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SHORT REPORT

Spontaneous Changes in Attentional Capabilities and Reasoning After an Alcohol Rehabilitation Treatment: Evidence About the Role of Age and Alcohol Use

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Purpose: In this study, we evaluated changes in attentional capabilities and reasoning among early abstinent alcohol-dependent individuals after a 28-day residential rehabilitation program (not including cognitive treatment). Furthermore, we explored the role of individual characteristics and disease-related factors (i.e., length of alcohol use, history of polysubstance dependence, severity of alcohol use) on spontaneous cognitive recovery.

Patients and Methods: Fifty-five patients with a diagnosis of Alcohol Use Disorder (AUD) were consecutively recruited from a residential rehabilitation hospital in Northern Italy. The majority were male (67.3%) with a mean age of 47.83 years (SD = 8.21). The computerized Psychology Experiment Building Language Test Battery was used to assess the performance at the Posner Cueing Test, Go/no-go Task, Trail Making Test (TMT), Tower of London (TOL), and Balloon Analog Risk Scale. The evaluation was performed twice: at the beginning (T0) and at its end (T1, before the hospital discharge).

Results: We observed statistically improvements over time in the performance at the: 1) TOL in the time amount required to solve the task ($p < 0.001$); and 2) TMT in the indexes relative to the number of errors ($p = 0.003$) and the total time required to solve the task ($p < 0.001$). Age played a significant role on the changes observed in the score relative to the time amount used by participants to solve the task in TMT (test ($p = 0.03$) and in TOL ($p = 0.02$). Moreover, the length of alcohol dependence had an effect on the change observed for the time amount to solve the TMT (time) ($p = 0.01$).

Conclusion: We found spontaneous recovery after alcohol detoxification on some, but not all, cognitive functions assessed in our study. The neuropsychological assessment and the identification of patients with cognitive impairment and specific risk factors (e.g., older age and longer history of alcohol use) is important to orient cognitive rehabilitation and increase the efficacy of AUD treatments.

Keywords: neuropsychological functioning, Alcohol Use Disorder, alcohol detoxification, rehabilitation, risk factors, AUD

Introduction

Alcohol Use Disorder (AUD) is a substance use disorder characterized by excessive and uncontrollable drinking that affects a person physically, emotionally, and socially.[1] Crucially, AUD negatively impacts not only mental and physical health,[2–4] but also multiple domains of cognitive functioning: from memory and learning capabilities, to multiple components of executive domain (i.e., working memory, problem solving and decision making, cognitive flexibility), and attentional resources (i.e., ideative speed processing and cognitive inhibition).[5–7] Indeed, some cerebral areas such as frontal lobes, limbic system, and cerebellum are particularly vulnerable to damage and dysfunction associated to alcohol abuse.[8–11]

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In this clinical condition, cognitive impairments can be moderate to severe, but their prevalence is not completely clear: mostly cognitive deficits are undiagnosed, since they are not systematically investigated in the clinical settings through appropriate neuropsychological assessment[12] resulting in a possible underestimation of their prevalence. Furthermore, there are divergent findings regarding the extent to which cognitive dysfunctions may recover upon cessation of alcohol intake.[13]

Some studies reported short-term improvement of cognitive performance, especially in executive functions,[12,14] after alcohol detoxification, in absence of specific neuropsychological treatment.[15–18] Instead, other studies reported persisting cognitive difficulties, especially in visuospatial ability[19] and complex executive functions,[17] after 3–4 weeks of abstinence. For examples, Pitel et al (2017) observed alterations in the working memory may reduce after 18 days of detoxification; however, difficulties in cognitive inhibition persisted.[20] A recent study (2020)[5] found that 31.7% of early-detoxified patients with AUD undergoing alcohol detoxification showed cognitive impairments, especially in executive functions, visuospatial abilities, and memory. Furthermore, a meta-analysis[7] showed that a global impairment was still present several months after alcohol detoxification and, in some cases, certain residual cognitive impairment may persist, suggesting fatal long-term negative outcomes of AUD on cerebral functioning.

Nevertheless, the role of interindividual differences, and specifically in terms of disease-related components (i.e., length of alcohol use, severity of alcohol use, length of abstinence and polysubstance comorbidity) on the neurocognitive effects of alcohol and the spontaneous cognitive recovery process were underlined, but results are mixed.[15,16,21]

Why the assessment of the cognitive functioning and its restoration represent an important issue in the field? Cognitive impartments may impair rehabilitation, quality of life, in terms of return-to-work, driving capacity, accidents, activities of daily living, and increased risk of relapse.[22]

An individual neuropsychological assessment could allow clinicians to better understand the abilities and deficits their patients may have during and after a detoxification period and to implement adapted neurocognitive treatments aimed at reducing the risk of relapse.[20]

The aim of this study was to evaluate changes in attentional capabilities and reasoning among early abstinent alcohol-dependent individuals, after 28-day residential treatment. Crucially, we did not deliver any cognitive treatment: thus, in this paper we verified the spontaneous recovery from cognitive difficulties. Furthermore, we explored the role of individual characteristics, such as age (since what reported by Rourke & Grant 2009; Pitel et al 2009),[23,24] and relevant disease-related factors (length of alcohol dependence, previous polysubstance dependence, severity of alcohol use, according to Le Berre et al 2019; Lookatch et al 2017; Woods et al 2016)[15,25,26] on spontaneous cognitive recovery.

Materials and Methods

Participants

This research was conducted in accordance with the Declaration of Helsinki and the study was approved by the Regional Ethics Committee of IRCCS AOU San Martino-IST (P.R.430REG2015). Subjects participated voluntarily; they gave informed written consent, were free to withdraw at will, and were naive to the rationale of the experiment. Moreover, they received no compensation for participating in the experiment; in fact, the Italian National Sanitary System in Italy covers all hospital charges. Because of that, a clinical trial of a rehabilitation group versus "sham rehabilitation" control group was not considered feasible and ethical. Thus, the study was conducted with a quasi-experimental pre–post design without a separate control group.

This study evaluated 65 inpatients consecutively recruited from a 28-day residential rehabilitation institute for alcohol addiction in Northern Italy across a time period of 24 months. Of the initially 65 screened patients, 10 (14%) were excluded because of exclusion criteria (n = 3), refusal to participate in the study (n = 5), or dropping out of treatment (n = 2).

Inclusion criteria to participate in the study were: 1) diagnosis of AUD according to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5);[1] 2) Italian mother tongue; 3) right-handed; and 4) no actual substance use. Exclusion criteria were: 1) previous traumatic brain injury or stroke; 2) presence of dementia, evaluated

with Mini Mental Examination <23.8;[27] 3) diagnosis of Korsakoff syndrome; and 4) severe psychiatric conditions (e.g., psychosis or suicidal ideations in the last month).

Procedure and Instruments

At hospital admission, all patients underwent a clinical assessment performed by a physician to collect relevant socio-demographic (e.g., age, educational level) and disease-related information (e.g., duration of addiction, previous poly-substance dependence). Alcohol Use Disorders Identification Test (AUDIT);[28] was used to assess the severity of alcohol use in terms of alcohol consumption, drinking behaviors, and alcohol-related problems; it consists of 10 items and the total score range from 0 (absence of problem drinking behavior) to 40 (relevant problem/alcohol dependence).

Neuropsychological assessment was performed by a neuropsychologist after 7 days of detoxification using the computerized Psychology Experiment Building Language (PEBL) Test Battery.[29,30] Since its first release in 2006, this computerized battery has been used to study the cognitive functioning in healthy individuals[31–36] as well as in clinical samples, such as individuals with neurodegenerative disorders[37] and with psychiatric diagnosis.[38,39] However, to the best of our knowledge, no previous study has investigated the applicability of PEBL Test Battery in populations with AUD. We decided to adopt a computerized assessment instead of the traditional paper-and-pencil versions, since the computerized software has the advantage to increase the correctness of the data processing, limiting human errors, as well as to reduce the time spent on this process; moreover, individual's performance is automatically scored in terms of timing and velocity,[36] which is very useful in a rehabilitation context requiring multiple cognitive assessments.

In Table 1, we reported an overview of the adopted neuropsychological PEBL tests and computed scores, as well as their interpretation. Technical details about the tests, including how the scores for each index are computed, can be found online (http://pebl.sourceforge.net) and in Mueller and Piper (2014).[30]

Specifically, we adopted the Posner Cueing task (1980) to study the visuospatial attentional shift. In the task, participants have to detect a visual target, which can be proceed by a cue, which may be valid (a left or a right cue is provided, indicating

Table 1 Overview of the PEBL Tests Adopted

	Test	Index	Clinical Interpretation
Attentional capabilities			
Visuospatial attentional shift	Posner Cueing task	Time difference in seconds between invalid trails and valid trials (i.e., effect's Δ)	↑ score = higher difficulty in attentional shift
Sustained attention and inhibition	Go/no-go Task	Number of false alarms	↑ score = higher difficulty in inhibiting automatic behaviour
Processing speed and sequencing in visuo-motor tracking	Trail Making Test	Total time in seconds to solve the test	↑ score = higher ideomotor slowness
		Number of errors	↑ score = higher difficulty in maintaining the alternated sequencing
Reasoning			
Planning and problem-solving	Tower of London	Number of more moves needed to solve the task	↑ score = higher difficulty in planning reasoning
		Mean time in seconds required to solve a problem	↑ score = higher ideative slowness
Risk-taking behaviour	Balloon Analog Risk task	Number of earning	↓ score = lower reward sensitivity
		Number of burst	↑ score = higher risk-taking propensity

Notes: For each test and version, the score computed automatically by the PEBL software and their clinical interpretation are indicated.

where the target is likely to be) or invalid. Traditionally, participants were faster in detecting the target in the case of valid cues, but slower for the valid cue, since the cue enhances the visual processing at the cued/attended location.

We used also the go/no go task, designed according to Bezdjian et al (2009):[40] this task assesses inattention and impulsivity. Specifically, it requires participants to respond to the presence of a target stimulus (e.g., a single digit or letter) amidst a stream of similar stimuli (e.g., other digits or letters). Participants have to make a motor response (button press) to one stimulus category (Go stimuli) and refrain from responding to the other (NoGo stimuli).

We included also the Trail Making Test (TMT; designed according to the Halstead–Reitan Neuropsychological Test Battery). It is a very well-known neuropsychological test used widely to assess visuo-motor attention (Trails A) and cognitive flexibility (Trails B) measuring the time amount used by the participants to connect dots that were either numbered (part A) or alternated between numbers and letters (part B).

The Tower of London (TOL) is another well-known neuropsychological test used to assess spatial planning designed originally by Shallice (1982). Specifically, in this version, designed according to Shallice (1982) participants are required to move colored balls on pegs individually from an initial state to match a goal state. Thus, optimal performance involves forming, retaining, and implementing a plan to make as few moves as possible.

Finally, the Balloon Analog Risk task is a laboratory-based behavioral measure of risk taking (i.e., the Impulsive decision making) which involves the evaluation of potential outcomes (risks or rewards) with the tendency to forego a large delayed reward in favour of a smaller immediate reward.[41] Designed according to Lejuez et al[42] in the task, participants are asked to pump up a series of balloons. On each trial, the larger the balloon is before the participant stops pumping, the greater the reward magnitude. However, each pump increases the likelihood that a balloon will pop, and popping results in no reward on that trial.

The order of the neuropsychological tests was randomized between participants and between conditions within the same subject, to decrease learning effects.

The neuropsychological assessment was performed twice: at the beginning of the rehabilitation after 7 days of detoxification (T0), and 3 days before hospital discharge (T1).

Treatment

The standard residential rehabilitation program in this study lasted 28 consecutive days.

The therapeutic approach is inspired by both American experience of the Minnesota Model, Croatian psychiatry studies, and finally by German and Austrian "psychosomatic clinics".[3,43,44]

It consisted of a high intensity of medical and psychological treatments (cognitive behavioural treatment group, physical training, health education sessions, and skills training).[3,5] Notably, no specific neuropsychological treatment was administered.

Statistical Analyses

Data have been analysed through IBM SPSS Statistics-Statistical Package for Social Sciences, version 22.0 for Windows. Descriptive statistics were used to describe the characteristics of the sample. Firstly, paired *t*-test was used to explore statistical difference in cognitive performance for each neuropsychological test between admission (i.e., T0) and discharge (i.e., T1). Effect size estimates (Cohen's d) were also calculated in order to explore the magnitude of the statistical difference. Considering the presence of multiple comparisons, we applied the Bonferroni correction; thus, p value was considered significant if less than (0.05/8) = 0.006.

Secondly, for each score independently, to verify the possible role of, we performed, an analysis of covariance to assess the within-group differences over time (T0 vs. T1), while statistically controlling for the effect of the age, length of alcohol dependence, AUDIT, and polysubstance dependence on cognitive performance. Alpha level was set at 0.05.

Results

Sociodemographic and clinical aspects of the sample are shown in Table 2. The majority of the sample were male (67.3%) with a mean age of 47.83 years (SD = 8.21). Most of the participants reported a history of more than 10 years of alcohol dependence (44.4%) and no previous polysubstance abuse (58.2%).

Table 2 Key Socio-Demographic and Disease-Related Characteristics of the Sample (N = 55)

Variable		M (SD) or % (n)
Age	(In years)	M = 47.83 (SD = 8.21)
Sex	Male	67.3% (n = 37)
	Female	32.7% (n =18)
Education	(In years)	M = 11.40 (SD = 3.25)
Marital status	Married	18.2% (n = 10)
	Not Married	49.1% (n = 27)
	Divorced	32.7% (n = 18)
Length of alcohol dependence	≤ 10 years	M = 44.4 (SD = 24)
	> 10 years	M = 55.6 (SD = 30)
Previous polysubstance dependence	No	58.2% (n = 32)
	Yes	23% (n = 41.8)

Abbreviations: M, mean; SD, standard deviation; n, number.

Cognitive Changes from Admission (T0) to Discharge (T1)

For each index of the neuropsychological test, we reported means and standard deviations together with the complete statistical results relative to the comparison between the scores at T0 (i.e., the admission) and the T1 (i.e., discharge) in Table 3.

Statistically improvement over time was found in two neuropsychological tests. Specifically, at the TOL test, participants reported a lower mean time required to solve a problem ($p < 0.001$) with a very large effect size and a significant lower numbers of more moves needed to solve the task ($p = 0.02$) with a nearly small effect size; notably, this value is not significant when we considered the Bonferroni correction for multiple comparison. Moreover, we observed a significant lower amount of total time required to solve the Trial Making Test ($p < 0.001$) with a very large effect size and a lower number of errors ($p = 0.003$) with a medium effect size. No other significant difference emerged.

Effect of Covariates on Cognitive Domains

No significant effect of previous *polysubstance dependence* and *alcohol severity* on cognitive performances were observed, as reported in Table 4.

Table 3 Spontaneous *Cognitive Changes After a 28-Day Residential AUD Treatment*

Cognitive Domain and Test	Admission T0	Discharge T1	t (df)	95% CI Lower, Upper	*p*	Effect Size (Cohen's d)
	M (SD)	M (SD)				
Spatial visual attention (Posner Cueing task)						
Effect's Δ	15.01 (10.90)	13.66 (10.25)	−0.03 (48)	−15.61,15.16	0.98	<0.001
Sustained attention and inhibition (Go/no-go Task)						
Number of false alarms[Φ]	15.01 (10.90)	13.66 (10.25)	1.10 (50)	−1.11, 3.82	0.27	0.14
Processing speed and sequencing in visuo-motor tracking (Trail Making Test)						
Total time (in s) to solve the test	52.16 (22.32)	39.34 (14.92)	4.15 (47)	6.60, 19.03	**< 0.001 ***	0.71
Number of errors	5.63 (4.27)	3.63 (3.24)	3.15 (45)	0.72, 3.27	**0.003 ***	0.48
Planning and problem-solving (Tower of London)						
Number of more moves needed to solve the task	115.86 (56.90)	92.23 (47.22)	2.49 (42)	4.51, 42.73	**0.02**	0.38
Mean time (in s) required to solve a problem	36.88 (13.99)	24.39 (8.53)	6.60 (43)	8.68, 16.31	**< 0.001 ***	0.99
Risk taking behaviour (Balloon Analog Risk task)						
Number of earning	21.22 (9.72)	22.84 (11.81)	−1.24 (53)	−4.22, 0.99	0.22	0.16
Number of burst	31.77 (10.02)	31.59 (12.26)	0.12 (53)	−2.94, 3.31	0.90	0.01

Notes: In bold significant difference for p < 0.005: * when the result was significant when the Bonferroni correction for multiple comparisons was applied; [Φ]range from 0 to 60.
Abbreviations: M, mean; SD, standard deviation; df, degree of freedom; CI, confidence interval.

Table 4 Effects of Covariates on Neuropsychological Tests

	T0	T1	Main Effect of Time	Main Effect of Covariate
	M (SD)	M (SD)		
Age (value = 47.14)				
TMT-Total time (in s) to solve the test	52.17 (3.20)	39.35 (2.02)	F(1,46) = 1.26; p = 0.26; η^2= 0.02	F(1,46) = 4.65; **p = 0.03**; η^2= 0.05
TMT-Number of errors	5.63 (0.62)	3.63 (0.48)	F(1,44) = 0.24; p = 0.62, η^2= 0.01	F(1,44) = 2.60; p = 0.11; η^2= 0.05
TOL-Number of more moves needed to solve the task	115.86 (8.74)	92.23 (7.26)	F(1,41) = 1.96; p = 0.17; η^2= 0.05	F (1,41) = 0.88; p = 0.88; $\eta^{2<}$= 0.00
TOL-Mean time (in s) required to solve a problem	36.88 (2.04)	24.39 (1.24)	F (1,42) = 0.12; p = 0.73; η^2< 0.00	F(1,42) = 5.47; **p = 0.02**; η^2= 0.11
Years of alcohol dependence (value = 15.1)				
TMT-Total time (in s) to solve the test	52.17 (3.11)	39.35 (2.07)	F (1,46)= 3.66; p = 0.06; η^2= 0.07	F (1,46) = 6.75; **p = 0.01**; η^2= 0.13
TMT-Number of errors	5.63 (0.62)	3.63 (0.48)	F(1, 44) = 0.56; p = 0.46; η^2= 0.01	F(1,44) = 1.67; p = 0.20; η^2= 0.04
TOL-Number of more moves needed to solve the task	115.86 (8.71)	92.23 (7.28)	F(1,41) = 0.86; p = 0.36; η^2= 0.02	F(1,41) = 0.48; p = 0.49; η^2= 0.01
TOL-Mean time (in s) required to solve a problem	36.88 (2.13)	24.39 (1.29)	F(1,42) = 14.29; **p < 0.001**; η^2= 0.25	F(1,42) = 0.29; p = 0.59; η^2= 0.01
Previous Polysubstance dependence 1 = no, 2 = yes (value = 1.44)				
TMT-Total time (in s) to solve the test	52.16 (3.26)	39.34 (2.16)	F(1,46) = 0.80; p = 0.37; η^2= 0.01	F(1,46) = 0.24; p = 0.62; η^2<0.00
TMT-Number of errors	5.63 (0.62)	3.63 (0.48)	F(1,44) = 4.61; **p = 0.04**; η^2= 0.09	F(1,44) =1.33; p = 0.25; η^2= 0.03
TOL-Number of more moves needed to solve the task	115.86 (8.77)	92.23 (7.28)	F(1,41) = 1.29; p = 0.26; η^2= 0.03	F(1,41) = 0.03; p = 0.85; η^2<0.00
TOL-Mean time (in s) required to solve a problem	36.88 (2.10)	24.39 (1.30)	F(1,42) = 8.78; **p = 0.005**; η^2= 0.17	F(1,42) = 0.90; p = 0.35; η^2= 0.02

Note: In bold significant results (p < 0.05).
Abbreviations: TMT, Trail Making Test; TOL, Tower of London.

Discussion

In this study, we described positive changes in some, but not all, assessed cognitive functions, even in absence of a tailored neuropsychological treatment, after a residential rehabilitation for AUD.

Specifically, changes in cognitive performance after the treatment was observed in the neuropsychological test measuring planning and problem-solving (TOL): specifically, participants seems to be faster in their reasoning. We found similar results about the TMT, which measured processing speed and sequencing: after the rehabilitation, we observed a significant lower amount of total time required to solve the test and a lower number of errors in comparison with T0: thus, an increased performance at this test, in terms of ideo-motor velocity and sequencing, emerged. So, overall, we may observe that participants were faster in their cognitive processing after the treatment. Crucially, no other differences emerged.

The Go/No go test and Posner test measure respectively motor inhibition and attentional shift, while Balloon Analog Risk task is a behavioral measure of risk taking, impulsivity, and deficiencies in behavioral constraint. So, overall, we may suggest that higher level cognitive functions (i.e., inhibition/impulsivity) present more persistent impairment over time among patients with AUD, and they would not recover spontaneously. This is in line with previous studies suggesting that dysfunctions among certain cognitive functions (e.g., complex executive abilities) may last form many months or even years following the cessation of alcohol consumption.[17,24]

According to our results, two individuals' characteristics interact with the changes observed in the cognitive functioning after the treatment. The first one was the age: spontaneous changes in processing speed and ideative/ideomotor velocity are explained by age, in line with previous studies.[26] This result is not surprising considering that it is well-known that older age decreases the spontaneous brain recovery, specifically in terms of plasticity.[45] Another crucial factor was the length of alcohol dependence, which is disease-specific: the shorter the length of alcohol abuse, the better the gains in ideative velocity/reasoning.[15] Then, in the rehabilitative contexts, it should be considered that age as well as

the length of alcohol dependence may have a significant negative effect on the cognitive outcome, suggesting the importance of early intervention in AUD.

Findings from this study also have important clinical implications for therapeutic strategies. Treatments typically were provided to patients during the first month of abstinence.[3] However, normalization of certain cognitive functions may require more time, then even over the end of the rehabilitation treatments; nevertheless, in some cases, tailored cognitive rehabilitation may be necessary, specifically when the cognitive difficulties may significantly impact on individual daily-functioning or compliance to the rehabilitative treatment. Indeed, to effectively learn and apply the strategies provided by therapeutic interventions for relapse prevention, cognitive functions (i.e., attention, memory as well as executive functions) need to be functional. Cognitive domains as decision making, controlling impulsive tendencies, and risk behaviours are also necessary for maintaining abstinence.

Finally, some limitations in this study may be underlined. First, we adopted computerized neuropsychological tests; even though the methodological advantages in using them (as previously stated), on the other as in our knowledge the adopted tests do not have normative data, limiting their applicability in clinical setting. On the other hand, the role of familiarity with technologies, which may impact on the individual performance, was not directly measured; however, we underlined that the neuropsychologist was always presented during the assessment, in order to assist the participants in case of technological issue. Also, the results may be limited by the relatively small study population and their clinical heterogeneity, as well as the absence of a control group, and should be regarded with caution.

Conclusions

In this study we found that patients with AUD who underwent a 28-day rehabilitation program (not including cognitive treatment) have a spontaneous recovery in reasoning and processing speed.

On the contrary, higher level cognitive functions (i.e., inhibition/impulsivity) present more persistent impairment over time and did not recover spontaneously. Furthermore, our findings suggest that age, as well as the length of alcohol dependence, may have a significant negative effect on the cognitive outcome.

Future studies should explore the effectiveness of tailored cognitive treatments on the functions that did not show spontaneous recovery, including inhibition and attentional shift and impulsivity.

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Disclosure

The authors report no conflicts of interest in this work.

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