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The role of social stimuli content in neuroimaging studies investigating alcohol cue-reactivity

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HIGHLIGHTS

- Stimuli content of 26 alcohol cue-reactivity neuroimaging studies was systematically reviewed.
- More social interaction was found in alcoholic compared to non-alcoholic beverage stimuli.
- Brain areas associated with processing of social and reward-related information overlap.
- Matching stimuli on social content improves the reliability of alcohol cue-reactivity studies.

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ABSTRACT

Introduction: Cue-reactivity is thought to play a fundamental role in the maintenance of addiction. The incentive sensitization theory proposes that conditioned responses are related to increased sensitivity of the reward-related dopaminergic pathways in the brain. However, neuroimaging studies on alcohol cue-reactivity show inconsistent results.
Methods: Stimuli content of 26 alcohol cue-reactivity studies was systematically reviewed.
Results: No differences were found between alcoholic beverage stimuli and non-alcoholic beverage stimuli in human display and brand factors; however, alcoholic beverage stimuli were more likely to display social interaction compared to non-alcoholic beverage stimuli.
Conclusions: Given that processing of social information activates brain areas that partly overlap with reward-related brain areas associated with cue-reactivity, such differences between conditions can introduce noise in the findings. We therefore suggest matching stimuli sets on the reviewed factors carefully to improve reliability of neuroimaging studies investigating alcohol-related cue-reactivity.

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1. Introduction

Reactivity to substance-related cues has been extensively investigated during the last decade, as it is perceived to be a key factor in the development and maintenance of addiction (Carter & Tiffany, 1999; Chase, Eickhoff, Laird, & Hogarth, 2011). The incentive sensitization theory (Robinson & Berridge, 1993, 2001) proposes that addiction is related to dopamine sensitization to substance-related cues, making these cues more attractive, attention grabbing and able to elicit drug-taking behaviour. These conditioned responses include physiological and subjective responses to alcohol-related cues in substance dependent patients (O'Brien, Childress, Ehrman, & Robbins, 1998; Powell et al., 1990). Conditioned responses to alcohol-related cues have been found to be associated with treatment outcome and the risk of relapse (Heinz, Beck, Grusser, Grace, & Wrase, 2009; Hogarth, Dickinson, & Duka, 2010; Ray, Mackillop, & Monti, 2010). For these reasons, many studies investigated reactivity to substance-related cues.

Neuroimaging techniques provide exciting opportunities to investigate the underlying neural processes of substance-related cue-reactivity. Yet, when studying neural responses to substance-related cues, stimuli content in both substance-related and control pictures largely determine neuroimaging findings. While in most studies attention has been given to adequate match alcohol and control stimuli for characteristics such as complexity and brightness (Pulido, Brown, Cummins, Paulus, & Tapert, 2010), the importance of stimuli content has received less attention. Stimuli content may be important, as it can evoke different reactions in both brain activation and behaviour. Given this gap in the literature, the aim of this commentary was to draw attention to the importance of stimuli content in alcohol-related cue-reactivity paradigms by systematically reviewing social stimuli content in neuroimaging studies on alcohol-related cue-reactivity.

A recent meta-analysis conducted by Schacht, Anton, and Myrick (2012) showed increased activation in the ventral striatum (VS), the ventral anterior cingulate cortex (vACC) and the ventro-medial prefrontal cortex (vmPFC) in heavy drinkers or individuals with alcohol dependence in response to alcohol-related stimuli relative to control stimuli. Alcohol-cue related brain activation in the ACC and VS was also reported in an earlier meta-analysis (Kuhn & Gallinat, 2011). This activation in areas of the reward-related dopaminergic pathway in response to alcohol-related stimuli is in line with the incentive sensitization theory. However, no significant group differences were found or reported in these brain areas when alcohol dependent individuals were compared with social drinking controls (Kuhn & Gallinat, 2011; Schacht et al., 2012). Moreover, when examining all twenty-eight studies included in this meta-analysis, only one study reported increased VS activity in heavy drinkers compared to controls (Ihssen, Cox, Wiggett, Fadardi, & Linden, 2011). The lack of group differences between individuals with alcohol dependence and social drinkers in reward-related brain areas is in contrast with the incentive-sensitization theory. Recently, Jasinska, Stein, Kaiser, Naumer, and Yalachkov (2014) proposed several individual-and-study specific factors, which modulate neural reactivity to drug cues that may introduce inconsistencies, for instance sensory modality, length of stimuli presentation as well as addiction severity and drug availability. In addition to these factors, we suggest that stimuli *content* in alcohol-related and control pictures during alcohol cue-reactivity tasks is pivotal for the generalization, validity and reliability of neuroimaging findings, especially since stimuli content is related to social information processing.

The emerging field of social neuroscience revealed that brain regions show specific activation patterns when processing social information, such as the amygdala, the vmPFC (Adolphs, 1999; Amodio & Frith, 2006) and the superior temporal sulcus (STS) (Allison, Puce, & McCarthy, 2000). Stimuli with social content can also be associated with feelings or thoughts of such a social context, which can then trigger (emotional) reactions reflected in brain responses (Adolphs, 2009; Nees, Diener, Smolka, & Flor, 2012). In nicotine dependence, stimuli with social content are found to elicited greater psychophysiological responses, such as skin conductance and electromyography, compared to stimuli displaying pure nicotine related objects (Choi et al., 2011). Importantly, individuals with different drinking patterns may differ in reactivity to social stimuli content in combination with alcohol-cues, as social content in alcohol stimuli may be more important to social and light drinkers compared to heavy drinkers or individuals with alcohol dependence (Larsen, Engels, Granic, & Overbeek, 2009). Lastly, misinterpretation of results can occur when imbalances exist between alcohol-related and control stimuli in terms of social content, e.g., when more stimuli with social content are displayed in the alcohol-related condition compared to the control condition.

Given that neuroimaging studies investigating alcohol related cue-reactivity have paid less attention to (social) stimuli content, the purpose of this commentary is to review the social content of stimuli used in visual alcohol cue-reactivity paradigms by focussing on three factors; 1) human display, since the perception of humans may require greater and different activation in brain areas such as the amygdala, vmPFC and STS (Bentin, Allison, Puce, Perez, & McCarthy, 1996), 2) social interaction, as alcohol use is a form of social behaviour (Larsen et al., 2009) and social alcohol contents can trigger emotional reactions or associations (Nees et al., 2012), and 3) brands, since familiarity and perception of a brand can be reflected in different brain activation in the ventral striatum, vmPFC, DLPFC, or amygdala (Pravettoni & Lucchiari, 2012; Schaefer & Rotte, 2007). The current commentary provides an overview of the included studies and their stimuli sets, followed by a description of the three factors of interest. We further discuss how these factors could have affected the current knowledge of the neurobiological basis of cue-reactivity. Finally, some recommendations for future studies are provided.

2. Materials and methods

2.1. Literature search and selection

A literature search was conducted in PubMed, using the keywords ‘alcohol’, ‘cues’ and ‘fMRI’ or ‘PET’. Inspection of the 124 initially identified studies (end-date of search is June 2014) revealed that 95 studies were excluded because they 1. did not focus on alcohol (i.e., studies on other substance uses or disorders ($n = 24$), 2. did not use visual cues (i.e., taste and odour cues, $n = 26$), 3. did not use a passive viewing paradigm ($n = 43$), 4. did not use human subjects ($n = 2$), and 5. did not use of fRMI or PET techniques ($n = 0$). One study was added based on reference sections, resulting in 30 studies that were included in this review. All authors of the selected studies were contacted and asked to provide their stimuli set.

2.2. Definition of factors of interest

Human display was defined as whether or not humans were depicted in the stimuli. The display of at least a hand was sufficient to score positive on this factor. The second factor was the presence of social interaction in the stimuli. When stimuli clearly depicted two or more individuals, the stimulus was scored positive on social interaction. The third factor was brands. If the names of brands were readable or the logos were clearly recognizable, stimuli were evaluated as displaying brand information.

3. Results

Stimuli sets from 22 studies were retrieved after contacting the authors of the identified studies. Based on the descriptions in the materials' sections such as a clear reference to stimuli sets in other papers that we retrieved from those authors, four additional studies could be included. This resulted in the final inclusion of 26 studies. The source of the stimuli (i.e., standardized picture sets, advertisement, and the internet) and the type of control stimuli are described in Table 1.

3.1. Source of the stimuli

Most stimuli sets (N = 21, 80%) came from standardized sets, such as the Normative Appetitive Picture System (NAPS) (Breiner, Stritzke, Lang, & Patrick, 1995) or the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1997). However, since these sets contained limited numbers of stimuli displaying alcoholic and non-alcoholic beverages, almost all stimuli sets (N = 25, 96%) were supplemented with advertisements, stimuli from the Internet or self-made stimuli to avoid stimulus repetition within a study.

One noteworthy finding is that four stimuli sets were used repeatedly (i.e., one stimuli set was used repeatedly in 8 studies, one stimuli set in 5 studies, and two stimuli sets in 3 studies); hence, 19 studies (73%) provided the results based on four stimuli sets (see Table 1).

3.2. Type of control stimuli

In the analyses of the included papers, 13 out of the 26 studies (50%) compared alcoholic and non-alcoholic beverages in the stimuli directly. The remaining 13 studies (50%) compared the alcoholic beverage stimuli with neutral stimuli displaying everyday objects or with positive and negative stimuli (see Table 1). Given that stimuli displaying alcoholic beverages and neutral stimuli displaying everyday objects differ in many non-alcohol specific factors, such as the overall attractiveness of the stimuli, we suggest using non-alcoholic beverage stimuli as control condition, thereby reducing confounding factors in the comparison of alcohol versus control stimuli.

3.3. Social content of the stimuli

Social content of the stimuli was reviewed for all studies in which non-alcoholic beverage stimuli were used as a control condition. The stimuli sets of these studies were scored and analysed systematically. The results of these 13 studies are summarized in Table 2 and reported below.

3.3.1. Human content

The percentage of stimuli displaying humans in the alcoholic beverage stimuli fluctuated between 10 and 45% (mean = 24.08%; SD = 16.16), whereas the percentage of stimuli displaying humans in the non-alcoholic beverage stimuli fluctuated between 7 and 50% (mean = 26.73%; SD = 14.65). A paired-sample t-test comparing these percentages revealed that the mean difference between alcoholic beverage stimuli and non-alcoholic beverage stimuli was not significant ($t\,(13) = 0.84$; $p = 0.416$). Concerning individual studies, an approximately equal number of stimuli displayed humans in alcoholic and in non-alcoholic beverages conditions, with a difference of either 4% in 46% of the studies (N = 6 studies) or a difference of 15–20% in 38% of the studies (N = 5 studies) (see Δscore in Table 2).

Table 1
Descriptives of the origin and control condition of all included papers.

First author	Year	Source of stimuli			Control condition				
		IAPS	NAPS	Advertisement/Internet/self-made	Non-alcoholic[a]	Neutral[b]	Positive	Negative	Visual control[c]
Braus et al. [1]	2001	x		x		x			x
George et al. [2]	2001		x	x	x				
Wrase et al. [1]	2002	x		x					x
Tapert et al. [4]	2003			x	x				
Grüsser et al. [1]	2004	x		x		x			x
Myrick et al.[2]	2004		x	x	x				x
Heinz et al. [1]	2004	x		x		x			x
Hermann et al. [1]	2006	x		x		x			x
Heinz et al. [1]	2007	x		x	x		x	x	
Wrase et al. [1]	2007	x		x		x	x	x	
Park et al.	2007		x	x	x				x
Myrick et al.[2]	2008		x	x	x				x
Myrick et al.[2]	2010		x	x	x				x
Vollstädt-Klein et al. [3]	2010	x		x		x			
Schacht et al.[2]	2011		x	x	x				x
Vollstädt-Klein et al. [3]	2011a	x		x		x			
Ihssen et al.	2011	x	x	x			x	x	
Vollstädt-Klein et al. [3]	2011b	x		x		x			
Beck et al.	2012		x			x			x
Dager et al. [4]	2013a			x	x				x
Schacht et al.	2013a		x	x	x				x
Schacht et al.	2013b		x	x	x				x
Dager et al.[4]	2013b			x	x				x
Langosch et al. [1]	2012	x		x		x			x
Holla et al.	2014			x	x				
Jorde et al.	2014	x		x		x			

Note: Numbers shown after author names indicate whether the same stimuli sets are used in multiple studies. Each number refers to a specific stimuli set that is used in multiple studies.
[a] Non-alcohol: stimuli display beverages without alcohol.
[b] Neutral: stimuli display no beverages.
[c] Visual control: stimuli are made unrecognizable by scrambling or blurring the alcohol-related stimuli.

Table 2
Scoring of stimuli content on the three factors of interest, for the alcohol-related and non-alcohol related stimuli separately.

First author	Year	Human			Social			Brands		13
		Alcohol	Non-alcohol	Δ	Alcohol	Non-alcohol	Δ	Alcohol	Non-alcohol	Δ
George et al.	2001	12.50% (3/24)	16.67% (4/24)	4.17%	4.17% (1/24)	0.00% (0/40)	4.17%	41.67% (10/24)	58.33% (14/24)	16.66%
Tapert et al.	2003	45.45% (10/22)	50.00% (11/22)	4.55%	27.27% (6/22)	13.64% (3/22)	13.65%	45.45% (10/22)	77.27% (17/22)	13.65%
Myrick et al.	2004	12.50% (3/24)	16.67% (4/24)	4.17%	4.17% (1/24)	0.00% (0/24)	4.17%	41.67% (10/24)	58.33% (14/24)	16.66%
Heinz et al.	2007	26.67% (4/15)	6.67% (1/15)	20.00%	6.67% (1/15)	0.00% (0/15)	6.67%	20.00% (3/15)	0.00% (0/15)	20.00%
Park et al.	2007	37.50% (9/24)	16.67% (4/24)	20.83%	16.67% (4/24)	0.00% (0/24)	16.67%	12.50% (3/24)	4.17% (1/24)	8.33%
Myrick et al.	2008	12.50% (3/24)	16.67% (4/24)	4.17%	4.17% (1/24)	0.00% (0/24)	4.17%	41.67% (10/24)	58.33% (14/24)	16.66%
Myrick et al.	2010	12.50% (3/24)	16.67% (4/24)	4.17%	4.17% (1/24)	0.00% (0/24)	4.17%	41.67% (10/24)	58.33% (14/24)	16.66%
Schacht et al.	2011	10.00% (3/30)	25.00% (4/16)	15.00%	3.33% (1/30)	0.00% (0/16)	3.33%	33.33%(10/30)	43.75% (7/16)	10.42%
Dager et al.	2013a	45.45% (10/22)	50.00% (11/22)	0.05%	27.27% (6/22)	13.64% (3/22)	13.63%	45.45% (10/22)	77.27% (17/22)	31.82
Dager et al.	2013b	45.45% (10/22)	50.00% (11/22)	4.55%	27.27% (6/22)	13.64% (3/22)	13.65%	45.45% (10/22)	77.27% (17/22)	31.82%
Schacht et al.	2013a	10.00% (3/30)	25.00% (4/16)	15.00%	3.33% (1/30)	0.00% (0/16)	3.33%	33.33%(10/30)	43.75% (7/16)	10.42%
Schacht et al.	2013b	10.00% (3/30)	25.00% (4/16)	15.00%	3.33% (1/30)	0.00% (0/16)	3.33%	33.33%(10/30)	43.75% (7/16)	10.42%
Holla et al.	2014	32.50% (13/40)	32.50% (13/40)	0.00%	0.00% (0/40)	0.00% (0/40)	0%	47.50% (19/40)	22.50% (9/40)	25.00%
Total		24.08% (SD 16.16)	26.73% (SD 14.65)	4.33%	10.14% (SD 10.49)	3.15% (SD 6.00)	7%	37.16% (SD 10.57)	47.93% (SD 25.70)	10.77%

Note: Within brackets the number of stimuli that scored positive out of the total stimuli. Δ is the calculated difference between the alcohol and non-alcohol conditions.

3.3.2. Social interaction

The results revealed that 10 studies (76%) did not include social interaction in the non-alcoholic beverage stimuli or the alcoholic beverage stimuli (see Table 2). The percentage of pictures showing social interaction across stimuli sets varied between 3 and 27% (mean = 10.14%; SD = 10.49) in stimuli sets displaying alcoholic beverages and between 0 and 14% (mean = 3.15%; SD = 6.00) in the stimuli sets displaying non-alcoholic beverages. All studies that scored positively on social interaction included human display as well. A paired-sample *t*-test comparing these percentages revealed a significant difference between alcoholic and non-alcoholic beverage stimuli ($t(13) = 4.69$; $p = 0.001$) in showing social interaction, with more social interaction displayed in stimuli sets displaying alcoholic beverages. Regarding individual studies, two main patterns can be defined. The alcoholic beverage stimuli matched the non-alcoholic beverage stimuli in terms of social interaction with a difference of about 3% (N = 7, 53%), or the stimuli matched less well with a difference of about 17% (N = 4, 30%).

3.3.3. Brands

The amount of brands across studies in the alcoholic beverage stimuli fluctuated between 13 and 48% (mean = 37.16%, SD = 10.57) and in the non-alcoholic beverage stimuli between 0 and 77% (mean = 47.93% SD = 25.70) (see Table 2). A paired-sample *t*-test comparing these percentages showed that the difference between the alcoholic and non-alcoholic beverage stimuli was non-significant ($t(13) = 2.11$; $p = 0.056$). However, a trend can be seen towards fewer brands depicted in the stimuli sets displaying alcoholic beverages. Within stimuli sets, the difference between alcoholic and non-alcoholic beverage stimuli was on average 11%. In other words, most studies did not match the stimuli in terms of the amount of brand display very well.

4. Discussion

The aim of the current paper was to review and emphasize the importance of stimuli selection, specifically the social content, in alcohol cue-reactivity neuroimaging studies. No differences between alcoholic and non-alcoholic beverage stimuli were found in the amount of human display and brands. However, significantly more social interaction was found in alcoholic compared to non-alcoholic beverage stimuli.

4.1. Human display

It is important to consider human display for several reasons. It has been found that human-related stimuli require greater cognitive processing compared to pictures of objects alone (Bentin et al., 1996). Additionally, previous literature has shown that cognitive biases to alcohol cues that include human content differ from cognitive biases to alcohol cues that do not include human content (Dickter, Forestell, Hammett, & Young, 2014; Forestell, Dickter, & Young, 2012). Since differences in the percentages of human content between alcoholic beverage stimuli and non-alcoholic beverage stimuli appeared to be small and non-significant in the samples we examined, we suggest that this factor does not interfere with the current neuroimaging literature on alcohol cue-reactivity much. Future studies should therefore continue to match alcohol-related and control stimuli sets and consider the proportion of stimuli displaying humans based on the research question at hand, given that unique brain activation has been found while processing faces and human body parts (Downing, Jiang, Shuman, & Kanwisher, 2001; Ishai, Ungerleider, Martin, & Haxby, 2000). This is of particular importance when investigating alcohol-related cue reactivity in individuals with an alcohol dependence, as previous studies showed impairments in the processing of faces and recognition of emotions (Donadon & Osorio Fde, 2014; Uekermann & Daum, 2008) in this group.

4.2. Social interaction

The largest group of alcohol users perceives alcohol use as a form of social behaviour. For example, individuals tend to drink in groups (Cullum, O'Grady, Armeli, & Tennen, 2012; van Schoor, Bot, & Engels, 2008) and model their peers who are drinking alcohol and to a lesser extend those who are drinking non-alcoholic beverages (Larsen et al., 2009; Larsen, Overbeek, Granic, & Engels, 2010, 2012). Therefore, displaying social interaction in alcoholic beverage stimuli might have a different effect on cue-reactivity for stimuli sets displaying alcoholic compared to non-alcoholic beverages. Hence, if alcoholic beverage stimuli display more social interaction compared to non-alcoholic beverage stimuli, associations with these social interactions may trigger happy feelings or thoughts and may therefore result in different brain activation patterns. In addition, displaying social interaction may influence comparisons between individuals with alcohol dependence and a control group of social drinkers, given that alcohol use is strongly driven by social cues in social drinkers (Nees et al., 2012), thereby probably masking group differences.

In the identified studies, a significantly greater number of social interactions were displayed in alcoholic beverage stimuli compared to the non-alcoholic beverage stimuli. Since the processing of social information can enhance vmPFC activation (Adolphs, 1999; Amodio & Frith, 2006), the processing of social interaction may have influenced activation related to alcohol cue-reactivity in the meta-analysis by

Schacht et al. (2012). In order to get more insight in the effect of social content in alcohol cues on brain activation, we reviewed the brain activation patterns between the included studies that used a small amount of social interaction in their alcohol stimuli (<5%) and compared this with studies that included more social interaction in their alcohol stimuli. Studies with more social content in the alcohol stimuli, showed relatively more often activation in areas associated with cognitive and social processing such as the cingulate cortex fusiform gyrus and superior temporal sulcus (Dager, Anderson, Stevens, et al., 2013; Heinz et al., 2007; Park et al., 2007). Thus, social alcohol stimuli may require more cognitive processing and may trigger more brain activation in regions involved in, for example, face recognition (i.e., the fusiform gyrus) (Kanwisher, McDermott, & Chun, 1997). Studies with mainly pure alcohol pictures (i.e., <5% of social content in alcohol cues) reported relatively more often activation in the reward related areas such as the ventral striatum (Myrick et al., 2004, 2008, 2010; Schacht et al., 2011; Schacht, Anton, Voronin, et al., 2013). Given that these findings were observed in heavy drinkers or alcohol dependent patients, it may be that incentive sensitization in this specific subtype of alcohol users has been developed more strongly to pure alcohol cues (Robinson & Berridge, 1993). To get more insight into the role of social stimuli content in alcohol cue-reactivity across different types of drinkers, future research should investigate cue-reactivity to pure alcohol cues and alcohol cues that display social interaction in different drinking populations. To summarize, more social interaction is displayed in alcoholic beverage stimuli sets compared to control sets in the current literature. We suggest that future studies carefully match stimuli sets in terms of social interaction. Furthermore, as alcohol use can be seen as a form of social behaviour, comparing non-social and social alcohol-related stimuli directly in future research may reveal new insights on neural processes involved in social drinking as well as alcohol dependence.

4.3. Brands

Everyone has certain brand preferences; thus, it is unlikely for individuals to respond to different brands in the same way (Field & Christiansen, 2012). When viewing favourite brands, activity in the ventral striatum is found (Schaefer & Rotte, 2007) and the processing of logos or brand names is associated with brain activity in the vmPFC, a region known to be associated with self-centred cognitions (Santos, Seixas, Brandao, & Moutinho, 2011). Familiarity with the brand has been linked to activity changes in the DLPFC/vmPFC area (Esch et al., 2012; Schaefer & Rotte, 2007), whereas likeability of the brands is associated with activity in the amygdala and the frontal temporal areas, respectively for liking and not liking of a brand (Dalli, Romani, & Gistri, 2006). Altogether, the current literature about brand processing shows that activation in several limbic and prefrontal areas can be related to the processing of brands. Interestingly, it seems that there is some overlap in regions involved in the processing of brands as well as reactivity to substance related cues, for example, in the DLPFC and vmPFC (Chase et al., 2011; Schacht et al., 2012). If stimuli sets are not well matched in terms of brand display, the reactivity in these regions to both brands and alcohol-cues may influence substance-cue reactivity findings.

The current results revealed no significant difference but a trend towards less brands in the alcoholic beverage stimuli, with an average of 37% relative to 48% in the non-alcoholic beverage stimuli. Given the slight imbalance in the display of brands in alcoholic versus control stimuli sets, brand display may have influenced the findings of the meta-analyses on the DLPFC and vmPFC. However, as only a trend was found in brand display between alcohol-related and non-alcohol related beverage stimuli, conclusions about possible confounding effects of brand display in current cue-reactivity findings cannot be drawn. Furthermore, since most studies use stimuli including a variety of different brands that each brand can be liked or disliked, we suggest selecting the most popular brands for the group participants included in the study and displaying the same percentage of brands across the stimuli.

In conclusion, future studies should consider three aspects. First, systematically investigating the stimuli sets revealed that four stimuli sets accounted for a large part of the studies. This certainly is an advantage in terms of consistency and replication, but it also limits the generalizability of the findings. Therefore, more standardized alcohol-related and control stimuli sets should be developed, shared, and used in cue-reactivity paradigms.

Second, it is essential to adequately match stimuli between conditions. It was found that almost half of the studies used neutral stimuli (i.e., a clock on a wall) as a control condition. Given that many non-alcohol specific factors, such as the overall attractiveness of the stimuli, also differ across alcoholic beverages and these kinds of neutral stimuli, we suggest using non-alcoholic beverage stimuli as control stimuli, thereby reducing confounding factors when comparing alcohol with control stimuli.

Third, analysing the stimuli sets based on human display, social interaction and brands revealed that the amount of social interaction displayed in stimuli should be better matched across stimuli sets displaying alcoholic and non-alcoholic beverages. The current results showed that alcoholic beverage stimuli are more likely to contain social interaction compared to non-alcoholic beverage stimuli. Better matching may increase the reliability of future findings concerning alcohol-related cue-reactivity, especially in regions like the vmPFC and the amygdala, which are both involved in alcohol-related cue-reactivity and social information processing. Social interaction may be particularly important when considering different types of drinkers, as social content is of different relevance to social drinkers and individuals with alcohol dependence.

More careful stimulus selection will improve the reliability and validity of cue-reactivity paradigms and offer more insights into the brain regions that are specifically related to cue-reactivity. This may also apply to cue-reactivity studies on other substances of abuse, such as smoking.

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Contributors

All authors have been personally and actively involved in substantive work leading to the report, and will hold themselves jointly and individually responsible for its content. Authors Groefsema, Engels, and Luijten were responsible for the design of the study. Author Groefsema conducted literature searches and contacted authors for their stimuli sets. Author Groefsema wrote the first draught of the manuscript and authors Engels and Luijten contributed to and have approved the final manuscript.

Conflict of interest

All authors declare that they do not have any conflicts of interest concerning the manuscript.

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