Journal of Substance Abuse Treatment 66 (2016) 1–8

Contents lists available at ScienceDirect

Journal of Substance Abuse Treatment

Regular articles

Assessment of Executive Function in Patients With Substance Use Disorder: A Comparison of Inventory- and Performance-Based Assessment

Egon Hagen, PhD [a,*], Aleksander H. Erga, PhD [b], Katrin P. Hagen [c], Sverre M. Nesvåg, PhD [a], James R. McKay [d], Astri J. Lundervold [e,f], Espen Walderhaug, PhD [g]

[a] KORFOR – Center for Alcohol and Drug Research, Stavanger University Hospital, PB 8100, 4068 Stavanger, Norway
[b] The Norwegian Centre for Movement Disorders, Stavanger University Hospital, PB 8100, 4068, Stavanger Norway
[c] Department of Pediatric Habilitation at Østerlide, Stavanger University Hospital, Østerlide, PB 8100, 4068, Stavanger, Norway
[d] Perelman School of Medicine, Department of Psychiatry, University of Pennsylvania, 3440 Market St., Suite 370, Philadelphia, PA, 19104, USA
[e] Department of Biological and Medical Psychology, University of Bergen, Bergen, Norway
[f] K. G. Jebsen Centre for Neuropsychiatric Disorders, University of Bergen, Bergen, Norway
[g] Department of Addiction Treatment, Oslo University Hospital, Gaustad, PB 4956, 0424, Oslo, Norway

ARTICLE INFO

Article history:
Received 3 September 2015
Received in revised form 15 February 2016
Accepted 28 February 2016

Keywords:
Executive function
Substance use disorder
Iowa Gambling Task
Stroop
BRIEF-A
Trail Making Test

ABSTRACT

Introduction: Chronic polysubstance abuse (SUD) is associated with neurophysiological and neuroanatomical changes. Neurocognitive impairment tends to affect quality of life, occupational functioning, and the ability to benefit from therapy. Neurocognitive assessment is thus of importance, but costly and not widely available. Therefore, in a busy clinical setting, procedures that include readily available measures targeting core cognitive deficits would be beneficial. This paper investigates the utility of psychometric tests and a questionnaire-based inventory to assess "hot" and "cold" neurocognitive measures of executive functions (EF) in adults with a substance use disorder. Hot decision-making processes are associated with emotional, affective, and visceral responses, while cold executive functions are associated with rational decision-making.
Material and Methods: Subjects with polysubstance abuse ($n = 126$) and healthy controls ($n = 32$) were compared on hot (Iowa Gambling Task) and cold (Stroop and the Trail Making Test) measures of EF, in addition to a questionnaire assessing everyday EF related problems (BRIEF-A; Behavior Rating Inventory of Executive Function – Adult, self-report version). Information about the substance abuse and social adjustment were assessed by self-report. Logistic regression analyses were applied to assess independent correlates of SUD status and social adjustment. A multiple linear regression was performed to predict the number of previous treatment attempts.
Results: The psychometric test of hot EF (the Iowa Gambling Task) did not differentiate the patients with polysubstance abuse from controls, and was not associated with social adjustment. The psychometric tests of cold EF distinguished somewhat between the groups and were associated with one indicator of social adjustment. The BRIEF-A differentiated between groups on all the clinical scales and was associated with three out of five social adjustment indicators ("criminal lifestyle," "conflict with caregiver," and "stable housing.").
Conclusions: The BRIEF-A inventory was the most sensitive measure of executive function in patients with substance use disorder, followed by measures of cold executive function. BRIEF-A should therefore be considered as an integral part of the clinical routine when assessing patients with SUD.

1. Introduction

Chronic substance use disorder (SUD) is associated with cognitive impairment (Rogers & Robbins, 2001; Vik, Cellucci, Jarchow, & Hedt, 2004; Yucel, Lubman, Solowij, & Brewer, 2007), with prevalence estimates varying between 20% and 80% among treatment-seeking abusers of alcohol and drugs (Bates, Bowden, & Barry, 2002; Copersino et al., 2009).

Although the majority of studies have focused on disorders related to alcohol use, there is growing evidence indicating similar cognitive

Abbreviations: SUD, Substance Use Disorder; EF, executive function; IGT, Iowa Gambling Task; BRIEF-A, Behavior Rating Inventory of Executive Function – Adult version; TMT A+B, Trail Making Test parts A and B; Stroop CW, The computerized Stroop Color Word test; AUDIT, The Alcohol Use Disorders Identification Test; DUDIT, The Drug Use Disorders Identification Test; WASI, Wechsler Abbreviated Scale of Intelligence; MI, Metacognition Index; BRI, Behavioral Regulation Index; GEC, Global Executive Composite.

* Corresponding author.
E-mail addresses: hagene@sus.no (E. Hagen), aleksander.hagen.erga@sus.no (A.H. Erga), katrin.pedersen.hagen@sus.no (K.P. Hagen), ness@sus.no (S.M. Nesvåg), jimrache@mail.med.upenn.edu (J.R. McKay), astri.lundervold@psych.uib.no (A.J. Lundervold), espwal@ous-hf.no (E. Walderhaug).

http://dx.doi.org/10.1016/j.jsat.2016.02.010
0740-5472/

deficits associated with polysubstance use (Fernandez-Serrano, Perez-Garcia, & Verdejo-Garcia, 2011; Grant & Judd, 1976; Vik et al., 2004). More specifically, abusers of alcohol, opiates, and stimulants show impairment on tasks assessing different aspects of executive function (EF), including decision-making and emotional control (Barry & Petry, 2008; Bechara, 2005; Dolan, Bechara, & Nathan, 2008; Verdejo-Garcia & Bechara, 2010; Verdejo-Garcia, Bechara, Recknor, & Perez-Garcia, 2006). Central symptoms of EF deficits include reduced sensitivity to future consequences and impaired decision-making in real-life situations (Bechara et al., 2001; Grant, Contoreggi, & London, 2000; Schoenbaum & Shaham, 2008), reduced ability to suppress responses and evaluate consequences, as well as a preference for smaller, instantaneous rewards over larger, delayed rewards (Cardinal, Winstanley, Robbins, & Everitt, 2004). These deficits commonly present even after 6 months of abstinence among polysubstance abusers (Fernandez-Serrano et al., 2011).

EF dysfunction has an impact on quality of life and occupational functioning, which subsequently affects the course of rehabilitation therapy and level of community integration among patients with SUD (Fernandez-Serrano et al., 2011). In a clinical context, patients with polysubstance abuse may demonstrate intelligence, learning and memory, language, and attention within the normal range, but may still show considerable impairment in emotional function, decision-making, and social behavior (Bechara, 2005). More specifically, an association has been reported between cognitive deficits and low treatment adherence (Bates, Pawlak, Tonigan, & Buckman, 2006), poor attendance at outpatient therapy sessions (Guthrie & Elliott, 1980), low willingness to change (Blume & Marlatt, 2009), reduced self-insight (Horner, Harvey, & Denier, 1999), denial of substance abuse (Rinn, Desai, Rosenblatt, & Gastfriend, 2002), increased impulsivity, and less abstinence from the substance of abuse following treatment termination (Aharonovich et al., 2006). Impaired EF has also been linked to medical and legal problems among this patient group (Bechara et al., 2001; Paulus, Tapert, & Schuckit, 2005).

With neurocognitive deficits recognized as an adverse variable affecting recovery and treatment adherence in SUD patients, a thorough examination of cognitive functioning, including assessment of EF, is of paramount importance with regard to formulation of an effective and clear individual treatment plan, and by this to facilitate improved everyday coping and functioning in this patient population.

However, neurocognitive assessment services are both expensive and time consuming. Furthermore, specialized neuropsychological expertise is usually rare in outpatient settings of SUD treatment. The infrequent inclusion of cognitive assessment in clinical practice was illustrated in a recent study from Norway (Vaskinn & Egeland, 2012), in spite of being recognized as important in the Norwegian national guidelines for diagnosing and treating patients with SUD.

To sum up, it is important to develop and apply assessment protocols that both are brief and simple enough to be included in a busy clinical setting, and of importance to real-life situations and treatment.

The need for clinic-friendly neurocognitive measures motivated the present study to investigate two theoretical EF components, referred to as "cold" and "hot" EF, in a group of patients with SUD. Both hot and cold neurocognitive processes are involved in decision-making (Seguin & Zelazo, 2005). Hot and cold decision-making processes are rarely investigated simultaneously. Often studies tend to emphasize the cold pathway at the expense of the hot pathway (Séguin, Arseneault, & Tremblay, 2007). Previous studies have found, that when compared with controls, SUD patients exhibit lower scores on performance based measures on EF and emotion processing measures, and PET studies have established an association between specific neural correlates related to cold and hot executive functions, respectively (Moreno-López et al., 2012).

Related to decision-making, cold EF refers to abilities of importance when contrasting various alternatives and comparing risk/benefit ratios (Séguin et al., 2007). Cold cognitive processes are thus involved in a wide range of abilities, including the ability to keep attention sustained and focused, to be cognitively flexible, and be able to plan and organize goal-directed behavior (Burgess, 2000; Stuss, Shallice, Alexander, & Picton, 1995). These abilities are commonly measured by psychometric tests such as the Stroop test (MacLeod, 1991) and the Trail Making Test (Kortte, Horner, & Windham, 2002; Strauss, Allen, Jorgensen, & Cramer, 2005). Neurobiologically, these cognitive processes are shown to be particularly associated with activation in dorsolateral prefrontal cortex (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006).

Hot EF involves processes with a more distinct emotional or motivational salience (Kerr & Zelazo, 2004; Zelazo & Müller, 2002), and have increasingly been linked to the orbitofrontal cortex (Anderson, Barrash, Bechara, & Tranel, 2006; Kerr & Zelazo, 2004). Impaired hot EF have a strong impact on behavioral choices in everyday situations, especially when stimuli with distinct emotional salience interact with logical or cold EF (Sonuga-Barke, 2003). The conventional method for assessing hot EF has been performance-based decision-making tasks with emotional-laden contingencies (Chan, Shum, Toulopoulou, & Chen, 2008). A key challenge for participants in these tasks is to make long-term advantageous decisions in uncertain and ambiguous test settings. The Iowa Gambling Task (IGT) is one such test (Bechara & Damasio, 2002), where impairments has been shown in individuals with alcohol, cocaine, and opioid use disorders (Bartzokis et al., 2000; Bechara & Damasio, 2002; Bechara et al., 2001). It has even been argued that the high proportion of relapse after treatment discharge may be attributed to impaired hot EF, particularly when exposed to emotional-laden situations previously associated with substance abuse (Hunt, Barnett, & Branch, 1971; McKay et al., 1997, 2004).

In addition to performance-based tests, EF can also be investigated using self-report scales or questionnaires in which participants are asked about their function in real-life situations. These scales, for example the 75-item Behavior Rating Inventory of Executive Functions – Adult Version (BRIEF-A) (Roth, Isquith, & Gioia, 2005; Roth, Lance, Isquith, Fischer, & Giancola, 2013), have been shown to have a higher ecological validity than results obtained in a structured test environment (Isquith, Roth, & Gioia, 2013; Roth et al., 2005). Furthermore, they clearly have time and cost advantages over laboratory-based performance measures.

With an aim to document EF impairment in patients with SUD of importance to real-life social adjustment and treatment, the present study included a set of tests of the theoretical cold and hot components of EF, including both psychometric tests and a questionnaire-based inventory (BRIEF-A). We investigated their efficiency in characterizing the SUD patients when compared to a control group.

2. Material and methods

2.1. Design

The study was part of a prospective, longitudinal cohort study of an SUD patient sample who started a new treatment sequence in the Stavanger University Hospital catchment area. This paper presents data collected from SUD patients admitted to both outpatient and residential treatment facilities. To minimize contamination from drug withdrawal and acute neurotoxic effects from psychoactive substance, participants were tested after 2 weeks of abstinence (Miller, 1985). The project was approved by the Regional Ethical Committee (REK 2011/1877).

2.2. Participants and procedures

One hundred and fifty participants were recruited from outpatient and residential treatment facilities within the region, across 10 enrollment sites. Patients were recruited between March 2012 and May 2013. Consecutive enrollment was continued until the required number of participants was recruited. The SUD group included patients reporting use of more than one drug at a single occasion or a history of having injected or abused multiple drugs, based on responses to the Alcohol Use Disorders Identification Test (AUDIT) (Bohn, Babor, &

Table 1
Substance use and treatment history.

	SUD patients (n = 126)
Age at initial use	13.1 (2.0)
Years of drug abuse	15.2 (8.0)
AUDIT total score	14.8 (10.5)
DUDIT total score	35.9 (8.5)
Have injected? n	82 (65.1%)
Treatment attempts, n	
0	44 (34.9%)
1	36 (28.6%)
2	19 (15.1%)
3	9 (7.1%)
4	7 (5.6%)
≥5	11 (6.5%)

All data are mean (SD) unless otherwise indicated.

Kranzler, 1995) and the Drug Use Disorders Identification Test (DUDIT) (Voluse et al., 2012). Scores on these tests are summarized in Table 1. Five patients were excluded due to not having a substance-related addiction. One patient was excluded due to only using cannabis, one due to only using opioids, and 14 due to only using alcohol. We did not exclude patients with comorbid psychiatric conditions. The control group (n = 38) was a convenience sample recruited using posters at social welfare and primary care offices. Controls and patients were offered compensation of NOK 400 for baseline testing. Nine patients (seven 17-years of age, two 16-years of age) were excluded due to age. The final group consisted of n = 126 SUD patients and n = 32 controls. Baseline demographic variables for the control vs the SUD groups are summarized in Table 2.

2.3. Inclusion procedure

To be eligible for admission to the study, patients needed to: a) sign a written informed consent to participate; b) embark on a new treatment sequence within the substance abuse treatment service; and c) be at least 18 years of age. Patients also had to be enrolled in the program to which they were admitted for at least 2 weeks, and abstinence was verified through self-report, for both inpatients and outpatients. In one of the first treatment sessions (1–3), patients were given an information sheet with a short project description.

2.4. Measures

Cold EF is commonly measured with the computerized Stroop test (Stroop CW) (Golden & Freshwater, 1978). Stroop is an assessment of attention, interference, and inhibition of dominant responses (MacLeod, 1991). Longer reaction times and number of errors indicate impaired performance. Another measure of cold EF is the Trail Making Test (TMT) (Kortte et al., 2002; Strauss et al., 2005). TMT provides data on visual–conceptual and visual–motor tracking and set shifting.

Table 2
Demographic variables for the control and SUD groups.

	Controls (n = 32)	SUD patients (n = 126)	*P*-value
Male, n	13 (40.6)	85 (67.5)	0.005[a]
Age	33.7 (13.0)	28.5 (8.0)	0.064[b]
Years of education	14.5 (3.1)	11.7 (1.8)	0.001[c]
Native Norwegian, n	32 (100)	120 (95.2)	1.000[d]
Permanent home, n	32 (100)	71 (56.3)	0.001[a]
Stable income, n	29 (90.6)	87 (69.0)	0.014[a]
Criminal lifestyle, n	0 (0.0)	32 (25.4)	0.001[a]
Years of work experience	11.6 (9.4)	5.8 (5.9)	0.001[b]
WASI Total IQ	106.2 (13.2)	98.6 (11.6)	0.002[c]

[a] Pearson's χ^2.
[b] Mann–Whitney *U* Test.
[c] Independent samples t-test.
[d] Fisher's exact test. All data are mean (SD), unless otherwise specified.

There are two test subsections: Trail Making-A (TMT-A), in which the targets are all numbers, and Trail Making-B (TMT-B), in which the subject alternates between numbers and letters. TMT-B is sensitive to cognitive flexibility, sequencing, motor speed, and response inhibition. Longer time to finish indicates impairment.

Hot EF has predominantly been examined using the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Anderson, 1994). The key challenge in the IGT is to make advantageous long-term decisions in conditions of uncertainty. For this test, subjects are given $2,000 to start and their task is to maximize profit across 100 trials by choosing cards from one of four decks. After 10 selections from decks A and B, the subject will have earned a net loss of $250, whereas decks C and D result in a net gain of $250. Consequently, decks A and B are the "risky" decks. The hot element of IGT varies throughout the testing procedure. It is assumed that the perception of risk within the IGT increases across trials, as subjects gain experience with the win/loss contingencies in the various decks (i.e. later trails have stronger emotional, or risky, associations) (Brand, Recknor, Grabenhorst, & Bechara, 2007).

The BRIEF-A is a self-report questionnaire composed of nine subscales and three composite scores. The Behavioral Regulations Index (BR-index) consists of the subscales inhibit, shift, self-monitor and emotional-control. The subscales initiate, plan/organize, working memory, organization of materials, and task-monitor comprise the Metacognition Index (MI). The BRI and MI can be combined to produce the overall global executive composite (GEC). Validity scales were examined, and two control and 10 SUD participants' profiles were excluded due to invalid response styles.

Specific information on substance abuse was based on self-reported responses on the AUDIT (Bohn et al., 1995) and the DUDIT (Voluse et al., 2012). The Wechsler Abbreviated Scale of Intelligence (WASI) was included as a control variable, because there was a significant difference between controls and SUD patients on the univariate analysis, and to ensure that EF deficits could not be attributed to general abilities. After ensuring validity of WASIs' index levels, WASI full scale score was used in further analysis. Experienced and trained psychometric staff administered all tests. An interview based on items from the preliminary version of the National Quality Register for Substance Abuse Treatment was used to collect demographics, type of addiction, initial age at use, treatment and work history, educational, and vocational data. Social adjustment scores were obtained based on a yes/no responses from the same quality register, and included the following categories: permanent housing, criminal lifestyle, conflict with caregivers, friends outside the drug environment, and stable income.

2.5. Statistical analyses

All statistical analyses were performed using IBM SPSS software (v. 22 for Windows). *P*-values < .05 were considered statistically significant. Group differences were analyzed using Student's t-test, Mann–Whitney tests, Pearson's χ^2 test and Fisher's exact probability test (for 2×2 tables) as appropriate. Normality was controlled for using histograms and Kolmogorov–Smirnov test, and Levene's test was used to select the appropriate *p*-values based on whether the assumption of equal variances within groups was met. Effect sizes are reported as Cohen's *d* (standardized mean differences), for which 0.3 is considered a small, 0.5 a medium, and ≥0.8 a large effect (Cohen, 1992).

Binary logistic regression analyses (enter method) were applied to assess independent correlates of SUD status and categorical variables indicating social adjustment. In these analyses, control variables (age, sex, years of education, and WASI Total IQ), and raw scores from the cold EF, hot EF, and BRIEF-A BRI and MI, were sequentially entered to the analyses. A multiple linear regression was performed to predict the number of previous treatment attempts. As a quantified measure of goodness-of-fit, Nagelkerke's R_2 was estimated and reported. Due to the significant difference in WASI total IQ between controls and patients, WASI total IQ was included in a control variable in these analyses.

3. Results

3.1. Demographics, substance abuse, and treatment history

A summary of the demographic variables is presented in Table 2. There were significant differences in gender (40.6 % vs 67.5 % males in control and SUD group) and years of education (14.5 ± 3.1 vs 11.7 ± 1.8) between the controls and SUD groups. The mean years of work experience was 11.6 (±9.4) in controls, compared to 5.8 (±5.9) in the SUD group. There was also a moderate but significant group difference in WASI Total IQ score in favor of the control group ($d = 0.611$, $p = 0.002$).

A summary of substance use and treatment history for SUD patients is presented in Table 1. The mean debut age of drug use was 13.1 (±2.0), and the mean years of drug abuse was 15.2 (±8.0) years. The mean AUDIT score was 14.8 (±10.5), and mean DUDIT score was 35.9 (±8.5). The majority (65.1 %) of the patients had tried injection as a form of drug administration. For a detailed overview of the treatment history of the patients, please refer to Table 1.

3.2. SUD vs control: executive functions

A summary of performance on cognitive tests for controls and SUD patients is presented in Table 3. The control group significantly outperformed the SUD group on the Stroop CW variables word reading, color naming and color/word naming, with moderate effect sizes. There was no group difference on the Stroop Interference task. There was a significant group difference on TMT part A ($d = 0.452$, $p = 0.028$) but not TMT part B ($d = 0.086$, $p = 0.658$). The SUD group was slightly better on IGT but this did not reach statistical significance for either the total score or the learning curve IGT variables. There was a significant increase in standard T-scores between SUD patients and controls on all BRIEF-A subtests.

The results of all the regression analyses are summarized in Fig. 1. Overall, SUD status was significantly associated with control variables ($\chi^2 = 53.53$, $p < 0.001$; $R^2 = 0.336$), and the BRIEF-A BRI and MI ($\chi^2 = 15.90$, $p < 0.001$; $R^2 = 0.110$). SUD status was not associated with hot ($\chi^2 = 1.49$, $p = 0.223$; $R^2 = .010$) or cold EF measures, although the association is close to statistical significant for cold EF ($\chi^2 = 12.23$, $p = 0.057$; $R^2 = 0.088$).

Table 3
Performance on cognitive tests for control and SUD groups.

	Controls (n = 32)	SUD patients (n = 126)	P- value[#]	Effect size[*]
Stroop				
Word reading	92.3 (13.9)	85.2 (12.8)	0.007	0.531
Color naming	69.0 (13.8)	62.3 (10.6)	0.013	0.545
Color/Word naming	43.8 (12.4)	38.9 (9.6)	0.019	0.441
Interference	4.3 (8.6)	5.9 (14.0)	0.524	0.137
Trail Making Test				
Part A	26.1 (9.2)	31.8 (12.3)	0.016	0.524
Part B	62.9 (32.2)	73.1 (43.6)	0.157	0.267
Iowa Gambling Task				
Total NET raw score	0.4 (18.6)	4.9 (26.0)	0.272	0.199
BRIEF-A[§]				
Inhibit	51.1 (7.9)	64.4 (11.7)	0.001	1.332
Shift	50.9 (9.5)	62.2 (10.4)	0.001	1.134
Emotional control	40.3 (8.0)	59.0 (9.2)	0.001	2.169
Self-monitoring	50.6 (10.3)	59.8 (11.3)	0.001	0.857
BRI	50.3 (10.7)	63.4 (9.8)	0.001	1.276
Initiate	51.0 (10.7)	66.0 (11.2)	0.001	1.369
Working memory	53.7 (11.6)	65.2 (11.3)	0.001	1.004
Plan/Organize	53.2 (10.5)	63.0 (10.4)	0.001	0.937
Task monitoring	54.2 (10.6)	60.9 (11.2)	0.004	0.614
Organization of materials	50.1 (8.7)	55.2 (10.9)	0.019	0.517
Metacognition Index	52.8 (10.7)	64.0 (10.4)	0.001	1.061

BRI = Behavioral Regulation Index; All data are mean (SD), unless otherwise indicated. The analysis on BRIEF-A shown above is therefore based on a sample of n = 30 control and n = 116 SUD participants.

[#] Student's *t*-test.

[*] Effect size reported as Cohen's *d*.

[§] Due to invalid BRIEF-A protocols, n = 2 control and n = 10 SUD participants were excluded from the analyses.

3.3. Social adjustment

Overall, social adjustment variables were not linked to control variables; except that higher education was significantly related to "stabile income" (B = 0.345, $p = 0.005$) and "friends outside the drug environment" (B = 0.464, $p = 0.008$). Increased age was also significantly related to "stabile income" (B = 0.051, $p = 0.048$). Overall, there were no significant associations between social adjustment and hot or cold cognitive tests. However, increased T-scores on BRIEF-A BRI was significantly related to adverse outcomes on "stabile income" (B = −0.77, $p = 0.007$), "conflict with caregiver," (B = 0.09, $p = 0.007$), "stabile housing" (B = −0.83, $p = 0.002$).

A multiple linear regression analysis (enter method) predicting the number of previous treatment attempts was performed using the same independent variables. The overall model was significant, and more treatment attempts were predicted by increased score on Stroop interference (B = 0.09, $p > 0.001$) and TMT part A (B = 0.04, $p > 0.038$). The number of previous treatment attempts was also negatively related to a reduced BRIEF MI score (B = −0.07, $p = 0.014$).

4. Discussion

Overall, the regression analyses in the present study found that the BRIEF-A inventory was a significant predictor of substance use status. The MI of BRIEF-A also predicted social adjustment scores, and the MI predicted number of previous treatment sessions within the SUD group. The contribution of the selected performance-based measures was sparse, although group comparisons showed that the control-group was faster on the three conditions from the Stroop test and the Trail Making Test part A.

4.1. Group membership

The measures of cold EF distinguished between patients with SUD and controls. The controls were faster on the Stroop reading and naming tasks, and the Trail Making Test part A. These findings are in line with previous research, where SUD patients often exhibit impairments in inhibitory control, set shifting and reduced ability to suppress responses (Cardinal et al., 2004). This difference in cold EF is even evident in adolescents at risk for developing SUD when compared to peers (McNamee et al., 2008).

The SUD group performed slightly (but not significantly) better on the hot EF, measured by the IGT total score. A similar paradoxical effect on IGT performance and education has been documented in a previous study, but existing studies vary in their findings. Functional impairments based on IGT have been found in individuals with alcohol, cocaine, and opioid use disorders, relative to healthy controls (Bartzokis et al., 2000; Bechara & Damasio, 2002; Bechara et al., 2001). However, findings are not conclusive, and a number of studies have shown that groups of healthy controls do not learn to successfully select cards from the advantageous decks, and also showing high variance in anticipatory electro-dermal responses (Dunn, Dalgleish, & Lawrence, 2006). The contradicting findings from some studies, where controls perform poorly on IGT while not showing any deficiencies in real-life decision making, makes it unclear whether IGT performance have predictive value on real life functioning.

The demographic variables age, gender, education and WASI IQ predicted group membership better than the hot and cold EF measures. WASI provides a brief assessment of general intellectual abilities (Canivez, Konold, Collins, & Wilson, 2009), and these results are not surprising, given the impact of the *G factor*; IQ scores correlate with academic performance and performance in other areas of life (Kline,

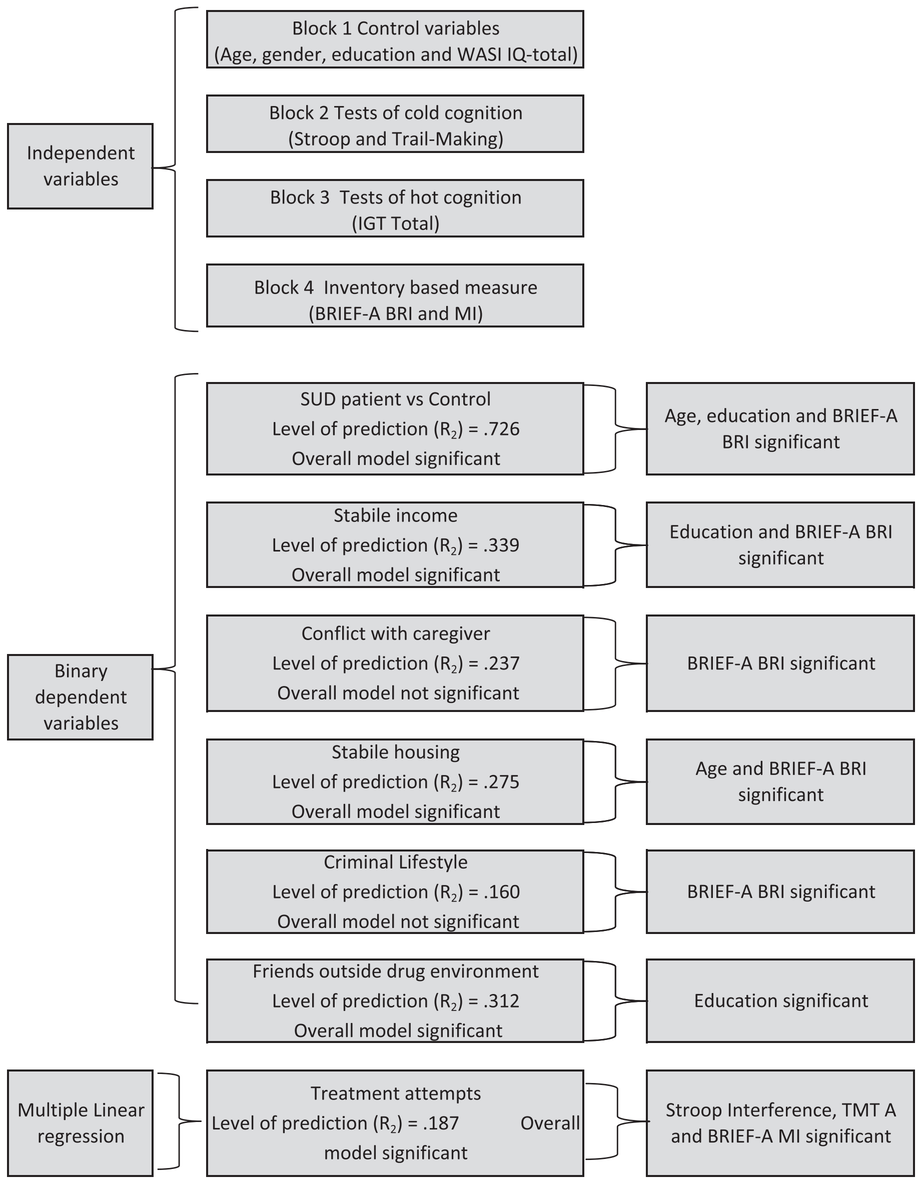

Fig. 1. Independent and dependent variables and results of the regression analyses. Level of prediction expressed as Nagelkerke's R_2.

2013b), and general intelligence can be understood as a broad reasoning ability that is useful in solving a wide variety of problems in life (Kline, 2013a).

Responses on BRIEF-A was significantly elevated on all the nine scales for SUD patients compared to the controls. Previous studies have found similar results, where current polydrug users report significantly more executive dysfunction on BRIEF-A, compared to non-users (Hadjiefthyvoulou, Fisk, Montgomery, & Bridges, 2012). Several studies have supported the validity of the BRIEF scales and other rating scales in assessing every-day executive functioning (Isquith et al., 2013). Moreover, there are established associations between BRIEF scores and corresponding neural substrates (P. Anderson, 2002), ecological validity with regard to predicting both every-day functioning (Isquith et al., 2013), and academic performance (Waber, Gerber, Turcios, Wagner, & Forbes, 2006).

Similar to our findings, it has proven difficult to establish associations between neuropsychological performance tests and rating scales of EF, and this has raised questions whether the two assessment strategies address different cognitive functions or different applications of cognitive skills (Isquith et al., 2013; McAuley, Chen, Goos, Schachar, & Crosbie, 2010). Isquith et al. (2013) offers a possible frame of explanation where neuropsychological performance tests are hypothesized to assess cold aspects of EF, and rating scales address a hot emotional aspect of EF. With regard to the BRIEF-A, this hypothesis draws support from research that have applied confirmatory factor analysis of the BRIEF-A scales, and detected a distinct emotional regulatory factor, consisting of the Emotional Control and Shift scales (Gioia, Isquith, Retzlaff, & Espy, 2002). Previous studies have speculated that the BR index is in fact a measure of hot EF, in contrast to the less emotional items constituting the remaining scales (Egeland & Fallmyr, 2010). This distinct hot factor in BRIEF has been replicated in several studies (McCandless & O' Laughlin, 2007; Peters, Algina, Smith, & Daunic, 2012). On the other hand, a recent study, (Skogli, Egeland, Andersen, Hovik, & Øie, 2014) on hot and cold EF in ADHD found no correlation between any of the BRIEF scales and performance based measures of hot performance EF. The correlation matrix displayed marginally higher correlation between cold EF tests and cold BRIEF scales than with the hot BRIEF scales. Overall cold BRIEF scales reached moderate correlation with cold EF tests. To our knowledge the majority of these findings have been based on studies of with attention deficit hyperactivity disorder, and we have not succeeded in finding previous studies investigating associations between neuropsychological performance tests and rating scales of EF adult SUD samples.

4.2. Social adjustment

BRIEF-A was associated with SUD as well as some indicators of social adjustment in SUD patients. Even when controlling for significant demographic variables, the BRI in BRIEF-A was associated with several domains of social adjustment, where increased scores on the BRI of the BRIEF-A were related to both substance abuse and lower social functioning. The BRI consists of four subscales crucial for real-life adaptive social behavior, which offers a plausible explanation for our findings. The Inhibit scale assesses the ability to assert impulse control (go/no-go), and to what extent one is able to inhibit, stop or adjust one's behavior when called for by the circumstances. The Shift scale assesses one's ability to flexibly change from alternating situations, tasks or aspects of challenges. The Emotional control scale assesses one's ability to regulate the expression of emotional responses, while the Self-Monitor scale assesses interpersonal awareness and to which extent one understands how one's behavior affects others (Roth et al., 2005). The BRIEF-A questionnaire measure participant's subjective evaluation about their function in real-life situations, and our findings suggest that the BRIEF-A have a higher ecological validity than results obtained on performance based tests.

We did not find any association between performance-based assessment of hot or cold EF and SUD, or social adjustment in the SUD group.

There is a scarceness of literature detailing the link between performance based measures of hot and cold EF in SUD, and their relation with social adjustment. However, regarding neurocognitive predictors of social adjustment, studies of patients with closed brain injury indicates that impairments in overall social adjustment (occupational status, leisure activities, social contacts and family life), are closely linked to the severity of the damage and subsequent cognitive sequela (Oddy, Coughlan, Tyerman, & Jenkins, 1985).

Our findings suggest that typical and commonly used neurocognitive performance based assessments might render a false negative outcome in an initial evaluation, while a questionnaire-based self-evaluation might predict impaired social adjustment associated with substance abuse.

The lack of relationships between self-rating measures and performance based measures of EF could imply that they are measuring different aspects of executive functions, and some suggest that performance measures are particularly sensitive to components of executive functions in isolation, while rating scales assess application of those skills, (Isquith et al., 2013). It has been argued that traditional neuropsychological tests artificially fractionate an integrated functional network (Burgess, 1997), and that the operationalization and types of methods used to measure EF impacts the conclusions and interpretations we can make. Our results indicate that IGT and BRIEF-A BRI assess two different cognitive constructs. IGT is presumably sensitive to subtle, unconscious perceptions of somatosensory feedback or “hunches” to guide decision-making, whereas the BR index from BRIEF-A captures the responder's own view of his or her ability to maintain appropriate control of their own behavior and emotional responses (Roth et al., 2005). This is supported by recent findings showing only minimal correlations between the two types of measures (Toplak, West, & Stanovich, 2013), providing further support for the hypothesis that there are separate EF pathways measured by IGT versus BRIEF-A (Sonuga-Barke, 2003).

4.3. Strengths and limitations

The SUD participants were recruited from ten different treatment facilities within the Stavanger University Hospital region. The patients were asked by their counselor whether they wished to participate. We have no data describing the patients that declined research participation. A Norwegian study found a threefold increase in the rate of disability pensions among patients who chose not to participate in the Hordaland Health Study (Knudsen, Hotopf, Skogen, Øverland, & Mykletun, 2010). Furthermore, nonparticipants were characterized by poorer lifestyle habits including smoking and drug and alcohol abuse (Korkeila et al., 2001; Shahar, Folsom, Jackson, & The Atherosclerosis Risk in Communities Study, I, 1996) and had lower scores on indicators of somatic and mental health (Drivsholm et al., 2006). It is therefore likely that the patients that declined research participation would have increased, rather than decreased, the group differences reported here.

The SUD and control groups were different on a number of demographic variables. Age, sex, education, and IQ were included as covariates in the statistical analyses to adjust for this limitation somewhat. The significant difference in education between the SUD and control group was challenging to avoid. It was almost impossible to find control participants with fewer than 10 years of education that did not have a substance abuse problem.

This research field faces a number of interpretive challenges as to the etiology of cognitive deficits associated with substance abuse. Psychiatric comorbidity, medical risk factors (e.g. head trauma, HIV, malnutrition, overdose), genetic predispositions, and premorbid vulnerability (e.g. genetic, psychosocial, and environmental) may all play significant causal roles leading to the current neuropsychological profile. Several psychiatric diagnoses are characterized by changes in EF, and psychiatric functioning was assessed with self-report, and not supplemented with observer-rated scales. To ensure validity and reliability in assessment of psychopathological symptoms, it is recommended that both subjective-, and observer rating are employed (Möller, 2009). Hence, it is possible that our findings could be impacted by comorbid psychiatric symptoms.

Furthermore, although there is marked evidence of an association between different aspects of SUD and cognitive impairment, the direct versus indirect roles of the various substances are not clear. Theoretically, a number of cognitive deficits could be viewed as antecedents to the onset of SUD, especially those involving EF connected to decision-making and impulsivity (Nigg, Blaskey, Huang-Pollock, & Rappley, 2002; Nigg et al., 2006).

5. Conclusions

The BRIEF-A inventory was the most sensitive measure of EF in patients with substance use disorder, followed by measures of cold EF. Evaluation with BRIEF-A should thus be considered as an integral part of the clinical routine when dealing with assessment of patients with SUD. Assessment of EF may contribute to the scientific and clinical effort of understanding the cognitive and behavioral aspects of SUD, and could prove vital in tailoring SUD treatment programs, particularly considering the high dropout numbers at early treatment stages. However, it is well known that neurocognitive assessment services are scarce, costly, and generally unavailable to SUD patients. Hence, it is crucial to develop, evaluate, and apply testing procedures that could be made more readily available in busy clinical settings and that could also be administered by a broader array of professions. Our data indicate a promising potential for inventory-based EF assessment in SUD patients as measured by BRIEF-A. Self-report measures of EF can be valuable, cost-effective, and accurate at an initial clinical evaluation, providing important complementary measures to performance based tests.

Role of the funding source

Funded by Helse-Vest, Strategic Initiative for Substance Abuse Research.

Competing interests

The authors declare that they have no competing interests. We certify that there is no conflict of interest with any financial organization or nonfinancial competing interests regarding the material discussed in the manuscript.

Acknowledgments

EH initiated the project, wrote the manuscript and contributed to project design, analysis, and interpretation; AHE contributed to statistical analyses, interpretation and manuscript revision; KPH contributed with writing and revising the manuscript and interpretation of the analyses; SMN, JRM and AL contributed to revision of the manuscript; and EW contributed to manuscript revision and overall supervision of this research. All authors read and approved the final manuscript.

We thank the staff and clients of the participating clinical services, the KORFOR staff, and in particular Thomas Solgård Svendsen, Anne-Lill Mjølhus Njaa and Janne Aarstad, who collected all of the initial and follow-up participant data.

References

Aharonovich, E., Hasin, D. S., Brooks, A. C., Liu, X., Bisaga, A., & Nunes, E. V. (2006). Cognitive deficits predict low treatment retention in cocaine dependent patients. *Drug and Alcohol Dependence*, *81*, 313–322. http://dx.doi.org/10.1016/j.drugalcdep.2005.08.003 (S0376-8716(05)00251-6 [pii]).

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*, 71–82.

Anderson, S. W., Barrash, J., Bechara, A., & Tranel, D. (2006). Impairments of emotion and real-world complex behavior following childhood- or adult-onset damage to ventromedial prefrontal cortex. *Journal of the International Neuropsychological Society*, *12*, 224–235. http://dx.doi.org/10.1017/S1355617706060346 (S1355617706060346 [pii]).

Barry, D., & Petry, N. M. (2008). Predictors of decision-making on the Iowa Gambling Task: Independent effects of lifetime history of substance use disorders and performance on the Trail Making Test. *Brain and Cognition*, *66*, 243–252. http://dx.doi.org/10.1016/j.bandc.2007.09.001.

Bartzokis, G., Lu, P. H., Beckson, M., Rapoport, R., Grant, S., Wiseman, E. J., & London, E. D. (2000). Abstinence from cocaine reduces high-risk responses on a gambling task. *Neuropsychopharmacology: official publication of the American College of Neuropsychopharmacology*, *22*, 102–103. http://dx.doi.org/10.1016/S0893-133X(99)00077-9.

Bates, M. E., Bowden, S. C., & Barry, D. (2002). Neurocognitive impairment associated with alcohol use disorders: Implications for treatment. *Experimental and Clinical Psychopharmacology*, *10*, 193–212 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12233981, http://psycnet.apa.org/journals/pha/10/3/193.pdf).

Bates, M. E., Pawlak, A. P., Tonigan, J. S., & Buckman, J. F. (2006). Cognitive impairment influences drinking outcome by altering therapeutic mechanisms of change. *Psychology of Addictive Behaviors*, *20*, 241–253. http://dx.doi.org/10.1037/0893-164X.20.3.241 (2006-10832-003 [pii]).

Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nature Neuroscience*, *8*, 1458–1463. http://dx.doi.org/10.1038/nn1584.

Bechara, A., & Damasio, H. (2002). Decision-making and addiction (part I): Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia*, *40*, 1675–1689 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11992656, http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6T0D-427JW9G-6-6&_cdi=4860&_user=5373805&_pii=S0028393200001366&_origin=gateway&_coverDate=12%2F31%2F2001&_sk=999609995&view=c&wchp=dGLzVzb-zSkzS&md5=b37e433edd94a130836fd011d64d3968&ie=/sdarticle.pdf).

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15. http://dx.doi.org/10.1016/0010-0277(94)90018-3.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia*, *39*, 376–389 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11164876, http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6T0D-454FB6G-3-24&_cdi=4860&_user=5373805&_pii=S0028393202000155&_origin=gateway&_coverDate=12%2F31%2F2002&_sk=999599989&view=c&wchp=dGLbVzz-zSkWb&md5=89dc6397e52d2c8c26f6bc316398e2ba&ie=/sdarticle.pdf).

Blume, A. W., & Marlatt, G. A. (2009). The role of executive cognitive functions in changing substance use: What we know and what we need to know. *Annals of Behavioral Medicine*, *37*, 117–125. http://dx.doi.org/10.1007/s12160-009-9093-8.

Bohn, M. J., Babor, T. F., & Kranzler, H. R. (1995). The Alcohol Use Disorders Identification Test (AUDIT): Validation of a screening instrument for use in medical settings. *Journal of Studies on Alcohol*, *56*, 423–432 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7674678).

Brand, M., Recknor, E. C., Grabenhorst, F., & Bechara, A. (2007). Decisions under ambiguity and decisions under risk: correlations with executive functions and comparisons of two different gambling tasks with implicit and explicit rules.Journal of. *Clinical and Experimental Neuropsychology*, *29*(1), 86–99.

Burgess, P. W. (1997). Theory and methodology in executive function research. *Methodology of frontal and executive function* (pp. 81–116).

Burgess, P. W. (2000). Real-world multitasking from a cognitive neuroscience perspective. *Control of cognitive processes: Attention and performance XVIII* (pp. 465–472).

Canivez, G. L., Konold, T. R., Collins, J. M., & Wilson, G. (2009). Construct validity of the Wechsler Abbreviated Scale of Intelligence and Wide Range Intelligence Test: Convergent and structural validity. *School Psychology Quarterly*, *24*, 252.

Cardinal, R. N., Winstanley, C. A., Robbins, T. W., & Everitt, B. J. (2004). Limbic corticostriatal systems and delayed reinforcement. *Annals of the New York Academy of Sciences*, *1021*, 33–50. http://dx.doi.org/10.1196/annals.1308.0041021/1/33 (pii).

Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: Beyond executive dysfunction. *Trends in Cognitive Sciences*, *10*, 117–123. http://dx.doi.org/10.1016/j.tics.2006.01.011.

Chan, R. C. K., Shum, D., Toulopoulou, T., & Chen, E. Y. H. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology*, *23*, 201–216. http://dx.doi.org/10.1016/j.acn.2007.08.010.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*, 155 (Retrieved from http://psycnet.apa.org/journals/bul/112/1/155.pdf).

Copersino, M. L., Fals-Stewart, W., Fitzmaurice, G., Schretlen, D. J., Sokoloff, J., & Weiss, R. D. (2009). Rapid cognitive screening of patients with substance use disorders. *Experimental and Clinical Psychopharmacology*, *17*, 337–344. http://dx.doi.org/10.1037/a0017260.

Dolan, S. L., Bechara, A., & Nathan, P. E. (2008). Executive dysfunction as a risk marker for substance abuse: The role of impulsive personality traits. *Behavioral Sciences & the Law*, *26*, 799–822. http://dx.doi.org/10.1002/bsl.845.

Drivsholm, T., Eplov, L. F., Davidsen, M., Jørgensen, T., Ibsen, H., Hollnagel, H., & Borch-Johnsen, K. (2006). Representativeness in population-based studies: A detailed description of non-response in a Danish cohort study. *Scandinavian Journal of Public Health*, *34*, 623–631. http://dx.doi.org/10.1080/14034940600607616.

Dunn, B. D., Dalgleish, T., & Lawrence, A. D. (2006). The somatic marker hypothesis: A critical evaluation. *Neuroscience and Biobehavioral Reviews*, *30*, 239–271. http://dx.doi.org/10.1016/j.neubiorev.2005.07.001.

Egeland, J., & Fallmyr, O. (2010). Confirmatory Factor Analysis of the Behavior Rating Inventory of Executive Function (BRIEF): Support for a distinction between emotional and behavioral regulation. *Child Neuropsychology*, *16*, 326–337. http://dx.doi.org/10.1080/09297041003601462.

Fernandez-Serrano, M. J., Perez-Garcia, M., & Verdejo-Garcia, A. (2011). What are the specific vs. generalized effects of drugs of abuse on neuropsychological performance? *Neuroscience and Biobehavioral Reviews*, *35*, 377–406. http://dx.doi.org/10.1016/j.neubiorev.2010.04.008 (S0149-7634(10)00092-8 [pii]).

Gioia, G. A., Isquith, P. K., Retzlaff, P. D., & Espy, K. A. (2002). Confirmatory factor analysis of the Behavior Rating Inventory of Executive Function (BRIEF) in a clinical sample. *Child Neuropsychology*, *8*, 249–257. http://dx.doi.org/10.1076/chin.8.4.249.13513.

Golden, C. J., & Freshwater, S. M. (1978). *Stroop color and word test.*

Grant, S., Contoreggi, C., & London, E. D. (2000). Drug abusers show impaired performance in a laboratory test of decision making. *Neuropsychologia*, *38*, 1180–1187.

Grant, I., & Judd, L. L. (1976). Neuropsychological and EEG disturbances in polydrug users. *The American Journal of Psychiatry*, *133*, 1039–1042 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/961924).

Guthrie, A., & Elliott, W. A. (1980). The nature and reversibility of cerebral impairment in alcoholism; Treatment implications. *Journal of Studies on Alcohol*, *41*, 147–155 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7366209).

Hadjiefthyvoulou, F., Fisk, J. E., Montgomery, C., & Bridges, N. (2012). Self-reports of executive dysfunction in current ecstasy/polydrug users. *Cognitive and Behavioral Neurology*, *25*, 128–138.

Horner, M. D., Harvey, R. T., & Denier, C. A. (1999). Self-report and objective measures of cognitive deficit in patients entering substance abuse treatment. *Psychiatry Research*, *86*, 155–161 (S0165-1781(99)00031-1 [pii]).

Hunt, W. A., Barnett, L. W., & Branch, L. G. (1971). Relapse rates in addiction programs. *Journal of Clinical Psychology*, *27*, 455–456 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/5115648).

Isquith, P. K., Roth, R. M., & Gioia, G. (2013). Contribution of rating scales to the assessment of executive functions. *Applied Neuropsychology: Child*, *2*, 125–132.

Kerr, A., & Zelazo, P. D. (2004). Development of "hot" executive function: The children's gambling task. *Brain and Cognition*, *55*, 148–157 (Retrieved from http://ac.els-cdn.com.pva.uib.no/S0278262603002756/1-s2.0-S0278262603002756-main.pdf?_tid=f140711c-b7d6-11e2-89b0-00000aab0f02&acdnat=1368014637_e0f488068ecd72d3b55a9ed3f86efc71).

Kline, P. (2013a). *Handbook of psychological testing.* Routledge.

Kline, P. (2013b). *Intelligence: The psychometric view.* Routledge.

Knudsen, A. K., Hotopf, M., Skogen, J. C., Øverland, S., & Mykletun, A. (2010). The health status of nonparticipants in a population-based health study: The Hordaland Health Study. *American Journal of Epidemiology*. http://dx.doi.org/10.1093/aje/kwq257.

Korkeila, K., Suominen, S., Ahvenainen, J., Ojanlatva, A., Rautava, P., Helenius, H., & Koskenvuo, M. (2001). Non-response and related factors in a nation-wide health survey. *European Journal of Epidemiology*, *17*, 991–999. http://dx.doi.org/10.1023/A:1020016922473.

Kortte, K. B., Horner, M. D., & Windham, W. K. (2002). The trail making test, part B: Cognitive flexibility or ability to maintain set? *Applied Neuropsychology*, *9*, 106–109 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12214820).

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, *109*, 163.

McAuley, T., Chen, S., Goos, L., Schachar, R., & Crosbie, J. (2010). Is the behavior rating inventory of executive function more strongly associated with measures of impairment or executive function? *Journal of the International Neuropsychological Society*, *16*, 495–505.

McCandless, S., & O' Laughlin, L. (2007). The Clinical Utility of the Behavior Rating Inventory of Executive Function (BRIEF) in the diagnosis of ADHD. *Journal of Attention Disorders*, *10*, 381–389. http://dx.doi.org/10.1177/1087054706292115.

McKay, J. R., Alterman, A. I., Cacciola, J. S., Rutherford, M. J., O'Brien, C. P., & Koppenhaver, J. (1997). Group counseling versus individualized relapse prevention aftercare following intensive outpatient treatment for cocaine dependence: Initial results. *Journal of*

Consulting and Clinical Psychology, *65*, 778–788 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9337497).

McKay, J. R., Lynch, K. G., Shepard, D. S., Ratichek, S., Morrison, R., Koppenhaver, J., & Pettinati, H. M. (2004). The effectiveness of telephone-based continuing care in the clinical management of alcohol and cocaine use disorders: 12-month outcomes. *Journal of Consulting and Clinical Psychology*, *72*, 967–979. http://dx.doi.org/10.1037/0022-006X.72.6.967 (2004-21587-006 [pii]).

McNamee, R. L., Dunfee, K. L., Luna, B., Clark, D. B., Eddy, W. F., & Tarter, R. E. (2008). Brain activation, response inhibition, and increased risk for substance use disorder. *Alcoholism: Clinical and Experimental Research*, *32*, 405–413.

Miller, L. (1985). Neuropsychological assessment of substance abusers: Review and recommendations. *Journal of Substance Abuse Treatment*, *2*, 5–17 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3900432).

Möller, H. -J. (2009). Standardised rating scales in psychiatry: Methodological basis, their possibilities and limitations and descriptions of important rating scales. *The World Journal of Biological Psychiatry*, *10*, 6–26.

Moreno-López, L., Stamatakis, E. A., Fernández-Serrano, M. J., Gómez-Río, M., Rodríguez-Fernández, A., Pérez-García, M., & Verdejo-García, A. (2012). Neural correlates of hot and cold executive functions in polysubstance addiction: Association between neuropsychological performance and resting brain metabolism as measured by positron emission tomography. *Psychiatry Research: Neuroimaging*, *203*, 214–221.

Nigg, J. T., Blaskey, L. G., Huang-Pollock, C. L., & Rappley, M. D. (2002). Neuropsychological executive functions and DSM-IV ADHD subtypes. *Journal of the American Academy of Child and Adolescent Psychiatry*, *41*, 59–66. http://dx.doi.org/10.1097/00004583-200201000-00012 (S0890-8567(09)60589-X [pii]).

Nigg, J. T., Wong, M. M., Martel, M. M., Jester, J. M., Puttler, L. I., Glass, J. M., ... Zucker, R. A. (2006). Poor response inhibition as a predictor of problem drinking and illicit drug use in adolescents at risk for alcoholism and other substance use disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, *45*, 468–475. http://dx.doi.org/10.1097/01.chi.0000199028.76452.a9 (S0890-8567(09)62067-0 [pii]).

Oddy, M., Coughlan, T., Tyerman, A., & Jenkins, D. (1985). Social adjustment after closed head injury: A further follow-up seven years after injury. *Journal of Neurology, Neurosurgery & Psychiatry*, *48*, 564–568.

Paulus, M. P., Tapert, S. F., & Schuckit, M. A. (2005). Neural activation patterns of methamphetamine-dependent subjects during decision making predict relapse. *Archives of General Psychiatry*, *62*, 761–768. http://dx.doi.org/10.1001/archpsyc.62.7.761.

Peters, C., Algina, J., Smith, S. W., & Daunic, A. P. (2012). Factorial validity of the Behavior Rating Inventory of Executive Function (BRIEF)-Teacher form. *Child Neuropsychology*, *18*, 168–181. http://dx.doi.org/10.1080/09297049.2011.594427.

Rinn, W., Desai, N., Rosenblatt, H., & Gastfriend, D. R. (2002). Addiction denial and cognitive dysfunction: A preliminary investigation. *Journal of Neuropsychiatry and Clinical Neurosciences*, *14*, 52–57 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11884655).

Rogers, R. D., & Robbins, T. W. (2001). Investigating the neurocognitive deficits associated with chronic drug misuse. *Current Opinion in Neurobiology*, *11*, 250–257.

Roth, R. M., Isquith, P. K., & Gioia, G. A. (2005). *Behavior rating inventory of executive function-adult version (BRIEF-A)*. Lutz, FL: Psychological Assessment Resources.

Roth, R. M., Lance, C. E., Isquith, P. K., Fischer, A. S., & Giancola, P. R. (2013). Confirmatory factor analysis of the behavior rating inventory of executive function-adult version in healthy adults and application to attention-deficit/hyperactivity disorder. *Archives of Clinical Neuropsychology*, *28*, 425–434.

Schoenbaum, G., & Shaham, Y. (2008). The role of orbitofrontal cortex in drug addiction: A review of preclinical studies. *Biological Psychiatry*, *63*, 256–262. http://dx.doi.org/10.1016/j.biopsych.2007.06.003 (S0006-3223(07)00534-3 [pii]).

Séguin, J. R., Arseneault, L., & Tremblay, R. E. (2007). The contribution of "cool" and "hot" components of decision-making in adolescence: Implications for developmental psychopathology. *Cognitive Development*, *22*, 530–543. http://dx.doi.org/10.1016/j.cogdev.2007.08.006.

Seguin, J. R., & Zelazo, P. D. (2005). *Executive function in early physical aggression.*

Shahar, E., Folsom, A. R., Jackson, R., & The Atherosclerosis Risk in Communities Study, I (1996). The effect of nonresponse on prevalence estimates for a referent population: Insights from a population-based cohort study. *Annals of Epidemiology*, *6*, 498–506. http://dx.doi.org/10.1016/S1047-2797(96)00104-4.

Skogli, E. W., Egeland, J., Andersen, P. N., Hovik, K. T., & Øie, M. (2014). Few differences in hot and cold executive functions in children and adolescents with combined and inattentive subtypes of ADHD. *Child Neuropsychology*, *20*, 162–181.

Sonuga-Barke, E. J. S. (2003). The dual pathway model of AD/HD: An elaboration of neurodevelopmental characteristics. *Neuroscience and Biobehavioral Reviews*, *27*, 593–604. http://dx.doi.org/10.1016/j.neubiorev.2003.08.005.

Strauss, G. P., Allen, D. N., Jorgensen, M. L., & Cramer, S. L. (2005). Test-retest reliability of standard and emotional stroop tasks: An investigation of color-word and picture-word versions. *Assessment*, *12*, 330–337. http://dx.doi.org/10.1177/1073191105276375 (12/3/330 [pii]).

Stuss, D., Shallice, T., Alexander, M., & Picton, T. (1995). A multidisciplinary approach to anterior attentional functionsa. *Annals of the New York Academy of Sciences*, *769*, 191–212.

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry*, *54*, 131–143. http://dx.doi.org/10.1111/jcpp.12001.

Vaskinn, A., & Egeland, J. (2012). Testbruksundersøkelsen: En oversikt over tester brukt av norske psykologer. *Tidsskrift for Norsk Psykologforening*, *49*, 658–665.

Verdejo-Garcia, A., & Bechara, A. (2010). Neuropsychology of executive functions. *Psicothema*, *22*, 227–235 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20423626).

Verdejo-Garcia, A., Bechara, A., Recknor, E. C., & Perez-Garcia, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychological Society*, *12*, 405–415 (Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16903133, http://proquest.umi.com/pdf/d7cc42227789addc3572a2465fe90462/1299662874//share3/pqimage/pqirs103v/201103090357/53958/12023/out.pdf).

Vik, P. W., Cellucci, T., Jarchow, A., & Hedt, J. (2004). Cognitive impairment in substance abuse. *The Psychiatric Clinics of North America*, *27*, 97–109. http://dx.doi.org/10.1016/S0193-953X(03)00110-2 (S0193953X03001102 [pii]).

Voluse, A. C., Gioia, C. J., Sobell, L. C., Dum, M., Sobell, M. B., & Simco, E. R. (2012). Psychometric properties of the Drug Use Disorders Identification Test (DUDIT) with substance abusers in outpatient and residential treatment. *Addictive Behaviors*, *37*, 36–41. http://dx.doi.org/10.1016/j.addbeh.2011.07.030.

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. *Developmental Neuropsychology*, *29*, 459–477.

Yucel, M., Lubman, D. I., Solowij, N., & Brewer, W. J. (2007). Understanding drug addiction: A neuropsychological perspective. *The Australian and New Zealand Journal of Psychiatry*, *41*, 957–968. http://dx.doi.org/10.1080/00048670701689444 (784650017 [pii]).

Zelazo, P. D., & Müller, U. (2002). *Executive function in typical and atypical development.*