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Relationship of Age to Impulsivity and Decision-Making: A Baseline Secondary Analysis of a Behavioral Treatment Study in Stimulant Use Disorders

Raj K. Kalapatapu, MD[1,2], **Daniel F. Lewis, BA**[3], **Sophia Vinogradov, MD**[1,2], **Steven L. Batki, MD**[1,2], and **Theresa Winhusen, PhD**[3]

[1]Department of Psychiatry, University of California, San Francisco, CA, USA

[2]San Francisco Veterans Affairs Medical Center, San Francisco, CA USA

[3]Cincinnati Addiction Research Center, Department of Psychiatry and Behavioral Neuroscience, University of Cincinnati College of Medicine, OH, USA

Abstract

Since stimulant use disorders (SUDs) remain prevalent across the lifespan, cognition is an important area of clinical care and research focus among aging adults with SUDs. This secondary analysis of a National Institute on Drug Abuse Clinical Trials Network study suggests that decision-making, verbal learning/memory, executive function and set shifting are important cognitive domains to screen clinically and treat in aging adults with SUDs. Some suggestions are made on how clinical treatment providers can practically use these results. An important direction for future research is the development of cognitively remediating treatments for impaired cognitive domains in aging adults with SUDs.

Keywords

cocaine; methamphetamine; aging; addiction; neurocognitive

Introduction

Stimulant use disorders (SUDs) remain a prevalent public health problem across the lifespan[1–3]. One important research area in the treatment of SUDs is cognition[4–7], since cognitive changes are associated with clinical outcomes such as abstinence and treatment completion[8, 9]. The cognitive domains typically involved in SUDs include attention, memory, executive function[10–13], impulsivity[14, 15] and decision-making[16–18]. As SUDs affect individuals across the lifespan and as evidence shows that SUDs remain prevalent even as adults grow older[1, 19–22], knowledge of age-specific cognitive differences in individuals with SUDs might help inform the development of age-specific cognitive treatments.

Impulsivity and decision-making are important cognitive domains affected by aging[23–28]. Some literature shows that impulsivity and decision-making improve with increasing age,

Address correspondence to: Raj K. Kalapatapu, MD, San Francisco Veterans Affairs Medical Center, Building 8 (Mental Health), Ground Floor, Room 4C, 4150 Clement Street, San Francisco, CA 94121. kalapatapu.raj.k@gmail.com, Phone: 415-221-4810 ext. 3075, Fax: 415-750-2187.

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such as in the context of borderline personality disorder[29, 30]. Other literature shows poorer impulsivity and decision-making with increasing age[24, 27]. Because of brain abnormalities in a middle-aged adult with a SUD that are not typically found in a healthy middle-aged adult[31, 32], changes in cognitive domains in a middle-aged adult with a SUD may be greater than the changes in cognitive domains expected in a healthy middle-aged adult. Thus, additional literature on the interaction between age and impulsivity and between age and decision-making might help develop age-specific treatments targeting these important domains in individuals with SUDs.

There is limited research exploring the relationship between age and the domains of attention, memory, and executive function[20, 33] in SUDs. However, there is even more limited research on the relationship between age and impulsivity and between age and decision-making in SUDs. One study of pathological gamblers, a classic disorder of impulsivity, found 18.2% of the males and 14.8% of the females in the older sub-group to report ever using cocaine[34]. In another study of participants who reported using methamphetamine at least twice in the past 2 months, participants in the high impulsivity group were younger than those in the low impulsivity group[35].

A recently published behavioral treatment study ($n = 183$) of individuals with SUDs, which included a baseline neurocognitive battery containing impulsivity and decision-making measures[36], can help add to the literature on the relationship between age and impulsivity and between age and decision-making in SUDs. Exploring this relationship can help theoretically understand how the aging process, in the context of concurrent SUDs, affects the underlying brain regions responsible for complex cognitive domains like impulsivity and decision-making (e.g., orbitofrontal cortex, anterior cingulate cortex)[18, 37]. Exploring this relationship can also help clinically develop cognitively remediating treatments (pharmacological and/or non-pharmacological) specific to affected cognitive domains[4, 6, 7] in aging adults with SUDs. Thus, the aim of this secondary analysis was to assess the association of age on baseline measures of impulsivity and decision-making, among other neurocognitive measures. We hypothesized that increasing age would be associated with greater impulsivity and poorer decision-making.

Methods

Study Setting and Measures

Full details of the parent study [38] and the ancillary study [36] used for this analysis are described elsewhere. Briefly, the National Institute on Drug Abuse Clinical Trials Network (NIDA CTN) ancillary study enrolled 183 adult participants from 6 substance abuse community treatment programs nationwide. Participants had a current diagnosis of stimulant abuse or dependence based on the DSM-IV Checklist[39], endorsed methamphetamine or cocaine as their primary drug of choice, were seeking outpatient substance use disorder treatment, used stimulants in the prior 60 days, and were medically and psychiatrically stable enough for participation based on medical history and the Addiction Severity Index-Lite interview[40]. Participants were randomized to Stimulant Abuser Groups to Engage in 12-Step (STAGE-12)[38] or treatment as usual (TAU). All participants provided informed consent, and the study was approved by the Institutional Review Boards of the participating sites.

Demographic variables included age, sex, race, ethncity, education, marital status, and employment status. Substance use variables included substance use disorder diagnosis, age of onset of illicit stimulant use, years of illicit stimulant use, years of non-stimulant use, and route of illicit stimulant use. The Patient Health Questionnaire [PHQ[41]] was used to assess for depression, panic, and non-panic anxiety disorders.

The baseline neurocognitive measures assessed: impulsivity and decision-making [Barratt Impulsiveness Scale version-11 (BIS-11), Frontal Systems Behavioral Scale (FrSBe), Comalli-Kaplan version of the Stroop Color Word Task (C-K Stroop), Iowa Gambling Task (IGT)], verbal learning/memory [Rey Auditory Verbal Learning Test (RAVLT)], executive function and set shifting [Wisconsin Card Sorting Task (WCST)].

The self-report BIS-11 is designed to assess the personality/behavioral construct of impulsiveness in three sub-domains: attention, motor, non-planning[42]. A total score and a score for each sub-domain were calculated; higher scores indicate greater impulsiveness. The self-report version of the FrSBe is a brief, valid, and reliable assessment of three areas of functioning associated with the pre-frontal cortex: apathy, disinhibition, and executive dysfunction[43]. An overall T-score and a T-score for each area of functioning were calculated; higher scores indicate poorer functioning. The C-K Stroop is an experimenter-administered measure that assesses impulsivity and response inhibition[44, 45]. Interference errors, Interference time (in seconds), and a Derived Interference score (Interference minus color naming) were calculated; higher scores indicate poorer performance.

The IGT is a computerized gambling exercise that simulates real-life decision making via selection of 100 cards from four decks in 5 trial blocks[46]. A Net Total T-score reflects a summary score, and each Net 1–5 T-score reflects a block of 20 cards; higher scores indicate the participant is more often choosing advantageous decks. Selection of cards 1–40 may be categorized as decision-making under ambiguity, and selection of cards 41–100 may be categorized as decision-making under risk[47, 48].

The RAVLT is an experimenter-administered measure of verbal learning and memory[49]. Scores for Learning (sum of Trials I to V of List A), Trial B (free recall of Interference list B), and Trial VI (free recall of List A after Interference List B) were calculated; higher scores indicate better performance. The WCST is a computerized test of executive function and set shifting[50]. T-scores for perseverative, nonperseverative and total errors, as well as perseverative responses, were calculated; higher scores indicate better performance.

Statistical Analysis

Descriptive statistics were conducted on the demographic, clinical and neurocognitive data. The Spearman's rho, a non-parametric test, assessed correlation between age and each neurocognitive measure. We analyzed all overall and sub-domain scores from all neurocognitive measures, because age can potentially affect various cognitive domains[51–53]. After controlling for sex, years of education, race (Caucasian or African-American), ethnicity (Hispanic or Non-Hispanic), years of illicit stimulant use, route of illicit stimulant use, and substance use disorder diagnosis as indicated by the Corrected Akaike Information Criteria (AIC-C)[54, 55], the Wald statistic assessed the contribution of age in each regression analysis. We controlled for sex, as hormonal factors may mediate sex differences in impulsivity[56]. We also controlled for other demographic features (years of education, race, ethnicity), since such factors can influence performance on neurocognitive measures[57]. Since this was an exploratory secondary analysis, p-values < 0.05 were considered significant. All analyses were conducted using SAS version 9.3 (Cary, NC).

Results

Table 1 presents baseline demographic and clinical data. Table 2 presents baseline neurocognitive data, and Table 3 presents the contribution of age to the neurocognitive data. The age range of the sample was 19–60, primarily being late 30's. Most participants were female, high school educated, unmarried, and unemployed. Most participants had a primary cocaine use disorder diagnosis and used smoking as their primary route of illicit stimulant use. Most participants also had a secondary alcohol use disorder diagnosis and smoked cigarettes. The mean values for the neurocognitive data in Table 2 are consistent with previous research (see Discussion).

BIS-11

Age was not significantly associated with any of the BIS-11 scores.

FrSBe

Age positively correlated with and was significantly associated with the current Executive dysfunction T-score ($\rho = 0.30$, $p = 0.03$) and the current Total T-score ($\rho = 0.27$, $p = 0.02$). Age was not significantly associated with the other FrSBe scores.

C-K Stroop

Age was not significantly associated with any of the C-K Stroop scores.

IGT

Age negatively correlated with and was significantly associated with the Net 1 T-score ($\rho = -0.23$, $p = 0.01$), and positively correlated with and was significantly associated with the Net 4 T-score ($\rho = 0.15$, $p = 0.04$) and Net 5 T-score ($\rho = 0.16$, $p = 0.049$). Age was not significantly associated with the other IGT scores.

RAVLT

Age negatively correlated with and was significantly associated with Trial VI ($\rho = -0.35$, $p = 0.01$) and Learning ($\rho = -0.33$, $p = 0.01$). Age was not significantly associated with Trial B.

WCST

Age negatively correlated with and was significantly associated with Perseverative errors T-score ($\rho = -0.37$, $p = 0.003$), Nonperseverative errors T-score ($\rho = -0.44$, $p = 0.0002$), Total errors T-score ($\rho = -0.42$, $p = 0.001$), and Perseverative responses T-score ($\rho = -0.38$, $p = 0.003$).

Discussion

The present analysis evaluated the association of age with impulsivity, decision-making, and other neurocognitive measures in cocaine- and/or methamphetamine-dependent patients. The results revealed that age was significantly associated with some of the scores on the FrSBe (positive correlation with executive dysfunction and total), IGT (Net 1 negative correlation, Net 4 and Net 5 positive correlation), and RAVLT (negative correlation with Trial VI and Learning). Age negatively correlated with and was significantly associated with all of the WCST scores. Age was not significantly associated with any of the BIS-11 and C-K Stroop scores. Thus, our hypotheses were partially supported.

Impulsivity and decision-making are complex cognitive domains that are not unidimensional[42, 58]. The neurocognitive battery used in this study measured these domains using four different measures (BIS-11, FrSBe, C-K Stroop, IGT), and the significant association with age to only some scores may be due to specific sub-domains or underlying neural pathways tapped by these measures. Also, in the presence of SUDs, the aging process may be differentially affecting brain regions, such as the orbitofrontal cortex and the anterior cingulate cortex, which might explain the significant association with age to only some scores; such brain regions are vulnerable to the aging process[59, 60]. However, since no

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neuroimaging was conducted in this study, it is hard to speculate too much about what underlying neural correlates explain the results. It is also important to note that the range of mean/S.D. values for each neurocognitive measure (Table 2) are similar to the range of mean/S.D. values found in previous research in those with SUDs and/or are worse than controls: BIS-11[61, 62], FrSBe[36, 63], C-K Stroop[44], IGT[64], RAVLT[65, 66], and WCST[67].

Studies comparing older and younger adults on the IGT have found conflicting results[68]. Our finding of age not correlating with the overall score is consistent with literature in healthy aging adults[69]. Our mixed findings on the Net 1 score versus the Net 4 and Net 5 scores may be reflecting the complex relationship between age and SUDs interacting with a change in learning and decision-making while completing the IGT[70, 71]. However, other literature has found differences of aging affecting decisions under ambiguity but not decisions under risk[72]. A future four-group study (older adults with SUDs, younger adults with SUDs, healthy older adults, healthy younger adults) using the IGT can help tease out this complex relationship.

The finding of age positively correlating with executive dysfunction on the FrSBe may be related to a loss of white matter structural integrity in the prefrontal cortex, which is found in both aging[73] and SUDs[74, 75]. We were surprised to find age not correlating with any of the BIS-11 scores, as age and SUDs can affect the three sub-domains captured by the BIS-11. But, this finding is consistent with previous research on the BIS-11[42]. We were also surprised to find age not correlating with any of the C-K Stroop scores, but the sample's age range may not have been large enough to see age-related differences on this measure. The domains tapped by the RAVLT and WCST are consistent with both aging literature[51–53], where verbal learning/memory and executive function are affected by aging.

This analysis has several strengths. First, we had a fairly large sample size for this analysis, as we benefited from data collected from 6 substance abuse community treatment programs nationwide. Second, the non-pure sample of participants allows these findings to be generalized to clinical samples, where participants don't necessarily use one substance alone. Third, we were able to analyze four different measures of impulsivity and decision-making. Fourth, we controlled for sex, years of education, race, and ethnicity as indicated by the AIC-C, especially after a recent review[76] warned about appropriate interpretations when examining neurocognitive data in SUDs. Finally, since age and years of substance use can be naturally positively associated and since years of illicit stimulant use can significantly affect cognition[6, 7], we controlled for years of illicit stimulant use as indicated by the AIC-C in each regression analysis. As we still found significant results even after controlling for chronicity of illicit stimulant use, this further supports our position that a unique aging effect may be explaining these results over and above what is cognitively expected from chronicity of illicit stimulant use alone.

This analysis also has several limitations. First, the primary study was not specifically designed to assess the aims of this *post-hoc* analysis. Second, the amount of illicit stimulant use was not quantified in grams or dollar-value, which may have interacted with age to affect cognition. Third, the age span may not have been enough to see further age-related cognitive differences, since there were no individuals above age 60 in the sample. Fourth, a comprehensive neurocognitive battery was not conducted, which might also include an assessment of premorbid intelligence, attention, processing speed, and attentional bias. These untested cognitive domains may have been impaired and unknowingly influenced the tested cognitive domains. Finally, since this sample does not consist of participants with pure SUDs, the comorbid substance abuse and depressive/anxiety disorders (Table 2) may have contributed to inconsistent findings across impulsivity and decision-making.

Clinical treatment providers might consider practically using these results in a few ways when clinically managing an aging adult with an SUD. First, a neurocognitive assessment might be considered as a standard at an initial visit and at periodic follow-up visits (e.g., every 1 or 2 years). Previous research shows that even recognizing and screening for cognitive impairment in addiction populations is poor overall[77–81]. Next, providers may consider adding adjunctive treatments in a patient's treatment plan to directly remediate the impaired cognitive domains (e.g., decision-making, executive function). Examples of adjunctive cognitively remediating treatments that have shown efficacy in addiction and other populations include pharmacological interventions[4–7] (e.g., cholinesterase inhibitors, nicotinic agonists) and non-pharmacological interventions[82–87] (e.g., computerized software, physical exercise). Finally, by capitalizing on unimpaired cognitive domains, treatment providers may modify their treatment approach to compensate for impaired cognitive domains. For example, instead of totally relying on verbal modalities, a provider may also consider using a visual modality (e.g., pictures, white board, computer screen) to convey information and compensate for a patient's impairment in verbal learning/memory. Such compensatory cognitive techniques have shown efficacy in other medical[88–90] and psychiatric[91–94] populations.

Conclusions

This analysis suggests that decision-making, verbal learning/memory, executive function and set shifting are important cognitive domains to screen clinically and potentially treat in adults with SUDs who continue to abuse stimulants as they grow older. Future directions include potentially conducting pre/post neuroimaging of frontal cortical regions in aging adults with SUDs, correlating neuroimaging findings with neurocognitive measures in aging adults with SUDs, and developing cognitively remediating treatments (pharmacological and/or non-pharmacological) specific to affected cognitive domains (e.g., decision-making, verbal learning/memory, executive function, set shifting) in aging adults with SUDs.

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Table 1

Baseline demographic and clinical data.

Demographic & Clinical Data (*n* = 183)		Mean (S.D.) or %
Age		38.6 (9.3), range 19 – 60, median 38.4
Age group 19–30		*n* = 47
Age group 31–40		*n* = 58
Age group 41–50		*n* = 66
Age group 51–60		*n* = 12
Male		31.7%
Race[a]	Caucasian	43.4%
	African-American	46.2%
	Other/Mixed	10.4%
Hispanic		5.5%[b]
Years of Education		12.0 (1.6)
Currently married		22.7%[c]
Employed in last 30 days		23%
Age of 1st illicit stimulant use		20.8 (6.1)
Years of illicit stimulant use		12.2 (7.6)
Years of non-stimulant use		14.8 (10.5)
Smoking as primary route of illicit stimulant use		72.4%[c]
Stimulant use disorder diagnosis[b]	Methamphetamine	25.8%
	Cocaine	68.7%
	Both	5.5%
Secondary substance use disorder diagnosis	Alcohol	60.7%
	Marijuana	38.3%
	Opiate	18%
	Benzodiazepine	8.2%
Currently smoking cigarettes		79.2%
PHQ[d] Depression		27.3%[e]

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Demographic & Clinical Data (*n* = 183)	**Mean (S.D.) or %**
PHQ Panic disorder	17.8%[f]
PHQ Non-panic anxiety disorder	17.2%[f]

[a] *n* = 182 due to missing data

[b] *n* = 182 due to missing data

[c] *n* = 181 due to missing data

[d] PHQ = Patient Health Questionnaire

[e] *n* = 176 due to missing data

[f] *n* = 180 due to missing data

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Table 2

Baseline neurocognitive data.

Neurocognitive measure (n = 183)		Mean (S.D.)
BIS-11	Attention impulsiveness total score	17.7 (3.5)
	Motor impulsiveness total score	25.2 (4.3)
	Non-planning impulsiveness total score	24.5 (4.6)
	Total score	67.4 (8.9)
FrSBe	Current – Apathy T-score	76.9 (12.9)
	Current – Disinhibition T-score	77.5 (17.5)
	Current – Executive dysfunction T-score	73.0 (13.7)
	Current – Total T-score	79.4 (15.7)
C-K Stroop	Interference errors	1.9 (3.8)
	Interference time	118.5 (27.4)
	Derived interference score	54.0 (22.4)
IGT	Net Total T-score	45.0 (9.6)
	Net 1 T-score	52.9 (11.5)
	Net 2 T-score	47.6 (9.7)
	Net 3 T-score	44.5 (11.4)
	Net 4 T-score	43.4 (11.6)
	Net 5 T-score	42.7 (12.5)
RAVLT	Learning	45.1 (9.6)
	Trial B	5.2 (1.6)
	Trial VI	8.7 (3.0)
WCST	Perseverative errors T-score	47.2 (13.7)
	Nonperseverative errors T-score	42.3 (12.1)
	Total errors T-score	43.5 (12.7)
	Perseverative responses T-score	48.2 (14.4)

Table 3

Baseline adjusted neurocognitive data[a] – association with age.

Neurocognitive measure		Parameter estimate with 95% confidence interval	Type III Wald Chi-Square[b]	*p*-value	Spearman's rho[c]
BIS-11	Attention impulsiveness total score	0.04 (−0.03, 0.12)	1.14	0.28	−0.17
	Motor impulsiveness total score	−0.07 (−0.15, −0.006)	3.33	0.07	−0.24
	Non-planning impulsiveness total score	0.03 (−0.05, −0.12)	0.65	0.42	−0.01
	Total score	−0.07 (−0.24, 0.10)	0.63	0.43	−0.17
FrSBe	Current – Apathy T-score	0.22 (−0.04, 0.48)	2.75	0.10	0.20
	Current – Disinhibition T-score	0.27 (−0.10, 0.65)	2.10	0.15	0.03
	Current – Executive dysfunction T-score	0.28 (0.02, 0.54)	4.56	0.03	0.30
	Current – Total T-score	0.37 (0.05, 0.68)	5.28	0.02	0.27
C-K Stroop	Interference errors	0.05 (−0.01, 0.11)	2.36	0.12	0.21
	Interference time	0.41 (−0.21, 1.03)	1.71	0.19	0.25
	Derived interference score	0.19 (−0.33, 0.71)	0.52	0.47	0.20
IGT	Net Total T-score	0.14 (−0.06, 0.34)	1.88	0.17	0.06
	Net 1 T-score	−0.29 (−0.52, −0.07)	6.57	0.01	−0.23
	Net 2 T-score	0.09 (−0.10, 0.29)	0.88	0.35	0.03
	Net 3 T-score	0.12 (−0.12, 0.35)	0.99	0.32	0.06
	Net 4 T-score	0.24 (0.01, 0.48)	4.20	0.04	0.15
	Net 5 T-score	0.25 (−0.002, 0.49)	3.85	0.049	0.16
RAVLT	Learning	−0.22 (−0.39, −0.05)	6.66	0.01	−0.33
	Trial B	0.004 (−0.02, 0.03)	0.10	0.75	−0.13
	Trial VI	−0.08 (−0.14, −0.02)	6.40	0.01	−0.35
WCST	Perseverative errors T-score	−0.43 (−0.71, −0.15)	8.99	0.003	−0.37
	Nonperseverative errors T-score	−0.49 (−0.75, −0.23)	13.79	0.0002	−0.44
	Total errors T-score	−0.46 (−0.73, −0.18)	10.83	0.001	−0.42
	Perseverative responses T-score	−0.45 (−0.75, −0.15)	8.90	0.003	−0.38

[a]Controlling for sex, years of education, race (Caucasian or African-American), ethnicity (Hispanic or Non-Hispanic), years of illicit stimulant use, route of illicit stimulant use, and substance use disorder diagnosis as indicated by the Corrected Akaike Information Criteria.

[b]Degrees of freedom for all results = 1

[c]Correlation between age and the respective neurocognitive measure. Calculated independent of regression.