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Reduced calibration between subjective and objective measures of episodic future thinking in alcohol use disorder.

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ABSTRACT

Background: A reduced capacity to mentally simulate future scenarios could be of clinical importance in alcohol use disorder (AUD). However, little is known about the mechanisms underlying episodic future thinking (EFT) impairment in AUD.

Methods: We tested patients with severe AUD using two measures of EFT: the individual's own subjective experience of their imaginings (phenomenology) and the objective number of details included in imagined events, as assessed by an independent observer (examination). The comparison between the two measures allowed us to investigate the extent to which the subjective and objective characteristics of EFT are calibrated in healthy and AUD participants matched for age, education, and gender. The possible impact of cognitive functioning and disturbed mood on EFT measures was also investigated.

Results: In terms of objective details of EFT, patients with AUD (n = 40) generated fewer episodic components and more non-episodic components than control participants (n = 40), even when controlling for cognitive functioning. However, self-ratings of phenomenological characteristics

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indicated that participants with AUD perceived imagined future events at a similar level of detail as control participants. Additionally, there was a significant correlation between objective and subjective measures in healthy individuals but not in the AUD group. A higher depression score in the AUD group was not associated with the EFT measures.

Conclusions: These results suggest a distorted self-assessment of the richness of imagined future events in individuals with AUD. We discuss these apparent limitations in metacognitive abilities and verbal descriptions of imagined events among individuals with AUD and their clinical implications.

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Introduction

With an estimated 283 million people aged 15 years and over facing serious alcohol use problems, alcohol use disorder (AUD) constitutes a substantial public health problem worldwide (World

Health Organization, 2018). Neurocognitive research has focused on markers of addictive behaviors, including higher-order cognitive functions (e.g., response inhibition, mental flexibility, and delay dis-counting; Bickel & Athamneh, 2020; Noël et al., 2013; Zilverstand et al., 2018), which has led to the development of interventions aimed at boosting deliberate control to improve clinical outcomes (Anderson et al., 2021). In this context, due to its key role in guiding action (Suddendorf & Moore, 2011), mental time travel has received growing attention in relation to psychopathology (Brunette & Schacter, 2021; Hallford et al., 2018). Episodic future thinking (EFT) represents a particular case of mental time travel (Tulving, 1985) that consists in the ability to imagine specific future scenarios (Suddendorf, 2010). Research has emphasized that people with short-sighted maladaptive behaviors tend to imagine future events that lack vividness and specificity (Boland et al., 2018; Boyer, 2008; Bulley et al., 2016; Jing et al., 2016). Indeed, drug misusers (alcohol, D'Argembeau et al., 2006; Haj et al., 2019; opioid, Moustafa et al., 2018) and excessive gamblers (Noël, et al., 2017) have been found to demonstrate impaired EFT.

Different measurement instruments have been used to investigate the capacity to generate mental models of future scenarios (Miloyan & McFarlane, 2019). When the subjective characteristics of EFT are self-assessed by participants (i.e., phenomenological assessment), recently detoxified patients with severe AUD have been found to rate imagined future events as subjectively less detailed (in terms of sensory, contextual, and self-referential details) than control participants (D'Argembeau et al., 2006, but see Moustafa et al., 2018). In another study (Haj et al., 2019), assessments by an examiner who scored verbal descriptions of imagined events (referred to as "examinations"; Miloyan & McFarlane, 2019) revealed difficulties in constructing specific future scenarios in patients with AUD, a phenomenon that was associated with depressive symptomatology (Haj et al., 2019). Other studies have shown that the acute effects of alcohol compromise future-oriented processing in healthy controls (HC; e.g., impaired prospective memory; Leitz et al., 2009), which might exacerbate chronic impairments and dramatically increase harmful behaviors (e.g., driving while intoxicated despite potential negative consequences). However, the psychological mechanisms that are involved in different facets of EFT remain debated (Miloyan et al., 2019). A comprehensive understanding of these mechanisms would be of great value given the emerging interest in providing autobiographical memory and EFT training to healthy and clinical populations (Hallford et al., 2020; Nandrino et al., 2017; Noel, et al., 2017; Snider et al., 2016; Voss et al., 2021).

Although phenomenological ratings and examinations are widely used measures of EFT, they each have their limitations (Miloyan & McFarlane, 2019). Phenomenological measures are inherently subjective and are strongly related to metacognitive assessments; thus, it remains unclear whether or not response scale items have similar meanings to different individuals, which limits the generalizability of comparisons across populations (Miloyan & McFarlane, 2019). For their part,

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examinations are highly variable in administration and scoring characteristics, and verbal productions do not necessarily reflect the subjective experience of imagined events (Miloyan & McFarlane, 2019). Interestingly, there is evidence that the subjective experience and objective content of EFT can be dissociated and rely on distinct neurocognitive processes (Thakral et al., 2020). In general, the subjective quality of representations is aligned with the objective amount of details, but there are specific instances in which a reduction of objective details is not accompanied by a similar reduction in the subjective quality of mental representations. For example, older adults objectively report fewer details than young adults when remembering or imagining autobiographical episodes but report equivalent levels of subjective details (Addis et al., 2010; see also Folville et al., 2020).

The calibration between phenomenological ratings and objective details of EFT could be weaker in people who overestimate or underestimate the richness and vividness of their mental representations, due, for instance, to metacognitive difficulties or impaired capacity for mental imagery. Interestingly, while no direct comparison between objective and subjective measures of EFT has been made in AUD, impaired metacognitive capacities and mental imagery have been both observed in this clinical population. For example, sober participants with AUD have been found to have inaccurate personal knowledge about their own ability to remember and recall information (i.e., poor feeling-of-knowing and overestimated memory skills; Le Berre et al., 2010, 2016; Le Berre & Sullivan, 2016). Additionally, poor metamemory skills can also result from alcohol intoxication (Evans et al., 2017). Regarding mental imagery capacity, it has been repeatedly shown that participants with AUD have higher levels of alexithymia (Cruise & Becerra, 2018). Although alexithymia is a multidimensional personality construct (Sifneos, 1973; Taylor et al., 1997), it encompasses restricted imaginative processes featured by a limited fantasy life, which may negatively impact the manner in which patients with alexithymic tendencies put their imagined events and feelings into words (Campos et al., 2000).

In the present study, we sought to fill this important gap in research on mental time travel in AUD by investigating the calibration between objective and phenomenological measures of EFT. We hypothesized that compromised EFT in AUD would notably manifest in the form of a reduced calibration between objective and subjective characteristics of mental representations of future events. Furthermore, we aimed to determine whether alterations of EFT in AUD are related to general cognitive functioning (e.g., executive control) and mood (e.g., depressive symptoms).

MATERIALS AND METHODS

PARTICIPANTS

Patients were recruited while undergoing alcohol rehabilitation at Brugmann University Hospital in Brussels, Belgium. The inclusion criteria for the clinical sample included French speakers between 18 and 65 years of age with severe AUD requiring alcohol rehabilitation. The detoxification regimen

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consisted of B-complex vitamins and decreased doses of sedative medication (diazepam). The experiment took place after a minimum of 21 days of sobriety and 5 days after the cessation of diazepam. No financial compensation was provided to the patients. The exclusion criteria based on th**e** International Neuropsychiatric Interview (Sheehan et al., 1998)

included neurological history (epilepsy, head injury, and stroke), mental confusion or severe cognitive impairment, schizophrenia, chronic psychotic disorders, and bipolar type 1 disorder. The 40 HC participants were matched for gender, age, and education. They were recruited by word of mouth and were compensated 20 euros for their participation. The exclusion criteria comprised persons meeting an Axis I psychiatric diagnosis of AUD who had experienced a drug use disorder in the year before enrollment in the study or who had consumed more than 54 g/day of alcohol for longer than 1 month and obtained a score >12 at the Alcohol Use Disorders Identification Test (AUDIT). This study was approved by the local ethics committee of Brugmann University Hospital.

MATERIALS

CLINICAL AND COGNITIVE EVALUATION

Following the provision of informed consent, participants underwent complete medical, neurological, and psychiatric examinations (*SCID-5*; First et al., 2015) at the time of selection. The *AUDIT* (Saunders et al., 1993) was used to assess the severity of alcohol problems (range: 0 to 40). The *Craving Experience Questionnaire* (May et al., 2014) assessed the intensity and frequency of craving in the previous week (range: 11 to 77). The *Impulsivity Behavior Scale (UPPS-P*; Billieux et al., 2012) assessed five facets of impul- sivity (positive urgency, negative urgency, lack of premeditation, lack of perseverance, and sensation seeking; 20 items; range: 20 to 80). The severity of depressive symptoms was measured using the *Beck Depression Inventory II* (*BDI- II*; 21 items; range: 0 to 63; Beck et al., 1961), and positive and negative affect were assessed using the *Positive Affect and Negative Affect Schedule (PANAS)*, which comprises two 10-item scales (range: 10 to 50; Watson et al., 1988).

Alexithymia was assessed using the *20-i tem Toronto Alexithymia Scale (TAS-20*; Bagby, Parker, et al., 1994; Bagby, Taylor, et al., 1994). This questionnaire comprises 20 items, each scored from 1 to 5. The three factors of this instrument are (a) difficulty in identifying feelings, (b) difficulty in describing feelings, and (c) externally oriented thinking. The sum of these sub-scores was then calculated.

To assess whether cognitive deficits typically found in AUD alter the characteristics of future thought, all participants completed the *Brief Evaluation of Alcohol- Related Neuropsychological Impairments* screening tool *(BEARNI*; Ritz et al., 2015), which assesses verbal episodic memory, working memory, executive function, and visuospa- tial abilities. A composite index of cognitive functioning was then calculated. We also used a French version of tasks assessing phonemic and semantic fluency (Cardebat et al., 1990). In one task (phonemic fluency), participants had 2 min to produce as many words as possible beginning with the letter "P." The semantic fluence task was to generate as many names as possible belonging to the category "animal."

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EFT TASK

Participants first received a future event fluency task (MacLeod & Byrne, 1996) in which they were given 60 s to generate as many events as possible for two emotional valences (positive and negative events) and three future time periods (1 week, 1, and 5 to 10 years). Following this task, the participants were instructed to select the first specific event that they generated for each category (i.e., a total of six events: a positive and a negative event in 1 week, in 1 year, in 5 to 10 years). They were asked to select precise and specific events (i.e., events that happen in a specific place at a specific time and last not more than 1 day). For each event that they selected, participants were instructed to imagine this event in as much detail as possible (i.e., "imagine the setting and course of the event, people and objects that would be present, your feelings, and so forth") to mentally "pre-experience" the situation and they described orally the imagined contents.

PHENOMENOLOGICAL CHARACTERISTICS

Immediately after having imagined each event, participants were instructed to rate several dimensions of their subjective experience using seven-point rating scales adapted from the *Memory Characteristics Questionnaire* (Johnson et al., 1988; see D'Argembeau & Van der Linden, 2006; Table 1). Evidence suggests that sensory- contextual characteristics and autonoetic experience (the subjective sense of "pre-experiencing" imagined events) are fundamental aspects of episodic future thoughts (D'Argembeau & Van der Linden, 2012). These two dimensions were investigated by computing two indices from participants' ratings: an index of sensory and contextual details, and an index of autonoetic experience. The sensory and contextual details were computed by averaging responses to the following items: (1) "My representation of this event involves visual details": 1 = none, 7 = a lot; (2) "My representation of this event involves other sensory details (sound, odors, taste)": 1 = none, 7 = a lot; (3) "My representation of the location where the event takes place is": 1 = not at all clear, 7 = extremely clear; and (4) "My representation of the people and objects involved is": 1 = not at all clear, 7 = extremely clear. Autonoetic consciousness was computed by averaging the responses to the following items: (1) "While imagining the event, I feel as though I am experiencing it": 1 = not at all, 7 = completely; and (2) "While imagining the event, I feel that I am traveling forward to the time when it would happen": 1 = not at all, 7 = completely.

SCORING OF EVENT DESCRIPTIONS

All responses provided during the future thinking task were audiorecorded and transcribed for scoring. Based on verbal descriptions of each transcribed event, the numbers of internal and external details were assessed using the standardized scoring procedure developedby Levine, Svoboda, Hay, Winocur, and Moscovitch (2002). The central event was defined to segment the transcription into internal details (i.e., details concerning the main event, including happenings, people, time, place, sensory perceptions, thoughts, and emotions) and external details (i.e., details that do not concern the main event, semantic information, repetitions, and metacognitive statements), and the numbers of internal and external details were tallied (for more detail, see Levine et al., 2002; Table 1). All transcriptions were scored by two raters properly trained for this

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procedure who independently scored a random selection (20%) of the descriptions to assess the reliability of the scoring. A two-way random effects model indicated high inter-rater agreement for both internal and external details (intraclass correlation coefficient (ICC) = 0.87 and 0.89, respectively). Cases of disagreement were subjected to joint evaluation.

Table 1. *Demographic and clinical data of the participants*

	ALC (*n* = 40)	**HC (*n* = 40)**	***P***	
Age (years)	40.90 (9.97)	38.48 (12.59)	0.34	HC = ALC
Education (years)	14.4 (2.3)	13.15 (1.52)	0.18	HC = ALC
Gender (F/M)	24/16	18/22	0.18	HC = ALC
AUDIT	30.25 (4.38)	4.72 (3.12)	<0.001	HC < ALC
Number of past detoxifications	3.79 (4.32)	-	<0.001	HC < ALC
PAS	35.30 (6.73)	36.23 (4.56)	<0.001	HC = ALC
NAS	28.90 (8.58)	20.43 (4.52)	0.47	HC < ALC
BDI	10.78 (7.46)	3.00 (3.43)	<0.001	HC < ALC
TAS-20	59.28 (11.38)	48.43 (11.80)	<0.001	HC < ALC
DIF	20.63 (5.52)	14.19 (4.90)	<0.001	HC < ALC
DDF	15.63 (3.70)	14.95 (3.38)	0.55	HC = ALC
EOT	27.05 (4.66)	26.76 (3.40)	0.82	HC = ALC
UPPS-P	47.45 (11.61)	45.98 (5.81)	0.48	HC = ALC
Premeditation	7.89 (3.30)	8.00 (2.28)	0.91	HC = ALC
Negative urgency	10.74 (3.51)	9.95 (2.78)	0.43	HC = ALC
Positive urgency	10.79 (3.01)	10.52 (2.77)	0.77	HC = ALC
Sensation seeking	9.63 (3.00)	9.19 (2.60)	0.62	HC = ALC
Perseverance	7.74 (3.03)	6.67 (2.06)	0.20	HC = ALC
BAERNI cognitive	9.45 (2.89)	12.78 (2.97)	0.006	HC > ALC
Semantic fluency	26.70 (5.45)	32.35 (7.71)	<0.001	HC > ALC
Phonetic fluency	2123 (5.83)	24.58 (7.03)	0.02	HC = ALC

Note: Values shown are the mean and standard deviation (between brackets) for each measure. AUDIT, Alcohol Use Disorders Identification Test; BAERNI, brief evaluation of alcohol related neuropsychological impairment; BDI, Beck Depression Inventory; NAS, Negative Affect Schedule; PAS, Positive Affect Schedule; TAS-20, Toronto Alexithymia Scale.

PROCEDURE

All participants were tested individually in two sessions of approximately 1.5 h each separated by a short break (around 15 min). The pencil-and-paper assessment consisted of tasks and questionnaires administered in the following order: semantic and phonetic fluency tasks, EFT tasks (fluency of future events, imagination of specific events, phenomenological characteristics), and finally, self-assessment questionnaires (AUDIT, PANAS, BDI, and cognitive assessment).

ANALYSIS

The sample size ($n = 80$) was determined to detect an effect size of .15 (D'Argembeau et al., 2006) for mixed ANOVAs with one between- subject factor and two or three repeated measures factors, with a power of .80. All statistical tests were two-tailed. An alpha level of 0.05 was used, and effect sizes

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were estimated using partial eta- squared (n2p)- SPSS (Statistical Package for the Social Sciences) version 27.0 and JASP (version 0.15) were used. Comparisons between groups on demographic variables (e.g., sex and age) and current clinical status (depression, anxiety, and positive mood) were performed. To assess differences between groups on future-oriented mental time travel (phenomenology and examinations), ANOVAs with event valence (positive, negative) and time (1 week, 1, and 5 to 10 years) as within-subject factors and group (AUD participants, HCs) as a between-subject factor were run. In case of significant between-group differences, we made an additional analysis with the score of cognitive functioning (BEARNI) included as a covariate in order to estimate its impact on EFT performance. Post hoc analyses were pairwise comparisons and *t*-tests with Holm's correction for

multiple comparisons when appropriate. Additional Bayesian analyses were carried out to quantify relative evidence of both alternative and null hypotheses. Pearson's product-moment correlations with Bonferroni correction were performed to examine the relations between the variables of interest (i.e., internal detail score, depression, alexithymia, and Negative Affect Schedule).

RESULTS

CLINICAL DATA

The two groups were similar in terms of age, gender, level of education, impulsivity, and intensity of positive affect (see Table 1), but differed with respect to cognitive functioning, alcohol problem severity, negative affect intensity, and depressive symptoms (Table 1).

PHENOMENOLOGICAL CHARACTERISTICS

We ran an ANOVA with event valence (positive, negative) and time (1 week, 1, and 5 to 10 years) as within-subject factors and group (AUD and HC) as a between-subject factor to investigate differences in ratings of sensory and contextual details, as well as autonoetic consciousness (see Tables 2 and 3 for *M*s, SDs, and main results). We found no main effect of group, nor any significant interaction involving the group. The Bayes factors (BF10) were <0.21, which was supportive of the null hypothesis. For both phenomenological dimensions, positive events received higher ratings than negative events, and sensory-contextual details were also affected by the temporal distance of imagined events (see Tables 2 and 3).

OBJECTIVE NUMBER OF EVENT DETAILS

We ran an ANOVA with type of details (internal and external), event valence (positive, negative), and time (1 week, 1, and 5 to 10 years) as within-subject factors and group (AUD and HC) as a between-subject factor (see Table 4 for *M*s, SDs, and main results). There was a significant interaction between group and types of details, showing that patients with AUD reported fewer internal details but more

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external details than control participants. Additionally, we conducted one-way ANCOVAs to determine whether differences between AUD and HC on internal and external details remained significant when controlling for cognitive functioning (cognitive score of the BEARNI). There was a significant effect of group on both internal and external details after controlling for BEARNI, F (1, 37) = 8.14, p = 0.007 and F (1, 37) = 11.91, p = 0.001, respectively.

ASSOCIATION BETWEEN OBJECTIVE DETAILS, PHENOMENOLOGICAL CHARACTERISTICS, AND CLINICAL VARIABLES

There was a significant correlation between the number of internal details and ratings for sensory and contextual details in HC (r(40) = 0.48, p = 0.002) but not in patients with AUD (r(39) = 0.12, p = 0.47; see Figure 1A,B). The comparison between these correlation coefficients using a Fisher r-to-z transformation revealed that the correlation was significantly higher in HC than in patients with AUD (z = 1.678, p = 0.04).

The alexithymia score was correlated with the number of internal details in the two groups (in HC, r(40) = -0.58, p < 0.001; in AUD, r(40) = -0.36, p = 0.02). Other correlations between EFT measures depression, and Negative Affect Schedule were not significant after Bonferroni corrections (all ps > 0.21).

Table 2. *Mean (SD) and results of sensory details and contextual information ratings for positive and negative events across temporal distance and group (HC:* n = *40; AUD:* n = *40)*

	Sensory details and contextual information								
	HC	**ALC**	**Time (2,156)**	**Time x group (2,156)**	**Valence (1,78)**	**Valence x group (1,78)**	**Time x valence (1,78)**	**Time x valence x group (2,156)**	**Group (1,78)**
Positive events									
1 week	4.88 (1.32)	4.75 (1.36)	F = 18.85 p < 0.001 η_p^2 = 0.20	F = 1.24 p = 0.30 η_p^2 = 0.02	F = 117.02 p < 0.001 η_p^2 = 0.60	F = 0.83 p = 0.37 η_p^2 = 0.01	F = 5.18 p = 0.007 η_p^2 = 0.06	F = 2.24 p = 0.11 η_p^2 = 0.03	F = 0.86 p = 0.36 η_p^2 = 0.01
1 year	4.37 (1.32)	4.46 (1.49)	1-week>1-year (p = 0.01)		Positive> Negative (p < 0.001)				
5/10 years	4.10 (1.41)	4.37 (1.42)	>5/10-year (p < 0.001)						
Negative events									
1 week	3.67 (1.52)	3.77 (1.43)							
1 year	3.02 (1.38)	3.77 (1.37)							
5/10 years	2.57 (1.18)	2.57 (1.26)							

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Table 3. *Mean (SD) and results of autonoetic consciousness ratings for positive and negative events across temporal distance and group (HC:* n = *40; AUD:* n = *40)*

	Autonoetic consciousness							
	HC	AUD	Time (2,156)	Time x group (2,156)	Valence (1,78)	Valence x group (1,78)	Time x valence (1,78)	Group (1,78)
Positive events								
1 week	4.66(1.34)	4.58(1.31)	$F = 0.89$	$F = 0.10$, p = 0.90	$F = 68.83$	$F = 1.65$	$F = 1.55$, p = 0.22	$F = 1.61$
1 year	4.35 (1.54)	4.40(1.80)	$p = 0.41$	$\eta_p^2 = 0.001$	$p < 0.001$	$p = 0.20$	$\eta_p^2 = 0.02$	$p = 0.21$
5/10 years	4.01 (1.48)	4.34(1.79)	$\eta_p^2 = 0.01$		$\eta_p^2 = 0.47$ Positive > negative ($p < 0.001$)	$\eta_p^2 = 0.02$		$\eta_p^2 = 0.02$
Negative events								
1 week	2.95 (1.71)	3.45 (1.80)						
1 year	2.86(1.60)	3.38(1.75)						
5/10 year	3.06(1.55)	3.44(1.55)						

Table 4. *Mean scores (SD) and results for internal and external details of positive and negative events across temporal distance and group (AUD:* n = *40, HC:* n = *40)*

	Internal details		External details								
	HC	AUD	HC	AUD	Type of details	Type of details x group	Valence	Valence x group	Time	Timex group	Type of details x time
Positive events											
1 week	13.65 (8.92)	10.08 (9.41)	0.40 (1.75)	1.18 (1.18)	F (1,78) = 131.24 $p < 0.001$, $\eta_p^2 = 0.63$	F (1, 78) = 7.72 $p = 0.007$ $\eta_p^2 = 0.09$	F (1,78) = 25.96 $p < 0.001$ $\eta_p^2 = 0.25$	F (1,78) <0.01 $p = 0.98$ $\eta_p^2 < 0.001$	F(2, 156) = 16.93 $p < 0.001$ $\eta_p^2 = 0.18$	F (2,156) = 0.02 $p = 0.98$ $\eta_p^2 < 0.001$	F (2,156) = 16.56 $p < 0.001$ $\eta_p^2 = 0.18$
1 year	10.13 (8.27)	7.18 (6.35)	0.23 (0.48)	1.65 (3.27)	Internal details>external details	Internal details in HC>AUD	details score for positive emotion > negative emotion		1-week>1-year>5 to 10 years		Internal details in 1-week>1-year>5 to 10 years
5/10 years	8.55(7.32)	6.15(5.51)	0.18 (0.67)	1.25(1.90)		External details in HC<AUD					
Negative events											
1 week	8.78 (8.10)	7.35 (7.62)	0.13 (0.40)	0.83 (0.90)							
1 year	8.58 (6.36)	5.48(4.67)	0.25 (1.15)	0.95(1.97)							
5/10 years	7.93 (7.13)	4.73 (3.86)	0.28 (1.06)	0.88 (1.42)							

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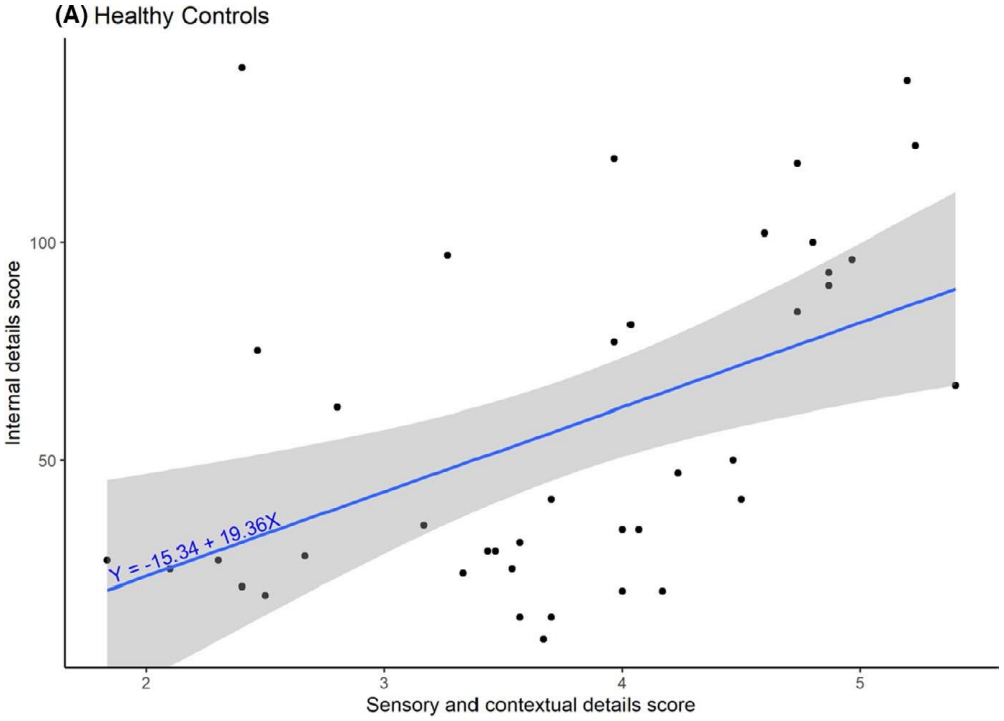
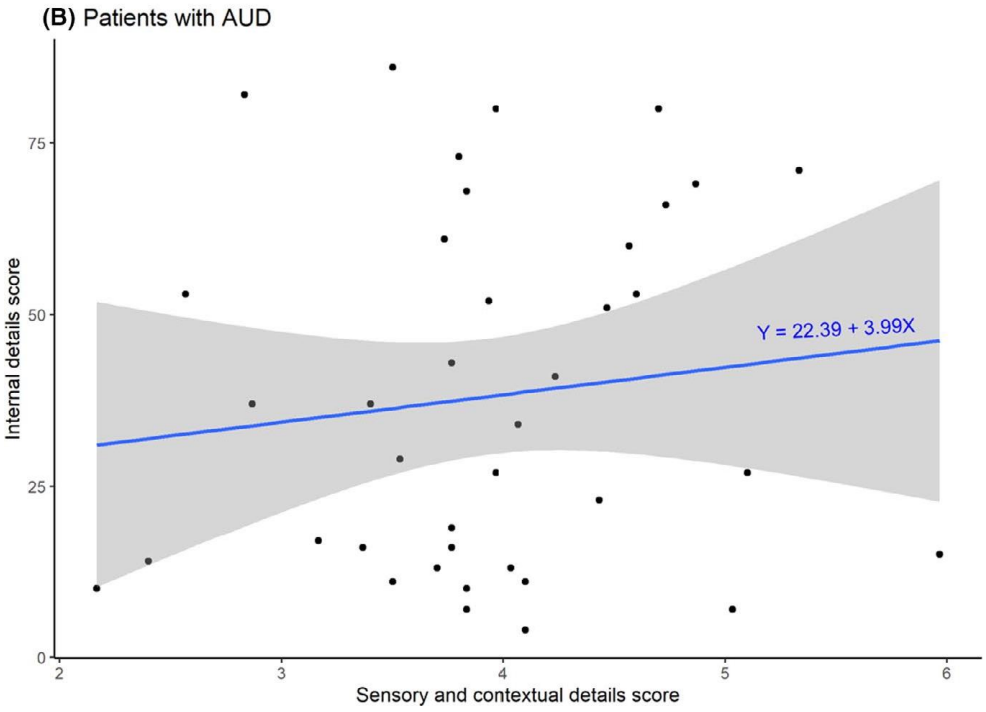
***Figure 1**. Relationship between internal details score and sensory and contextual details score in healthy controls (A) and in patients with AUD (B). Regressions lines and 95% confidence intervals (grey zone) are presented*





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DISCUSSION

The aim of this study was to investigate the calibration between the subjective experience of EFT and the objective quantity of reported details in a clinical sample of patients with severe AUD. To this end, we compared two measures of EFT, namely phenomenological ratings and the examination of details by independent coders, in HC and patients with AUD. Our primary results indicated that patients with AUD reported similar level of subjective vividness and richness of future event representations as participants without AUD, while the external assessment showed that patients with AUD objectively reported fewer internal details and more external details than HC, even when general cognitive functioning was controlled for. In addition, there was a strong correlation between subjective and objective measures of EFT in HC but not in patients with AUD. The observed difference between subjective ratings and objective evaluation suggests two possible mechanisms underlying alterations of EFT in AUD. First, patients with AUD might overestimate the phenomenological richness of EFT, which might indicate an abnormal metacognitive evaluation. Second, the reduced calibration might reflect the difficulty of patients in verbalizing imagined contents. These possibilities are now considered in detail.

The objective assessment of imagined events by observers revealed that participants with AUD provided fewer internal details (and more external details) for imagined future events than HC, regardless of the time period (1 week, 1, and 5 to 10 years) and valence (positive and negative) of the events. This result complements a recent study demonstrating that AUD is associated with a reduced specificity of future thinking (Haj et al., 2019). In this latter study, patients reported fewer specific events (defined as events situated in time and space and enriched with details such as feelings, perceptions, thoughts, or visual imagery), both for past and future events. The fact that we found similar results using a different scoring procedure suggests that the objective reduction of imagined details in AUD is a robust phenomenon.

The phenomenological ratings obtained in the present study replicate results from previous clinical studies, including that participants reported more sensory and contextual details for positive and near future events than negative and distant future events (e.g., Noel, et al., 2017). However, contrary to some previous study (D'Argembeau et al., 2006), we did not find that future events were subjectively rated as less vivid and detailed in patients with AUD compared to control participants. A difference between the two studies is that, in D'Argembeau et al.'s study, participants were asked to imagine future events without further instruction regarding temporal distance. Imagining future scenarios at multiple time points (1 week, 1, 5 to 10 years), as was the case in the present study, might place greater demands on metacognition about the rating value that most closely matches the aspect of the imagination

in question (Miloyan & McFarlane, 2019). This explanation is particularly relevant considering the discrepancy between the objective and subjective measurements that we observed in participants with AUD. Indeed, this reduced calibration raises the possibility that participants with a severe form of AUD overestimate the richness of their mental representations of future events. This overestimation might be similar to the lack of calibration between objective performance and

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subjective experience in various tasks (e.g., memory and decision making) that has been observed in subjects with drug and behavioral addiction (Noël, et al., 2017), including problem gambling (Brevers et al., 2014), cocaine (Moeller et al., 2010, 2016), alcohol (Le Berre & Sullivan, 2016), and methadone (Sadeghi et al., 2017). The present finding of a significant correlation between the score of internal details and richness of sensory details and contextual information in healthy participants, but not in participants with AUD, supports the notion of inaccurate metacognitive calibration in this population. Additionally, neural correlates of metacognition assessment point to regions of the prefrontal cortex (particularly, the fronto-polar cortex, ventro-medial prefrontal cortices, and posterior medial frontal cortex; Fleming et al., 2010; Seow et al., 2021), the insula and anterior cingulate (Moeller et al., 2016; Moeller & Goldstein, 2014), and the hippocampus (Allen et al., 2017), as many regions in which abnormal functioning has been found in subjects with AUD (Sullivan & Pfefferbaum, 2019).

An alternative explanation for the lack of calibration between subjective and objective measures of EFT is that participants with AUD have limited capacities to verbalize their own imaginings. Indeed, as suggested by previous studies, there is a strong association between visual imagery ability and alexithymia, as assessed by the TAS-20 (Campos et al., 2000), and participants with alexithymic tendencies find it difficult to identify feelings in the self and to describe them to others (Sifneos, 1973; Taylor et al., 1997). Therefore, the objective reduction in event details provided by AUD patients, despite a subjective experience comparable to that of HC, could be associated with alexithymic tendencies, as evidenced by (1) the higher alexithymic tendencies of AUD patients found in the present study and in many other studies (for a review see; Cruise & Becerra, 2018), and (2) the significant correlation between theTAS-20 global score and the internal details score found in both HC and AUD patients.

The AUD group showed poor performance on tasks assessing verbal episodic memory, working memory, executive function, and visuospatial abilities, as assessed by the BEARNI (Ritz et al., 2015). This level of performance is in line with previous reports demonstrating that impaired episodic memory and executive functioning are cardinal features of AUD (Koob & Volkow, 2016; Le Berre et al., 2017; Lindgren et al., 2019; Noel et al., 2001). However, these measures of cognitive functioning did not correlate with the examination scores (i.e., internal and external details) and alterations in the objective content of EFT in AUD remained significant when controlling for the BEARNI score, which is also consistent with a recent study investigating objective measures of EFT in AUD (Haj et al., 2019). Taken together, our results combined with those of previous studies converge on the idea that impaired episodic foresight and overall cognitive functioning are distinguishable aspects of AUD. This is interesting to note because it is unlikely that recovering executive control deficits over a prolonged period of sobriety (see for example (Le Berre et al., 2017) is an effective means of improving EFT in this population).

It should also be noted that depression, which is prevalent in the AUD population (Foulds et al., 2015), was not associated with our measures of EFT. This result contrasts with a recent study showing an association between the intensity of depression in patients with AUD and their tendency to generate general rather than specific past and future events (Haj et al., 2019). Although differences

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between the two studies in terms of characteristics of participants (e.g., lower number of abstinence days in the present study, normal cognitive and executive functioning in Haj et al.'s study only) and the methods used to assess EFT (e.g., one future personal event in the study by Haj et al. versus six in the present study; specificity of future thinking versus the number of internal details) may explain this discrepancy, the association between depression in AUD and EFT remains to be investigated in detail. In any case, it is unlikely that targeting only depressive symptoms could lead to the normalization of EFT in patients with AUD.

The present results may have clinical relevance for alcohol rehabilitation. There are many psychological mechanisms involved in the lack of motivation to stop drinking or to stay sober (Noël et al., 2013; Zilverstand et al., 2018), and EFT is a good candidate (Noel, et al., 2017). Indeed, EFT has been implicated in a range of adaptive functions, such as planning, goal-directed behavior, and emotional regulation (Schacter et al., 2017). This is potentially relevant to targeting and enhancing EFT in addictive behaviors where an overreliance on habits (Robbins, 2019; Sebold et al., 2017; Voon et al., 2015; Wyckmans et al., 2019) and steeper delay discounting (Bickel & Athamneh, 2020) have been found. The recognition of dysfunctional EFT and its possible mechanisms are of importance in the context of therapeutic interventions. Indeed, a direct approach targeting EFT has been successfully enhanced through training sessions (e.g., future specificity training) for healthy participants (Hallford et al., 2020) and psychiatric disorders (Bickel & Athamneh, 2020). Reductions in alcohol demand indices and delay discounting rates have also been recently reported following EFT training (Athamneh et al., 2021; Noel, et al., 2017; Patel & Amlung, 2020). Regarding interventions aimed at improving metacognition, dedicated (Seow et al., 2021) or global treatment plans such as metacognitive therapy (Wells, 2011) could be useful in improving EFT in AUD. Indeed, providing participants with feedback on their metacognitive judgments led to greater metacognitive calibration, which generalized to untrained stimuli (Carpenter et al., 2019). Whether this improvement in global metacognition could transfer to better-calibrated EFT remains to be investigated, as well as metacognitive training directly applied to EFT paradigms. Additionally, although alexithymic tendencies can be improved by several types of therapies that promote verbal expression of the internal imaginary world (Cameron et al., 2014; Haj et al., 2019; Moustafa et al., 2018; Norman et al., 2019), whether this improvement benefits EFT in clinical populations remains an open question. It would also be interesting to determine whether our findings can be generalized to other substance use disorders (e.g., cannabis, opioids), thereby increasing the scope of potentially useful clinical interventions.

The present study has several limitations. The first limitation refers to the unknown real-life consequences of compromised EFT in patients with AUD. The ability to imagine future possibilities is believed to have a strong adaptive significance (Suddendorf et al., 2018). For example, mental simulations of the future can play a key role in motivating future-oriented behaviors (Damasio & Carvalho, 2013) and reducing delay discounting (O'Donnell et al., 2017). Although increasing motivation and decreasing delay discounting are important for reducing relapse risk in AUD (Noel, et al., 2017; Snider et al., 2016), the exact role of compromised EFT and metacognition remains unknown, as does the deficit prior to or following a prolonged period of alcohol consumption. Second, although the lack of calibration between objective and subjective measures of EFT may be

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due to reduced metacognitive capacities, this explanation remains hypothetical as meta-cognition was not directly assessed in the present study (Fleming et al., 2010). Additionally, HCs, but not patients, were compensated financially for their participation, which could have increased their motivation to perform the task. Although this possibility cannot be completely ruled out, it is not clear how this possible difference in motivation would explain the contrasting results for subjective and objective measures of EFT that were observed in patients versus HC.

It should also be noted that, unlike other studies about EFT in AUD (e.g., Athamneh et al., 2021; Voss et al., 2021), we asked participants to describe imagined future events orally rather than in written format. The extent to which the mode of production of autobiographical narratives influences their characteristics remains unclear, with mixed evidence regarding similarities and differences between oral and written narratives (Lyubomirsky et al., 2006; Vanaken et al., 2021). Nevertheless, it would be interesting in future studies to investigate whether the present results can be replicated when future events are described in written narratives. Finally, previous studies have used a variety of measurement instruments to study the qualitative characteristics of EFT, most of which have not been appropriately validated for use (Miloyan & McFarlane, 2019). In future studies, it would be worthwhile to devote research efforts to validate a single instrument to assess the subjective characteristics of EFT in clinical populations, which would facilitate comparison across studies.

In conclusion, the present study shows that the subjective and objective characteristics of EFT are less calibrated in AUD than in healthy participants. This difference between the subjective and objective dimensions of EFT could be explained by poor metacognitive ability and a compromised ability to verbalize self-generated episodic future events.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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