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Drawing alcohol craving process: a systematic review of its association with thought suppression, inhibition and impulsivity

Laura BERNARD^{a,c}, Laura CYR^{a,c}, Agnès BONNET-SUARD^b, Christophe CUTARELLA^c, Vincent BRÉJARD^a

^aAix Marseille University, LPCPP, Aix-en-Provence, France
29 Avenue Robert Schuman, 13100 Aix-en-Provence, France

^bUniv Lyon, Université Claude Bernard– Lyon 1, L-VIS, 69 622 Villeurbanne, Lyon, France
Bâtiment Raphaël Dubois, 8 Rue R. Dubois, 69 622 Villeurbanne, France

^cClinique Saint Barnabé, 72 Chemin de Fontainieu, 13014 Marseille, France

Laura BERNARD : laura.bernard.2@etu.univ-amu.fr; laura.bernard.05@hotmail.fr

Laura CYR : laura.cyr@etu.univ-amu.fr

Agnès BONNET-SUARD : agnes.bonnet-suard@univ-lyon2.fr

Christophe CUTARELLA : c.cutarella@ramsaygds.fr

Vincent BRÉJARD : vincent.brejard@univ-amu.fr

Corresponding author.

- Laura BERNARD : laura.bernard.2@etu.univ-amu.fr; laura.bernard.05@hotmail.fr

Abstract

Alcohol Use Disorder (AUD) is a worldwide public health problem. In recent years, there has been growing evidence supporting craving, the irrepressible desire to drink, as a major mechanism implicated in AUD. Impulsivity is identified as playing a significant role in craving in many studies. However, relationships with inhibition and thought suppression remain unclear in the existing literature. A systematic review was conducted to evaluate their associations in order to better understand the cognitive processes involved in craving.

Studies were identified by searching PubMed, PsycINFO and Web of Science using PRISMA procedure and PICOTS framework. There were included if they assessed craving and thought suppression or inhibition or impulsivity, and sample was composed of AUD participants.

Thirteen studies were included and were categorized in accordance with the evaluated cognitive process. The first part dealt with thought suppression and the second with impulsivity and inhibition. Four studies showed a positive association between thought suppression and increased craving. Two studies showed that poorer inhibition was associated with increased craving and four studies showed that impulsivity was positively associated with craving. Three studies showed a negative association between impulsivity and inhibition and higher craving.

Our review highlights the association of alcohol craving with poorer inhibition and greater impulsivity. Further investigations are needed to give support to different theories and lead to propose an integrative model involving the cognitive process of inhibition in alcohol craving.

Key words: Alcohol Use Disorder, craving, inhibition, impulsivity, thought suppression, self-regulation

1 Introduction

Alcohol consumption is a major risk factor for public health, causing three million deaths per year. It accounts for 5.1% of the global burden of disease and injury (WHO, 2016). Craving, defined as a strong desire or urge to use alcohol, is a new DSM-5 criterion of Alcohol Use Disorder.

Concern for craving in the search literature and more precisely for alcohol craving is quite recent, with numerous articles since the early 2000s. In PubMed, search results for number of studies by year statistics, found eleven articles in 1999 and a peak in 2013 with 71 articles. Previous studies and theoretical frameworks deal with emotion regulation, negative affects, stress or attentional bias in alcohol craving. A systematic review of theoretical models predicting consumption or relapse led to the selection of four models (van Lier et al., 2018) but the cognitive process independently from lapse was not really investigated, other components such as impulsivity, inhibition and thought suppression were much less explored.

Impulsivity and inhibition are two widely similar processes, and the distinction between them is unclear. Impulsivity is often described as a manifestation of an inhibition deficit that erase divergences between these two processes yet distinct (Aichert et al., 2012; Gay, Rochat, Billieux, d'Acremont, & Van der Linden, 2008; Gay, Schmidt, & Van der Linden, 2011; Logan, Schachar, & Tannock, 1997; Nigg, 2017). Impulsive behaviour is defined as a deficit in the ability to inhibit a prepotent response (Logan et al., 1997). However, prepotent response inhibition paradigms can account for psychometric trait impulsivity only to a limited extent (Aichert et al., 2012). Even if trait impulsivity and behavioural inhibition present some relationship, they can't be reduced at the same and unique process, and they can't be used interchangeably (Nigg, 2017). A major difference lies in the definition of these two processes. Impulsivity is studied as a personality trait leading to impulsive behaviour (Whiteside & Lynam, 2001) and assessed by self-assessment questionnaires, whereas inhibition refers to a cognitive process evaluated by behavioural measures. Nonetheless, there can be considered as opposite ends of the spectrum while very similar neuroanatomically.

A relevant observation is that a failure of inhibitory processes lead to impulsive behaviour (Bari & Robbins, 2013), as shown by behavioural tasks assessing behavioural inhibition. However, there is no behavioural paradigm giving the opportunity to assess cognitive inhibition, and its links with impulsivity. A relation was found between impulsivity and intrusive thoughts resulting in an inability to inhibit unwanted thoughts. More precisely, a facet of impulsivity, called negative urgency, is related to the inhibition of a prepotent response, and has a positive association with intrusive thoughts (Gay et al., 2011). Otherwise, the kind of mental intrusion is an important factor in studies on thought suppression (Gay et al., 2008).

Craving is partly considered as a phenomenon involving a cognitive effort to inhibit automatic response to alcohol (APA, 2013). It can appear when an alcohol-dependent patient tries to maintain abstinence (Tiffany & Conklin, 2000). The Elaborated Intrusion Theory of Desire (Kavanagh, Andrade, & May, 2005; May, Andrade, Panabokke, & Kavanagh, 2004) proposes a cognitive model of craving including emotional and motivational aspects. In this model, craving consists in intrusive thoughts of drinking followed by mental images referred to as elaborated thoughts. The hyperaccessibility of suppressed thoughts results from the operation of two cognitive processes. A controlled process that looks for distractors in order to avoid the unwanted thought and an automatic process that searches the suppressed thought. If this process finds the target thought, the controlled process is activated to eliminate the thought. The paradoxical effect is that the automatic target search makes the person very sensitive to the suppressed thought. Under time pressures or cognitive demands, the intention to suppress a thought leads to the opposite, unwanted thoughts are more accessible to consciousness (Wegner & Erber, 1992). In this way, craving is considered as associated with inhibition mechanisms through the ironic process theory of thought suppression (Wegner, 1994), which refers to a "rebound effect" of undesired thoughts. It means that the more alcohol-dependent

patients try to suppress alcohol related thoughts the more these thoughts become frequent and intrusive. Data on this process remain unclear and need further exploration (Abramowitz, Tolin, & Street, 2001). Indeed, most studies on thought suppression failed to show an immediate enhancement of suppressed thoughts in the absence of cognitive load (Wenzlaff & Wegner, 2000). Otherwise, a distinction between trait and state suppression begins to emerge in the search literature, but these two similar processes seems to be different. Only one study investigated them together while, in general, thought suppression is studied as a unique variable.

Currently, very few studies have explored links between craving and the ironic process. Moreover, the state of knowledge about inhibition, impulsivity and craving is poor. Otherwise, the present study focused on alcohol craving to enhance the homogeneity of selected studies and to diminish possible bias due to specificities of other substances or addictive behaviours. A large number of studies investigate the consequences of alcohol consumption on executive functions, generally in social drinker's samples. However, the goal of the present study is to identify the implication of these functions in craving experienced by patients with an AUD. The objectives are to define the inhibition processes involved in craving and to specify the role of cognitions. This study attempts to identify empirical evidence supporting the relation between craving for alcohol and self-regulation, including the impulsivity trait, inhibition and thought suppression.

2 Method

2.1 Search strategy and selection criteria

The review protocol was submitted to OpenScience (<https://osf.io/daqsb>). The Preferred Reporting Items for Systematic reviews and Meta Analyses (PRISMA) were followed.

A PICOTS (Population, Interest/Intervention, Context/Comparison, Outcome, Type of question and Study) framework was used to conceptualise the search strategy for this review. Studies investigating the links between impulsivity, inhibition and craving in alcohol-dependent patients were included. Studies using the alcohol exposure paradigm were also eligible for inclusion. Those that tested the effect of alcohol consumption or administration on inhibition and impulsivity were excluded. Indeed, the literature on this subject is fairly well documented and the purpose of this study was to identify links between these processes and craving without the effect of alcohol consumption. Studies of multicomponent interventions were eligible if they assessed the specific effects of inhibition or impulsivity or the alcohol cue-reactivity paradigm on craving. Studies evaluating attentional biases were excluded. The selective attention for alcohol stimuli has been previously developed and studied. The present study referred to thought inhibition. There is evidence of interactions between attention and inhibition (Howard, Johnson, & Pascual-Leone, 2014). Attentional biases are defined both as a facilitated attention to salient cues or a difficulty in disengagement from these stimuli (Cisler, Bacon, & Williams, 2009). However, the systematic review paid attention to the inhibition as both automatic or effortful process, upstream from attentional processes, and not necessarily in presence of

addiction cues, as it is reproduced in cue-exposure paradigms. Reports of any study design and conducted in any country, at any date, reported in English, were eligible for inclusion in the review, except for doctoral dissertations.

The literature search was carried out using online databases (PubMed, PsycInfo and Web of Science). The following filters were applied: humans, adults, articles and English. In order to check the adequacy of the search terms, forward and backward searching were performed. The search terms used for PubMed were MeSH Terms arranged according to the following algorithm: (alcohol craving OR craving for alcohol OR alcohol urge OR alcohol cues OR alcohol stimuli) AND (inhibition psychology OR impulsivity OR impulsive behaviour OR thought suppression). This was used for each database.

A pilot test from a sample including 30% of the articles was performed in order to verify the reliability of the interpretation of the selection criteria and to ensure that the application of the selection criteria was carried out systematically and consistently by all evaluators. All authors were involved in data sifting. Two reviewers (LB and LC) of the team conducted eligibility assessments of titles and abstracts independently. Disagreements between reviewers were resolved by consensus or by discussion with a third researcher (VB).

2.2 Quality assessment

The limits of articles were established according to the AXIS tool for systematic review including cross-sectional studies (**Fig. 1**) and checked by another researcher.

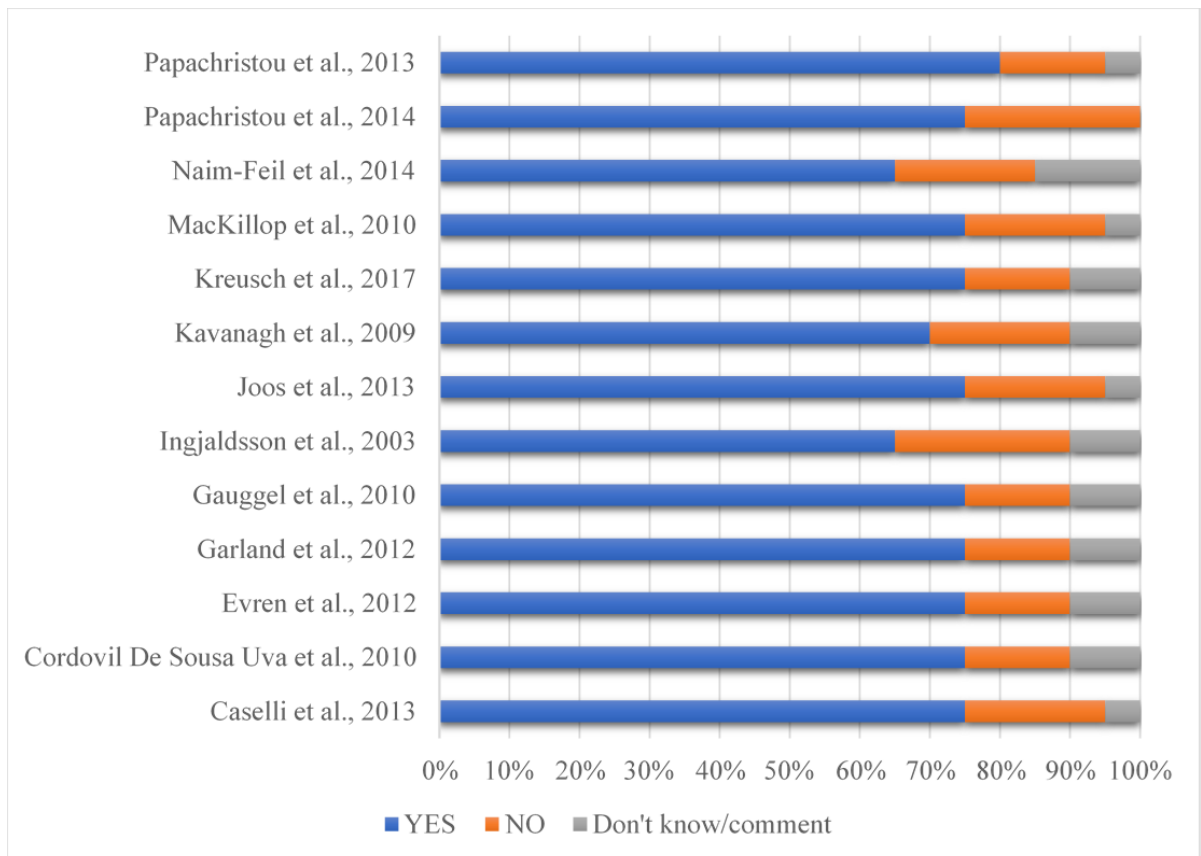


Fig. 1. Results of studies' limits according to the AXIS tool for cross-sectional design risk of bias.

Only three studies compared the experimental group with a control group (Cordovil De Sousa Uva et al., 2010; Ingjaldsson, Laberg, & Thayer, 2003; Naim-Feil, Fitzgerald, Bradshaw, Lubman, & Sheppard, 2014). One study only involved males (Evren, Durkaya, Evren, Dalbudak, & Cetin, 2012), four studies included both genders (Cordovil De Sousa Uva et al., 2010; Kavanagh, May, & Andrade, 2009; Naim-Feil et al., 2014; Papachristou et al., 2013) with a majority of females in three of these; other studies had a majority of males (Caselli et al., 2013; Garland, Carter, Ropes, & Howard, 2012; Gauggel et al., 2010; Ingjaldsson, Laberg, et al., 2003; Joos et al., 2013; Kreusch, Billieux, & Quertemont, 2017; MacKillop et al., 2010; Papachristou, Nederkoorn, Giesen, & Jansen, 2014).

2.3 Data extraction

Data were extracted by one reviewer (LB) on study location, design, average age, gender and severity of alcohol-dependence. A second reviewer (LC) checked all data extraction.

A meta-analysis was not conducted as there were differences between studies in location, design, assessment tools used, and frequency of outcomes sampled.

3 Results

3.1 Characteristics of included studies

Of all documents found, 1379 were imported to an online reference manager, Mendeley. After checking for duplicates, 1016 articles were retrieved. Then, relevant articles were selected in three

stages. Preliminary scrutiny of the titles was undertaken to remove articles irrelevant to the review. Next, articles deemed irrelevant by abstract content were discarded and full texts of the remaining potentially relevant articles were obtained. Data from included studies were extracted and summarized in **Table 1**. Forty-two articles deemed relevant by titles and abstracts were identified for further consideration and full texts of these articles were obtained. Ultimately, 13 articles that conformed to the eligibility criteria were included in this review (**Fig. 2 and Table 2**).

Author/Year	Country	Population	Methods and measures			Summary of results presented in the paper	
		Groups (Inpatient/Outpatient) Clinical assessment	Mean [SD] age	Gender	Dimension and methods of measure (self-assessment/behavioural)	Time Paradigm (alcohol cue exposure: yes/no)	
(Caselli et al., 2013)	Italy UK	Comparisons Matched groups Alcohol-dependence (n=26 inpatients) Problem drinking (n=26) Social drinking (n=29)	44.69 [10.58] (inpatients)	Men (majority)	Self-assessment BDI RRS VAS (craving)	Single session 2 conditions: ruminations/distractions 3 times of craving assessment: baseline/post-induction/post-resting phase Alcohol cue exposure: no	Time × Condition × Group: F, p 5.98, 0.001 Alcohol-dependence 5.18, 0.01 Current craving: Mean difference, p 0.05, 5.74 to 6.70, 0.03
(Cordovil De Sousa Uva et al., 2010)	Belgium	Matched groups Inpatients (n=35) Controls (n=22)	48.40 [8.2] (inpatients)	48,5% men 51,5% women	Self-assessment OCDS Behavioural measures Stroop task (inhibition) LGT (decision making)	2 times: T1 (day 1), T2 (days 14-18) Except LGT at T1 or T2 (learning test-retest effects) Alcohol cue exposure: no	Inpatients craving scores Time x Group: t(31) > 4.26, p<0.001, Cohen's ds > 0.62 Control group, ns Craving scores x Group t(51) > 2.1, p<0.04, Cohen's ds > 0.59 Prepotent response inhibition: F, p Group: > 14.80, 0.001 Time: > 8.10, 0.01 Group × Time: > 8.98, 0.01 Decision making: scores inpatients < controls T1: t(41) = -2.855, p=0.025, Cohen's d = -0.69 T2: t(29) = -2.391, p=0.024, Cohen's d = -0.96
(Evren et al., 2012)	Turkey	Inpatients (n=102)	46.44 [9.9]	Men	Self-assessment BIS-11 TCI PACS	2 evaluations: Baseline: 4-6 weeks after the last day of alcohol use Follow-up: 12 months later (n=102) Alcohol cue exposure: no	PACS: r, p BIS-11: 0.43, 0.001 Impulsiveness: 0.31, 0.01 Novelty seeking: 0.37, 0.001 β,SE,t,p Non-planning impulsiveness (BIS-NPI): 0.259, 0.191, 2.389, 0.019

Table 1. Included studies

(continued on next page)

BDI: Beck Depression Inventory; **RRS:** Rumination Response Scale; **VAS:** Visual Analogue Scale; **OCDS:** Obsessive Compulsive Drinking Scale; **LGT:** Iowa Gambling Test; **BIS-11:** Barratt Impulsiveness Scale; **TCI:** Temperament and Character Inventory (novelty seeking); **PACS:** Penn Alcohol Craving Scale.

Author/Year	Country	Population	Methods and measures			Summary of results presented in the paper	
		Groups (Inpatient/Outpatient) Clinical assessment	Mean [SD] age	Gender	Dimension and methods of measure (self-assessment/behavioural)	Time Paradigm (alcohol cue exposure: yes/no)	
(Garland et al., 2012)	USA	Inpatients (n=57)	39.6 [9.4]	47 men 11 women	Self-assessment WBSI IRISA VAS (craving) Physiological responsivity HRV responsivity to alcohol cues: ECG	Single session Alcohol cue exposure: yes	Craving: r, p IRISA: 0.40, 0.003 WBSI : 0.38, 0.005 VAS: No association VAS: r, p IRISA: 0.51, 0.001 WBSI: 0.30, 0.05 HRV x VAS: β, p -.104, .048
(Gauggel et al., 2010)	UK Germany	Inpatients (n=20)	44.9 [not specified]	1 woman	Semi-structured interview Craving Behavioural measure SST (inhibition)	Single session Alcohol cue exposure: yes 2 conditions: alcohol/water Each participant had been detoxified and abstinent from alcohol for at least 4 weeks	Craving: mean, SD Alcohol cue exposure group: 15.6, 9.0 Control cue exposure group: 7.2, 4.5 p<0.05 Inhibitory performance: F, p Cue exposure: 6.84, 0.018

Table 1. Included studies

(continued on next page)

WBSI: White Bear Suppression Inventory; **IRISA:** Impaired Response Inhibition Scale for Alcoholism; **VAS:** Visual Analogue Scale; **HRV:** Heart Rate Variability; **ECG:** Electrocardiogram; **SST:** Stop-Signal Task.

Author/Year	Country	Population	Methods and measures			Summary of results presented in the paper	
		Groups (Inpatient/Outpatient) Clinical assessment	Mean [SD] age	Gender	Dimension and methods of measure (self-assessment/behavioural)	Time Paradigm (alcohol cue exposure: yes/no)	
(Ingjaldsson et al., 2003)	Norway USA	Matched groups Inpatients (n=49) Controls (n=45)	45.4 [not specified] (inpatients)	Men (majority) 12 women 14 women	Self-assessment WBSI OCDS VAS (3 dimensions : craving) Physiological responsivity HRV: Beckman Electrode Electrolyte	Single session Forced choice task: picture identification task in which 26 masked slides of alcoholic and non-alcoholic content were briefly (20 msec) presented, and the viewer was asked to decide whether the pictures had alcoholic or non-alcoholic content. alcohol cue exposure: imaginary alcohol exposure	HRV x Group: F, p 2.67, 0.05 HRV x Group x Preimaginary exposure: 3.08, 0.04 HRV x Group x Exposure: 2.66, 0.05 Craving (VAS) x exposure: 14.01, 12.13, 17.75, <0.001 Inpatients HRV: r, p WBSI (pre-exposure, exposure) : -0.31, <0.05 OCDS compulsive (exposure) : -0.31, <0.05
(Joos et al., 2013)	Belgium Netherlands	Inpatients (n=87)	41.8 [9.7]	86.2% men	Self-assessment BIS-11 DDT (impulsivity) IST (impulsivity) AUQ (emotional craving) OCDS (cognitive craving) Behavioural measures SST (impulsivity)	Two sessions 1) Demographic characteristics and BIS-11 2) AUQ, OCDS, SST Alcohol cue exposure: no	OCDS compulsive (high group) x craving : F, p 8.77, 0.0048 Low group: ns AUQ: β, p BIS-11: 0.33, 0.002 SSRT: 0.25, 0.023 IST-fixed win: -0.28, 0.008 IST-decreased win: -0.32, 0.003 Inpatients subgroups (higher/lower heavy drinking days) For higher, AUQ: β, p BIS-11: 0.56, 0.001 IST-decreased win: -0.42, 0.01 Inpatients subgroups (long/shorter alcohol use history) For long, AUQ: β, p IST-decreased win: -0.46, 0.003 For shorter, AUQ: β, p BIS-11: 0.33, 0.05

Table 1. Included studies

(continued on next page)

WBSI: White Bear Suppression Inventory; **OCDS:** Obsessive Compulsive Drinking Scale; **VAS:** Visual Analogue Scale; **HRV:** Heart Rate Variability; **BIS-11:** Barratt Impulsiveness Scale; **DDT:** Delay Discounting Task; **IST:** Information Sampling Task; **AUQ:** Alcohol Urge Questionnaire; **SST:** Stop-Signal Task

Author/Year	Country	Population			Methods and measures		Summary of results presented in the paper
		Groups (Inpatient/Outpatient) Clinical assessment	Mean age	Gender	Dimension and methods of measure (self-assessment/behavioural)	Time Paradigm (alcohol cue exposure: yes/no)	
(Kavanagh et al., 2009)	Australia UK	Outpatients (n=232)	46.9 [10.5]	55% women	Self-assessment ACE	3 times: 3 weeks, 3 months, 6 months Unlear Alcohol cue exposure: no	Higher alcohol dependence at baseline: r, p Urges to drink: 0.45, 0.001 Craving: 0.30, 0.001 Image frequency: r, p Urge frequency: 0.38, 0.001 Craving strength: 0.32, 0.001 Alcohol thoughts without image: r, p Urge frequency: 0.19, 0.01 Craving strength: 0.19, 0.01 Trying to stop thinking about alcohol: r, p Intrusive thoughts (87% participants): 0.34, 0.001 Craving strength: 0.25, 0.01 Urge frequency: 0.25, 0.001
(Kreusch et al., 2017)	Belgium Luxem- bourg	Inpatients (n=31)	46.1 [not specified]	10 women Men (majority)	Self-assessment VAS (craving) UPPS-P (impulsivity) Behavioural measure Modified SST (inhibition)	Single session Alcohol cue exposure: yes 2 conditions/groups: alcohol/water	Craving scores: mean difference, SD (Z, p) Alcohol cue exposure: 1.42, 3.7 Control cue exposure: -0.47, 0.77 (2.64, 0.008) Alcohol cue exposure group Craving score: r, p RT alcohol related words (stop signal): -0.49, 0.044 % errors alcohol related words: 0.61, 0.009 % errors neutral words: 0.57, 0.016
(MacKillop et al., 2010)	USA	Participants (n=61)	42.4 [13.1]	38% women Men (majority)	Self-assessment PACS APT MCQ	Single session Not clear Alcohol cue exposure: no	Craving (PACS): r, p AUD severity: 0.58, 0.001 Intensity of demand: 0.25, 0.05 Large temporal discounting function: 0.33, 0.01

Table 1. Included studies

(continued on next page)

ACE: Alcohol Craving Experience questionnaire; **VAS:** Visual Analogue Scale; **UPPS-P:** Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency (Impulsive Behavior Scale); **SST:** Stop-Signal Task; **PACS:** Penn Alcohol Craving Scale; **APT:** Alcohol Purchase Task; **MCQ:** Monetary Choice Questionnaire (delayed reward discounting).

Author/Year	Country	Population			Methods and measures		Summary of results presented in the paper
		Groups (Inpatient/Outpatient) Clinical assessment	Mean [SD] age	Gender	Dimension and methods of measure (self-assessment/behavioural)	Time Paradigm (alcohol cue exposure: yes/no)	
(Naim-Feil et al., 2014)	Australia	Matched groups Outpatients (n=24) Controls (n=23)	40 [11]	11 men 13 women	Self-assessment OCDS Behavioural measures SART (inhibition/attention) RNG (inhibition/attention)	Single session Alcohol cue exposure: no	SART x Group: F, p Commission errors: 9.120, 0.004 RT: 4.714, 0.036 SART (outpatients): r, p Commission errors with age: -0.433, 0.035 RT with age: 0.417, 0.043 RT with OCDS scale: 0.424, 0.039 RNG x Group: F, p Total repetitions: 5.603, 0.023 Response bias index: 7.124, 0.011 RNG (outpatients): r, p Random Number Index ratio with years of alcohol use: 0.460, 0.027
(Papachristou et al., 2014)	Netherlands	Inpatients (n=20)	53.25 [10.15]	12 men 8 women	Self-assessment BIS-11 VAS	Single session Patients were contacted at least three months after the end of their treatment to assess lapse Alcohol cue exposure: yes	Lapse: B, SE, p Trait impulsiveness: -0.17, 0.08, 0.01 Cue-elicited craving: 0.11, 0.05, 0.007
(Papachristou et al., 2013)	Netherlands	Inpatients (n=41)	51.15 [10.9]	22 men 19 women	Self-assessment BIS-11 VAS (craving) Behavioural measures SST (inhibition)	Two sessions T1 : BIS-11, VAS, SST T2: exposure Alcohol cue exposure: yes	Alcohol exposure: F, p Craving: 26.86, 0.001 Cue type x Time x Age: F, p Craving: 7.91, 0.01 Increase in craving to alcohol cues: β, p Trait impulsiveness: 0.33, 0.05 Motor impulsiveness: 0.36, 0.05

Table 1. Included studies

OCDS: Obsessive Compulsive Drinking Scale; **SART:** Sustained Attention to Response Task; **RNG:** Response Number Generation task; **BIS-11:** Barratt Impulsiveness Scale; **VAS:** Visual Analogue Scale; **SST:** Stop-Signal Task

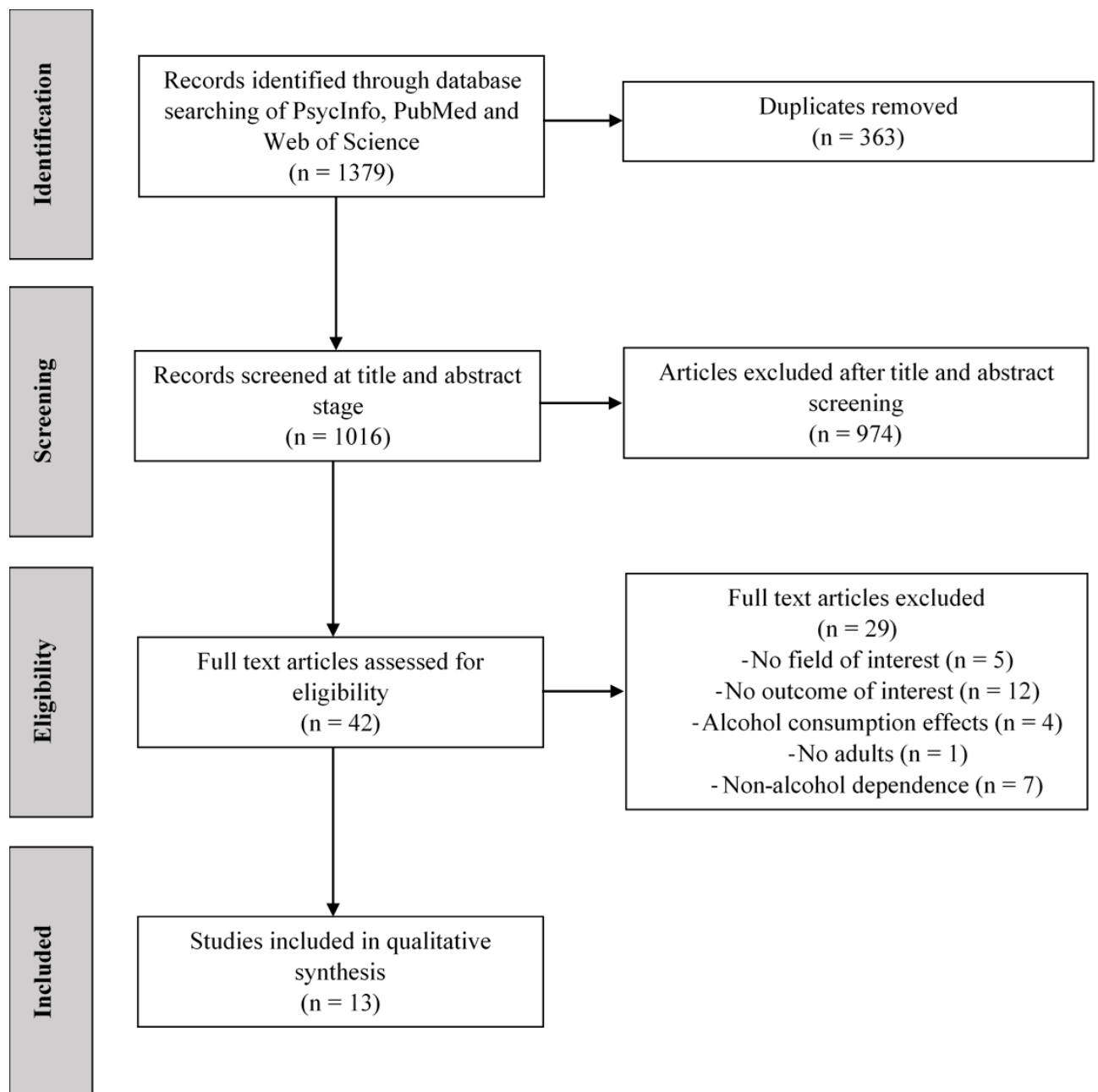


Fig. 2. Flowchart of search strategy.

STUDY		EXCLUSION CRITERIA				
		No field of interest	No outcome of interest	Alcohol consumption effects	No adult	Non-alcohol dependence
1	(Abroms & Fillmore, 2004)			✗		
2	(Abroms, Fillmore, & Marczinski, 2003)			✗		
3	(Acker, Amlung, Stojek, Murphy, & MacKillop, 2012)		✗			
4	(Adams, Ataya, Attwood, & Munafo, 2013)			✗		
5	(Adams, Attwood, & Munafo, 2017)			✗		
6	(Bowley et al., 2013)	✗				
7	(Bradizza et al., 1999)		✗			
8	(Bulley & Gullo, 2017)				✗	
9	(Christiansen, Cole, & Field, 2012)	✗				
10	(Christiansen, Cole, Goudie, & Field, 2012)	✗				
11	(Christiansen, Jennings, & Rose, 2016)					✗
12	(Marta Czapla et al., 2015)					✗
13	(Czapla et al., 2016)		✗			
14	(Di Nicola et al., 2015)		✗			
15	(Field & Jones, 2017)					✗
16	(Field, Schoenmakers, & Wiers, 2008)		✗			
17	(Flaudias et al., 2019)		✗			
18	(Garland & Roberts-Lewis, 2013)		✗			
19	(Grusser et al., 2002)		✗			
20	(Ingjaldsson, Thayer, & Laberg, 2003)		✗			
21	(Jones, Tiplady, Houben, Nederkoorn, & Field, 2018)		✗			
22	(Kruse et al., 2012)	✗				
23	(Lindgren, Neighbors, Westgate, & Salemink, 2014)					✗
24	(MacKillop, 2006)					✗
25	(Palfai, Monti, Colby, & Rohsenow, 1997)					✗
26	(Sinha et al., 2009)	✗				
27	(Thomas, Randall, Brady, See, & Drobos, 2011)		✗			
28	(VanderVeen et al., 2016)		✗			

STUDY		EXCLUSION CRITERIA				
		No field of interest	No outcome of interest	Alcohol consumption effects	No adult	Non-alcohol dependence
29	(Yarmush, Manchery, Luehring-Jones, & Erblich, 2016)					✘

Some articles met several exclusion criteria. Only the most relevant was retained.

Table 2. Full text articles excluded (n=29).

All the studies used a single session design except two using two sessions (Joos et al., 2013; Papachristou et al., 2013) and four studies had a prospective design (Cordovil De Sousa Uva et al., 2010; Evren et al., 2012; Kavanagh et al., 2009; Papachristou et al., 2014). Studies were conducted in different countries (Australia: n=1; Australia and UK: n=1; Belgium: n=1; Belgium and Luxembourg: n=1; Belgium and Netherlands: n=1; Germany and UK: n=1; Italy and UK: n=1; Netherlands: n=2; Norway and USA: n=1; Turkey: n=1; USA: n=2) (**Table 1**).

3.2 Assessment tools used

Concerning thought suppression, one study used the Ruminative Responses Scale (RRS) from the Response Styles Questionnaire (RSQ) in order to measure ruminative styles (Caselli et al., 2013), another used the Alcohol Craving Experience questionnaire (ACE; Kavanagh et al., 2009) and two studies used the White Bear Suppression Inventory (WBSI; Garland et al., 2012; Ingjaldsson et al., 2003).

For inhibition, one study used a self-assessment questionnaire, the Impaired Response Inhibition Scale for Alcoholism (IRISA) that was more linked to alcohol craving than inhibition (Garland et al., 2012). Three studies used a stop signal task (Joos et al., 2013; Kreusch et al., 2017; Papachristou et al., 2013), one used a Random Number Generation (RNG) task and a Sustained Attention to Response Task (SART) (Naim-Feil et al., 2014). One study used both a stroop task and a measure of impulsivity with a decision making task (Cordovil De Sousa Uva et al., 2010). Inhibition as an executive function was also assessed by Heart Rate Variability (HRV) response in two studies (Garland et al., 2012; Ingjaldsson, Laberg, et al., 2003).

Regarding impulsivity, four studies used the Barratt Impulsiveness Scale, version 11 (BIS-11) which is a self-assessment questionnaire and one also used a Stop Signal Task (SST), a Delay Discounting Task (DDT) and an Information Sampling Task (IST) which are behavioural measures (Joos et al., 2013). One study used the Impulsive Behaviour Scale (UPPS-P), another self-assessment questionnaire which refers to other dimensions of impulsivity (Kreusch et al., 2017). A final study used a Delay Reward Discounting task called the Monetary Choice Questionnaire (MCQ) and an alcohol demand task in regard to drink prices (MacKillop et al., 2010).

Alcohol craving was widely assessed using the Obsessive Compulsive Drinking Scale (OCDS), Visual Analog Scales (VAS) and the Penn Alcohol Craving Scale (PACS). One study used the Alcohol Urge Questionnaire (AUQ) (Joos et al., 2013), another used an interview (Gauggel et al., 2010) and a last used a daily self-monitoring of alcohol urges and craving (Kavanagh, 2010).

Due to the different types of scales/measures used across studies, they were classified based on the type of process assessed: thought suppression, inhibition and impulsivity.

Four studies used a thought suppression assessment (Caselli et al., 2013; Ingjaldsson, Laberg, et al., 2003; Kavanagh et al., 2009) and one of these evaluated both thought suppression and inhibition (Garland et al., 2012). Two studies measured inhibition processes only (Gauggel et al., 2010; Naim-Feil et al., 2014) and four studies evaluated impulsivity only (Evren et al., 2012; Joos et al., 2013; MacKillop et al., 2010; Papachristou et al., 2014). Three studies explored both inhibition and impulsivity (Cordovil De Sousa Uva et al., 2010; Kreusch et al., 2017; Papachristou et al., 2013).

Of the thirteen studies, six used an alcohol exposure paradigm (Garland et al., 2012; Gauggel et al., 2010; Ingjaldsson, Laberg, et al., 2003; Kreusch et al., 2017; Papachristou et al., 2014, 2013). A description of the associated results is given in this review to provide a more comprehensive overview of the findings reported.

3.3 Thought suppression

A total of four studies investigated relationships between thought suppression and alcohol craving. One study including alcohol abusers and alcohol dependent drinkers (n=232) evaluated different mechanisms involved in craving according to the Elaborated Intrusion Theory of Desire (EITD). Using a correlational and longitudinal design, it also examined the validity of the ACE, a questionnaire based on the EITD. This study showed a moderate positive association between level of alcohol dependence and self-monitored urge frequency on the one hand and craving intensity on the other. It also showed that attempts to stop thinking about alcohol were moderately associated with intrusive thoughts and with longer, stronger and more frequent cravings. Imaginal thoughts of alcohol were also associated with stronger craving, more than non-imaginal thoughts and with episode duration (Kavanagh et al., 2009). Another study with a sample of alcohol-dependent participants (n=49) and a control group (n=45) used Heart Rate Variability (HRV) as an indirect marker of inhibition mechanisms; the lower it was, the poorer inhibition was. Indeed, sympathetic and parasympathetic activities seemed to be associated with executive functions. Most of studies showed that lower HRV could predict poorer performance on tasks involving executive functioning independently from demographic, clinical and behavioral confounding variables (Forte, Favieri, & Casagrande, 2019). The neurovisceral integration model proposes that performances in executive functions, like inhibitory control, can be explained by functional relationship with HRV. Indeed, higher levels of resting HRV is associated with better performances on tasks involving executive functions and prefrontal cortex activity, likewise, reduced HRV is associated with hypoactivity in the

prefrontal cortex (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). Participants were exposed to an imaginary alcohol script in order to manipulate alcohol craving. This study showed a negative and moderate association between HRV and the compulsive dimension of craving after alcohol cue exposure on the one hand, and thought suppression before and after exposure on the other (Ingjaldsson, Laberg, et al., 2003). The third study compared three samples of participants: alcohol dependent drinkers (n=26), problem drinkers (n=26) and social drinkers (n=29). It was a correlational study using a manipulation task of rumination versus distraction to evaluate their effect on alcohol craving. Rumination, involving intrusive thoughts, was associated with an increased level of craving compared to distraction only for alcohol dependent drinkers (Caselli et al., 2013). The fourth study included alcohol dependent patients (n=58) and used an alcohol cue exposure paradigm. It is the only study where state and trait suppression were distinguished. State suppression was evaluated as the ability to suppress alcohol-thoughts during a cue-reactivity paradigm whereas trait suppression was defined as a general chronic thought suppression. However, this study produced many significant results. Alcohol cue exposure was associated with an increase in craving. The impaired regulation of alcohol urges assessed with IRISA was moderately associated with an increase in craving and the state of thought suppression. Moreover, whereas state and trait thought suppression were moderately associated, this study showed a moderate relationship between craving and trait thought suppression only. Finally, in this study HRV responsivity was also measured and data showed that high trait thought suppression was associated with lower HRV compared to state suppression of thoughts. HRV was considered as reflecting executive functions and could explain a rebound effect of chronic suppressed thoughts involved in craving (Garland et al., 2012). The two studies reporting an association between the inhibition process and craving used an alcohol exposure paradigm via photographs or alcoholic beverages (Garland et al., 2012; Ingjaldsson, Laberg, et al., 2003), one used a control group (Ingjaldsson, Laberg, et al., 2003). Of the three studies reporting evidence of an association between thought suppression and craving (Garland et al., 2012; Ingjaldsson, Laberg, et al., 2003; Kavanagh et al., 2009), one included participants who were not currently inpatients in residential treatment for alcohol use disorder but in correspondence-based treatment trials for alcohol abuse or dependence (Kavanagh et al., 2009).

3.4 Inhibition and impulsivity

Three studies investigated inhibition and craving for alcohol. The first study used an alcohol cue exposure paradigm and a stop-signal task with a small sample of alcohol dependent patients (n=20). It showed that alcohol cue exposure induced a significant urge to drink and that reaction times were significantly longer during alcohol cue exposure indicating poorer inhibitory performance (Gauggel et al., 2010). The other study compared two groups of participants, one including alcohol dependent participants in the post-detoxification stage (n=24) and a non-alcohol dependent control group (n=23). Patients had greater difficulty stopping on a no-go trial on the SART and had longer

reaction times (RT) compared to the control group which revealed poorer inhibition abilities. This study showed a positive association between the SART RT, age and craving, assessed by the OCDS, which involved the relationship between increased craving and lower inhibition. RNG task performances were poorer in the alcohol dependent group than in the control group, which showed poorer abilities for patients. The relationship between duration of abstinence and improved performance on cognitive tasks was not significant (Naim-Feil et al., 2014). The third study focused on detoxified alcohol-dependent patients (n=31). This showed a significant increase in craving during alcohol-cue exposure, shorter reaction times (RT) and higher number of errors for alcohol related words in the alcohol-cue exposure group with the SST. The craving score was moderately and negatively associated with RT for alcohol related words and positively and strongly associated with errors recorded for both neutral and alcohol related words in the alcohol-cue exposure group. These results support the association between poorer inhibition and higher craving with alcohol-cue exposure situations (Kreusch et al., 2017). These studies differed in relation to gender, with a majority of males for two and equal representation of gender for the other.

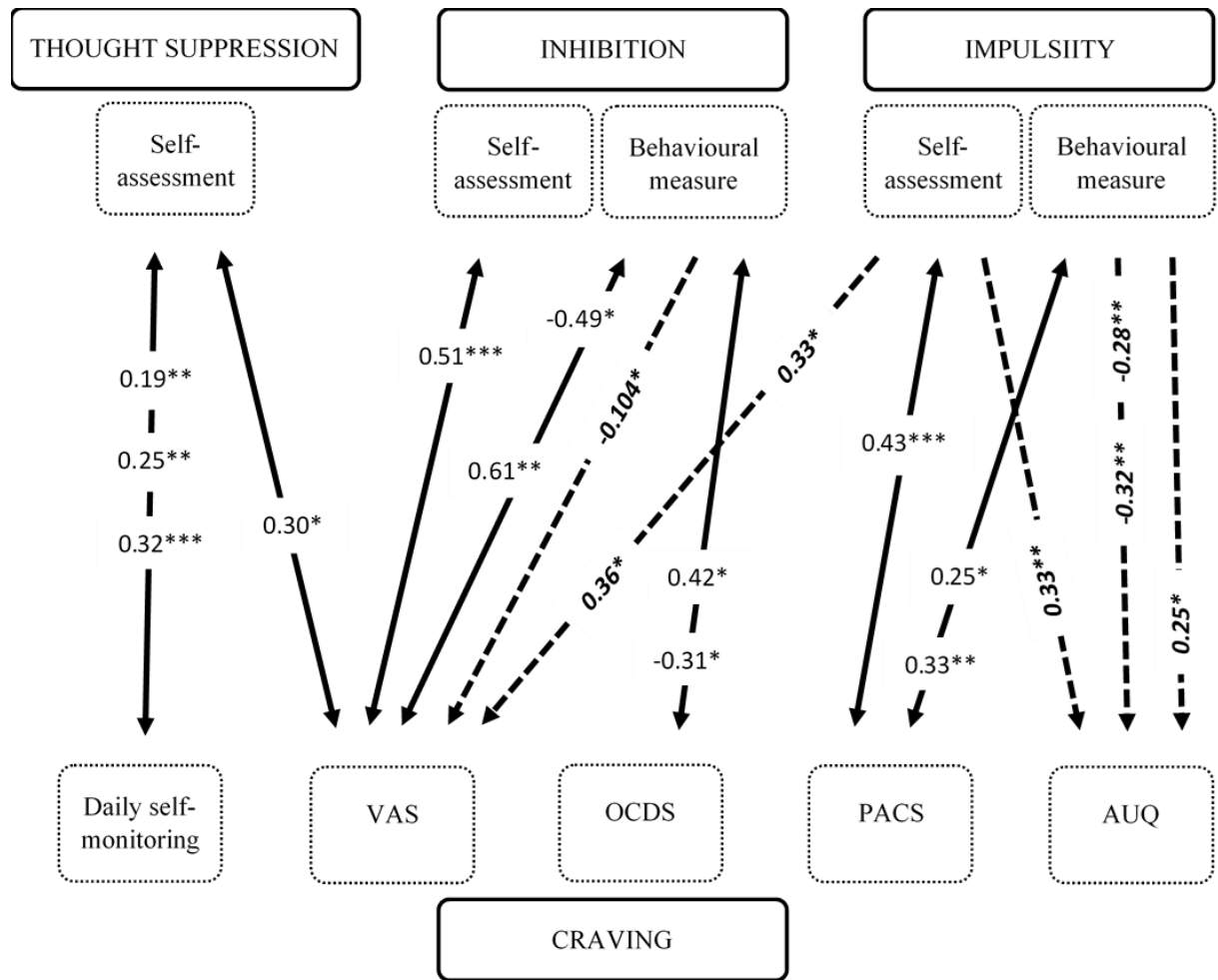
Four studies investigated both impulsivity and craving. The first study including a unique sample of alcohol-dependent inpatients (n=102) showed a moderate and positive association between craving assessed with PACS and impulsivity measured with BIS-11 on the one hand and novelty seeking on the other (Evren et al., 2012). The second study dealing with abstinent alcohol-dependent patients (n=87) highlighted that craving was significantly associated with impulsivity. Indeed, craving scores for the AUQ and the OCDS were positively and moderately associated with scores on the BIS-11. In the same way, AUQ showed a negative moderate relationship with the probability of making correct choices in the decreased win condition of the IST. The higher the number of years of alcohol use was, the higher were the scores for the AUQ and the BIS-11 and the lower was the probability of making correct choices in the decreased win condition of the IST (Joos et al., 2013). However, impulsivity self-assessment was not correlated with behavioural measures except with the DDT that highlighted differences in impulsivity measures and paradigms. The third study which focused on the weekly alcohol consumption of participants who were not seeking treatment (n=61) showed significant relationships between craving and impulsivity. Craving was weakly and positively associated with the intensity of alcohol demand, moderately and positively associated with a large temporal discounting function and strongly and positively associated with the severity of alcohol use disorder (MacKillop et al., 2010). The fourth study included a small sample of patients with an abstinence goal (n=20) and used an alcohol exposure paradigm in a real alcohol-related setting. It showed that trait impulsivity assessed with the BIS-11 and cue-elicited craving were not associated, in disagreement with initially reported results. Impulsivity was surprisingly associated with a lower probability of relapse whereas craving was associated with a higher probability of relapse. Their interaction was not significant. Results could be interpreted with caution given the small sample size

(Papachristou et al., 2014). All studies used self-assessments of impulsivity and one used a stop signal task, a delay discounting and an information sampling task (Joos et al., 2013) whereas another used an alcohol exposure paradigm (Papachristou et al., 2014). There were a majority of males, and only one study evaluated gender effects (Papachristou et al., 2014).

Two studies investigated inhibition, impulsivity and craving together. The first study focused on a sample of alcohol dependent patients (n=41) with an alcohol exposure paradigm. Exposure, time and age had a significant effect on an increase in peak craving. The older were the participants, the lower the peak craving was. Participants with higher trait impulsivity, assessed with the BIS-11, were more likely to experience higher cue-elicited craving than those who had lower impulsivity. This previous research showed results in line with but less predictive than the aforementioned study with lower response inhibition levels and cue-elicited craving. Overall, this study showed associations between craving and impulsivity on the one hand and inhibition on the other (Papachristou et al., 2013). The second study used a control group (n=22) to make a comparison with alcohol-dependent patients (n=35). It showed that patients reacted more slowly in the Stroop Task and had lower scores in the Decision Making Task than the control group. Performances were better at a second time of evaluation, however, craving scores and impulsivity remained higher for the alcohol-dependent group as inhibition remained lower (Cordovil De Sousa Uva et al., 2010).

4 Discussion

The aim of this systematic review was to investigate the association between craving, impulsivity, inhibition and thought suppression. In general, the findings support the association between alcohol craving and higher thought suppression, greater impulsivity and poorer inhibition (**Fig.3**). Only one study did not show an association between impulsivity and alcohol craving. Two studies dealt both with impulsivity and inhibition without identifying causal links between these processes. Participants were middle aged and were undergoing treatment for alcohol dependence or were just at the end of medical care. Regarding these results, studies were quite homogeneous in the participant samples. Only one study focused on regular drinkers who were not seeking treatment for alcohol problems (MacKillop et al., 2010).



*: $p \leq 0.05$, **: $p \leq 0.01$, ***: $p \leq 0.001$.

Negative correlations are due to the type of assessment.

Fig. 3. Regressions and correlations between thought suppression, inhibition, impulsivity, and craving.

Evidence supporting the positive association of thought suppression and craving experience was found. A rebound effect was observed for studies investigating the association between thought suppression and alcohol craving, however, any control for moderator effects of thought suppression was performed. It could be related to alcohol exposure paradigm or to ruminations which involved cognitive performances. The internal state, like stress in relation to the experiment setting, could also explain the ironic process. Studies investigating inhibition and alcohol craving showed that inhibition performances seemed to be clearly associated with craving experience. Other studies found evidence to support a positive association between impulsivity and craving (Evren et al., 2012; Joos et al., 2013;

MacKillop et al., 2010). A high impulsivity level is associated with a high level of craving and they expose to a high risk of relapse (Papachristou et al., 2014). When exposed to alcohol-related stimuli, people with high impulsivity trait present a poorer inhibition ability and increased craving (Papachristou et al., 2013). Moreover, compared to control group, alcohol-dependent patients show higher craving scores, higher impulsivity and lower inhibition assessed with behavioural tasks (Cordovil De Sousa Uva et al., 2010). This supports difficulties in cognitive and behavioural self-regulation among people with AUD (Baumeister & Vonasch, 2015).

The six studies using an alcohol cue paradigm to observe craving variations tended to support correlational results of the seven other studies. Duration of heavy drinking was related to impulsivity, inhibition, and craving. These results suggest that inhibition and impulsivity deficits could be associated with alcohol dependence severity, beyond age. Another explanation is that these processes are altered for alcohol stimuli only.

Even though some studies used the WBSI, rebound effect was not investigated whether for the paradigm of study or for the variables included. An interesting study not included in this systematic review due to the selection criteria, jointly studied roles of mindfulness and its opposite, suppression, in post-traumatic stress and substance craving. It showed that craving and thought suppression, measured by WBSI, were positively and moderately associated whereas each of them were negatively associated with dispositional mindfulness and four of its sub-dimensions. It also showed that dispositional mindfulness but not thought suppression significantly predicts craving (Garland & Roberts-Lewis, 2013). These results were not in line with another study showing a relationship between trait suppression and craving. Some points remain unclear such as distinctions between state and trait suppression and their links with ironic process on the one hand and craving on the other. The inhibition process was preliminarily associated with impulsivity considering the ability to inhibit a prepotent response. However, the Elaborated Intrusion Theory seems to bring out two facets of the inhibition process which are resistant to proactive interference and the inhibition of prepotent responses. Indeed, craving can be induced by external cues or internal stimuli inducing intrusive thoughts that could involve the inhibition of prepotent responses. Then imagery is activated and could involve difficulties in resistance to proactive interference.

The literature review showed that many studies focused on alcohol problems in general and not alcohol dependence exclusively which can explain the small number of studies included. Moreover, a lot of studies excluded focused on alcohol consumption effects on inhibition and impulsivity processes whereas the objective of this systematic review was to identify these processes independently as factors associated with alcohol craving. All studies including attentional biases were also excluded. An integrative model of attentional biases was previously proposed. It exposed, among others, the implication of executive functions like impulsivity and inhibitory control in attentional biases and subjective craving (Field & Cox, 2008). The scope of this review was to especially

investigate the role of impulsivity, inhibition and thought suppression in alcohol craving, upstream attentional processes which whom they are in relation.

This review helps to better identify processes implicated in craving by systematically reviewing and describing the results of different studies. It also puts the spotlight on the complexity of craving in the field of addiction, and at the same time gives us multiple pathways of understanding. This systematic review found evidence of an association between impulsivity, inhibition, thought suppression and craving. As these variables were assessed using different scales, it is difficult to paint a precise picture of the craving mechanism. The exact relationships remain unclear however, and surprisingly, thought suppression and craving relations are more explored than was previously presumed. Like craving, thought suppression is also assessed with various scales highlighting the complexity in clearly defining this experiential phenomenon. A literature search should focus on the black box more than on behaviour in order to develop knowledge on the cognitive processes of craving.

There are limitations that should be considered when interpreting these results. First, the studies included used several measures for the same process in favour of generality and not specificity. However, the homogeneity of the results suggests an overall involvement of these mechanisms in association with craving. Although some studies within this review used the same measures, paradigms were not necessarily the same. Secondly, most studies were cross-sectional with a single session revealing a disposition of participants at a point in time rather than an evolution. However, participants were mostly patients who had undergone an alcohol treatment program which could be a limitation in terms of the ecological value of the research and a possible bias related to the uncontrolled effects of therapy. Thirdly, the control group was used in three studies only to assess the specificities of alcohol-dependence mechanisms. Fourthly, the methods employed for cue-exposure were heterogeneous, such as a: real glass of alcohol or water, photographs, and the context of consumption which makes comparisons between studies difficult. Fifthly, studies included a majority of men and gender effects were controlled only in one study which showed no significant differences in trait impulsiveness and cue-elicited craving (Papachristou et al., 2014). A study showed a negative association between age and craving (Papachristou et al., 2013). However, age was not controlled in several studies involving statistical analyses. Moreover, craving was measured with many different assessments and had also been assessed regarding relapse (Papachristou et al., 2014). This reflects a major limitation in systematic reviewing as there are many assessment tools for craving which make comparisons difficult. Indeed, some scale included other concepts while measuring craving. The OCDS encompassed items reflecting perceived control and functional impact or distress about drinking. One item at the PACS measured self-efficacy belief. The AUQ included items giving information about intentions and perceived control of drinking (Kavanagh et al., 2013). These different scales assessed extraneous phenomena which may be correlated with craving, but didn't

directly measured it. This was also the case for VAS which gave us a current measure of craving like its intensity for a part, and for another part took into account other concepts. Lastly, samples were composed of alcohol-dependent patients which assumes that alcoholic withdrawal had been completed but abstinence was not systematically specified. Only English language studies were included in this review, as there is no clear evidence of a bias using language restriction in systematic reviews in conventional medicine (Morrison et al., 2012). However, further studies could pay attention to this possible bias in the field of neuropsychology and psychopathology. Publication date was not a selection criteria and the oldest study dates from 2003. Moreover, the included studies were from different countries which reveals craving as a recent and consensual concept in the field of addiction around the world.

Despite heterogeneity across studies, differences in study design and paradigms, there is evidence of thought suppression as a self-regulation attempt to regulate craving. This can explain inhibition both as a strategy and as a difficulty, as it was described for impulsivity, dysfunctional, or functional. Otherwise, there is some difference between proactive and reactive inhibition, and these association with impulsivity. Tasks used in the different studies of this review assessed proactive inhibition. This component of inhibition is positively associated with impulsivity trait and seems to influence reactive inhibition (Li et al., 2015). Further studies are needed to clarify the respective implication of impulsivity and inhibition and their interaction in the mechanism of craving and, potentially, identify directional pathways. It could be interesting to outline their specificities in link with thought suppression. Moreover, it will be interesting to conduct longitudinally designed studies and to include control groups in order to clarify size effects of different variables as well as the role of age and the duration of alcohol dependence. If sample sizes are increased and gender effects controlled, data could show more significant results. Last but not least, it will be interesting to specify cognitive inhibition processes and to develop a paradigm or measure to clearly assess it.

On one hand, this systematic review highlights the importance to use multilevel assessments of craving, impulsivity and inhibition to improve studies on these complex relationships and their comparison. On another hand, it had clinical implications. The cognitive processes involved in craving for abstinent alcohol dependent patients seemed to result from a conflict between thoughts, behaviours and both of them. This could be a strong target in self-regulation enhancement strategies, using cognitive behavioural therapy. As craving is a major relapse risk factor, it is of strong interest to pay attention to upstream processes that feed craving beyond alcohol-exposure paradigm.

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