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EDITORIAL REVIEW

Social cognition abilities in people with HIV: the role of stigma and other factors

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Social cognition refers to the ability to perceive social stimuli, interpret their meaning, and respond appropriately to navigate dynamic social environments, including various professional and personal relationships to secure interpersonal and external resources for effective social functioning. More basic, social cognition is the complicated ability to interact with others. Known to impact everyday functioning and quality of life, deficits in this essential ability have been well documented in schizophrenia, autism spectrum disorders, depression, and other mental health conditions. Studies in other clinical populations also indicate that even subtle deficits in social cognition can impact social everyday functioning. Such social cognitive abilities include emotional face recognition/perception, prosody, theory of mind, and empathy. This review aims to survey our current knowledge on social cognition in people with HIV (PWH), focusing on the following questions: Do people with HIV show impaired social cognition? Is social cognitive impairment of PWH related to neurocognitive impairment? Are social brain regions compromised in PWH? How is social cognition related to social experiences of PWH (e.g., stigma). These questions and more are explored, from which implications for future research are posited.

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What is social cognition?

In our everyday life, we frequently interact with others (e.g., staff at local grocery stores, friends, co-workers). While many of us consider these interactions easy and effortless, these social interactions actually rely on a complex set of abilities, as we constantly need to recognize social cues from others (e.g., emotional expressions of faces, voices, or body gestures) and understand/infer their internal states (e.g., intentions, thoughts) in order to make appropriate responses. Difficulties in any of these abilities could substantially affect how one navigates the social environment and harness necessary social resources to manage complex diseases such as neuropsychiatric disorders or HIV. This set of abilities to process socially relevant information from oneself and others and make appropriate responses is referred to as social cognition [1,2].

Over the past two decades, a large body of work in social neuroscience has substantially advanced our knowledge on social cognition. Here in this section, we briefly summarize key findings that are most relevant to this article on social cognition in HIV. First, it is now well established that social cognition is a multifaceted construct that is composed of several subconstructs [1]. For instance, emotion recognition refers to an ability to understand emotional expressions of

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others from socially relevant stimuli (e.g., faces, voices, body gestures). Emotion recognition is typically assessed by presenting a picture of an emotionally expressive face and asking people to identify which emotional expression a picture represents (e.g., angry, happy, sad) [3]. Theory of mind (i.e., also known as mental state attribution) refers to an ability to accurately infer and understand mental states of others (e.g., belief, intention) by presenting stories or videos on social interactions [4–6]. Empathy concerns an ability to share and understand emotional states of others, which can be referred to as emotional empathy and cognitive empathy respectively [7]. Emotional empathy concerns the relatively automatic tendency to share emotional experiences of another person (e.g., mimic emotional facial expressions), whereas cognitive empathy concerns an ability to explicitly infer emotional states of others.

Second, social cognition is shown to be linked to a unique set of brain regions that are collectively known as social brain [8,9]. For instance, facial affect recognition has been linked to a set of brain regions, including the fusiform gyrus and amygdala [10,11]. Affect recognition using voices of others (i.e., prosody) involves brain areas including the superior temporal gyrus and inferior frontal gyrus [12,13]. Theory of mind has been shown to be linked to brain areas including the temporo-parietal junction, temporal pole, and precuneus [14]. Cognitive empathy has been shown to be associated with the dorsal medial prefrontal cortex/anterior cingulate cortex whereas emotional empathy is thought to be related to anterior insular and the mirror neuron system including the ventral premotor cortex and anterior parietal lobule [15]. These social brain regions are shown to be distinct from brain regions that are aligned to neurocognition, such as the fronto-parietal circuits and the medial temporal lobe including hippocampus that are related to working memory [16,17] and the medial temporal lobe for episodic memory [18,19], respectively. These findings suggest that at a neural circuit level, social cognition is distinct from neurocognition.

Third, several studies focusing on performance provide further supporting evidence for the distinctiveness of social cognition from neurocognition (e.g., verbal memory). For instance, a divergent pattern of social cognitive performance and neurocognitive performance was found across multiple populations [20–22], such that some show intact neurocognitive performance with impaired social cognitive performance whereas others show the opposite pattern of performance across social cognition and neurocognition. In line with these findings, the correlations between social cognitive performance and neurocognitive performance are weak or moderate (i.e., ranging from 0.1 to 0.4) in a sample recruited from the general community [23,24], people with neurological disorders [25], and people with severe mental illness [23,26]. These findings suggest that intact neurocognition is not a necessary prerequisite to have intact social cognitive ability, further supporting that social cognition is mechanistically distinct from neurocognition.

Fourth, a substantial body of work has shown the critical role of social cognition in social functioning, including social integration. Social integration broadly refers to the way one interacts and forms relationships with others and can be evaluated both objectively and subjectively [27,28]. Objective social integration (i.e., social network size) involves the quantity of social relationships (e.g., the number of friends). Subjective social integration (i.e., loneliness) involves the quality of social relationships (e.g., feeling lonely and not connected regardless of social interactions). Studies have shown that both smaller social networks and greater levels of loneliness are contributing factors to poorer health-related outcomes [29,30]. Notably, social network size and loneliness are not strongly related to each other [31] and may independently affect health-related outcomes [32]. Poor social cognitive performance has shown to be related to smaller social network size and higher levels of loneliness across multiple populations, including people recruited from the general community [33–35], people with neurological disorders [36–38], and people with substance use disorders [39,40].

Fifth, emerging evidence shows that internal and external social environment such as social conceptual knowledge (e.g., social stereotypes, prejudice) and social stress affect the way social stimuli are perceived and understood to some extent. For instance, people categorized stimuli with angry body movement to more likely to be male whereas stimuli with sad body movement to more likely to be female [41] or rate facial expressions of the ingroup members more favorably compared to the outgroup members [42]. Similarly, while social conceptual knowledge could provide a useful (albeit) simple guideline in navigating social environment, social conceptual knowledge can also negatively affect social functioning by implicitly promoting discrimination, as shown by a large body of work on implicit social cognition [43–45].

As briefly described above, over the past two decades, a large body of work in social neuroscience and clinical neuroscience has substantially advanced our knowledge on social cognition. Not surprisingly, a NIMH Research Domain Criteria (RDoC) project identified social cognition as one of the "fundamental aspects of human behaviors" [46,47], and strongly encouraged researchers to evaluate social cognition across multiple levels of assessments (e.g., performance, neural circuits) to uncover the underlying causes of poor social functioning and identify potential treatment targets.

Why is it important to study social cognition in HIV?

As stated above, social cognition is supported by a unique set of social brain regions that are largely distinct from

brain areas related to neurocognition and subserves our daily social activities, including forming intimate and meaningful connections with others and maintaining these relationships (e.g., friends, family, co-workers). In this way, optimal social cognitive health is considered the bedrock of efficient social functioning. Conversely, any impairments in social cognition could result in difficulty in navigating the social environment (e.g., negotiating well tolerated sex practices with others, having successful job interviews), harming well being, and lowering quality of life. A better understanding of social cognition in HIV both in terms of its underlying mechanisms and functional consequences can make substantial contributions to neuroHIV research in several ways. For instance, poor social integrations such as reduced social network size and higher levels of loneliness are frequently observed in people with HIV (PWH). Both social network size and loneliness of PWH are shown to be related to poor health-related outcomes, including poorer quality of life [48,49] and inadequate treatment adherence [50], and HIV-related risk behaviors [50]. Considering the key role of social cognition in social integration across multiple populations [23,37], it is possible that social cognition likely contributes to reduced social network size and greater levels of loneliness of PWH. In other words, social cognition could be a promising treatment target for improving social integration, leading to promoting quality of life and overall well being of PWH. There is a growing call to better understand the central nervous system (CNS) complications in HIV, including HIV-associated neurocognitive disorders (HAND) and heterogeneity of cognitive impairments in PWH. Considering that social cognition is shown to be supported by a unique set of social brain regions that are distinct from brain areas related to neurocognitive domains, a better understanding of neural circuits of social cognition in PWH could provide novel knowledge on the extent to which the HIV virus affects the CNS. Further, social cognitive processes are shown to be critical for understanding psychological mechanisms of discrimination and stigma. Considering the critical role of discrimination/stigma in quality of life of PWH, a systematic evaluation of the relationship between social cognition and stigma in PWH could provide novel insights into our understanding of stigma related to HIV to improve quality of life of PWH.

What do we know about social cognition in HIV?

As mentioned above, a better understanding of social cognitive processes in PWH can result in substantial public health impact. In this section, we reviewed the current state of our knowledge on social cognition in PWH, focusing on what we know and what we do not know.

Do people with HIV show impaired social cognition?

A general understanding of social cognition in HIV was summarized with a recent systematic review and meta-analysis [51] of 14 studies that focused on a sample of PWH and included measures pertaining to these social cognitive concepts: facial emotion recognition/perception, theory of mind, prosody, and empathy (Table 1). Overall, out of 14 studies, eight studies compared performance between PWH and controls using a range of social cognitive tasks. A meta-analysis using a correlated effects model produced the estimated effect size of 0.305 (95% confidence interval: 0.108–0.502), indicating mild to moderate social cognitive deficits of PWH. This review provides empirical evidence supporting impaired social cognitive performance of PWH. However, this review article also identified several gaps in our knowledge on social cognitive performance in PWH. First, as the majority of studies included in this meta-analytic review focused on facial emotion recognition (e.g., six out of eight studies in the meta-analytic review), it remains unclear whether PWH show impaired performance on other social cognitive domains. Second, while the majority of studies on affect perception compared performance of PWH to performance of community controls, as shown in Table 1, two studies on theory of mind [52,53] in PWH recruited people with substance use disorder or people with schizophrenia as a comparison group. It is unclear whether PWH have difficulty understanding and inferring mental states of others compared to community controls. It will be important to evaluate performance of PWH on a theory of mind task along with community controls to determine the extent to which PWH show impaired ability to infer mental states of others. Third, for empathy, one study [54] found lower levels of empathy in PWH; however, this study only used a self-report questionnaire, leaving a question about whether PWH show impaired performance on empathy tasks. Finally, as few studies evaluated social cognitive ability of PWH across multiple domains, it remains unknown whether the degree of impairment of PWH is similar or heterogeneous across multiple social cognitive domains.

Is social cognitive impairment of people with HIV related to neurocognitive impairment?

The finding of mild to moderate social cognitive impairment of PWH raises an important question about the relationship between social cognitive impairment and neurocognitive ability. Specifically, considering the prevalence of neurocognitive impairments in HIV, it is important to determine whether social cognitive impairments of PWH can be largely explained by neurocognitive impairments. Two studies showed that better intellectual ability (assessed with WTAR) was related to better performance on emotion recognition in PWH [55,56]. These findings suggest that social cognition and neurocognition are moderately related in PWH, similar to the

Table 1. Summary of social cognitive domains in people with HIV.

Social cognitive domain	Definition	Corresponding brain regions	Studies in HIV	Findings in HIV
Facial Emotion Recognition/ Perception	The ability to accurately infer the emotional state of others based on their facial cues (i.e., angry, sad, happy, surprise, disgust, fear, neutral)	• fusiform face area • amygdala	Baldonero *et al.*, $N=69$ [112] Clark *et al.* , $N=100$ [55] Clark *et al.* , $N=88$ [66] González-Baeza *et al.* , $N=147$ [113] Grabyan *et al.* , $N=121$ [57] Heilman *et al.*, $N=83$ [56] Homer *et al.*, $N=56$ [52] Kamkwalala *et al.*, $N=65$ [114] Lane *et al.*, $N=110$ [58] Lysaker *et al.*, $N=65$ [53] Lysaker *et al.*, $N=217$ [115] Rubin *et al.* , $N=58$ [116,117]	Most studies observed across various basic emotions (angry, sad, happy, surprise, disgust, fear).
Prosody (a.k.a., affect recognition using voices of others)	The ability to accurately infer the emotional state and intentions of others based on tonal inflections of one's voice	• superior temporal gyrus • inferior frontal gyrus	González-Baeza *et al.* $N=146$ [59]	PWH without HAND and controls performed similarly in detecting the emotional content of the sentences. However, PWH with HAND scored significantly lower than controls.
Theory of Mind (a.k.a., mental state attribution)	The ability to accurately infer and understand mental states of others (e.g., belief, intention)	• temporo-parietal junction • temporal pole • precuneus	Homer *et al.*, $N=56$ [52] Lysaker *et al.* , $N=65$ [53]	Findings were mixed. Comparison groups were either those with schizophrenia or methamphetamine users.
Empathy	The ability to accurately understand emotional states of others	• dorsal medial prefrontal cortex/anterior cingulate cortex • anterior insular	Walzer *et al.*, $N=79$ [54]	Less empathy was related to engaging in more risky behaviors that could harm others.

relationship that was also found across multiple populations. However, the moderate relationship between social cognition and neurocognition in PWH does not indicate that social cognitive impairments of PWH can be largely explained by neurocognitive impairments.

Two studies compared PWH with HAND and PWH without HAND on emotion recognition [57,58] and produced mixed findings: one found poorer performance of PWH with HAND compared to PWH without HAND [58], whereas the other study found comparable performance between two groups [57]. One study [59] compared the performance of controls to performance of PWH with HAND and without HAND on a prosody task. While PWH with HAND showed poorer performance than controls, PWH without HAND showed performance that was comparable to that of controls. Thus, it remains unknown the extent to which impaired nonsocial cognitive functioning, such as fluid neurocognitive abilities (e.g., attention, executive function, verbal and episodic memory, language, speed of processing) contribute to poor social cognitive performance of PWH [51,60,61]. It will be important to evaluate neurocognitive domains and social cognitive domains consistently across studies and longitudinally if possible.

Are social brain regions compromised in people with HIV?

Impaired performance of PWH on some social cognitive domains raises a question about the functional integrity of social brain regions in PWH. To the best of our knowledge, no study evaluated how key social brain regions of PWH function during social cognitive tasks in the scanner. However, several studies using structural neuroimaging methods showed that HIV status is related to structural changes in key social brain regions. For instance, compared to controls, PWH showed smaller amygdala volume [62], thinner temporoparietal junction [63], and smaller medial prefrontal cortex/anterior cingulate cortex [64,65]. Clark *et al.* [66] found that compared to individuals without HIV, PWH had smaller anterior cingulate cortex volumes but larger amygdala volumes, which was related to difficulty recognizing fearful facial expressions. While these studies indicate the presence of structural abnormalities in key social brain regions in PWH, the direction of abnormalities, especially concerning the amygdala, has not been consistently reported. Further studies are needed to determine whether the amygdala volume could be related to certain subgroups in PWH. Structural abnormalities in key social brain regions in PWH suggest that functional

integrity of social brain regions may also be compromised in PWH, leading to impaired social cognitive performance.

Is impaired social cognition of people with HIV related to social functioning?

To the best of our knowledge, two studies examined the relationship between social cognition and social functioning in PWH. Clark *et al.* [55] found that poorer recognition of anger in facial expressions was linked to greater distress related to maintaining social connectedness. Grabyan *et al.* [57] observed that facial emotion recognition accuracy correlated with social ability, as measured by the Communication subscale of the UCSD Performance-based Skills Assessment-Brief. These findings support initial evidence for the potential role of social cognition in impaired social functioning of PWH. Future work is needed to determine how robust these relationships are, whether similar relationships would be present across other social cognitive domains and other aspects of social functioning including social isolation, network quality, and integration into support systems, patient-medical provider communication, negotiating safe sex practices, among others, and whether social cognition explains variance in social functioning beyond that explained by other determinants such as neurocognition and stigma (i.e., incremental validity) to better understand the extent to which social cognition influences the social functioning of PWH and guide intervention development.

How is social cognition related to social experiences of people with HIV (e.g., stigma)?

While little is known about the underlying causes of social cognitive impairments in PWH, emerging literature on implicit social cognition suggests that existing social conceptual knowledge or social experiences is likely to affect social cognitive processes. People with certain attributes or identities (e.g., economic/racial/ethnic/sexual marginalized communities, HIV) often experience prejudice or discrimination in their everyday life as they can be seen as having lower social values than others, which is referred to as stigma [67]. In HIV, nearly 50% of PWH experience stigma [68], and many PWH report the toll of dealing with stigma in their everyday life. Not surprisingly, a large body of work has shown that HIV-related stigma substantially affects treatment outcomes and quality of life of PWH as well as HIV-related complications, such as neurocognitive impairments [67,69–71]. However, stigma was never considered in the context of social cognition studies in HIV, even though the effect of prejudice/discrimination on social cognitive processes has been well documented in other populations. Likewise, the impact of stigma derived from mental health/psychiatric conditions that often co-occur with HIV were also largely missing from this literature, which is surprising given the impact they have on neurocognition and social interaction [72–74].

What is the relationship between stigma and neurocognition of people with HIV?

Emerging evidence suggests that greater levels of stigma may compromise neurocognition in PWH. In a cross-sectional sample of 780 women living with HIV who participated in the Women's Interagency HIV Study (WIHS), Thompson *et al.* [70] found that higher levels of internalized HIV-related stigma were significantly associated with poorer global neurocognitive functioning as well as with seven neurocognitive domains (e.g., executive function, learning). This finding on global neurocognitive functioning remained after adjusting for age, race, education, income, years on antiretroviral therapy, viral load, illicit drug use, and prior nonsocial cognitive test scores. In a related cross-sectional study of 512 older white men living with HIV in Canada, Lam *et al.* [75] found that higher levels of HIV-related stigma were related to lower levels of neurocognitive performance and poorer mental health outcomes, which could also contribute to poorer neurocognitive performance.

There are several ways stigma can affect neurocognitive impairments of PWH. First, according to the cognitive load theory, people have limited neurocognitive capacity and if there are competing tasks or additional information to process, such as experiencing stigma in one's life, this could result in less neurocognitive resources (i.e., decreased neurocognitive efficiency) [71]. Second, prolonged stress from chronic stigma can activate the hypothalamic-pituitary-adrenal (HPA) axis [76] which overtime can inflame tissues including the brain and lead to synaptic loss and neuronal atrophy, impairing neurocognition [77–79]. And third, stigma can shrink one's social networks; stimulation from social interactions provides neuroplastic benefits to support brain function [80], leading to impaired neurocognition. Work in healthy older adults shows that reduced social networks correspond to changes in the brain, including brain interconnectivity [60]. It should be noted that these possible pathways between stigma and neurocognitive impairments in HIV are not mutually exclusive. In other words, it is possible that stigma could affect neurocognitive impairments through multiple pathways. Different types of stigmas, whether anticipated, perceived, or internalized [81], may also impair neurocognition in multiple ways.

What is the relationship between stigma and social everyday functioning of people with HIV?

Stigma (i.e., experienced, internalized, or anticipated) may influence one's motivation to seek out social experiences and prevent someone from disclosing

his/her HIV status or from fully engaging in social interactions, resulting in the inability to form close connections with others. Such stigma-related social withdrawal, leading to poor social integration, is well documented [82] in HIV research. For example, in a global survey of PWH ($N = 2035$), Nachega *et al.* [83] reported that 37% of PWH report loneliness due to their HIV status. Furthermore, in a study of 1082 PWH, using a series of latent growth curve analyses, Lightner *et al.* [84] observed that both cross-sectionally and longitudinally greater anticipated stigma predicted a smaller social network. Similarly, greater internalized stigma cross-sectionally predicted a smaller social network. Unfortunately, such social withdrawal prevents the building of such social connections and social support which can serve as a buffer against many of the negative consequences of living with HIV including mortality [85,86]. These maladaptive social interactions can obviously influence innate neural networks of social cognitive heuristics, shaping how PWH view their social world. Thus, interventions that reduce stigma and improve resilience may be a strategy to ultimately improve social everyday functioning among PWH [87,88].

What is the relationship between stigma and social cognition?

While stigma has not been investigated in the context of social cognition in HIV, the relationship between stigma and social cognition has been studied using a variety of methods across multiple populations. In this section, we reviewed these findings that can be largely divided into two lines of work and then discuss possible relationships between stigma and social cognition of PWH for future studies.

In one line of work, a few studies directly examined how internalized stigma and related self-experiences affect social cognition in individuals who are at clinical high risk for developing psychosis. These individuals typically experience sub-threshold psychotic symptoms (e.g., suspicious thoughts, hearing sounds that are not fully formed) but do not have a diagnosis of schizophrenia spectrum disorder [89]. Compared to those who did not feel ashamed of their symptoms [90], those who felt greater shame due to their psychotic symptoms reported lower accuracy for recognizing fearful facial expressions, but not for other emotional expressions. This finding suggests that self-stigma may be related to heighted perception of fearful social cues. When evaluating the relationship between emotion recognition and specific types of stigma, slower reaction time for recognizing emotional expressions of faces was related to greater levels of internalized stigma and personally experienced discrimination but not to stigma awareness [91]. These findings indicate internalized stigma and related discriminatory experiences, rather than stigma awareness, affect the way social information is perceived. However, it remains to be determined whether internalized stigma and experienced stigma are related to other social cognitive constructs, as one study did not find the relationship between shameful feeling (due to psychotic-like experiences) and performance on a theory of mind task among people who are at clinical high risk for psychosis [92].

The second line of work involves studies that primarily focused on social cognitive processes related to social conceptual knowledge (e.g., social stereotype, prejudice, discrimination). These social cognitive processes are collectively referred to as implicit social cognition, as they can be more accurately measured with implicit measures, such as a priming paradigm or an Implicit Association Task. In other words, implicit measures indirectly assess the way social conceptual knowledge, the construct of interest (e.g., social stereotype, bias based on the identity or other unique attributes), is related to the way individuals process socially relevant information from others. For example, during a priming task that assess the effect of racial bias on facial perception, people are asked to rate the levels of danger of an object (e.g., guns or tools) that appear right after the priming faces (e.g., Black or White) [93]. They are instructed to ignore the priming faces, which is the construct of interest. The effect of this construct of interest can be only indirectly inferred from performance (e.g., reaction time differences per the type of priming faces), rather than being directly measured. Participants were faster at responding to guns when Black faces were used as a primer, which is thought to represent racial stereotype. Implicit bias related to racial stereotype was also related to larger N170 amplitude [94], an event-related potential (ERP) signal that is thought to be sensitive to early visual processing of facial information, suggesting that people with a stronger racial stereotype may process faces of other races differentially at a neural level as well.

During an Implicit Association Task (IAT) on sex, people are asked to categorize exemplars (e.g., names) into one of two categories: target category (e.g., female versus male) and attribute category (e.g., career versus family) [95]. People are thought to respond quickly when the same response key is assigned to the target and attribute categories that are more strongly associated (e.g., male-career). In this study, female and male participants showed similar levels of implicit gender bias but male participants were more likely to show explicit gender bias than female participants. Using the IAT, several studies showed the relationship between implicit bias and the evaluation of social stimuli and subsequent decision making. For example, among Chinese people, greater anti-White implicit bias was related to greater perceived intensity of negative facial emotional expressions [96]. People with greater implicit bias for other races rated other-race faces less trustworthy [97,98]. People with greater implicit pro-white bias also made more generous financial offers to white players during a social decision-making task [98].

These findings indicate that social conceptual knowledge (e.g., social stereotype) influences the way social stimuli are perceived, which in turn affect subsequent social interactions.

Social cognition is employed to detect threats and other potential pitfalls in the larger social environment. Greater implicit bias toward HIV could affect social relationships in several ways. For instance, greater implicit bias toward HIV in the community/social setting could result in greater micro-aggressive behavior toward PWH. Likewise, with HIV infection being such a highly stigmatized disease resulting in real and/or perceived discrimination (e.g., job termination, loss of friends/significant others), the greater someone perceives and/or internalizes HIV stigma, the greater this may compromise or alter his/her social cognitive abilities. This stigmatizing impact on social cognition may be exacerbated when combined with other stigmatizing characteristics among PWH such as race, sexual minority status, and poverty status. As discrimination in everyday life could become stressful chronically over time, it could also affect one's social cognitive abilities. Alternatively, better social cognitive ability could be important for utilizing optimal coping strategies to harness social support needed to address discrimination in everyday life.

As different groups of people experience various levels of stigma by race, biological sex, gender, age, income, sexual orientation, and sexual identity, disentangling these intersectional stigmas and their relationships present an enormous challenge. Although one can try to employ complex statistical techniques and administer instruments that measure different types of stigma (i.e., homophobia, racism, HIV-related stigma, etc.), as mentioned one strategy is to study these relationships in homogenized samples (e.g., Lam *et al.* [75]).

Implications for interventions and future studies

In this article, we reviewed our current understanding of social cognition in PWH and gaps in our knowledge on social cognition in PWH with an emphasis on stigma. In this section, we address several important topics related to social cognitive research in HIV that have not been mentioned previously. First, in several clinical populations, in-depth mechanistic knowledge on social cognition and social brain has led to successful evaluation of novel interventions using innovative biomarkers. For instance, a group-based psychosocial intervention over a period of 12 weeks improved performance of people with psychotic disorders on facial affect perception, the improvement that was still present 6 weeks after the intervention was completed [3]. Another study showed that social cognitive skills training in conjunction with vocational rehabilitation improved both social cognitive performance and social skills work behavior of Veterans with psychotic disorders compared to a time- and format-mated control training [99], suggesting that social cognitive skills training could benefit work outcomes. Further, a recent study showed that a computerized training on social cognition also improved social cognitive performance of people with psychosis [100], suggesting that the effect of social cognitive training is not dependent on the specific format. Furthermore, a computerized social cognitive skills training has been shown to be effective in improving social cognitive performance of community-dwelling people without psychiatric disorders [101,102]. As computerized training also can be scalable and administered remotely, the adaptation of computerized social cognitive training could benefit PWH with impaired social cognitive performance. As these interventions were developed and evaluated in psychiatric research, it will be important to carefully consider contextual factors unique to PWH when adapting social cognitive training to improve social cognitive ability of PWH. While existing evidence largely supports the effect of psychosocial intervention on social cognitive performance, it remains to be determined whether pharmacological interventions such as oxytocin could strengthen the effect of social cognitive skills training on social cognitive performance, as existing studies on psychiatric population showed mixed findings [103,104]. While one may wonder if intervention studies targeting social cognitive performance of PWH are premature given our limited understanding of social cognition in this population, we believe it will be beneficial to adapt validated psychosocial interventions and conduct a carefully designed clinical trial study that could inform us about the mechanistic pathway between social cognition and social functioning of PWH.

Related to social cognitive training approaches, given the small to modest association between neurocognition and social cognition, perhaps approaches to improve neurocognition could benefit social cognition and improve social connectedness. Many studies on cognitive training in PWH have been conducted that show that the cognitive domain that was targeted for training usually improves (i.e., speed of processing training improves speed of processing). But these studies also show that transfer effects are sometimes observed in which everyday functioning (i.e., improved medication adherence) and quality-of-life indicators (i.e., decreased depressive symptomatology) show positive changes after such cognitive training [105–107]. Although not examined yet in the literature, such cognitive training approaches could bolster social cognitive abilities and perhaps social connectedness.

Second, for future studies, it will be important to systematically evaluate neural systems related to social

cognitive processes of PWH [103,104,108]. As briefly mentioned above, while studies using structural neuroimaging methods have shown structural aberrations of social brain regions in PWH, little is known about the functional integrity of social brain in PWH. For example, we do not know whether certain social brain regions are more functionally compromised than others or whether each social brain region functions properly but do not efficiently work together to support efficient social cognitive performance. Advanced knowledge on social brain of PWH could also provide novel insights into the extent to which HIV virus affects CNS. It would also provide novel biomarkers or treatment targets for developing and evaluating innovative interventions (e.g., neuromodulation). Thus, we recommend future studies to employ a rigorous data collection and analytic method to systematically evaluate neural circuits related to social cognition of PWH, similar to the NIH Human Connectome Protocol [109].

Third, a recent systematic review of cognitive intra-individual variability (IIV) suggests that for some PWH, their cognitive abilities may fluctuate within cognitive trials (i.e., inconsistency) or between cognitive domains (i.e., dispersion) more than others, even though their mean-based cognitive performance may seem normal [110]. In fact, cognitive IIV may be more sensitive than baseline mean-based cognitive functioning at predicting cognitive decline years later, dementia, everyday functioning impairments, and even mortality [110]. Given emerging evidence demonstrating the innovation and sensitivity of cognitive IIV in predicting such everyday functional ability in women with HIV [111], cognitive IIV may also be a more sensitive marker of social cognition than neurocognition alone. If one's cognitive abilities fluctuate widely, this could impair everyday functioning, and perhaps social everyday functioning; likewise, this internal cognitive state may influence how some PWH interact and perceive their social world, impacting their social cognition. Thus, social cognitive abilities may also fluctuate in relationship to cognitive IIV or could fluctuate separately. Either way, this represents a unique and innovative way in which this field might move forward, potentially creating a profile of social cognitive abilities in PWH not only represented by mean estimates of performance but also by cognitive IIV in social cognitive abilities.

Fourth, studies of social cognition in PWH should consider indicators of social everyday functioning beyond social network size and loneliness. Although these are adequate and face valid measures, there are other indicators of social everyday functioning that should be considered, especially within the context of stigma. These include social alienation as well as social support availability and satisfaction as other parameters of social support.

Fifth, while we touched on stigma, mainly experienced, internalized, and anticipated, we did not delve deeper into the role of self-stigma versus social (i.e., structural) stigma and what these other types of stigma may have in influencing social cognition. Clearly, one's social cognitive abilities may influence the impact that different types and strengths of stigma exert on the individual; likewise, different types and strengths of stigma may impair social cognitive abilities. This dynamic becomes more complicated when one considers the role of actual or perceived discrimination. Compounding this complexity is not only the stigma and discrimination related to one's HIV status, but the interaction of other types of stigmas related to being an ethnic minority, female, sexual minority, socioeconomically disadvantaged, overweight/obese, older, and using psychoactive substances. In fact, for many PWH, they may have two or more stigmas that interact that influence or impair their social cognitive abilities.

Sixth, the lens of social cognition in PWH allows us to reexamine much of the work that has already been conducted, in particular HIV prevention and adherence approaches along the continuum of care. As posited in this article, some PWH may have suboptimal or more frank impairments in social cognition; this could influence how health-related information concerning PrEP or HIV prevention strategies or medication adherence communicated from doctors and nurses is interpreted or misinterpreted. Likewise, even doctors and nurses may have suboptimal cognitive abilities and overlook or misinterpret vital social information from patients and miss opportunities for effective treatment delivery. Thus, such health information approaches may be reexamined with strategies to better convey health information that may be missed by suboptimal social cognition in both PWH and care providers.

Finally, these future directions must be directed with one primary outcome, and that is to improve the social everyday functioning of PWH to improve their social resources, negotiate complex social environments safely while maneuvering through stigma, and ultimately form meaningful connections with others despite the complications of HIV. Thus, future interventions should target how to mobilize personal and social resources to attenuate the negative effects of stigma and related mood disturbances that can erode both social and neurocognitive resources in PWH.

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Conflicts of interest

The authors report no real or perceived vested interest that relate to this article that could be construed as a conflict of interest.

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