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ARTIGO ORIGINAL

Assessment of executive functions and inhibitory control in alcohol and crack use disorders

Fernanda Rasch Czermainski
Felipe Ornell
Universidade Federal do Rio Grande do Sul, RS, Brasil
Luciano Santos Pinto Guimarães
Hospital de Clínicas de Porto Alegre, RS, Brasil
Félix Kessler
Lísia von Diemen
Rosa Maria Martins de Almeida
Universidade Federal do Rio Grande do Sul, RS, Brasil

Abstract

This study assessed executive functions and inhibitory control in alcohol and crack users, as previous research suggests an association between substance-related disorders and impaired self-regulation and impulse control. In this study, 67 men aged 18-65 years completed the following instruments: sociodemographic questionnaire, Vocabulary and Matrix Reasoning (Wechsler Abbreviated Scale of Intelligence), Five Digit Test, and Behavioral Assessment of the Dysexecutive Syndrome. Alcohol and crack users showed deficits involving processing speed, response inhibition, flexibility, abstraction, planning, and monitoring. Analysis per type of drug revealed poorer cognitive performance among alcohol users. Years of drug use were associated with planning deficits. These findings are consistent with the hypothesis of an association between drug abuse and cognitive changes. In conclusion, impairments in executive functioning and inhibitory control were found in the study samples.

Keywords: assessment; cognition; drugs; inhibition; executive functions.

Avaliação das funções executivas e controle inibitório nos transtornos por uso de álcool e crack

Resumo

Este estudo investigou as funções executivas e o controle inibitório em usuários de álcool e crack, pois pesquisas prévias sugerem associação entre os transtornos relacionados a substâncias e o comprometimento das capacidades de autorregulação e de controle dos impulsos. Neste estudo, 67 homens com idades entre 18-65 anos responderam aos seguintes instrumentos: questionário sociodemográfico, Vocabulário e Raciocínio Matricial (Wechsler Abbreviated Scale of Intelligence), Five Digit Test e Behavioural Assessment of the Dysexecutive Syndrome. Os usuários de álcool e crack apresentaram déficits envolvendo velocidade de processamento, inibição de respostas, flexibilidade, abstração, planejamento e monitoramento. A análise por droga de abuso revelou desempenho cognitivo inferior entre os alcoolistas. O tempo de abuso de drogas foi associado a déficits de planejamento. Esses achados são consistentes com a hipótese de associação do abuso de drogas com alterações cognitivas. Em conclusão, foram observadas alterações do funcionamento executivo e do controle inibitório nas amostras de usuários avaliadas.

Palavras-chave: avaliação; cognição; drogas; inibição; funções executivas.

Evaluación de las funciones ejecutivas y control inhibitorio en las adicciones por alcohol y cocaína

Resumen

Este estudio investigó las funciones ejecutivas y el control inhibitorio en usuários de alcohol y crack, ya que estudios anteriores sugieren una asociación entre las adicciones y alteraciones de las capacidades de auto-regulación y control de los impulsos. En este estudio, 67 hombres con edades entre 18-65 años respondieron a los siguientes instrumentos: cuestionario sociodemográfico, Vocabulario, Matriz de Razonamiento, Test de Los Cinco Dígitos y *Behavioral Assessment of the Dysexecutive Syndrome*. Usuarios de alcohol y crack presentaron déficits de velocidad de procesamiento, inhibición de respuestas, flexibilidad, abstracción, planificación y monitoramiento. El análisis por droga de abuso mostró menor rendimiento cognitivo entre los alcohólicos. El tiempo de abuso de drogas se asoció con déficit de planificación. Estos resultados son consistentes con la hipótesis de la asociación del abuso de drogas con deterioro cognitivo. En conclusión, fueram observadas alteraciones del funcionamiento ejecutivo y del control inhibitorio en las muestras evaluadas.

Palabras clave: cognición; drogas; evaluación; inhibición; funciones ejecutivas.

Substance-related disorders (SRDs) have been understood as chronic, recurrent conditions characterized by a compulsive behavior and loss of control over drug consumption, leading to changes in several aspects of life and impairment in global functioning (American Psychiatric Association, 2013). Such impairments are believed to be associated with the harmful effects of drugs on the central nervous system (CNS), involving alterations in the dopaminergic system and several neural circuits, such as an impulsive, amygdala system related to immediate rewards and a reflective, prefrontal cortex system related to non-immediate rewards (Bechara, 2005; Koob & Volkow, 2011).

The chronic use of psychoactive substances (PAS) would lead to the activation of these systems in a dysfunctional manner, "hijacking" the cognitive resources that are needed for goal-driven cognitive functioning and self-regulation, thus making individuals more vulnerable to problematic drug use (Bechara, 2005). Changes in neural circuits involved in the management of cognitive and behavioral processes, such as the ventrolateral prefrontal cortex, the anterior cingulate, and the frontal, temporal, and parietal gyri, have been described in individuals with SRD (Czermainski, Willhelm, Santos, Pachado, & De Almeida, 2017). The harmful effects of alcohol and other drugs on cognitive functions are related mainly to attention, memory, cognitive flexibility, inhibitory control, and executive functions (EFs) (Fernández-Serrano, Pérez-García, Río-Valle, Verdejo-García, 2010; Rigoni, Susin, Trentini, & Oliveira, 2013; Suska, Lee, Huang, Dong, & Schlüter, 2013; van der Plas, Crone, van den Wildenberg, Tranelv, & Bechara, 2009; Verdejo-Garcia & Perez-Garcia, 2007).

EFs are complex processes whose management is performed by the prefrontal cortex circuit and involve the ability to plan and solve problems, predict consequences, and change strategies in a flexible way, monitoring one's behavior and adapting it to the context (Chan, Shum, Toulopoulou, & Chen, 2008; Lezak, 1995). EFs comprise a wide range of components, such as attention, abstraction, planning, flexibility, working memory, and inhibitory control (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006). According to the literature, EF deficits in PAS users may be associated with frequent relapses and treatment dropout, even though individuals are able to recognize the negative effects of drug use (Bechara, 2005; Fernandez-Serrano et al., 2010; Koob & Volkow, 2010).

Inhibitory control is an EF component with an important role in SRDs. Recent studies have provided evidence of impaired inhibition related both to the input (attentional selection, visual scanning, ability to deal with irrelevant information bias) and the output (response inhibition) of the inhibitory system, as well as an increase in impulsive behavior, lack of emotional control, inconsistency in long-term reward tasks, lack of interest in the needs of others, and preference for magical and irrational explanations to solve problems (De Almeida, Trentini, Klein, Macuglia, Hammer, & Tesmmer, 2014; Fernandez-Serrano et al., 2012; Pedrero-Pérez & León, 2012; Sellaro et al., 2014; Verdejo-Garcia & Perez-Garcia, 2007). Neuropsychological studies have reported the presence of cognitive processing deficits, low resistance to interference, failed planning and monitoring, higher rates of disadvantageous decisions (measured through response inhibition errors and perseverative errors), and higher levels of impulsivity in individuals with SRD (Colzato et al., 2007; Cunha & Novaes, 2004; De Oliveira, Barroso, Silveira, Sanchez, De Carvalho Ponce, Vaz, & Nappo, 2009; Fernandez-Serrano et al., 2012; Kjome et al., 2010; Madoz-Gúrpide et al., 2011; Soar et al., 2015; Verdejo-García et al., 2005).

Alcohol abuse is considered a public health issue by the World Health Organization (WHO, 2007). Alcohol is a legal CNS depressant drug often used excessively in order to promote behavioral disinhibition and a sense of relief and relaxation (Lemos & Zaleski, 2004). Its consumption has been associated with cognitive changes involving learning and memory, visuospatial capacity, perceptual-motor skills, abstraction and problem-solving, and executive dysfunctions (Cunha & Novaes, 2004; Rigoni, Susin, Trentini, & Oliveira, 2013).

Cocaine and crack are the illegal drugs responsible for the highest number of treated cases in Brazil, which reveals the personal and family impact of drug-related problems (Oliveira & Nappo, 2008; Ribeiro, Dunn, Sesso, Dias, & Laranjeira, 2006). Crack is a CNS stimulant drug and a cocaine by-product, which is cheaper than cocaine and has a great addictive potential. Cocaine use has been associated with impaired cognitive functions related to self-control (Fernández-Serrano, Pérez-García, Río-Valle, & Verdejo-García, 2010; Kjome, Lane, Schmitz, Green, Ma, Prasla, Swann, & Moeller, 2010). However, few studies have investigated the effects of crack use on cognition and behavior, inferring that crack-related deficits may be associated with an even higher impact on these areas (Narvaez, Magalhães, Trindade, Vieira, Kauer-Sant'Anna, Gama, Diemen, Kapczinski & Kapczinski, 2012).

The concomitant use of cocaine and alcohol is the most common combination among PAS users, probably because it prolongs the sense of euphoria and compensates the sedative effects of alcohol compared to

the isolated use of these drugs (Flannery, Morgenstern, McKay, Wechsberg, & Litten, 2004; Pedrero-Perez & Leon, 2012; Pennings, Leccese, & Wolff, 2002). When used together, alcohol and cocaine interact producing cocaethylene, an active metabolite whose half-life is three times longer than that of cocaine, with higher toxicity. The concomitant use of these drugs leads to serious health risks and has been associated with poorer prognosis (Gossop, Manning, & Ridge, 2006; Harris, Everhart, Mendelson, & Jones, 2003; McCance, Price, Kosten, & Jatlow, 1995).

Research has provided evidence of cognitive changes in alcohol and crack users (Colzato & Hommel, 2009; Cunha & Novaes, 2004; De Oliveira, Barroso, Silveira, Sanchez, De Carvalho Ponce, Vaz, & Nappo, 2009; Pace-Schott, Morgan, Malison, Hart, Edgar, Walker, & Stickgold, 2008; Pérez & De León, 2012; Woicik et al., 2011). However, few studies have assessed the changes caused by each type of drug (Fernández-Serrano et al., 2010; van der Plas, Crone, van den Wildenberg, Tranel, & Bechara, 2009; Verdejo-Garcia et al., 2005; Verdejo-Garica et al., 2007). Additionally, we could not find empirical studies on the impact of the concomitant use of alcohol and crack on behavior and cognition (EFs and inhibitory control) using a neuropsychological assessment protocol.

To contribute to relevant research on damage caused by PAS on cognition, the present study aimed to assess EFs and inhibitory control in samples of alcohol and crack users. We sought to understand cognitive deficit profiles according to each drug and to investigate impairments in executive functioning resulting from the concomitant use of alcohol and crack.

Method

Participants

Sixty-seven men aged 18 to 65 years were included in this study. The clinical sample consisted of 54 men diagnosed with alcohol and/or crack use disorders recruited at a voluntary, free, specialized inpatient unit for chemical dependency treatment located in a general hospital in the city of Porto Alegre, Brazil.

The initial control sample consisted of 30 men aged 18 to 46 years. However, some individuals did not meet the inclusion criteria and were excluded from the study. The final control sample consisted of 13 participants. The final study sample (n=67) was divided into four groups: Controls – Co (n=13); Crack users – CU (n=25); Alcohol users – AU (n=13); and Alcohol+crack users – ACU (n=16).

The following inclusion criteria were applied: 1) being male; 2) being aged 18 to 65 years; 3) being able to complete research instruments; 4) being diagnosed with alcohol and/or crack use disorder (clinical sample); 5) being abstaining from drugs; 6) not being diagnosed with SRD and not having history of drug abuse and drug treatment (control sample); and 7) having intelligence quotient (IQ) within normal limits. Individuals considered ineligible on psychiatric examination (e.g., withdrawal symptoms, severe psychosis) and those with IQ<70 were excluded.

The initial study sample consisted of 80 participants. After inclusion/exclusion criteria were applied, 13 individuals were excluded: three candidates for the control group who had IQ<70 or a history of drug-related problems and 10 candidates for the clinical groups who did not complete the tasks or requested to leave the treatment program.

Procedures

Data collection was performed individually, in a private room, for all participants. Participants in the clinical groups were assessed at a hospital. The treatment program was divided into two phases, detoxification and rehabilitation, in which patients were seen by a multidisciplinary team and participated in different activities, such as mutual support groups, craving management, contingency management, cognitive restructuring, and physical and playful activities. Patients were invited to join the study after an initial withdrawal period, when they were cognitively able to understand the study purposes. Assessments were performed approximately on the 10th day of hospital stay by previously trained researchers under the supervision of a psychologist with specialized training in neuropsychological assessment and chemical dependency.

The control sample was recruited and evaluated at a public school offering youth and adult education classes. Mean duration of assessments was 40 minutes for all groups. All individuals voluntarily agreed to participate in the study and signed an informed consent form. This study was conducted in accordance with regulatory standards for research with human subjects and was approved by an Ethics Committee.

Instruments

1. *Sociodemographic questionnaire*: Information on personal and family characteristics and drug use was collected.

2. *Wechsler Abbreviated Scale of Intelligence* – WASI (Wechsler, 1999; adapted and standardized by Trentini, Yates, & Heck, 2014): A brief instrument of intelligence assessment applicable to individuals aged 6 to 89 years. It provides total IQ, performance IQ,

and verbal IQ based on four subtests (Vocabulary, Block Design, Similarities, and Matrix Reasoning) administered within a short period of time. This scale also provides IQ assessment by applying only two subtests (Vocabulary and Matrix Reasoning), which was the option used in this study.

3. *Five Digit Test* – FDT (Sedó, 2007; Brazilian version developed by Sedó, de Paula, & Malloy-Diniz, 2015): An instrument to assess processing speed, ability to direct and change attentional control, and inhibitory control. It allows assessing the Stroop effect in individuals who cannot read or who speak a different language. The test is divided into four successive parts: 1) reading; 2) counting; 3) choosing; and 4) shifting. Each part involves the production of four identical verbal lists using the aforementioned activities and is preceded by a training session with 10 items. The test showed satisfactory reliability and validity results (>70) in a Spanish study.

4. *Behavioural Assessment of the Dysexecutive Syndrome* – BADS (Wilson, Alderman, Burgess, Emslie, & Evans, 1996): A battery of tests to assess EFs such as inhibitory control, planning, priorities, problem-solving, cognitive flexibility, and behavioral changes. It consists of 30 questions divided into six subtests with a maximum score of 24 points and two questionnaires. All six subtests were used in this study.

4.1 *Rule Shift Cards*: assesses perseverative tendencies and mental flexibility. It requires participants to respond to stimuli (red or black playing cards) according to one of two rules that are presented consecutively. Performance is evaluated according to the ability to respond and adapt to rule changes.

4.2 Action Programme: assesses the ability to plan and implement a solution to a practical problem. Performance is evaluated according to the number of steps completed without assistance.

4.3 Key Search: assesses the ability to plan a strategy to solve a problem. Performance is evaluated according to the number of strategies that were created and how systematic, efficient, and effective they were.

4.4 *Temporal Judgement*: involves judgment and abstract thinking based on common knowledge. The respondent is required to estimate times for everyday events. Performance is evaluated according to the accuracy of the estimate.

4.5 *Zoo Map*: assesses the ability to formulate and implement a plan and to follow a pre-formulated plan. It involves plotting or following a route through a map. Performance is evaluated according to the successful implementation of the plan.

4.6 *Modified Six Elements*: assesses the ability to manage time. Participants are required to divide the available time between a number of simple tasks (picture naming, arithmetic, and dictation) while observing some rules.

Data analysis

Data analysis consisted of descriptive and inferential procedures. The Shapiro-Wilk test was used to assess the distribution of the variables of interest. The Kruskal-Wallis test with post-hoc Dunn's test was used for comparisons due to the size of the groups. A second analysis, using a generalized linear model, was performed to compare groups while controlling for age. In addition, the Spearman's correlation test was used to correlate cognitive variables with years of alcohol and crack use. Analyses were performed using SPSS (version 18.0), and the significance level was set at 0.05.

Results

Sociodemographic data

The total sample of drug users (n=54) consisted of predominantly white men (64%), single or divorced (78%), with low level of education: 56% reported less than 8 years of schooling, 35% reported complete high school, and 9% reported incomplete higher education. More than half of users (57%) were unemployed at assessment and 48% reported having been arrested.

Early use of PAS (before 18 years of age) was fairly common among participants: 78% had used alcohol, 65% had smoked cigarette, 63% had smoked marijuana, 50% had used cocaine, and 22% had used crack. Mean age at onset of alcohol use was lower than at onset of crack use. Mean time using alcohol was much higher than mean time using crack. **Table 1** shows these data per group. It is worth mentioning that users were abstaining from drugs for at least 10 days at data collection.

Group comparison revealed statistically significant age differences (F=13.541; df=3.63; p=0.001). The oldest group was AU with mean age of 42.38 years (SD=11.66), followed by ACU with mean age of 36.56 years (SD=8.56). CU showed mean age of 32.12 years (SD=6.10). Co was younger than all other groups, with mean age of 22.69 (SD=7.20). No statistically significant differences were found between groups in level of education (H=3.372; df=3; p=0.338), and median level of education ranged from 6.50 to 8.00 years of schooling. There were differences in IQ scores (H=18.734; df=3; p<0.001). AU showed the lowest IQ score (median=85 [79-86]), followed by ACU (median=86 [82-95]), compared to Co (median=102 [95-104]). **Table 2** shows the results of group comparisons in cognitive measures.

TABLE 1
Characteristics of clinical samples related to age of onset and years of alcohol and crack use.

Variable	*CU Crack (n=25)*		*AU Alcohol (n=13)*		*ACU Alcohol+crack (n=16)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age at onset of crack use	23.14	5.52	–	–	26.67	9.54
Years of crack use	7.71	4.30	–	–	9.91	5.39
Age at onset of alcohol use	–	–	14.77	2.86	13.90	2.23
Years of alcohol use	–	–	20.85	9.91	20.44	8.26

TABLE 2
Group comparison in intelligence, executive functioning, and inhibitory control measures.

	Co – Controls (n=13)		*CU – Crack users (n=25)*		*AU – Alcohol users (n=13)*		*ACU - Alcohol+crack users (n=16)*		*p*
	q2 [q1-q3]	*min-max*	*q2 [q1-q3]*	*min-max*	*q2 [q1-q3]*	*min-max*	*q2 [q1-q3]*	*min-max*	
WASI									
Vocabulary	53 [47-57][a]	39-62	38 [35-50][b]	22-68	36 [28-41][b]	24-54	41 [33.5-49][b]	26-54	0.001
Matrix Reasoning	26 [24-27][a]	19-29	18 [14-21][b]	8-29	12 [9-16][b]	7-29	14.5 [11-18.5][b]	7-22	<0.001
IQ final score (two subtests)	102 [95-104][a]	92-109	89 [85-97][b]	62-120	85 [79-86][b]	76-112	86 [82-95][b]	75-100	<0.001
FDT									
Reading (time)	21 [19-23][a]	19- 27	25 [22-30][ab]	19-54	31 [25.5-34.5][b]	23-40	32.5 [23-40][b]	22-90	<0.001
Reading (errors)	0 [0-0]	0-0	0 [0-0]	0-0	0 [0-0]	0-17	0 [0-0]	0-2	0.382
Counting (time)	23 [22-24][a]	21-31	28 [26-35][b]	20-52	30 [27-37][b]	26-46	34 [25-38][b]	22-76	0.002
Counting (errors)	0 [0-0]	0-1	0 [0-0]	0-1	0 [0-0]	0-12	0 [0-0]	0-2	0.996
Choosing (time)	35 [33-44][a]	28-58	46 [38-53][ab]	25-81	46.5 [42-58.5][ab]	36-68	50 [39-59.5][b]	33-81	0.042
Choosing (errors)	0 [0-1]	0-5	1 [0-3]	0-17	1.5 [0-3.5]	0-22	0 [0-3.5]	0-8	0.313
Shifting (time)	45 [42-50][a]	36-74	55 [52-70][ab]	41-110	70.5 [55.5-83][b]	44-125	66 [59-81.5][b]	42-137	0.001
Shifting (errors)	1 [1-2][a]	0-4	3 [2-5][ab]	1-15	4 [3.5-12.5][b]	0-33	4.5 [1-6][b]	0-25	0.005
Inhibition	15 [12-24]	7-33	18 [12-25]	2-45	15.5 [12.5-24]	9-34	18 [11.5-23]	(-13)-35	0.902
Flexibility	25 [21-29]	13-50	36 [28-48]	18-291	38 [25.5-54]	15-93	35 [24-48.5]	11-84	0.114
BADS									
Rule Shift Cards									
Part 1 – Error score	0 [0-0]	0-1	0 [0-0]	0-14	0 [0-3]	0-15	0 [0-0]	0-8	0.195
Part 1 – Time score	17 [16-18][a]	14-20	21 [18-24][b]	17-31	23 [20-25][b]	18-28	21.5 [20-25.5][b]	17-31	<0.001
Part 2 – Error score	2 [1-3][a]	0-7	3 [1-7][b]	0-9	8 [5-9][b]	3-14	5 [1.5-5.5][ab]	0-14	0.001
Part 2 – Time score	23 [22-27]	20-30	27 [24-30]	21-37	27 [25-29]	21-35	27 [25-35]	23-47	0.063
Action Programme	5 [4-5]	1-5	5 [4-5]	2-5	5 [5-5]	0-5	4 [4-5]	0-5	0.434
Key Search									
Time score	41 [32-50]	27-72	45 [32-84]	15-115	71 [38-127]	19-453	41 [33.5-92]	15-260	0.347
Score	10 [7-11][a]	6-16	6 [4-8][ab]	2-15	4 [2-6][b]	2-12	7 [4-13][a]	4-16	0.001
Temporal Judgement	2 [2-2]	1-3	2 [2-3]	0-4	2 [2-2]	1-3	2 [1.5-2.5]	1-3	0.665
Zoo Map									
Part 1 – Planning time	19 [3-32]	0-166	5 [1-13.5]	0-210	16 [5-46]	1-62	6.5 [3-15]	1-55	0.272
Part 1 – Total time	206 [121-220][ab]	55-374	171 [115-219][a]	41-429	242 [228-346][b]	96-547	179.5 [156-223.5][ab]	86-322	0.022
Part 1 – Error score	2 [1-8][a]	0-11	4 [2-8][ab]	0-18	8 [6-14][b]	1-21	4 [2-8.5][ab]	0-16	0.026
Part 1 – Final score	2 [0-4]	0-8	0 [0-1]	(-13)-8	0 [0-2]	0-7	0 [0-1.5]	(-11)-5	0.084
Part 2 – Planning time	2 [0-5]	0-9	2 [0-3]	0-47	4.5 [2-12.5]	2-30	2.5 [1-11.5]	0-40	0.057
Part 2 – Total time	81 [49-104][a]	36-300	97.5 [63-119][a]	30-258	139 [131-268][b]	67-445	114 [89-150][ab]	44-222	0.003
Part 2 – Error score	1 [0-2][a]	0-4	2 [1-4][ab]	0-11	4 [2-13][b]	0-26	1 [1-4][ab]	0-11	0.015
Part 2 – Final score	7 [6-8][a]	0-8	5 [2-7][ab]	0-8	1 [0-5][b]	0-8	6.5 [2.5-7][ab]	(-4)-8	0.022
Modified Six Elements	5 [3-5][a]	2-6	3 [2-4.5][ab]	1-6	3 [2-6][ab]	1-6	2 [2-3][b]	1-4	0.045
BADS final score	16 [15-17][a]	8-19	13 [10.5-15][ab]	4-21	9 [9-12][b]	5-17	11 [9-13][b]	5-20	0.001

Expressed as median [1st quartile-3rd quartile]. The Kruskal-Wallis test was used to compare groups. Dunn's multiple comparison test; #different letters indicate statistically different measures of central tendency.
BADS, Behavioural Assessment of the Dysexecutive Syndrome; FDT, Five Digit Test; WASI, Wechsler Abbreviated Scale of Intelligence.

In the FDT, Co performed the reading component in less time (median = 21 [19-23]) than AU (median=31 [25.5-34.5]) and ACU (median=32.5 [23-40]) (H=19.626; df=3; p<0.001). Similarly, Co performed the counting component in less time (median=23 [22-24]) than CU (median=28 [26-35]), AU (median=30 [27-37]), and ACU (median=34 [25-38]) (H=14.501; df=3; p=0.002). Co also performed the choosing component in less time (median=35 [33-44]) than ACU (median=50 [39-59.5]) (H=8.211; df=3; p=0.042). The shifting component was performed in less time by Co (median=45 [42-50]) than by ACU (median=66 [59-81.5]) and AU (median=70.5 [55.5-83]) (H=16.200; df=3; p=0.001). Co made fewer shifting errors (median =1 [1-2]) than AU (median=4 [3.5-12.5]) and ACU (median=4.5 [1-6]) (H=12.675; df=3; p=0.005).

In the first part of the Rule Shift Cards subtest, controls were faster (median=17 [16-18]) than all other groups (H=21.506; df=3; p<0.001). AU took longer to perform the task than the other groups (median=23 [20-25]). There were no statistically significant differences between groups in error scores in the first part of this subtest (H=4.701; df=3; p=0.195). In the second part, controls made fewer errors (median=2 [1-3]) than the other groups (H=16.140; df=3; p=0.001), and AU was the group that made more errors (median=8 [5-9]).

No statistically significant differences were found between groups in the Action Programme (H=2.736; df=3; p=0.434) and Temporal Judgement (H=1.573; df=3; p=0.665) subtests and in performance time in the Key Search subtest (H=3.305; df=3; p=0.347). However, Co obtained a higher score (time score+ error score) in the Key Search subtest (median=10 [7-11]) than AU (median=4 [2-6]) (H=16.721; df=3; p=0.001).

In the first part of the Zoo Map subtest, there were no significant differences between groups in planning time (H=3.903; df=3; p=0.272) and final score (H=6.657; df=3; p=0.084). However, AU took longer to complete the task (median=242 [228-346]) than CU (median=171 [115-219]) (H=9.672; df=3; p=0.022). In addition, AU was the group that made more errors (median = 8 [6-14]), compared to Co (median=2 [1-8]) (H=9.270; df=3; p=0.026). In the second part of the Zoo Map subtest, no differences were found in planning time (H=7.510; df=3; p=0.057), but AU took longer to complete the task (median=139 [131-268]) than Co (median=81 [49-104]) and CU (median=97.5 [63-119]) (H=14.278; df=3; p=0.003). AU was the group that made more errors (median=4 [2-13]), compared to Co (median=1 [0-2]) (H=10.448; df=3; p=0.015). AU also obtained the lowest score in the second part of the subtest (median=1 [0-5]), compared to controls (median=7 [6-8]) (H=9.590; df=3; p=0.022).

In the Modified Six Elements subtest, ACU obtained the lowest score (median=2 [2-3]), compared to Co (median=5 [3-5]) (H=8.064; df=3; p=0.045). AU was the group with the lowest BADS final score (median=9 [9-12]), followed by AUC (median=11 [9-13]), compared to controls (median=16 [15-17]) (H=15.962; df=3; p=0.001). Group comparison adjusted for age showed that the between-group differences in the first analysis were maintained in intelligence measures, in performance time in the first part and in error score in the second part of the Rule Shift Cards subtest, in Key Search score, in error score in the first and second parts and in performance time in the second part of the Zoo Map subtest, and in BADS final score.

Discussion

This study aimed to assess EFs and inhibitory control in samples of alcohol and/or crack users compared to controls. As expected, statistically significant differences were found between groups in all measures, suggesting that individuals with alcohol and/or crack use disorders show executive dysfunctions compared to individuals with no drug-related problems.

Clinical samples showed cognitive processing speed deficits, as observed in performance times in all FDT components and in the first part of the Rule Shift Cards subtest, compared to controls. Groups AU and ACU had lower FDT scores, suggesting that alcohol use, associated or not with crack use, was related to a higher impact on cognitive processing speed in the study samples. AU was also the group that took longer to perform the first part of the Rule Shift Cards subtest. Slowness in performing EF tasks among alcohol users has already been described by Chao et al. (2003) and Durazzo et al. (2006). Additionally, these results may be associated with deficits in early learning, attention, and visual processing, which have been found in alcohol users in studies assessing EFs (Rigoni et al., 2013). It is important to emphasize that groups AU and ACU showed lower IQ scores than CU and Co (**Table 2**), which may be associated with their performance in the FDT and the Rule Shift Cards subtest, which require, among other skills, reading, flexibility, attention, and working memory skills.

Clinical groups also had poorer performance in tasks involving inhibitory control, and impairments in response inhibition were observed through error scores in the FDT shifting component and in the second part

of the Rule Shift Cards subtest, compared to controls (**Table 2**). ACU was the group that made more FDT shifting errors, and AU was the group that made more errors in the second part of the Rule Shift Cards subtest, followed by CU. These two tasks require the participant to inhibit previously learned responses. In the FDT, these responses involve reading, counting, or choosing. In the second part of the Rule Shift Cards subtest, the participant should be able to adapt responses to changing rules as stimuli are presented (red or black playing cards).

Inhibition deficits have been reported in samples of alcohol users who were administered the Wisconsin Card Sorting Test (WCST), an instrument to assess response adaptation to rule changes through playing card stimuli (Rigoni et al., 2013). Consistent with our findings, previous studies have also demonstrated impaired inhibitory control in samples of cocaine users assessed by the FDT (Fernandez-Serrano et al., 2010; Verdejo-Garcia & Perez-Garcia, 2007) and Rule Shift Cards (Madoz-Gurpide, Blasco-Fontecilla, Baca-Garcia, & Ochoa-Mangado, 2011). Although two reviews have provided evidence of impaired inhibitory control in alcohol and cocaine and/or crack users, a small proportion of the reviewed studies did not find inhibition deficits in their samples (Czermainski et al., 2017; Rigoni et al., 2013). Such disagreement may be related to methodological differences between these studies, making it difficult to compare findings as discussed by Czermainski et al. (2017).

In the present study, clinical samples showed poorer performance in tasks requiring response planning and monitoring than controls. Planning and monitoring deficits were observed in Key Search scores, in performance times and error scores in the first and second parts of the Zoo Map subtest, and in Modified Six Elements scores. AU was the group with the worst performance in the Key Search and Zoo Map subtests, and ACU had the lowest score in the Modified Six Elements subtest. It is important to note that, although CU took longer to perform the first part of the Zoo Map subtest, it made fewer errors than the other groups; thus, it performed the task more accurately, suggesting that the extra time required to perform the task is related to the attention required to learn new things. The Key Search subtest assesses the ability to plan a strategy in order to solve a problem. To perform this task, the participant must develop systematic, efficient, and effective strategies, which demands abstraction and working memory capacity. These abilities are also required to complete the Modified Six Elements subtest, which consists of multiple tasks (picture naming, arithmetic, and dictation) that involve monitoring responses and managing time (5 minutes) while observing some rules. This subtest is more complex and requires more attentional effort and previous knowledge about vocabulary and arithmetic. Therefore, poor performance of groups AU and ACU in these subtests may be associated with their lower level of education and lower IQ score, compared to controls and CU.

It is worth mentioning that the clinical samples of the present study showed different characteristics in terms of years of alcohol and/or crack use (**Table 1**). A previous study has already correlated impaired planning (assessed by the Zoo Map subtest) and inhibition (assessed by the Rule Shift Cards subtest) with years of cocaine use (Madoz-Gúrpide et al., 2011). In our study, two planning measures were also significantly correlated with years of alcohol and crack use (**Table 3**) – planning time in the second part of the Zoo Map subtest negatively correlated with years of crack use, and performance time in the Key Search subtest positively correlated with years of alcohol use. That is, the longer the participants used crack, the shorter they took to plan the Zoo Map task, while the longer the participants used alcohol, the longer they took to perform and complete the Key Search task. These findings suggest that chronic drug use is associated with executive dysfunctions related to abstraction, cognitive flexibility, and planning in alcohol users, and to more impulsive responses in crack users. However, further studies are needed to correlate years of alcohol and crack use with performance in EF tasks, and to infer the specific effects of the chronic use of these drugs on EF components.

TABLE 3
Correlations between cognitive measures and years of alcohol and crack use.

Variable	*Years of crack use*		*Years of alcohol use*	
	R	*p*	*R*	*p*
Zoo Map part 2 – Planning time	-0.450*	0.041	–-	–
Key Search – Performance time	–	–	0.609*	0.027

The analysis per type of drug revealed that groups that used alcohol (AU and ACU) showed poorer performance in EFs and inhibitory control than the group that used crack alone (CU). This may be associated with age at onset of alcohol and crack use and duration of drug use (**Table 1**). Mean age at onset of alcohol use was 14.77 years (SD=2.86) for AU and 13.90 years (SD=2.23) for ACU. Groups AU and ACU had used alcohol for approximately 20 years, and ACU had used crack for an average of 9.91 years (SD=5.39). Conversely, participants in the CU were older at onset of crack use (mean=23.14 years; SD=5.52) and had used it for a shorter time (mean=7.71 years; SD=4.30). Early and prolonged alcohol use, therefore, may be associated with poorer performance in EFs and inhibitory control.

Another important aspect concerns the individual's perception of damage caused by alcohol and crack use. One hypothesis is that alcohol users have to drink it for a longer period until they perceive the negative consequences of alcohol and start looking for help or treatment. The fact that alcohol is a legal drug and its use is culturally accepted may contribute to a failed or late perception of drug-related damage. In contrast, crack is a highly compulsive and addictive drug, which may make drug-related damage more noticeable, for instance, through more intense craving and frequent need to use it again. Possible differences in the perception of alcohol- and crack-related damage may explain the age differences across clinical groups, since all participants voluntarily sought treatment for drug abuse. It is important to highlight, however, that the EF and inhibitory control deficits showed by our clinical samples were maintained even after controlling for age. Therefore, the present findings cannot be attributed to the age differences in the study samples.

This study has some limitations. A small sample size is the first one. It is worth mentioning that our clinical samples consisted of individuals admitted to a voluntary treatment program for drug abuse and could, therefore, request to leave at any time. Thus, there were sample losses due to early treatment dropout. The second one was group comparability – groups were different in terms of age and IQ. Group comparability in terms of age, level of education, and IQ is desirable, but, as in other studies (Ilyuk et al., 2012; van der Plas et al., 2009), this was not possible because alcohol and/or crack users had low level of education. Thus, the groups were comparable in terms of level of education, and data analysis was performed controlling for age. To minimize these differences, only individuals with IQ score > 70 were included in this study.

Conclusions

The results of the present study are consistent with the hypothesis that SRDs are associated with impaired EFs and inhibitory control. Clinical samples' performance suggests the presence of EF deficits involving processing speed, inhibitory control, flexibility, abstraction, and response planning and monitoring, compared to controls. Factors such as low level of education, IQ score, age at onset of alcohol and/or crack use, and time using these drugs were considered and may be related to the findings of this study.

An analysis per type of drug suggested that chronic alcohol use, associated or not with crack use, was related to poorer performance in EF and inhibitory control measures. These findings reinforce the importance of identifying and treating PAS-related problems – not only those associated with the use of illegal drugs, but also those associated with the harmful consumption of alcohol, a legal drug which is highly tolerated and culturally accepted in society.

Studies focusing on the impact of different drugs, such as alcohol and crack, on cognition and behavior may contribute to advances in SRD treatment and prevention. According to Calheiros et al. (2006), cognitive deficits found in alcohol users may have direct implications in their treatment, both in choosing the strategy to be adopted and in performing a prognostic analysis, as well as in the identification of the patient's motivational status. A previous study assessing EFs in individuals with severe alcohol dependency and low level of education has demonstrated an association between cognitive impairments and treatment motivation. Alcohol users showed psychomotor slowing, impaired visual perception and immediate memory, and decreased mental flexibility. Cognitive decline and low IQ potential were associated with difficulty in being aware of alcohol-related problems and low motivation to change behavior, which may interfere with treatment adherence (Rigoni, Oliveira, Susin, Sayago, & Feldens, 2009).

In conclusion, a neuropsychological investigation of individuals with SRDs considering the peculiarities of each drug may contribute to the identification of a cognitive functioning profile and its changes as well as to the adoption of more effective treatment strategies tailored to the patient's needs and to the development of cognitive and behavioral rehabilitation programs aimed at social reintegration.

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Dados dos autores:
Fernanda Rasch Czermainski – Doutora, Universidade Federal do Rio Grande do Sul.
Felipe Ornell – Especialista, Universidade Federal do Rio Grande do Sul.
Luciano Santos Pinto Guimarães – Mestre, Hospital de Clínicas de Porto Alegre.
Félix Kessler – Doutor, Universidade Federal do Rio Grande do Sul.
Lísia von Diemen – Doutora, Universidade Federal do Rio Grande do Sul.
Rosa Maria Martins de Almeida – Doutora, Universidade Federal do Rio Grande do Sul.

Endereço para correspondência:
Fernanda Rasch Czermainski
Rua Travessa Vileta, 230, apto 401
90690-150 – Porto Alegre, RS, Brasil
<ferrasch@gmail.com>

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