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RESEARCH

Beyond accuracy: facial emotion perception bias in people with HIV in Uganda

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Abstract

Cognitive complications remain common among people with HIV (PWH) globally, yet social cognition, critical for daily functioning, has received little attention, particularly in sub-Saharan Africa. We examined facial emotion perception (FEP), a core social cognitive process, among 235 PWH and 224 people without HIV (PWoH) from the Rakai Neurology Cohort Study. FEP was assessed using the FEP task and associations with cognitive and psychosocial factors were examined. While overall accuracy did not differ between groups, PWH demonstrated greater fear bias (Cohen's d=0.20, 95%CI 0.01,0.38) and lower sad bias (Cohen's d=-0.21, 95%CI -0.40,-0.03) than PWoH. In PWH, better declarative memory was associated with higher accuracy for fear and neutral faces and with lower fear bias, whereas psychomotor speed was related to higher accuracy for sadness and higher sad bias. In PWoH, declarative memory related to anger recognition and reduced sad bias, whereas psychomotor speed was associated with improved accuracy for fear and neutral faces and lower anger bias. Psychosocial factors (e.g., anxiety, PTSD symptoms) were not related to FEP in either group. Findings indicate that HIV status is associated with differential patterns of FEP bias, with PWH showing heightened fear bias and PWoH demonstrating greater sad bias. These results highlight the potential value of FEP bias as a marker of brain health in HIV and underscore the importance of declarative memory and psychomotor speed as potential intervention targets to improve social functioning.

Keywords HIV · Uganda · Facial emotion processing · Cognition · Psychosocial

Introduction

The HIV epidemic continues to have a significant impact on sub-Saharan Africa, where nearly two-thirds of all people with HIV (PWH) reside (UNAIDS 2022). Brain health disorders, including cognitive impairment and mental health disorders, remain common despite effective antiretroviral therapy (Rao et al. 2023). The burden of these complications is particularly high in resource-limited settings such as Uganda (Opio et al. 2022; Vecchio

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et al. 2021), underscoring the need for region-specific data to identify modifiable factors and inform interventions to preserve brain health.

Facial emotion processing (FEP), the ability to rapidly and accurately interpret others' emotions, is a core aspect of social cognition and has been identified by the National Institute of Mental Health's Research Domain Criteria (RDoC) framework as a fundamental process underlying brain health. FEP engages multiple cognitive operations, with strongest links to attention and memory (Mano and Brown 2013; Neumann et al. 2021; Rocca et al. 2009; Santos et al. 2008; Schupp et al. 2007) and more mixed evidence for executive function (Jiang et al. 2022; Rocca et al. 2009). Deficits in FEP are well-documented in psychiatric and neurological disorders and are strongly linked to impaired social functioning (Aparicio et al. 2017; Beaudoin and Beauchamp 2020; Cotter et al. 2018; Couture et al. 2006; Green et al. 2015; Sasson et al. 2020; Vlad et al. 2018).

In HIV, fewer studies have examined FEP, but evidence suggests that PWH show lower accuracy and slower reaction times than people without HIV (PWoH)(Baldonero et al. 2013; Clark et al. 2015; González-Baeza et al. 2016; Grabyan et al. 2018; Lane et al. 2012), particularly for negative emotions such as fear, sadness, and anger (Baldonero et al. 2013; Clark et al. 2015; Gonzalez-Baeza et al. 2014; Lane et al. 2012). Beyond accuracy, FEP bias, the tendency to misinterpret or misattribute emotions, is an important but understudied dimension of social cognition. In PWoH, heightened negativity bias has been consistently linked to conditions such as depression, posttraumatic stress disorder, and borderline personality disorder (Armstrong et al. 2013; Assed et al. 2019; Bourke et al. 2010; Langenecker et al. 2007; Seo and Park 2015; Unoka et al. 2011), implicating overlap with the RDoC-defined negative valence system. To date, FEP bias has not been studied in PWH, and nearly all prior work has been conducted in high-income countries, leaving substantial gaps in regions most affected by the epidemic. To address these gaps, we examined both FEP accuracy and bias among PWH and PWoH in the Rakai Neurology Cohort Study (RNCS) in Uganda. We hypothesized that PWH would demonstrate lower accuracy for negative emotions and greater negativity bias compared to PWoH. Using the RDoC framework, we also evaluated cognitive, mental health, and demographic correlates of FEP to identify pathways that may inform targeted intervention strategies.

Method

Study design

Participants were recruited between November 2020 and June 2022 from local HIV clinics and the Rakai Community Cohort Study (RCCS), an ongoing community-based study in 40 communities in Rakai District, Uganda. The study was approved by the Western Institutional Review Board (IRB00209786), the Uganda Virus Research Institute Ethics Committee (GC/127/789), and the Uganda National Council for Science and Technology (HS634ES). All participants were aged ≥ 18 years and provided written informed consent. Exclusion criteria were: (1) active psychiatric disorders or cognitive impairment of sufficient severity to interfere with participation (clinician assessed); (2) active tuberculosis; (3) inability to travel to the clinic; or (4) current central nervous system opportunistic infections (e.g. cryptococcal meningitis, toxoplasmosis, HIV encephalopathy). The parent study enrolled 350 PWH and 250 PWoH, providing > 80% power to detect group differences in FEP (PWH vs. PWoH) of ≥ 0.116 at baseline (assuming standard deviations = 0.5, false discovery rate = 0.05, two-sided t-test). The present analysis included all participants with available FEP and cognitive testing data, excluding two PWH with virologic failure (viral load > 1000 cp/mL).

Procedures

Participants completed a structured protocol including sociodemographic questionnaire, psychosocial self-report measures, a RDoC-informed test battery (e.g., cognition and social processing), and blood draw. The RDoC-informed test battery was administered by study nurses who received structured training from team members with expertise in cognitive assessment, including a neuropsychologist (R. Paul), a cognitive neuroscientist (L. Rubin), and a Ugandan psychiatrist experienced in cognitive test administration (N. Nakasujja). To ensure reliability and fidelity of administration, senior investigators periodically observed testing sessions (in-person and remotely) and provided feedback as needed, and electronic training materials were available for reference throughout the study. In PWoH, HIV serostatus was confirmed using rapid diagnostic testing. In PWH, plasma HIV-1 RNA was quantified using the Abbott Realtime HIV-1 assay. All assessments were translated into Luganda, the predominant local language in Rakai, and back-translated to English for accuracy.

Facial emotion perception

FEP was measured using the Facial Emotion Perception Test (FEPT)(Rapport et al. 2002), a tablet-based task assessing accuracy and reaction time for perception of happy, sad, angry, fearful, and neutral faces. The FEPT includes affective blocks and animal blocks (control). Stimuli

(black-and-white faces)(Ekman 1976) were presented for 300ms, followed by a 2600ms response window with a forced-choice format. Given many participants lacked prior tablet experience, they pointed to their choice and research staff entered responses. Reaction time was therefore not analyzed. For each emotion, accuracy was calculated as the proportion of correctly identified faces. Bias was calculated as the proportion of neutral or other-valanced faces misidentified as a target emotion (e.g. proportion of non-sad faces incorrectly identified as sad). Bias scores are zero-sum, such that more errors for one emotion correspond to fewer errors in identifying other emotions.

Cognitive and psychosocial function

Cognitive performance was assessed with standardized neuropsychological tests: Color Trails Test (CTT)(D'Elia et al. 1996), Symbol Digit Modalities Test (SDMT)(Smith 1973), Grooved Pegboard (GPEG)(Matthews and Klove 1964), and WHO/UCLA Auditory Verbal Learning Test, including total learning long delay free recall, and recognition trials (AVLT)(Maj et al. 1993). Psychosocial functioning was assessed with validated self-report measures including the PTSD Checklist – Civilian Version (PCL-C)(Weathers et al. 1993), State-Trait Anxiety Inventory (STAI)(Spielberger et al. 1983), Beck Anxiety Inventory (BAI)(Beck et al. 1988), and Childhood Trauma Questionnaire (CTQ)(Bernstein and Fink 1998), using physical and sexual abuse subscales.

Data analysis

Analyses were performed in Stata (18.0) and SPSS (29). Sociodemographic characteristics, medical history, cognitive measures, and FEP accuracy and bias were summarized descriptively by serostatus. Between-group differences were assessed using Chi-square tests for categorical data and t-tests for continuous data. Standardized differences in FEP accuracy and bias were calculated using Cohen's *d* with 95% confidence intervals. To reduce dimensionality of the cognitive test battery, principal components analysis (PCA) with Kaiser-normalized varimax rotation identified two latent factors (See Supplemental Digital Content 1). The first factor, representing psychomotor speed (RDoC: sensorimotor systems), had high loadings (>0.7) for GPEG, CTT, and SDMT. The second factor, representing declarative memory (listed under the RDoC cognitive systems), included high loadings (>0.65) for the AVLT indices (total learning, long delay free recall, recognition). Pearson correlations (r) were used to examine associations between cognitive factor scores, psychosocial measures, socio-demographics, and FEP outcomes separately for PWH and PWoH. Variables showing associations at $P<0.10$ were considered in multivariable linear regressions, which were conducted separately by serostatus. All models adjusted for sex and years of education, given their between-group differences and associations with FEP performance. Given the exploratory nature of the analyses, false discovery rate adjustments were not applied.

Results

A total of 459 participants (235 PWH, 224 PWoH) with complete data were included (Table 1). The mean age was 43 years (PWH: 42.6 [SD 8.6]; PWoH: 43.1 [8.0]), and approximately half were women (PWH: 51%; PWoH: 45%). Medical comorbidities were uncommon, and few reported tobacco or other non-alcohol substance use. All PWH had viral loads < 1000 copies/mL, with 96% undetectable (<40cp/ml). Most PWH were on Tenofovir Disoproxil Fumarate and Lamivudine-based regimens (+Dolutegravir, 91%; +Efavirenz, 6%) and had been taking ART for a mean of 7.7 years. Compared to PWoH, PWH had modestly lower psychomotor speed (−0.11 vs. 0.11, t=2.41, $P=0.016$), a greater history of childhood sexual abuse (low severity: 11% vs. 9%, moderate/severe: 16% vs. 7%; $x^2=11.41$, $P=0.003$), and lower STAI anxiety scores (8.31vs. 8.98, t=2.65 $P=0.008$). BAI and PCL-C scores did not differ by serostatus.

HIV status differences and FEP accuracy

Overall and emotion-specific accuracy did not differ significantly between PWH and PWoH after adjustment for sex and education (Table 2). Across groups, accuracy was highest for fear (~70%) and lower for sadness, anger, and neutral faces (~40%).

Within groups, distinct cognitive correlates emerged. In PWH, better declarative memory was associated with greater accuracy for fear ($r=0.19$, $P=0.004$) and neutral faces ($r=0.20$ $P=0.002$), whereas psychomotor speed was related to accuracy for sadness ($r=0.23$, $P<0.001$) and neutral ($r=0.18$ $P=0.004$) (Fig. 1, Supplemental Digital Content 2). Regression models confirmed these associations (Fig. 2, Supplemental Digital Content 3). In PWoH, declarative memory related to anger accuracy ($r=0.17$, $P=0.011$), and psychomotor speed was associated with accuracy for fear ($r=0.20$, $P=0.002$) and neutral ($r=0.42$, $P<0.001$). In addition, female sex was associated with better fear ($\beta=0.23$ SE=0.07 $P=0.001$) and neutral accuracy ($\beta=0.14$ SE=0.06 $P=0.031$) but poorer sad accuracy ($\beta=-0.16$ SE=0.07 $P=0.022$). There was also a trend between childhood sexual

Table 1 Demographic, Medical, Cognitive, and psychosocial characteristics of study participants

	PWH ($n=235$)	PWoH ($n=224$)		
	M (SD)	M (SD)	t/ x^2	*P*-value
Age, years	42.69 (8.58)	43.07 (8.01)	0.49	0.623
Female sex, n (%)	119 (51)	100 (45)	1.65	0.199
Years of education	6.57 (3.48)	6.00 (3.76)	−1.71	0.087
Medical history				
Diabetes, n (%)	1 (0)	6 (3)	3.88	**0.049**
Hypertension, n (%)	9 (4)	12 (5)	0.61	0.434
Smoking, n (%)	22 (9)	17 (8)	0.46	0.496
Illicit substance use, n (%)	4 (2)	5 (2)	0.17	0.682
Viral load (copies/mL), n (%), $n=234$				
Below detection (<40)	224 (96)			
Detectable (40–999)	10 (4)			
Years on ART, $n=224$	7.71 (3.55)			
Efavirenz-based regimen, $n=223$, n (%)	14 (6)			
Medication use, n (%)				
Diabetes medication	1 (0)	4 (2)	1.97	0.161
Antihypertensive medication	6 (3)	9 (4)	0.78	0.378
Cognitive factor scores				
Psychomotor speed	−0.11 (1.04)	0.11 (0.95)	2.41	**0.016**
Declarative memory	0.06 (1.08)	−0.06 (0.91)	−1.33	0.185
Psychosocial measures				
PCL-C total score	25.29 (9.52)	24.67 (8.48)	−0.74	0.459
STAI total score	8.31 (2.94)	8.98 (2.49)	2.65	**0.008**
BAI total score	3.45 (5.24)	3.51 (4.66)	0.13	0.893
CTQ: Physical abuse, n (%)			0.21	0.902
None	192 (82)	183 (82)		
Low	22 (9)	23 (10)		
Moderate/severe[a]	21 (9)	18 (8)		
CTQ: Sexual abuse, n (%)			11.41	**0.003**
None	171 (73)	189 (84)		
Low	26 (11)	20 (9)		
Moderate/severe[a]	38 (16)	15 (7)		

[a] Moderate and severe abuse were combined into one group

PCL-C Post-Traumatic Stress Disorder Checklist for Civilians; *STAI* State-Trait Anxiety Inventory; *BAI* Beck Anxiety Inventory; *CTQ* Childhood Trauma Questionnaire; *ART* antiretroviral therapy

abuse and sad accuracy (β=−0.13 SE=0.08 $P=0.089$). No psychosocial measures (e.g., anxiety, PTSD symptoms, or childhood trauma) were significantly related to accuracy in either group.

Table 2 Facial emotion perception accuracy and bias (%) adjusted for sex and education

	PWH ($n=235$)	PWoH ($n=224$)	Cohen's d	95% CI	*P*-value
Accuracy, mean (SE)					
Fear	70.3 (2.0)	67.5 (1.9)	0.11	−0.08, 0.29	0.24
Sad	39.6 (1.8)	41.9 (1.7)	0.01	−0.18, 0.19	0.94
Anger	40.2 (1.7)	40.1 (1.7)	−0.10	−0.29, 0.08	0.26
Neutral	41.1 (2.2)	39.0 (2.2)	0.08	−0.11, 0.26	0.41
Bias, mean (SE)					
Fear	14.1 (0.5)	12.8 (0.5)	0.20	0.01, 0.38	**0.03**
Sad	14.5 (0.7)	16.5 (0.7)	−0.21	−0.40, −0.03	**0.02**
Anger	12.9 (0.8)	12.8 (0.8)	0.01	−0.17, 0.19	0.91

PWH People with HIV; *PWoH* People without HIV; *SE* standard error; *CI* confidence interval

HIV status differences and FEP bias

Compared to PWoH, PWH exhibited greater fear bias (Cohen's $d=0.20$, 95%CI 0.01, 0.38, $P=0.03$) and lower sad bias (Cohen's $d=-0.21$, 95%CI −0.40, −0.03, $P=0.02$) after adjusting for sex and education (Table 2).

Within groups, distinct cognitive correlates also emerged for bias. In PWH, declarative memory was inversely correlated with fear bias ($r=-0.23$, $P<0.001$) whereas psychomotor speed was positively associated with sad ($r=0.15$ $P=0.018$) and inversely with anger bias ($r=-0.21$, $P=0.001$) (Fig. 1, Supplemental Digital Content 2). Regression models confirmed these associations (Fig. 2, Supplemental Digital Content 3). Female sex was also associated with lower fear (β=−0.18 SE=0.06 $P=0.006$) and higher anger bias (β=0.16 SE=0.06 $P=0.014$). In PWoH, declarative memory was inversely correlated with sad ($r=-0.15$, $P=0.021$) and psychomotor speed with anger bias ($r=-0.28$, $P<0.001$) (Fig. 1, Supplemental Digital Content 2). Regression models confirmed these associations (Fig. 2, Supplemental Digital Content 3). Female sex was also inversely associated with sad bias (β=−0.29 SE=0.07 $P<0.001$).

Discussion

This study provides new evidence that PWH and PWoH in rural Uganda differ in FEP biases but not in overall accuracy. PWH exhibited greater fear bias, whereas PWoH showed greater sad bias. Although effect sizes were modest, they align with prior studies documenting serostatus differences in FEP accuracy (Baldonero et al. 2013; Clark

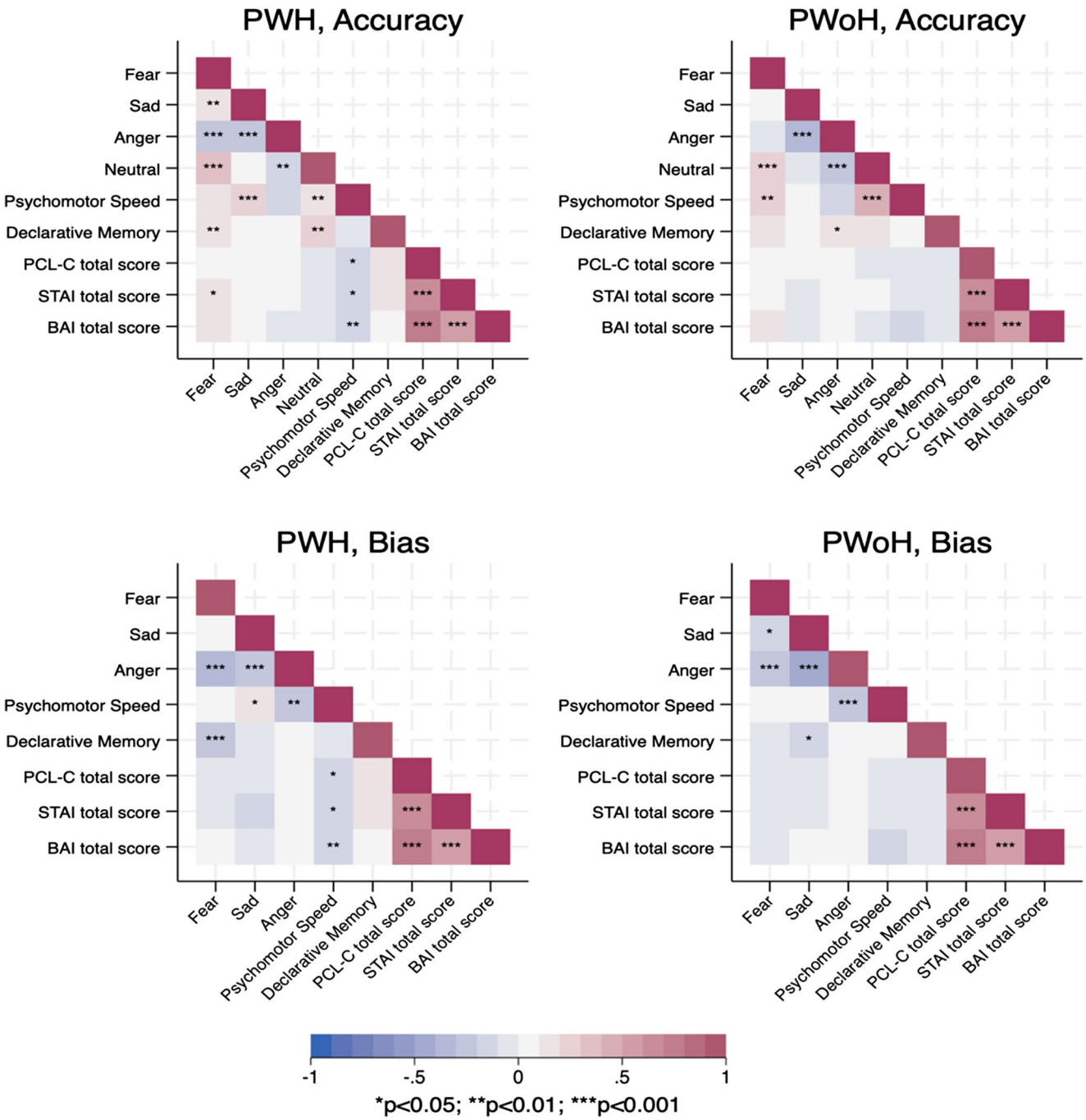

Fig. 1 Heat Plots of FEP Accuracy and Bias, Cognitive Factor Scores, and Psychosocial Measures

et al. 2015; Lane et al. 2012). Given that facial expressions serve as critical social cues (e.g. fear informs about potential threat) (Frith 2009; Marsh et al. 2005; Xavier et al. 2016), these distinct biases may contribute to different interpersonal communication challenges in PWH versus PWoH. To our knowledge, this is the first study of FEP bias in HIV and first conducted in sub-Saharan Africa.

Cognitive correlates of FEP varied by serostatus, consistent with the RDoC framework. In PWH, declarative memory was associated with greater accuracy and lower bias for fear, suggesting more precise discrimination of threat cues. Psychomotor speed related to higher accuracy for sadness and neutral expressions and lower anger bias, highlighting the role of psychomotor speed in emotion perception. In PWoH, declarative memory supported anger recognition and reduced sad bias, while psychomotor speed was associated with accuracy for fear and neutral faces and lower anger bias. These findings extend prior work

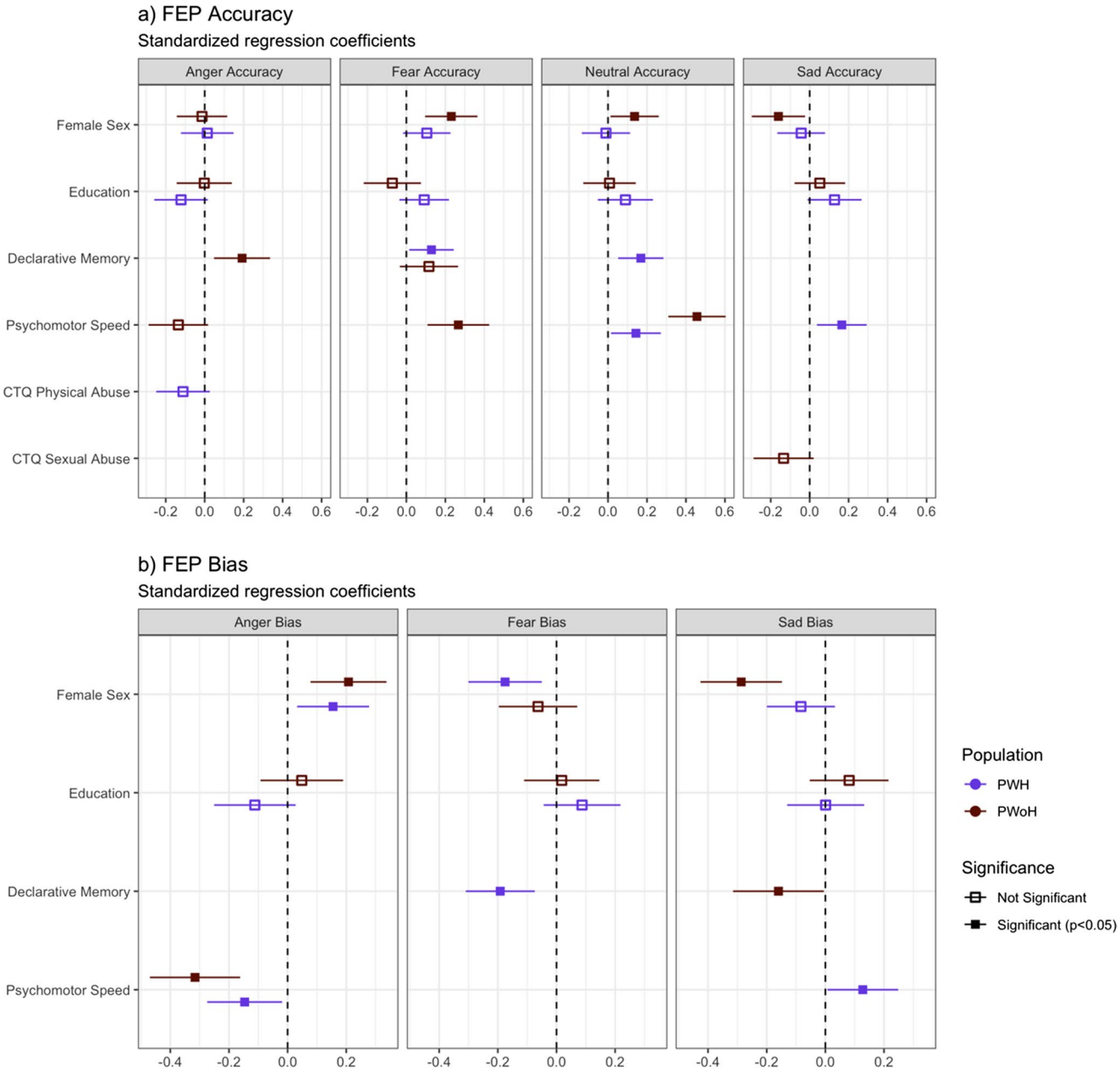

Fig. 2 Correlates of FEP Accuracy and Bias in People with and without HIV

linking memory and psychomotor speed to social cognition (Grabyan et al. 2018; Mathersul et al. 2009) and highlight potential intervention targets to improve social functioning in PWH.

Sex as a biological variable was also associated with FEP performance, particularly in PWoH. Women generally showed higher accuracy, consistent with prior studies (Hall et al. 2000; Thayer and Johnsen 2000), but also higher anger bias across groups. Interestingly, sex differences were attenuated in PWH, suggesting that HIV may alter typical sex-related patterns in emotion processing.

Contrary to prior studies in U.S. cohorts (Bourke et al. 2010; Reisch et al. 2023; Sussman et al. 2016), self-reported psychosocial symptoms were not related to FEP outcomes. Several factors may explain these null results including a sample of individuals without severe psychiatric symptoms, incomplete depression data for PWH, and limited cross-cultural validity of measures.

Prior research highlights cultural differences in the conceptualization and presentation of psychiatric symptoms in Ugandan populations compared to American and European cohorts, with Ugandan populations more likely to endorse somatic rather than affective symptoms (Betancourt et al.

2014; Bolton et al. 2004; West et al. 2024; Wilk and Bolton 2002). Measurement limitations and use of a FEPT version with white American faces may also have constrained sensitivity. Although "basic" emotions (happiness, sadness, fear, anger) can be identified cross-culturally at a minimal, higher-than-chance level of accuracy, people are generally more accurate with in-group faces (Elfenbein and Ambady 2002). This likely contributed to the lower-than-expected accuracy rates (40–70% for negative emotions) in our sample compared with U.S. and European cohorts of PWH (45–80%) (Clark et al. 2015; González-Baeza et al. 2016; Rubin et al. 2022). Future studies should incorporate culturally relevant stimuli (e.g., Black Ugandan faces) to improve sensitivity.

In summary, by examining FEP bias as well as accuracy, our study identifies a previously unexplored dimension of social cognition in HIV. Differences in bias between PWH and PWoH, and their associations with memory and psychomotor speed, underscore the value of an RDoC framework for detecting subtle brain health changes. Future work should incorporate culturally validated tools and extend these findings to other populations and HIV subtypes to better inform interventions aimed at supporting social and cognitive function in PWH.

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Data availability This study was not preregistered. Analytic materials and data will be made available upon request.

Declarations

Ethical considerations The study protocol was approved by the Western Institutional Review Board (IRB00209786), the Uganda Virus Research Institute Ethics Committee (GC/127/789), and the Uganda National Council for Science and Technology (HS634ES).

Consent to participate All participants provided written informed consent to participate in the study.

Consent for publication Not applicable.

Competing interests Scott A. Langenecker reports a relationship with Secondary Triad LLC that includes: equity or stocks. The other authors have no relevant financial or non-financial interests to disclose.

Transparency and openness We report all data exclusions, manipulations, and relevant measures. This study adheres to the EQUATOR Network's STROBE guidelines for observational studies. Data and analysis code are available from the authors upon request. The study design and analytic plan were not preregistered.

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