related stimuli. AB stability is a key issue for the clinical implementation of rehabilitation programs, as it is supposed that AB measures give a reliable index of the presence and extent of AB in each individual (which notably determine the decision to rehabilitate these AB). Would AB be labile

and strongly varying with short-term environmental or internal contingencies, the usefulness and reliability of its evaluation and training in clinical context would be strongly questioned.

(3) AB are specific to alcohol-related stimuli. Previous studies have mostly investigated the presence of AB towards alcohol-related stimuli compared to non-alcohol-related and emotionally neutral stimuli. Thus, the generalization of the observed AB towards other rewarding stimuli cannot be excluded. Recent research among student drinkers have compared alcoholic stimuli with non-alcoholic appetitive stimuli and/or neutral stimuli, and have shown stronger AB for both appetitive cues (Pennington et al., 2019; Qureshi et al., 2019) or only for the non-alcoholic ones (Bollen et al., 2020). However, what can be considered as a neutral or appetitive non-alcoholic stimulus remains unclear, since various studies used soft drinks or water pictures as neutral cues, while more recent ones used them as appetitive cues. Further work is needed to clarify the concept of appetence and the distinction with thirst or hunger before challenging AB specificity, as a generalized AB towards all appetitive cues without any preference for the alcohol-related ones would initiate an in-depth revision of the current assumptions regarding AB in SAUD.

(4) AB are independent of the reflective system. The presence of AB is the most frequent index used to characterize the modification of the reflexive system, its occurrence in patients with SAUD being commonly considered as the behavioral result of the reflexive system's over-activation, independently of reflective processing (as hypothesized by dual-process models). Nevertheless, results from recent studies in anxiety and substance use disorders have shown that AB could at least partly vary following changes in higher-level cognitive abilities like executive control (e.g., Heeren et al., 2017). For example, Liu et al. (2011) found that cocaine-dependent patients with poor inhibitory control showed stronger AB towards cocaine-related words, compared to controls or patients without inhibition deficits. According to the biased competition model of selective attention (Kastner & Ungerleider, 2000), the attentional capture

of salient cues (e.g., threat or alcohol-related stimuli) is determined by both bottom-up sensory mechanisms sensitive to stimuli salience and top-down control mechanisms prioritizing the processing of task-relevant stimuli. Such interaction between automatic and controlled processes has also been suggested by Field and colleagues (2010), who postulated that drinking alcohol increases automatic appetitive responses to alcohol cues (such as AB) and impairs response inhibition, but also that these effects interact: response inhibition may moderate the influence of AB on alcohol-seeking behavior, this moderating effect being reduced when inhibitory abilities are impaired. Similarly, Goldstein & Volkow (2002) proposed the existence of the "impaired response inhibition and salience attribution" (I-RISA) syndrome, leading to the proposal that inhibition deficit and increased salience towards drug-related cues would both be caused by frontal cortex disruption in drug addiction, and would be involved in AB. In the same line, previous research in anxiety has shown that AB towards salient stimuli are no longer observed when increasing the perceptual load of the task, suggesting the involvement of cognitive functions to inhibit distractor processing and facilitate task-relevant ones (Pessoa et al., 2005). Even the addiction Stroop task, commonly used to measure AB in SAUD, requires to inhibit a predominant response (i.e., reading the word) in favor of a largely less automated one (i.e., name the color of the word). The possible implication of reflective functioning in the reported AB thus raises doubt on the validity of AB measures to specifically index the reflexive system's functioning.

Moving forward: four research perspectives on AB

We argue that experimentally addressing these four theoretical assumptions would clarify the nature of AB in SAUD, and thus pave the way for theoretically grounded and experimentally valid research on this topic. To reach a comprehensive understanding of AB in

SAUD, four main research axes can be proposed based on the above-mentioned limits of earlier studies, to respectively explore:

(1) The nature of the mechanisms underlying AB: This axis firstly aims to determine whether AB is purely automatic, as assumed in most previous studies. For that purpose, the exploration must go beyond behavioral measures by recording eye-tracking data while patients with SAUD are performing AB tasks. As suggested by several researchers (e.g., McAteer et al., 2015), eye-tracking allows the dissociation between automatic and controlled processes. The automaticity of AB would be confirmed by the observation of an increased tendency to quickly orient attentional resources towards alcohol-related cues (in comparison with neutral ones), as indexed by *first saccadic latency* and the *first area of interest visited*. Moreover, a vertical presentation of stimuli should be proposed to avoid the classical left gaze bias that occurred in earlier studies (all of them using horizontal cue presentation) and potentially prevailed over AB during early processing stages. The second goal of this axis is to test whether AB are totally attentional or also rely on low-level perceptual differences. As suggested by preliminary works (Harrison & McCann, 2014), low-level features such as color can influence the magnitude of AB towards alcohol-related stimuli. Other low-level perceptual variables (e.g., luminosity, contrast, visual salience, the distance between stimuli) should thus be controlled and/or experimentally manipulated to determine their influence on AB, and more fundamentally to dissociate the role played by exogenous and endogenous attention in AB. Moreover, although AB are conceptualized as centrally relying on reward history (e.g., Anderson, 2013; Marchner & Preuschhof, 2018), they could also be influenced by other associative learning processes, such as selection history (i.e., the fact that stimuli which have been selected or salient in previous trials develop the ability to automatically catch attentional resources towards their location in upcoming trials). Selection history has been shown to strongly influence the allocation of attentional resources (e.g., Anderson & Britton, 2019; Belopolsky, 2015), but the

paradigms previously used to measure AB in SAUD (i.e., visual probe and addiction Stroop tasks) did not allow to evaluate the influence of this process on AB.

(2) The stability of AB: This research axis aims to define whether AB are constant or can be modulated by temporal or contextual factors. Three types of stability have to be addressed, namely: (a) short-term intra-individual stability, as the vast majority of previous studies have only offered a unique AB measure, without measuring its test-retest value and more globally without testing the psychometric properties of the task (reliability and validity); (b) long-term intra-individual stability, as AB have to be tested across multiple sessions during the successive stages of the detoxification process (e.g., early/late withdrawal, post-detoxification); (c) inter-contextual stability, as the extent of AB might be influenced by external factors or motivational states, and notably by the experimental manipulation of craving intensity.

(3) The alcohol specificity of AB: This axis aims at determining whether AB are exclusively found for alcohol-related stimuli or generalize to a larger set of appetitive stimuli. To do so, the first step should be to determine which type of stimuli can be considered as appetitive among healthy and addicted populations, at least by systematically measuring the self-reported appetence level associated with each stimulus type in each participant. Adding a comparison between other appetitive stimuli and neutral or alcohol-related stimuli in classical AB tasks would moreover offer a double insight. First, reduced or suppressed alcohol-related AB when other appetitive stimuli are used as controls instead of neutral ones would suggest that the alcohol-related AB reported in earlier studies might have been over-estimated through the use of non-appetitive stimuli as control. Second, the observation of a generalized AB towards other appetitive stimuli when compared to neutral ones would show that AB are not specifically related to alcohol in SAUD, reducing the empirical and clinical interest of the so-called alcohol-related AB.

(4) The influence of reflective abilities on AB: This last axis first aims at testing whether AB can be modulated by the manipulation of the cognitive load recruited by the reflective system to perform a concurrent and independent task (e.g., auditory N-back task). For example, this could be explored by comparing the magnitude of alcohol-related AB under low or high cognitive load, with an AB task using eye-tracking measures combined with a concurrent cognitive task of various difficulty. Second, this axis also aims to further investigate the possibility of direct control of reflective abilities on early saccadic movements towards alcohol cues, through task-related requirements (i.e., gaze contingency paradigm; Wilcokson & Pothos, 2015; Qureshi et al., 2019). In this eye-tracking paradigm, participants are asked to deliberately control and inhibit the production of early saccadic movements towards alcohol-related or neutral stimuli, thus testing the ability of reflective abilities to take control over alcohol-related AB. In both cases, the observation that AB (a) are significantly modified by a concurrent task involving reflective abilities or (b) can be significantly reduced through a voluntary control on attentional resources would raise serious doubts regarding the validity of AB to exclusively index reflexive system's over-activation, as proposed by earlier studies.

Impact and conclusions

The experimental plan proposed in the present paper bares critical insights at theoretical and clinical levels. First, the experimental reconsideration of the theoretical assumptions made on alcohol-related AB will refine some aspects of the dual-process models and provide a comprehensive understanding of the underlying processes. Indeed, the dual-process framework is based on the key proposal that reflective and reflexive systems are underlined by distinct brain networks, but can also be dissociated at the behavioral level, AB being the main correlate of the over-activation presented by the reflexive system. This core assumption of the model would thus be questioned by experimental evidence showing that AB are not automatic, purely attentional, or relying exclusively on the reflexive system. Such data would question the distinguishability of the systems, and potentially favor more integrated and unitary views of decision-making and cognitive abilities (Hommel & Wiers, 2017). More globally, given the high temporal resolution of the eye-tracking technique, applying it for the first time in SAUD will have key implications for cognitive and experimental psychology: the clarification of the nature, extent, and specificity of AB will determine whether AB constitute a relevant measure of the reflexive system and, if not, will highlight the need for developing behavioral paradigms efficiently and selectively assessing its functioning. Finally, it would provide a better understanding of AB in SAUD but also in other psychopathological states, as well as offer a new approach to decision-making among healthy individuals. Second, this research plan will also have crucial implications for clinical psychology and psychiatry, notably to determine the exact role played by AB in addictive disorders. Thanks to the better characterization of the underlying processes, more valid evaluations of AB and optimal retraining programs could then be implemented in clinical settings and replace those currently offered to SAUD patients, to raise a better rehabilitation efficiency and finally reduce relapse rate.

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Declaration of interest statement

The authors declare no conflict of interest.

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