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Journal

AIDS and Behavior, 27(8)

ISSN

1090-7165

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Publication Date

2023-08-01

DOI

10.1007/s10461-023-03987-4

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AIDS and Behavior
https://doi.org/10.1007/s10461-023-03987-4

ORIGINAL PAPER

A Pilot Assessment of the Effects of HIV and Methamphetamine Dependence on Socially Dysregulated Behavior in the Human Behavioral Pattern Monitor

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Accepted: 9 January 2023
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Abstract

Deficits in social cognition are seen in both people living with HIV (PWH) and people with a history of methamphetamine (METH) dependence. Dually affected individuals may experience additive negative effects on social cognition due to these conditions. We evaluated social cognition in 4 diagnostic groups (HIV−/METH−, HIV−/METH+, HIV+/METH−, HIV+/METH+). First, we used traditional social-emotional functioning assessments, the Difficulties in Emotion Regulation Scale and the Faux Pas Task, to determine any significant effects of METH dependence and HIV on social cognition. Next, we quantified social cognition using the Human Behavioral Pattern Monitor by evaluating social behavior represented by interaction with novel objects. METH dependence significantly affected social-emotional functions and HIV significantly affected on object interactions, however no significant additive effects were observed using these methods. The nuanced relationship between HIV and METH dependence suggests that other factors (i.e., adaptive life skills) likely mediate social cognition-related behaviors.

Keywords HIV · Methamphetamine dependence · Social cognition · Emotion regulation

Resumen

Los déficits en la cognición social se observan tanto en las personas que viven con el VIH (PWH) como en las personas con antecedentes de dependencia de la metanfetamina (METH). Las personas con ambas condiciones pueden experimentar efectos negativos aditivos en la cognición social. Evaluamos la cognición social en 4 grupos de diagnóstico (VIH−/METH−, VIH−/METH+, VIH+/METH−, VIH+/METH+). En primer lugar, utilizamos evaluaciones tradicionales del funcionamiento socioemocional, la Escala de Dificultades en la Regulación Emocional y la Prueba de Faux Pas, para determinar efecto significativo debido a la dependencia de METH y el VIH en la cognición social. Entonces, cuantificamos la cognición social utilizando el Monitor de Patrones de comportamiento humano mediante la evaluación del comportamiento social representado por la interacción con objetos novedosos. La dependencia de METH afectó significativamente las funciones socioemocionales y el VIH afectó significativamente las interacciones con los objetos, sin embargo, no se observaron efectos aditivos significativos al usar estos métodos. La relación compleja entre el VIH y la dependencia de METH sugiere que otros factores (i.e., habilidades adaptativas) probablemente regulan los comportamientos relacionados con la cognición social.

Introduction

In 2019, 1.2 million adults in the United States were estimated to be infected with HIV [1] and 1.6 million adults in the United States reported a methamphetamine (METH) dependence in 2020 [2]. The comorbidity rate of HIV infection and METH dependence is unclear, however only 0.6% of the general population report injection drug use, such as METH, yet 10% of all HIV diagnoses occurs among this subset population that

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Published online: 04 February 2023

participate in injection drug use; thus there is considerable overlap between the two populations [3]. Risky behaviors, such as injection drug use and risky sexual practices, confer increased risks for HIV transmission and METH dependence, thus partially explaining the high prevalence of co-morbid HIV infection and METH dependence [4]. However, both HIV infection and METH dependence are also associated with cognitive deficits which could worsen risky-decision making [5–11]. Thus, it is possible that each condition may contribute to cognitive impairments that increase an individual's tendency towards engaging in other risky behaviors. Furthermore, the co-occurrence of these conditions may result in additive negative impacts on cognition.

Recent literature suggests that in addition to neurocognitive impairment, both people with HIV (PWH) and people with a history of METH dependence (PWMD) have difficulties in social-emotional functioning, including emotion regulation and social cognition [12, 13]. Social cognition is defined as the distinct set of processes through which individuals regulate social interactions [14]. These processes are largely regulated through emotional and cognitive functions. On the emotional side, individuals must be capable of regulating and identifying their own emotions, as well as identifying the emotions of others. On the cognitive side, individuals must have the capacity to not only recognize and identify emotions, but to take the perspective of another person in order to fully understand that person's beliefs, motivations, and actions during a social interaction, which is an ability known as cognitive theory of mind (TOM). Both HIV and METH dependence have been associated with poorer cognitive TOM [12, 15–17].

Since deficits in emotion regulation and cognitive TOM are shared by PWH and PWMD, these domains may be disproportionately affected by both risk factors. Given that social-emotional functioning is essential for the inhibition of inappropriate social behaviors, we hypothesize that emotion dysregulation and poor cognitive TOM may contribute to, or in-part underlie, risk-taking and impulsive behavior observed in PWH and PWMD. In this pilot study, we aim to (1) assess social cognition using a novel experimental method by quantifying interactions with novel objects, in particular "personal objects" (items that clearly belong to someone else), in the human Behavioral Pattern Monitor (hBPM); (2) assess emotion regulation and cognitive TOM using traditional social cognition assessments and (3) test for correlation of these measures with object interactions in the hBPM.

Method

Participants

Participants were drawn from the Translational Methamphetamine AIDS Research Center (TMARC). TMARC is a research program dedicated to investigating the effects of HIV and METH on neurocognition. The University of California San Diego Human Research Protections Program approved of this study. A retrospective analysis was conducted using data from a subset of this sample (n = 135) for which hBPM and social cognition data were available. Participants were stratified into one of four groups: HIV−/METH−, HIV−/METH+, HIV+/METH− and HIV+/METH+. Exclusion and inclusion criteria have been described in full in previous publications and are described in brief here as well [18, 19].

In order to meet inclusion criteria for METH+ groups, potential participants were screened for a history of METH use disorder via the DSM-IV criteria for METH abuse and dependence as assessed by the Composite International Diagnostic Interview Version 2.1. Participants who met lifetime METH dependence and METH abuse or dependence within the past 18 months were included in the study. Potential participants were excluded if they reported histories of psychosis or significant medical conditions, such as hepatitis C infection, or neurological conditions, such as seizure, stroke, or multiple sclerosis, that are known to affect cognitive functions. Participants were also excluded if they met diagnostic criteria for current abuse or dependence on alcohol or any illicit drugs. For HIV+ participants, status was confirmed by enzyme-linked immunosorbent assay (ELISA) and a confirmatory Western blot.

Human Behavioral Pattern Monitor

Prior to entering the hBPM, participants are fitted with an Equivital Life Monitoring Sensory System (Hidalgo, 2010) which is used to track acceleration. Participants are then placed in the hBPM and video recorded for 15 min, without direction except to wait for the experimenter to return. During the informed consent process, participants are informed that they may be videotaped during the experimental process, however they are not informed prior to entry into the hBPM.

The hBPM has been described previously [20–24]. The hBPM is a rectangular room meant to appear "in transition" containing several filing cabinets, two bookcases, a corkboard and desks, but no chairs; therefore, individuals within the room are encouraged move about the room, as opposed to remaining seated. A number of objects are placed throughout the room. Some objects, termed "impersonal objects", are meant to invite exploration (i.e., office toys, artwork), whereas other objects, termed "personal objects", clearly belong to someone else (i.e., a cell phone, personal calendars, prescription medicine bottles, items of clothing). Interacting with personal objects or spending an increased amount of time with personal objects would be a violation of social norms, thus interactions with personal objects

are proposed to represent inappropriate social behavior. Social cognition is quantified by the number of personal object interactions and time spent interacting with personal objects in seconds. Increased personal object interactions and increased time spent with personal objects putatively indicate impaired social cognition.

Videos are analyzed frame by frame using Vivosense^{Tm} PC-based software, as well as by trained scorers blinded to the diagnostic group of the participants. Object interactions are scored based on physical interaction with a given object (i.e., with hand or foot).

Difficulties in Emotion Regulation Scale (DERS)

The DERS is a self-report measure of domains of emotion regulation difficulties [25]. The six subscales of the DERS used in this study included the following: (1) Lack of Emotional Awareness (AWARENESS), (2) Lack of Emotional Clarity (CLARITY), (3) Impulse Control Difficulties (IMPULSE), (4) Difficulties in Engaging in Goal-Directed Behavior (GOALS), (5) Nonacceptance of Emotional Responses (NONACCEPTANCE) and (6) Limited Access to Emotion Regulation Strategies (STRATEGIES). DERS total score is also reported as an overall measure of emotional dysregulation. Higher DERS scores indicate greater emotion dysregulation.

Faux pas Task (FP) and Control Stories

The FP is an index of cognitive theory of mind [26]. In this task, 20 brief stories are read by the participant, half of which are test stories and half are control stories. The test stories contain an element in which a character commits a faux pas, typically by saying something inappropriate. Participants are asked if someone "said something they shouldn't have said, or something awkward?", then asked to explain why the identified statement was socially problematic. Lower scores in the FP indicate diminished accuracy at identifying faux pas and thus reduced cognitive theory of mind.

Statistical Analyses

For group analysis of hBPM, DERS scores and FP scores were conducted using the Kruskall-Wallis nonparametric test [27], followed by post-hoc analyses using pairwise Wilcoxon tests (W) to determine group differences. Spearman's rho correlation coefficients (r_s) were used to test for correlation between the social cognition battery measures (DERS and FP) and all hBPM object interaction measures. Significant correlation values were set at a higher threshold ($p < 0.025$) to account for multiple comparisons.

Results

Demographic Information and Group Differences

Table 1 includes demographic information for each participant group, as well as HIV and METH dependence characteristics. There was no significant association of HIV or METH with age or education. There were also significantly fewer women in the HIV+ groups, however this gender ratio is consistent with the gender distribution of PWH in California [28].

Decreased Interactions with Objects in HIV+ Individuals

HIV+/METH+ participants had significantly lower object interactions compared to the HIV−/METH+ group ($W = 494$; $p < 0.05$) and the HIV−/METH− group ($W = 838.5$; $p < 0.05$; Fig. 1A). This effect appeared to be driven by a decrease in the number of impersonal object interactions in HIV+ groups, however this did not reach significance (Fig. 1B). Time spent with objects was also significantly lower in HIV+/METH+ participants compared to HIV−/METH− ($W = 870$; $p < 0.05$) and HIV−/METH+ ($W = 492$; $p < 0.05$) participants. There were no significant group differences in time spent with personal or impersonal objects. Means and standard deviations for object interactions by HIV and METH dependence status can be found in Table 2.

Impaired Social Cognition in METH+ Individuals

Means and standard deviations of social cognition battery scores can be found in Table 3. There were significant group differences in all DERS subscales and total DERS score. METH+ groups reported significantly higher IMPULSE scores compared to METH− groups (Fig. 2). HIV+/METH+ participants scored significantly higher than HIV−/METH− participants in all DERS subscales. HIV−/METH+ participants also scored significantly higher than HIV−/METH+ participants in all DERS subscales except S1 NONACCEPTANCE. HIV+/METH+ participants also scored significantly higher than HIV+/METH− participants in all subscales except S5 STRATEGIES subscale. Interestingly, there were no significant differences in DERS score between the HIV−/METH+ and HIV+/METH+ participants (Table 3).

HIV−/METH− participants had significantly higher FP scores than all other groups (HIV−/METH+, HIV+/

Table 1 Participant demographic information

	HIV−/METH− (n = 51; A)	HIV−/METH+ (n = 15; B)	HIV+/METH− (n = 41; C)	HIV+/METH+ (n = 28; D)	Group differences
Age	47.42(17.10)	45.80(13.71)	49.63(14.29)	39.89(7.33)	D < A C
Gender (%Male)	53%	53%	93%	96%	A B < C D
Education (years)	15.28(2.03)	12.93(3.19)	14.58(2.37)	13.64(2.08)	A > B D
Ethnicity (n)					ns
White	31	9	23	14	
Black	7	2	8	1	
Hispanic	10	3	7	11	
Asian	2	0	0	1	
Other	1	1	3	1	
Methamphetamine characteristics					
Current Meth use	–	5	–	6	ns
Ever used Meth	3	15	4	28	D > C > A B
Age at first use	28.67 (7.09)	25.50 (11.92)	28.00 (8.72)	24.67 (6.72)	ns
Total days	342 (300)	3831 (2591)	227 (227)	2320 (1791)	A C < B D
Total quantity (g)	1163 (1005)	4717 (6056)	117 (183)	2815 (3209)	D > C
HIV characteristics					
Duration of HIV infection (years)[a]	–	–	16.5 (4.9–22.3)	6.5 (2.4–11.8)	C > D
Currently on ART	–	–	38	28	C > D
Plasma viral load[a]	–	–	0(0–35)	20.00(0–77.8)	D > C
% undetectable			92.5%	69.2%	C > D

Unless otherwise noted, values are presented as the mean (standard deviation)

ns not significant

[a]Median (Interquartile Range)

METH− and HIV+/METH+). There were no significant differences between groups on the control stories (Table 3).

Significant Correlations Between Object Interactions in the hBPM and Social Cognition Measures

Correlations between the social cognition assessments and object interactions were calculated by diagnostic group (Tables 4, 5, 6, 7). Object interactions significantly correlated with the traditional social cognition assessment scores in the HIV−/METH+ group and the HIV+/METH− groups (Fig. 3A and B). In the HIV−/METH+ group, all hBPM measures were significantly correlated with IMPULSE scores, with the exception of "time spent with impersonal objects" ($r_s = 0.516$; $p = 0.059$). There was also a significant negative correlation between FP score and time spent with objects in HIV+/METH− participants. Negative correlations were also found between FP score and total object interactions ($r_s = -0.302$; $p = 0.055$), personal object interactions ($r_s = -0.30$; $p = 0.056$) and time spent with personal objects ($r_s = -0.323$; $p = 0.042$), however these values did not reach the significance threshold used in our analyses. There were no significant correlations between any of the social cognition assessments and hBPM measures in the HIV−/METH− or HIV+/METH+ groups.

Discussion

Social-emotional functioning, such as emotion regulation and cognitive TOM, are domains critical for everyday functioning, and deficits in these domains likely increases risk for HIV transmission due to a greater likelihood of engaging in risky behaviors. PWH and those with METH dependence independently demonstrate significant problems with these domains. Given the high degree of co-morbid METH dependence and HIV infection, it is important to understand how these conditions interact and whether there exist any additive effects on social-emotional functioning. Our results showed that PWH and METH dependence had greater emotion dysregulation and worse cognitive TOM. Although our results do not indicate the causal direction of this relationship, it may be the case that the effects of HIV and METH exposure increases risk for deficits in these abilities [29]. Alternatively, it may be that individuals with greater emotion dysregulation and/or worse cognitive TOM

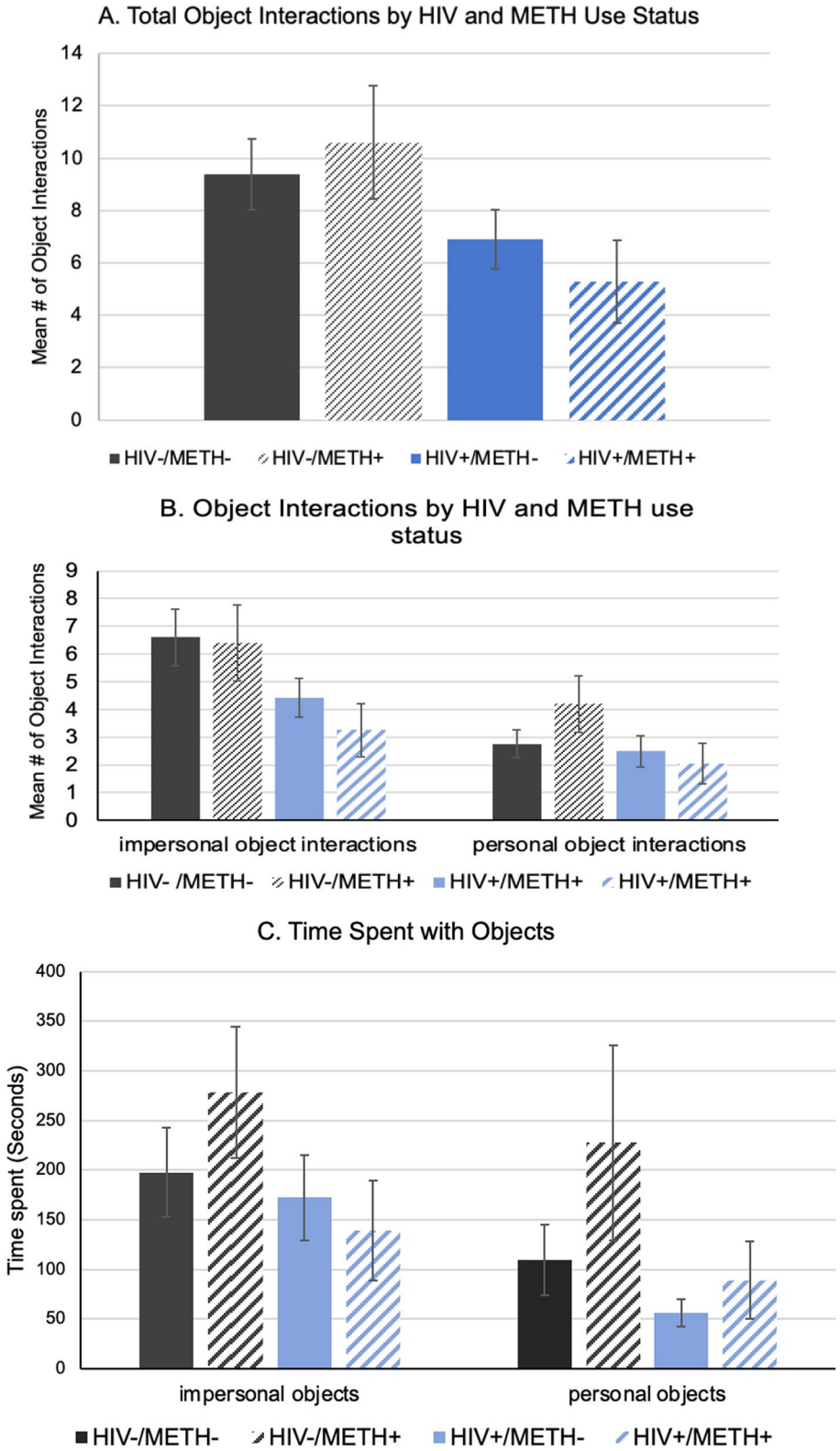

Fig. 1 PWH exhibited fewer object interactions in the hBPM driven by fewer impersonal object interactions versus seronegative individuals. (n = 135). **A** Mean number of object interactions by diagnostic group. HIV+/METH+ participants interacted with significantly fewer objects compared to HIV−/METH+ participants. **B** Mean number object interactions grouped by type (impersonal and personal objects). No significant effects of HIV or METH dependence status on object interactions by type. **C** Mean time spent with personal and impersonal objects. No significant effects of HIV or METH dependence status on time spent with object interactions

are at greater risk of contracting HIV or becoming addicted to METH. Regardless, it is important to know that emotion dysregulation and poor cognitive TOM are prominent deficits in these populations given the potential downstream consequences of these deficits irrespective of the directionality of the effect.

In this report we aimed to expand our evaluation of social cognition in HIV and METH dependence with a novel

Table 2 Means and Standard deviations of hBPM measures, unless otherwise noted

	HIV−/METH− (n = 51; A)	HIV−/METH+ (n = 15; B)	HIV+/METH− (n = 41;C)	HIV+/METH+ (n = 28; D)	Group differences
Total object interactions	9.37 (9.66)	10.60 (8.33)	6.90 (7.19)	5.36 (8.052)	B > D
Total time spent with objects (s)[a]	173 (26–397)	475 (35–698)	98.5 (20.3–388.5)	25 (0–317)	A, B > D
# of personal object interactions[a]	1 (0–4)	4 (1–7)	1 (0–4)	0 (0–1)	ns
Time spent with personal objects (s)	109.78 (253.43)	227.67 (379.89)	56.20 (88.38)	86.68 (197.12)	ns
# of impersonal object interactions[a]	4 (1–10)	6 (2–8)	3 (1–8)	2 (0–4)	ns
Time spent with impersonal objects (s)	197.71 (318.67)	278.47 (255.59)	172.28 (269.89)	137.50 (257.45)	ns

ns not significant

[a]Median (interquartile range)

Table 3 Means and standard deviation of social cognition assessments

	HIV−/METH− (n = 51; A)	HIV−/METH+ (n = 15; B)	HIV+/METH− (n = 41; C)	HIV+/METH+ (n = 28; D)	Group differences
DERS-S					
AWARENESS	11.59 (4.05)	14.00 (5.51)	12.24 (5.13)	17.00 (5.33)	D > A, C
CLARITY	7.49 (2.40)	11.21 (4.06)	9.12 (4.00)	13.33 (3.15)	B, D > A, C
IMPULSE	7.98 (2.45)	15.14 (5.36)	10.24 (4.700)	14.11 (5.60)	B, D > C > A
GOALS	9.71(4.02)	16.21(4.12)	12.34 (5811)	14.78 (4.64)	B, D > C > A
NONACCEPTANCE	9.08 (3.13)	12.64 (5.69)	12.02 (6.20)	13.81 (6.20)	B > A,C; D > A
STRATEGIES	11.14 (3.69)	17.86 (6.85)	14.66 (6.86)	18.07 (7.22)	B, D > C > A
TOTAL	56.98 (12.49)	87.07 (23.25)	70.63 (27.33)	91.11 (26.33)	D > C > A; B > A
Faux pas test score	48.41 (6.74)	45.21 (6.73)	43.95 (8.64)	42.33 (8.29)	B, C, D < A
Faux pas control score	19.61 (0.80)	19.29 (1.07)	19.32 (1.08)	19.48 (0.70)	ns

ns not significant

measure of observed behavior in our experimental paradigm (hBPM) and in more traditional social cognition assessments (DERS and FP). The combination of these measures allowed us to validate our proposed experimental paradigm (interaction with personal objects = impaired social cognition) by comparing this outcome to the social cognition assessments. Indeed, we found significant associations between some key social-emotional functioning measures and interactions with personal objects (described in more detail below) thus validating personal object interactions in the hBPM as a useful method to quantify impaired social cognition.

We also hypothesized that both HIV infection and METH dependence would be associated with increased engagement with personal objects. Engaging with objects which clearly belong to another individual represents impaired social cognition via increased risk-taking and impulsivity, traits which are observed in both PWH and METH dependence. However, in the hBPM, PWH had significantly fewer object interactions, and thus engaged in less risky-taking behavior, seemingly contradicting another study wherein PWH were found to have impaired risky decision-making skills [30]. This difference could be explained by the skills developed by PWH to manage their medical condition. Previously, we have also reported that HIV+/METH+ individuals have improved everyday functioning skills relative to HIV+/METH+ individuals [19]. Thus, the inhibition of socially inappropriate behavior in the hBPM by HIV+ participants could be interpreted as an extension of the adaptive skills PWH likely develop in response to the challenges of managing their disease. This adaptive behavior could partially help mitigate engagement in risky behaviors.

Overall, we observed that both HIV and METH dependence were associated with increased emotional dysregulation compared to healthy controls. When evaluating group differences, we found that METH dependence was related to increased emotional dysregulation in both HIV+ and HIV− participants. Our findings that METH dependence in people without HIV may be associated with increased emotional dysregulation are consistent with results from a previous study [31]. Our study further demonstrated that METH dependence also appeared to be associated with increased emotional dysregulation in HIV+ participants. This synergistic effect of METH dependence and HIV infection on emotion dysregulation may be partially explained by

Table 4 Correlations between social cognition assessments and hBPM measures across HIV−/METH− participants

	HIV−/METH−					
	Impersonal object interactions	Personal object interactions	Total object interactions	Impersonal object time spent	Personal object time spent	Total time spent with objects
AWARENESS						
r_s	0.063	0.173	0.114	−0.098	0.047	−0.133
p	*0.662*	*0.226*	*0.426*	*0.495*	*0.743*	*0.353*
CLARITY						
r_s	0.057	0.196	0.107	0.226	0.073	0.19
p	*0.689*	*0.168*	*0.453*	*0.111*	*0.608*	*0.181*
IMPULSE						
r_s	0.063	0.172	0.112	0.209	0.055	0.148
p	*0.66*	*0.227*	*0.434*	*0.141*	*0.702*	*0.301*
GOALS						
r_s	−0.215	−0.128	−0.189	−0.025	−0.095	0.007
p	*0.131*	*0.372*	*0.185*	*0.86*	*0.505*	*0.963*
NONACCEPTANCE						
r_s	−0.091	0.084	−0.032	−0.069	0.014	−0.028
p	*0.527*	*0.557*	*0.825*	*0.631*	*0.923*	*0.846*
STRATEGIES						
r_s	−0.177	0.094	−0.125	−0.185	−0.035	−0.242
p	*0.214*	*0.511*	*0.384*	*0.194*	*0.808*	*0.087*
DERS total						
r_s	−0.122	0.105	−0.057	−0.057	−0.004	−0.069
p	*0.395*	*0.465*	*0.691*	*0.69*	*0.978*	*0.631*
Faux pas task						
r_s	−0.062	−0.076	−0.068	−0.053	−0.134	−0.155
p	*0.664*	*0.598*	*0.637*	*0.713*	*0.348*	*0.278*
Faux pas control						
r_s	0.054	0.071	0.066	−0.036	0.05	−0.136
p	*0.706*	*0.619*	*0.645*	*0.804*	*0.728*	*0.343*

Bold values indicate significant correlation ($p < 0.025$)

Italics differentiate rows of p-values from rows of correlation coefficient values

r_s = Spearman's rho correlation coefficient

differences in viral load between the HIV groups. Even low levels of HIV viral load have been associated with cognitive impairment and emotional states such as apathy; these relationships may be stronger as viral loads increase [32, 33]. In our cohort, HIV+/METH+ participants had significantly higher viral loads and higher DERS scores compared to HIV+/METH− participants. Although this cross-sectional study cannot establish that higher viral loads were the cause, or possibly even the effect, of greater emotion dysregulation, this finding raises the possibility of a connection that is consistent with prior literature and should be evaluated directly in future studies. This is important because viral load is a modifiable treatment target that may have benefits to emotional functioning as well as medical HIV disease management.

Although our primary goal in correlating object interaction measures with social cognition assessments was to validate object interactions as a metric for social cognition, we also found several of the correlations were specific to diagnostic groups. For example, both METH+ groups reported significantly higher impulse control difficulties when distressed (such as a testing situation in which one is left alone in an office for an unknown period of time, as occurs per the hBPM protocol), compared to METH− groups. However, a positive correlation between personal objects interactions and IMPULSE score was specific to the HIV−/METH+ group. Thus, HIV+/METH+ participants may retain the capacity to self-regulate their behavior in a social setting and inhibit interactions with inappropriate objects, whereas their

Table 5 Correlations between social cognition assessments and hBPM measures across HIV−/METH+ participants

	HIV−/METH+					
	Impersonal object interactions	Personal object interactions	Total object interactions	Impersonal object time spent	Personal object time spent	Total time spent with objects
AWARENESS						
r_s	0.08	0.168	0.098	0.004	0.263	−0.106
p	*0.786*	*0.566*	*0.74*	*0.988*	*0.363*	*0.718*
CLARITY						
r_s	0.25	0.177	0.224	0.032	0.237	−0.083
p	*0.388*	*0.544*	*0.44*	*0.913*	*0.414*	*0.777*
IMPULSE						
r_s	***0.821***	***0.641***	***0.816***	0.516	***0.742***	***0.707***
p	***< 0.001***	***0.013***	***< 0.001***	0.059	***0.002***	***0.005***
GOALS						
r_s	−0.208	−0.302	−0.174	−0.02	−0.417	−0.267
p	*0.475*	*0.294*	*0.552*	*0.946*	*0.138*	*0.355*
NONACCEPTANCE						
r_s	0.095	−0.11	0.051	0.251	−0.053	0.056
p	*0.746*	*0.709*	*0.863*	*0.387*	*0.856*	*0.848*
STRATEGIES						
r_s	0.388	0.337	0.432	0.305	0.282	0.16
p	*0.17*	*0.239*	*0.123*	*0.288*	*0.328*	*0.585*
DERS total						
r_s	0.282	0.192	0.306	0.262	0.181	0.117
p	*0.329*	*0.511*	*0.288*	*0.365*	*0.535*	*0.691*
Faux pas task						
r_s	0.22	0.275	0.288	0.338	0.178	0.108
p	*0.451*	*0.341*	*0.318*	*0.237*	*0.544*	*0.713*
Faux pas control						
r_s	0.028	0.159	0.119	−0.304	0.06	−0.387
p	*0.923*	*0.586*	*0.686*	*0.29*	*0.84*	*0.172*

Bold values indicate significant correlation ($p < 0.025$)

Italics differentiate rows of p-values from rows of correlation coefficient values

r_s = Spearman's rho correlation coefficient

HIV−/METH+ counterparts do not. Although number of personal object interactions was not significantly different between groups, the directionality of this correlation is consistent with results from a previous study where impulsivity was found to be associated with METH+ participants, but not PW [34].

Our data also suggest that HIV− associated poor cognitive TOM correlates with inappropriate engagement with personal objects in the hBPM. Interestingly, the relationship between FP and personal object interactions was only observed in the HIV+/METH− group. HIV+ participants with lower FP scores (poorer cognitive TOM) interacted with more personal objects. This performance-based task examines whether an individual can detect an awkward situation, or faux pas, in a social scenario. Therefore, PWH who were less skilled at detecting faux pas situations were more likely to inappropriately interact with personal objects when left alone in an office per the hBPM procedure, which would have been an awkward situation if they were to be "caught in the act" of these interactions. HIV infection did not significantly affect the number of personal object interactions or time spent with personal objects. However, it may be the case that the impaired ability to anticipate such social awkwardness leads those PWH with lower cognitive TOM to engage inappropriately with others' belongings, both in terms of how many items with which they interacted, and how long they interacted with them. It is not clear why there was no significant association between poor cognitive TOM and the hBPM measures in the HIV−/METH+ group considering that they demonstrated the poorest performance on

Table 6 Correlations between social cognition assessments and hBPM measures across HIV+/METH− participants

	HIV+/METH−					
	Impersonal object interactions	Personal object interactions	Total object interactions	Impersonal object time spent	Personal object time spent	Total time spent with objects
AWARENESS						
r_s	0.219	0.193	0.224	0.014	0.174	0.014
p	*0.168*	*0.226*	*0.159*	*0.933*	*0.284*	*0.932*
CLARITY						
r_s	0.224	0.192	0.233	0.093	0.219	0.102
p	*0.159*	*0.229*	*0.143*	*0.567*	*0.175*	*0.531*
IMPULSE						
r_s	0.073	0.2	0.127	0.109	0.198	0.127
p	*0.65*	*0.21*	*0.43*	*0.502*	*0.221*	*0.435*
GOALS						
r_s	0.085	0.059	0.096	0.176	0.014	0.121
p	*0.597*	*0.713*	*0.549*	*0.278*	*0.932*	*0.457*
NONACCEPTANCE						
r_s	0.212	0.037	0.16	0.274	−0.001	0.187
p	*0.184*	*0.818*	*0.316*	*0.087*	*0.994*	*0.247*
STRATEGIES						
r_s	0.12	0.08	0.101	0.137	0.04	0.088
p	*0.453*	*0.618*	*0.528*	*0.399*	*0.808*	*0.59*
DERS total						
r_s	0.161	0.121	0.16	0.167	0.089	0.129
p	0.314	0.452	0.318	0.302	0.586	0.426
Faux pas task						
r_s	−0.213	−0.301	−0.302	−0.226	−0.323	***−0.381***
p	*0.181*	*0.056*	*0.055*	*0.162*	*0.042*	***0.015***
Faux pas control						
r_s	0.093	−0.07	0.012	0.07	−0.077	−0.046
p	*0.564*	*0.665*	*0.943*	*0.67*	*0.638*	*0.778*

Bold values indicate significant correlation ($p < 0.025$)

Italics differentiate rows of p-values from rows of correlation coefficient values

r_s = Spearman's rho correlation coefficient

the FP measure. It could be that the group was too small to detect those differences or that in this group another factor was more likely to drive the inappropriate interactions with the items, such as the difficulty controlling impulsive behaviors when distressed that we observed using the DERS.

Though significant group differences and relationships were observed, this study was nonetheless limited by small sample sizes and unequal variances. This limitation was particularly highlighted in the analysis of DERS, in which nearly all subscales had significantly unequal variances. Although we identified group differences for these measures using non-parametric statistical tests, we were unable to test for interactive effect of HIV and METH or assess their main effects, when controlling for each other, as could be done with parametric models. However, many of the trends supported the limited existing studies on the effects of HIV and METH on social cognition. Specifically, Homer and colleagues observed that HIV, METH and their combination were associated with poor cognitive TOM. Another limitation was the significant difference in characteristics between the HIV+ groups. HIV+/METH+ participants were younger than their METH− counterparts, had a shorter duration of HIV infection, fewer reported current antiretroviral medications and higher viral load. As such, these cohort differences may have affected our ability to detect and interpret putative effects of HIV and METH dependence in our measures. There was also a wide range of METH use patterns across the diagnostic groups which may have also contributed to the observed effects of METH on social cognition. Lastly, although we observed consistent object interactions

Table 7 Correlations between social cognition assessments and hBPM measures across HIV+/METH+ participants

	HIV+/METH+					
	impersonal object interactions	personal object interactions	total object interactions	impersonal object time spent	personal object time spent	Total time spent with objects
AWARENESS						
r_s	0.027	0.033	0.008	−0.166	−0.101	−0.201
p	*0.897*	*0.874*	*0.971*	*0.419*	*0.624*	*0.324*
CLARITY						
r_s	−0.19	−0.056	−0.15	−0.208	−0.072	−0.261
p	*0.353*	*0.784*	*0.464*	*0.308*	*0.728*	*0.197*
IMPULSE						
r_s	0.038	0.219	0.075	−0.014	0.229	−0.008
p	*0.853*	*0.282*	*0.714*	*0.946*	*0.26*	*0.969*
GOALS						
r_s	0.05	0.155	0.069	0.124	0.147	0.098
p	*0.807*	*0.449*	*0.737*	*0.546*	*0.474*	*0.634*
NONACCEPTANCE						
r_s	−0.038	−0.07	−0.038	−0.007	−0.082	−0.068
p	*0.853*	*0.734*	*0.854*	*0.972*	*0.689*	*0.74*
STRATEGIES						
r_s	−0.109	0.044	−0.1	−0.054	−0.025	−0.107
p	*0.595*	*0.829*	*0.626*	*0.792*	*0.903*	*0.604*
DERS total						
r_s	−0.039	0.097	0.001	−0.025	0.054	−0.062
p	*0.851*	*0.637*	*0.997*	*0.904*	*0.795*	*0.763*
Faux pas task						
r_s	0.075	−0.253	−0.052	−0.021	−0.115	0.05
p	*0.715*	*0.212*	*0.803*	*0.919*	*0.576*	*0.807*
Faux pas control						
r_s	−0.251	−0.205	−0.264	−0.247	−0.231	−0.261
p	*0.216*	*0.315*	*0.192*	*0.223*	*0.257*	*0.198*

Bold values indicate significant correlation ($p < 0.025$)

Italics differentiate rows of p-values from rows of correlation coefficient values

r_s = Spearman's rho correlation coefficient

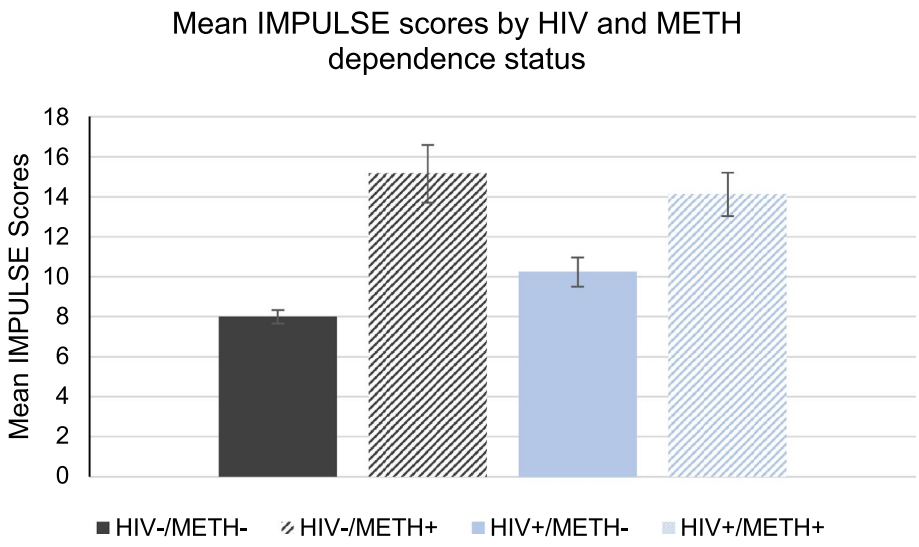

Fig. 2 IMPULSE mean score by HIV and METH dependence status (n = 133). METH+ participants had significantly higher IMPULSE scores than non-users. HIV+ participants had higher IMPULSE scores compared to HIV−/METH− controls

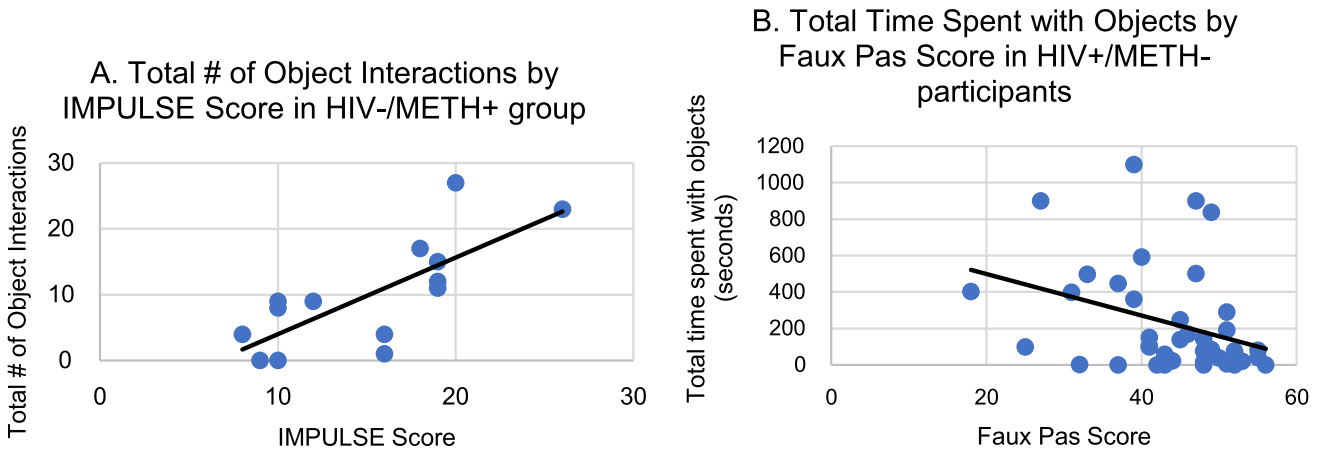

Fig. 3 Number of Object Interactions and Time spent with objects significantly correlates with social cognition assessment scores. **A** DERS score positively correlates with total number of object interactions ($r_s = 0.816$; $p < 0.001$) in HIV−/METH+ participants and **B** Faux Pas scores negatively correlate with total time spent with object interactions ($r_s = -0.381$; $p = 0.015$)

during this study, these experiments were completed prior to COVID-19; thus, we acknowledge that future studies using the hBPM may be limited by participant reluctance to engage with objects as a result of COVID-19 precautionary measures.

In conclusion, we have demonstrated that the quantification of personal object interactions in the hBPM demonstrates construct validity in evaluating social cognition. Although we hypothesized that HIV and METH dependence would produce additive detrimental effects on social cognition, we instead observed a more nuanced relationship between HIV and METH dependence. Notably, we found that despite self-reports of difficulty with impulse control when distressed among PWH, this deficit was not associated with inappropriate engagement with personal objects as measured by the hBPM in this group. Instead, PWH who demonstrated poor cognitive TOM, or poor ability to anticipate and detect awkwardness in a social situation were more likely to demonstrate greater interaction with personal objects in the hBPM. In contrast, those with a history of METH dependence without HIV self-reported emotional dysregulation (difficulty controlling impulsivity when distressed) and demonstrated socially dysregulated behavior in the laboratory. These findings provide important information about the individual and combined effects of HIV and METH on social-emotional functioning and how these conditions may alter social behavior differently. Specifically, the relationship demonstrated by our findings may suggest unique risk factors for socially inappropriate or risky behaviors in these groups, which could be addressed with interventions to reduce the likelihood of real-world dysfunction. Although this pilot assessment has enhanced our understanding of the relationships between social cognition, METH dependence and HIV infection, future studies are needed with larger sample sizes with improved matching on demographics and clinical characteristics in order to better delineate these relationships.

Author Contributions AM: Data analysis, Writing-Original draft preparation, conceptualization; WP: Methodology, Subject recruitment, data collection, Writing- review and editing; AU: Data analysis, methodology, writing- review and editing; JWY: Data analysis, Writing-Review and editing, methodology; EEM: Data analysis, Writing-Original draft preparation, methodology, data collection, funding acquisition; AM: Data analysis, Writing-Original draft preparation, methodology, data collection, funding acquisition.

Funding This study was supported by P50DA26306, R01DA043535, and R01DA051295.

Declarations

Conflict of interest Authors declare no conflicts or competing interests.

Ethical Approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee (UCSD Human Research Protections Program) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to Participate Informed consent was obtained from all individual participants included in this study.

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