Review

Social motivation in schizophrenia: How research on basic reward processes informs and limits our understanding

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HIGHLIGHTS

- Social impairment in schizophrenia arises from skill, cognition, and motivation deficits.
- Research on reward has improved understanding of general motivation.
- This work, however, lacks specificity for understanding social motivation.
- Insights emerge from research focused on social reward and punishment interactions.

ABSTRACT

Limited quantity and quality of interpersonal exchanges and relationships predict worse symptomatic and hospitalization outcomes and limit functional recovery in people with schizophrenia. While deficits in social skills and social cognition contribute to much of the impairment in social functioning in schizophrenia, our focus on the current review is social motivation—the drive to connect with others and form meaningful, lasting relationships. We pay particular attention to how recent research on reward informs, and limits, our understanding of the construct. Recent findings that parse out key components of human motivation, especially the temporal nature of reward and effort, are informative for understanding some aspects of social motivation. This approach, however, fails to fully integrate the critical influence of uncertainty and punishment (e.g., avoidance, threat) in social motivation. In the current review, we argue for the importance of experimental paradigms and real-time measurement to capture the *interaction* between social approach and avoidance in characterizing social affiliation in schizophrenia. We end with suggestions for how researchers might move the field forward by emphasizing the ecological validity of social motivation paradigms, including dynamic, momentary assessment of social reward and punishment using mobile technology and other innovative tools.

"Perhaps in no other domain of life is the simultaneous potential for rewards and threats so clear as it is for interpersonal relationships" (Gable & Prok, 2012, p. 352)

Social impairment in schizophrenia is pervasive and debilitating (Lipton, Cohen, Fischer, & Katz, 1981; Mueser, Bellack, Douglas, & Morrison, 1991). Impaired social functioning, including limited quantity (e.g., few number of friends, low frequency of contacts with family) and quality (e.g., low perceived benefit, diminished social skills) of interpersonal exchanges and relationships, is often the norm (Bellack, Morrison, Wixted, & Mueser, 1990; Corrigan & Phelan, 2004; Mueser &

Bellack, 1998). While recent work has shown that impaired social functioning is common across the developmental course of schizophrenia spectrum disorders (Barbaro & Dissanayake, 2007; Fulford et al., 2013; Fulford et al., 2013; Schlosser et al., 2015), we still know very little about what contributes to social impairment (Green et al., 2017). What we know from research in the general population, however, is that limited social engagement (i.e., social isolation), and especially the subjective experience of social isolation (i.e., loneliness), can have profound negative physical and psychological consequences (Cacioppo, Cacioppo, Capitanio, & Cole, 2015; Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006; Fett, Viechtbauer, Penn, van Os, &

Krabbendam, 2011; Green et al., 2017). Recent studies underscore robust links between social engagement and loneliness with increased likelihood of mortality, putting social isolation on par with smoking as a leading cause of early death (Holt-Lunstad et al., 2015; Steptoe, Shankar, Demakakos, & Wardle, 2013).

In the current review, we will focus on social motivation as a key contributor to social functioning impairment in schizophrenia. We will make a case that the dynamic interplay between the experience of pleasure/reward and rejection/punishment in social interactions is key for our understanding of social motivation and related social functioning impairments. We will argue that it is time for the field to move beyond basic reward processing as a means of understanding what goes awry in social functioning—that the complexity of social motivation cannot be modeled with monetary rewards and losses and instead must involve real-life social exchanges that involve the dynamic interaction between rewards and punishments.

1. Current understanding of contributors to social functioning in schizophrenia

Three primary contributors to social functioning have been examined extensively in schizophrenia: social skills, social cognition, and social motivation[1] (see Table 1). Among these components, deficits in social skills and social cognition have been the most widely studied (Bellack et al., 1990; Couture et al., 2006; Fett, Viechtbauer, Penn, van Os, & Krabbendam, 2011; Green et al., 2017; Mueser & Bellack, 1998; Mueser et al., 1991).

Social skills include the observable behaviors occurring during social exchanges that support social competence, or the ability to achieve goals through social interaction (Bellack, Mueser, Gingerich, & Agresta, 2004). These skills are typically measured using standardized role-play scenarios, where observers code the quality and quantity of particular skills expressed. Social skills encompass a variety of behaviors, including reciprocity, problem solving, active listening, and appropriate eye contact and affective expression. Due at least in part to the broad neurobiological vulnerability of the disorder, individuals with schizophrenia experience deficits in social skills from an early age (Schiffman et al., 2004), and these deficits are relatively stable over time (Mueser, Bellack, Douglas, & Morrison, 1991). Importantly, social skill deficits contribute to lower subjective quality of life and well-being in schizophrenia (Salokangas, Honkonen, Stengård, & Koivisto, 2006).

Social cognition, as commonly studied in schizophrenia, includes abilities such as facial affect recognition, theory of mind, and emotion regulation. These abilities are believed to encompass the broad cognitive and emotional facets underlying social behavior. Given its multifaceted nature, social cognition is measured using a variety of instruments. While social cognition overlaps with more basic neurocognitive variables (e.g., working memory, processing speed), it is a separable construct that has been shown to mediate the relationship between general neurocognition and functional outcomes in schizophrenia (Green & Harvey, 2014). The surge in research on social cognition in schizophrenia has consistently documented a relationship to community functioning. For example, while neurocognition accounts for roughly 6% of the variance in community functioning, upwards of 16% may be explained by social cognitive abilities (Couture et al., 2006; Fett et al., 2011).

Despite the critical roles of social skills and social cognition in social functioning, there remains much to be explored in understanding contributors to successful forming and maintaining of interpersonal relationships in schizophrenia. For many years, researchers and

clinicians believed that diminished interest or pleasure in social relationships (i.e., social anhedonia) explained the majority of the social isolation witnessed in schizophrenia (Kwapil, 1998). This belief was largely driven by observations that people with schizophrenia appeared to be uninterested in social contact. Recent evidence, however, suggests that people with schizophrenia report a desire for social affiliation in standardized tasks (e.g., Blanchard, Park, Catalano, & Bennett, 2015) and in their daily life experiences (Gard et al., 2014), and they report improved social activity and inclusion as a top priority for treatment outcome (Shumway et al., 2003). Despite the clearly expressed need for connection, people with schizophrenia set fewer social goals in their daily lives (Gard et al., 2014), and consistently report being more alone and socially isolated than do people without schizophrenia (Andreasen, 1982; Grant, Addington, Addington, & Konnert, 2001). Thus, rather than a general impairment in the experience of pleasure from relationships, there appear to be deficits in other social-affiliative behaviors that contribute to forming and maintaining social connections.

How can we reconcile the observation that people with schizophrenia often report a healthy desire to connect with others, yet show challenges in initiating and maintaining interpersonal relationships? One fruitful area to draw from is the burgeoning research in motivation and reward—in particular, recent translational research on objectively measured effort. Although this area of work has provided a new understanding of motivational impairment in schizophrenia, we still know relatively little about the mechanisms that drive deficits in *social* motivation, partly because motivation for social connection is inherently more complex than motivation for basic rewards (e.g., money, food), and thus more difficult to operationalize using self-report scales, or even laboratory tasks. The inherent uncertainty of social reward and punishment, for example, requires more cognitive and emotional resources than simply striving for consistently positive outcomes (as is measured in existing motivation/reward paradigms). Social interactions also have high potential for negative outcomes, such as criticism. In fact, the rewarding properties of social stimuli have the unique characteristic of potentially shifting to punishment (e.g., rejection) at any moment, which is quite distinct from the rewarding stimuli used in most basic reward studies (e.g., winning or losing money), where losing a rewarding stimulus is not the same thing as the experience of pain of criticism or rejection.

Given these complexities, the focus of this review will be on the current state of knowledge surrounding social motivation in schizophrenia, paying particular attention to how recent research on reward informs, and limits, our understanding of social motivation, or behaviors in the service of connecting with others. We will highlight recent findings that parse out key components of human motivation, especially the temporal nature of reward and effort. In reviewing this research, we emphasize how studies have not fully integrated the critical influence of uncertainty—i.e., the challenge in predicting whether an activity/task will result in reward (e.g., praise) or punishment (e.g., rejection)—a construct we believe is key to understanding motivation for social interaction in schizophrenia (see Fig. 1). We also emphasize that social motivation can be distinguished from social cognition and social skills on the basis of drive for social interaction, including observable exertion of effort needed to form and maintain social bonds. After covering the broader research on social motivation and application to schizophrenia, we argue for the critical importance of real-time measurement approaches that capture in-the-moment *interactions* between social approach and avoidance in order to best characterize social motivation and affiliation in schizophrenia. We end with suggestions for how researchers can move the field forward by emphasizing the ecological validity of social motivation paradigms, including dynamic assessment of social reward and punishment interactions.

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[1] There are certainly other features that contribute to social functioning, including trait affiliation (Depue & Morrone-Strupinsky, 2005), extraversion (Cohen, Doyle, Skoner, Rabin, & Gwaltney, 1997), sociability (Cheek & Buss, 1981), and attachment (Bohlin, Hagekull, & Rydell, 2000). In the current review we focus on those facets most studied in the context of schizophrenia.

Table 1

Three domains of social behavior commonly studied in schizophrenia.

| Domain	Definition	How measured	Findings in schizophrenia
Social skills	Learned, observable behaviors that contribute to social competence	- Role-plays - Clinician-rated assessment	- Impaired skills present across course of illness - Associated with negative symptoms - Associated with stigma
Social cognition	Cognitive and emotional facets underlying and supporting social behavior	- Performance- based tasks (e.g., RMET, TASIT, MSCEIT)	- Primary deficits in emotion recognition and theory of mind - Associated with general neurocognition and psychosocial functioning deficits
Social motivation	The drive to form and maintain social bonds	- Self-reports of affiliative tendencies and enjoyment of social interaction - Interview-based measures of objective markers of social contact	- Normative reports of desire for connection with others - Deficits in ability to derive pleasure from interpersonal relationships (i.e., social anhedonia)
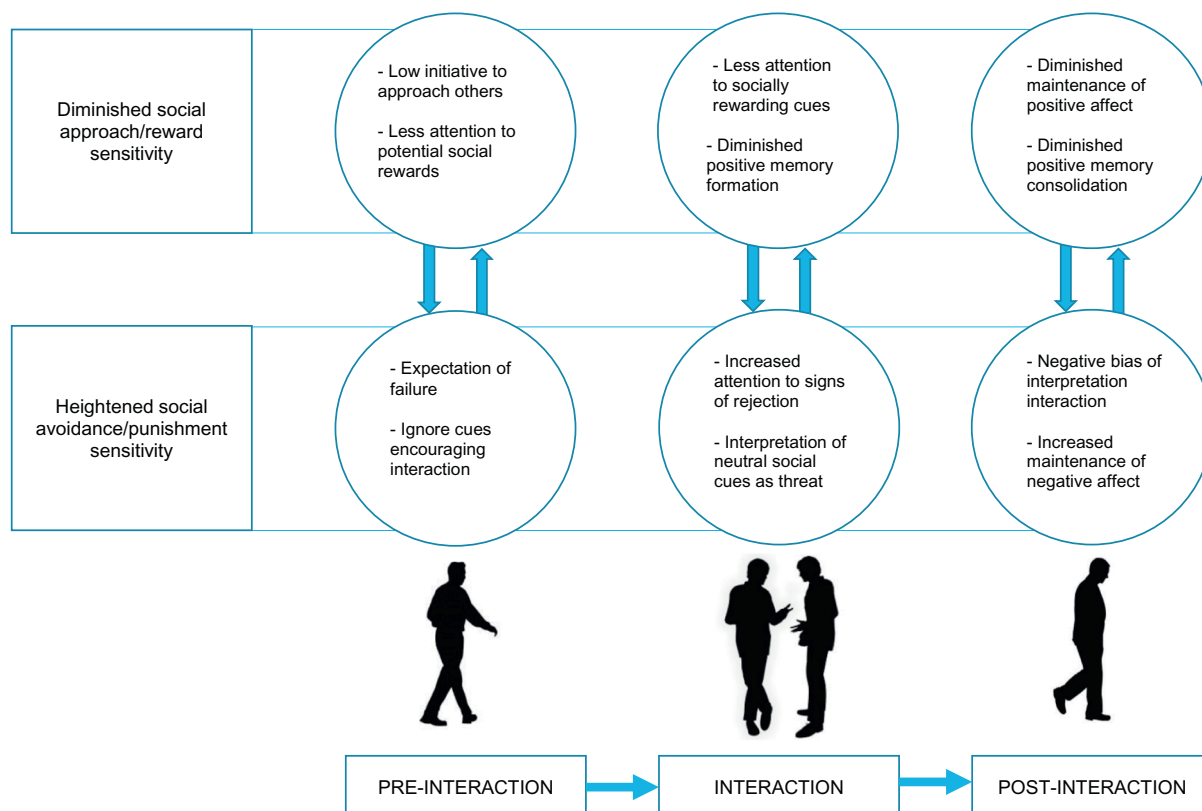
Fig. 1. Temporal nature of social motivation in schizophrenia: Interactions between approach and avoidance.

2. General (non-social) motivation in schizophrenia: a (brief) review and integration of behavioral and neuroscientific evidence

Behavioral neuroscience has contributed to the understanding of motivation through the use of manipulations (e.g., drug administration, lesions, genetic knock-outs, optogenetics) in human and animal models that serve to parse out component parts of complex behavior. In this work, reward is usually operationalized as the motivational and emotional effects of reinforcing stimuli (Salamone & Correa, 2012; Salamone, Correa, Farrar, Nunes, & Pardo, 2009). In humans, this reinforcement is typically direct monetary gain, and in animals, preferred food. In animals, motivation is often conceptualized in behavioral terms (e.g., the amount of effort given to seek out and consume food). Historically, much of the evidence for human motivation was based on self-report data or observations from clinical interviews. More recent research has focused on behavioral data, such as button presses to indicate physical effort (see Green, Horan, Barch, & Gold, 2015). As such, while motivation is clearly complex and multifaceted, we can think of the construct as being comprised of three key components that

contribute synergistically to goal-directed behavior: 1) reward learning, 2) hedonic experience, and 3) effort computation and expenditure. Using this framework for understanding human goal-directed behavior, we will cover some helpful translational models of reward in psychopathology research, and conclude with the sparse findings linking these processes to social functioning outcomes in schizophrenia.

Because our focus is on the big picture of how research on basic reward processes both informs and limits our understanding of social motivation in schizophrenia, we do not cover this work in extensive detail. Instead, we identify areas of work most critical for informing our organizational framework for studying social motivation in schizophrenia (see Fig. 1). In this framework, we highlight the extent to which social approach and avoidance tendencies influence a) preferences for initial engagement in interactions (pre-interaction), b) understanding of interpersonal dynamics during interactions (during interaction), and c) interpretation of interaction outcomes (post-interaction). In each of these situations, tendencies toward approaching and avoiding social stimuli interact to influence the extent to which social connection occurs across time. As we discuss below, research on basic reward
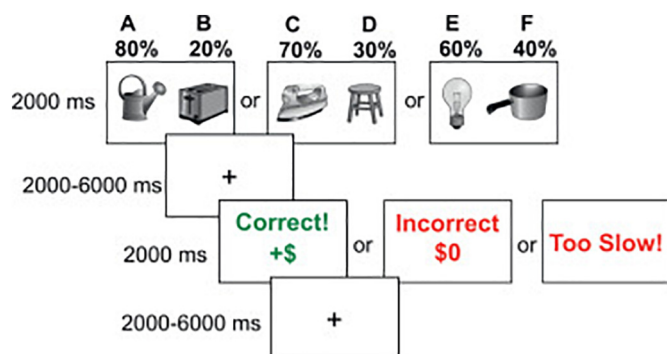
Fig. 2. Example reward learning task. Participants are presented with one of three pairs of stimuli (i.e., "AB," "CD," or "EF") in pseudorandomized order and are instructed to choose the stimulus that they believe is "correct" based on feedback received over time. Participants are told they will win money for each correct choice. For stimulus pair AB, the choice of A was rewarded 80% of the time, while B was rewarded 20% of the time; for pair CD, C was rewarded 70% of the time and D was rewarded 30% of the time; and for pair EF, E was rewarded 60% of the time and F was rewarded 40% of the time. From Dowd, Frank, Collins, Gold, & Barch (2016).

processes has provided a useful framework for conceptualizing social motivation as a temporal process. Despite this promise, studies to date have failed to integrate the influence of avoidance (e.g., sensitivity to punishment, rejection) on motivated behavior—an omission we feel is critical to understanding social motivation impairment in schizophrenia.

2.1. Reward learning

A key paradigm researchers have used to understand motivation is 'reward learning.' Reward learning is a type of reinforcement learning in which organisms respond to potentially rewarding stimuli, using behavioral actions in contexts that predict positive (or lack of positive) outcomes. Research in humans has shown reward learning deficits in both depression and schizophrenia (e.g., Pizzagalli et al., 2009; Waltz, Frank, Wiecki, & Gold, 2011). Tasks that assess reward learning are constructed such that participants learn gradually or rapidly which behavioral response is rewarded (or which behavioral response results in a loss of reward), often interspersed with trials in which a non-response is rewarded (or where a nonresponse results in a loss of reward) (see Fig. 2). Research has shown that people with schizophrenia show deficits in the initiation of responses that are reinforced, but typically no deficit in learning when rewards are removed, described in this literature as 'punishment.' In other words, learning that is associated with the receipt of reward, and not necessarily the removal of reward (or loss), is impaired in schizophrenia (e.g., Reinen et al., 2014). Interestingly, other studies suggest people with schizophrenia appear to have intact learning from passive avoidance; that is, in avoiding actions that lead to monetary loss (see Strauss, Waltz, and Gold, 2014 for a review). These findings have been supported with neurobiological evidence. For example, Gradin et al. (2011) investigated the neural correlates of expected and unexpected rewards in people with depression, people with schizophrenia, and healthy controls. In people with schizophrenia, reduced activity was observed in various regions of the brain associated with reward processing (e.g., caudate, thalamus, insula) during trials in which there was a difference between expected and actual outcomes. Thus, learning the extent to which reward will follow an instrumental response appears to be processed differently in schizophrenia, in a way that may lead to motivational deficits. It has been suggested that deficits in the representation of value may underlie some of these differences (Gold et al., 2008).

In consideration of the application of this work to understanding social motivation, it is possible that generalized deficits in the representation of value influence the perception of the degree to which social connection results in reward. In fact, given that social interaction is much more complex and dynamic than receipt (or loss) of a monetary reward, any broad deficits in the representation of reward are much more likely to have an impact on motivation for social interactions, where the signal for reward is likely to be less salient and potentially fraught with punishment, such as criticism. Furthermore, the instrumental responses in social engagement are also likely to be more complex and dynamic. That is, to obtain a social reward, one must identify the potential of a reward, seek it out, and follow through with appropriate behavior, all the while avoiding punishments such as social rejection, an outcome which can be hard to predict.

Importantly, findings of basic reward learning differences in schizophrenia do not tell us *why* rewarding outcomes are less valued. For example, it could be that subjective value is depreciated because the costs outweigh the potential benefit. Notably, this research does not address how learning of basic rewards (e.g., money, food) might influence more complicated goal-directed behavior, such as social interaction, and subsequently social functioning outcomes. Indeed, we could identify only one study finding links between reward learning deficits and global functioning, with no specific connections to social functioning (Somlai, Moustafa, Kéri, Myers, & Gluck, 2011). (It should be noted, however, that commonly used measures of functioning may be limited in their sensitivity to detect short-term changes in social functioning.) In addition, while many studies incorporate both obtaining and losing rewards, they have not fully integrated *punishment* in a way that might provide insight into the impact of unexpected loss (for example, during anticipated reward or neutral trials). We now turn to recent work addressing the connection between time-dependent hedonic experience and instrumental behavior, which has uncovered additional complexities of motivated behavior with high potential applicability for understanding functioning in schizophrenia.

2.2. Hedonic experience: liking and wanting

One key area of research on hedonic (pleasure) experience has been particularly informative in psychopathology research. Specifically, fundamental research over the past two decades has challenged the hypothesis that the neurotransmitter dopamine was primarily implicated in the passive experience of pleasure, and is instead more temporally situated. That is, dopamine systems appear to modulate the motivational value or salience of stimuli in a manner that is distinct from hedonic experience and reward learning (Berridge & Robinson, 1998). This work was initially informed by a series of translational experiments. Berridge and Robinson (1998) applied the 'taste reactivity' measure of affective reactions to assess the capacity of dopamine-depleted rats for: 1) affect reactions, 2) affect modulation by associative learning, and 3) enhancement of affect by pharmacological manipulation of palatability. The authors found normal hedonic-based outcomes, concluding that dopamine systems are not central to affect-based responding and learning. Instead, they identified dopamine as important to attributions of *incentive salience* for neural representations of rewarding stimuli. As such, dopamine systems are considered necessary for 'wanting' of rewards, but not for 'liking' them or for learning new 'likes' and 'dislikes' (Berridge & Robinson, 1998).[2]

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[2] While the role of dopamine in schizophrenia is not straightforward, there is some evidence that dopamine synthesis and expression may influence different symptom domains in different ways. For example, hyperactivity of D2 receptor neurotransmission in subcortical regions may contribute to positive symptoms (i.e., hallucinations and delusions), while negative symptoms may be more related to hypofunctionality of D1 receptor neurotransmission in the prefrontal cortex (e.g., Toda & Abi-Dargham, 2007). Furthermore, studies show that perceived effort cost is increased by pharmacologic manipulations that enhance D2 receptor excitability in the striatum, while perceived effort cost is reduced after decreasing this excitability (Nunes et al., 2010). Despite the impact of antipsychotic medications on dopamine blockade, findings to date suggest that antipsychotic medications do not influence willingness to exert effort for reward among

This model has subsequently been used in understanding motivation deficits in schizophrenia, and has shown that temporal processes in reward are crucial to understanding these deficits. For example, while people with schizophrenia report experiencing lower levels of pleasure than controls on self-report measures and in semi-structured interviews (Horan, Green, Kring, & Nuechterlein, 2006), they report experiencing as much pleasant emotion as controls in response to emotionally evocative stimuli (Berenbaum & Oltmanns, 1992; Earnst & Kring, 1999; Kring & Neale, 1996). In an attempt to reconcile these discrepant findings, Gard, Kring, Germans Gard, Horan, and Green (2007) examined consummatory (in the moment 'liking') and anticipatory ('wanting') pleasure across two studies, one using ecological momentary assessment (EMA) and the other based on the Temporal Experience of Pleasure Scale (TEPS; Gard, Germans Gard, Kring, & John, 2006). In both studies, people with schizophrenia reported deficits in anticipatory, but not consummatory, pleasure. They also found that lower patient ratings of anticipatory pleasure were associated with clinician ratings of patient anhedonia and social functioning. More recently, two behavioral studies of anticipatory pleasure found that, compared to controls, people with schizophrenia anticipated less pleasure in response to cues associated with pictures of positive scenes (Edwards, Cella, Tarrier, & Wykes, 2015) and potential monetary rewards (Wang et al., 2015).

Despite the above findings, in a recent review of the 23 studies to date in people with schizophrenia using the TEPS, only half found lower levels of self-reported anticipatory pleasure (Frost & Strauss, 2016). This is in line with recent findings from a study that found *higher* reported anticipatory pleasure for daily life events in people with schizophrenia (Gard et al., 2014). It is likely that demographic variables influence reports of anticipatory pleasure on the TEPS (Frost & Strauss, 2016). For example, some questions may be more applicable to controls, who tend to be younger, than to people with schizophrenia. The impact of typical antipsychotic medication on anticipatory pleasure may also play a role in mixed TEPS findings.

In contrast to the mixed self-report evidence, there is more consistent evidence for an anticipatory pleasure deficit using neurobiological methods. Wynn and colleagues (Wynn, Horan, Kring, Simons, & Green, 2010) identified impaired anticipatory brain response in schizophrenia. People with schizophrenia and healthy controls completed a cued, reaction-time contingent picture viewing task to assess two types of anticipatory Event Related Potentials (ERPs), one involving motor response preparation and one not involving motor preparation. The ERP paradigm included emotional and nonemotional pictures, and participants also completed trait anhedonia questionnaires. Participants demonstrated generally lower ERPs (Contingent Negative Variation and Stimulus Preceding Negativity) across pleasant, neutral, and unpleasant pictures. They also reported lower anticipatory pleasure than controls on a trait questionnaire. In another study using ERP, healthy controls displayed a larger early P3 amplitude for larger rewards and losses, with late P3 amplitude related to larger rewards specifically (Vignapiano et al., 2016). In schizophrenia, however, early P3 did not discriminate the incentive magnitude, but the late P3 was larger for larger losses. The authors concluded that people with schizophrenia showed abnormalities in integrating incentive magnitude and reward value of future events. Further evidence comes from a recent meta-analysis showing that people with schizophrenia have hypoactivation in the ventral striatum during reward anticipation (Radua et al., 2015).

It is important to note that antipsychotic medications may also influence reduced anticipatory pleasure witnessed in schizophrenia. Using the monetary incentive delay task, Juckel et al. (2006) showed that both unmedicated people and those treated with typical antipsychotics showed reduced ventral striatal activation during reward anticipation. Those treated with atypical antipsychotics showed striatal responses similar to healthy controls (Juckel, Schlagenhauf, Koslowski, Filonov, et al., 2006; Juckel, Schlagenhauf, Koslowski, Wüstenberg, et al., 2006). Severity of negative symptoms, and apathy/amotivation in particular, was associated with these deficits (Simon et al., 2010).

Another angle that researchers have investigated, that differs somewhat from a 'wanting' deficit, is the connection between emotion experience and behavior. Heerey and Gold (2007), for example, suggested that anhedonia in schizophrenia reflects a decoupling of affect from motivated behavior. In a behavioral paradigm, participants with schizophrenia and healthy controls were given the options to prolong or decrease exposure, or alter the likelihood of future exposure, to pleasant or unpleasant photographs on the basis of internal representations. They also provided self-report of current affect during the task. People with schizophrenia showed weaker correspondence between behavior and ratings than did comparison participants. This effect was amplified when they responded on the basis of internal rather than evoked stimulus representations, suggesting that motivational deficits in schizophrenia reflect problems in the ability to translate experience into action.

In an influential review, Barch and Dowd (2010) hypothesized that people with schizophrenia have difficulty using internal representations of emotional experiences, previous rewards, and motivational goals to drive current and future behavior. They cite a large body of evidence suggesting impairments in executive functions, including goal maintenance and planning. In addition, there are a number of studies indicating that people with schizophrenia have difficulty integrating and updating reward value, and that this is related to how experiences of emotion are maintained For example, using an fMRI paradigm in which subjects were asked to report on their affect experience in viewing pictures following a delay, Ursu et al. (2011) found that people with schizophrenia did not differ from healthy controls in their in-the-moment affect experience. They did, however, show reduced activity in dorsolateral prefrontal cortex and other prefrontal, limbic, and para-limbic areas following the delay in picture viewing in comparison to controls. The authors suggested their findings were evidence of abnormal maintenance of affect experience in schizophrenia. Two additional studies, one using a simple behavioral task, and a second using the affective startle modulation, also support the idea that people with schizophrenia have difficulty maintaining an affective experience, even when given explicit instructions to do so (Gard et al., 2011; Kring, Germans Gard, & Gard, 2011).

In sum, findings from laboratory, self-report, and ecological momentary assessment studies suggest that people with schizophrenia have some form of diminished 'wanting', anticipation of pleasure (and experience of pleasure in anticipation of an outcome or goal-directed effort), and/or maintenance of an emotional experience. Yet 'liking', or in-the-moment experience of pleasure in the context of positive stimuli, seems to be intact. There is some evidence that the liking-wanting discrepancy may be due to impaired ability to integrate previous affective experience with decisions to pursue reward and associated goal-directed behavior. There is also neurobiological support for the anticipatory pleasure deficit in schizophrenia.

The above body of work can potentially improve our understanding of social motivation deficits in schizophrenia. The idea that reductions in the anticipation of positive affect experience, influenced by cognitive processes, might result in diminished goal-directed activity suggests that social impairments may be at least partly due to this deficit. Nonetheless, studies to date have not connected anticipatory pleasure or wanting with social motivation. In addition, there is no work we are aware of that examines the impact of punishment (i.e., not just loss of reward) on reward anticipation in schizophrenia, especially using ecologically-valid paradigms.

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(*footnote continued*)

people with schizophrenia (Gold, Waltz, & Frank, 2015).

2.3. Effort computation and expenditure

Recent evidence suggests an additional facet of motivation included in the reward framework. Drawing directly from translational paradigms, effort computation (i.e., decisions about whether or not to expend effort, or how much effort to expend), and behavioral indicators of effort expenditure, are perhaps the most proximally related constructs to goal-directed behavior (Green et al., 2015). Decision-making is influenced by effort "cost" in relation to the potential reward. Consistent with findings in major depression (Sherdell, Waugh, & Gotlib, 2012; Treadway, Bossaller, Shelton, & Zald, 2012), people with schizophrenia tend to overestimate effort costs, resulting in behavioral outcomes that suggest a lower likelihood to choose outcomes that could result in a higher reward (Barch, Treadway, & Schoen, 2014; Fervaha et al., 2013; Gold et al., 2013; Waltz & Gold, 2016). Importantly, fewer choices of 'hard' tasks have been associated with more negative symptoms and worse community and work function in schizophrenia (Barch, Treadway, & Schoen, 2014). Neurobiological research suggests that differences in effort-based decision-making may be associated with impaired networks involving the nucleus accumbens, anterior cingulate cortex, amygdala, and mesolimbic dopamine neurons (Gold et al., 2013; Treadway & Zald, 2011), which have been shown to be involved in the evaluation of costs and benefits, including computation of probability of reward and loss, effort requirements, and pain (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009; Walton, Bannerman, Alterescu, & Rushworth, 2003).

Despite promising connections between effort-based decision-making and psychosocial functioning outcomes broadly, there remains a lack of evidence in specific associations with social motivation and functioning. That is, while a relatively higher willingness to exert effort for monetary reward might generalize to community and work functioning (Barch, Treadway, & Schoen, 2014), there is little evidence suggesting effort-based decision-making is informative for understanding social motivation and associated social functioning. Finally, as with the research on wanting and liking, there is reason to believe that antipsychotic medication may play a role in effort-based decision making. Nonetheless, researchers have found little in the way of a direct link between antipsychotic dosage and effort-based decision making in people with schizophrenia (see Gold, Waltz, & Frank, 2015 for a summary and review of this issue).

One potential reason for the lack of evidence that effort-based decision-making translates to social motivation and associated functioning is that—as with much of the research on basic reward process reviewed above—studies to date have largely neglected to examine the interactive nature of reward and punishment, including the uncertainty of their presentation, in decisions to exert effort. Decisions to exert effort made in daily life are rarely based on the potential for reward alone—they rely on active consideration of the potential for both reward and punishment, and in the case of social interactions, the high likelihood of rejection, especially when taking risks associated with meeting someone new. That is, effort in the service of social connection is often a high risk-high reward decision-making process, where the benefits must always be weighed against the (often unpredictable) costs of rejection. In other words, effort in and of itself does not directly result in reward as is the case with current tasks assessing effort-based decision-making. We now turn to research on social motivation that highlights the unique features of social interaction relevant to understanding social impairment in schizophrenia.

2.4. Moving into the social domain: Neurobiology and theoretical approaches

As summarized above, recent research—from animal models to clinical samples—highlights key behavioral outputs of reward anticipation, reward responsiveness, and willingness to exert effort. In turn, this work has added specificity to our understanding of deficits in goal-directed behavior in schizophrenia. We have moved from a basic conceptualization that motivation deficits in schizophrenia are broad-based and originate from diminished capacity to experience pleasure, to a better specified understanding that parses out the phenomenology and various brain regions implicated in liking rewards, wanting them, and choosing to exert the effort required to attain them. Nonetheless, there is still much to be understood about why people with schizophrenia experience difficulty initiating goal-directed behavior in the service of enhancing social connection, despite reported need for affiliation.

Several theories have been proposed to account for individual differences in social motivation. Given the importance of human development in the formation and maintenance of social relationships, many of these theories are grounded in the fields of developmental, personality, and social psychology. Our focus here is to cover theories with application to schizophrenia. We will also cover the somewhat sparse empirical literature on social motivation in psychopathology, with a particular focus on applications for our understanding of social impairment in schizophrenia. Before we do, however, we will briefly summarize emerging work on the neurobiological correlates of social motivation and reward. Coverage of this work helps lay the foundation for our argument that a consideration of both social reward and punishment is critical for understanding social functioning impairment in schizophrenia.

2.5. Neurobiology of social reward and punishment

Emerging work suggests at least some neural responding to social stimuli can be distinct from responding to nonsocial stimuli. For example, using the Social Incentive Delay (SID) task in which participants are rewarded by smiling faces (in place of monetary reward), Spreckelmeyer et al. (2009) have demonstrated differential responding to social and nonsocial rewards that are moderated by gender—anticipation of both social and monetary rewards activated identical brain regions in females, but anticipation of social rewards activated a smaller set of regions than did monetary rewards in males. In regards to receipt of reward, social and monetary stimuli activated distinct brain regions (amygdala and thalamus, respectively; Rademacher et al., 2010). Thus, the extent to which responsiveness to social and monetary rewards reflects shared neurobiological mechanisms may depend on both gender and timing of reward (anticipation vs. consummation).

There is some emerging work on the neurobiology of social punishment. Rejection from others in a cooperative game paradigm, for example, leads to increased anterior cingulate activity (Eisenberger, Lieberman, & Williams, 2003), which correlates with social stress-related inflammatory responses (Slavich, Way, Eisenberger, & Taylor, 2010). In another study, feedback about rejected romantic interest (punishment) activated different brain regions than did feedback about mutual romantic interest (reward) (i.e., anterior cingulate and ventromedial prefrontal cortex, respectively; Cooper, Dunne, Furey, & O'Doherty, 2014). Regarding anticipation of social rewards and punishment, Kohls et al. (2013) developed a task that incorporated video clips of nonverbal displays of social reward and punishment in relation to task performance. Anticipation of both social reward and punishment was associated with activation in regions implicated in motivation (i.e., the ventral striatum/nucleus accumbens). Thus, findings suggest that the neurobiological representation of social punishment may differ from that of social reward, and that anticipation and consummation of reward and punishment may be represented in distinct brain regions.

While findings suggest that social and nonsocial rewards may activate distinct brain circuitry, it is still relatively unclear how anticipation or responsivity to social rewards translates to action (i.e., effortful drive) in the service of forming and maintaining interpersonal bonds. That is, this important work provides evidence that at least some regions of the brain are uniquely responsive to social vs. nonsocial rewards and punishments, but it does not tell us about the extent to which measurable social behavior is potentially guided by this brain

activation. In our framework (Fig. 1), relative sensitivity to social sti-
muli could influence the extent to which a person attends to potential
social reward and/or punishment both when anticipating an interaction
and while engaging in an interaction. In addition, this neurobiological
sensitivity could influence the extent to which relative positive or ne-
gative memories of social interactions are formed and maintained. We
are unaware, however, of studies that examine the dynamic interaction
between anticipated and experienced social rewards and punishments,
or that examine how these interactions may differ in people with
schizophrenia, especially using ecologically-valid paradigms. Studies
that simultaneously measure social approach and avoidance before,
during, and after an interaction could provide meaningful information
about how these constructs interact with each other to influence social
motivation in people with schizophrenia.

2.6. Broad-based theories of social motivation and psychopathology

Much of what we know about the association between social mo-
tivation and psychopathology is derived from theories and descriptive
studies in developmental, social, and personality psychology. Social
goal theory, for example, asserts that there is individual variation in
sensitivity to social reward and punishment (Erdley, Cain, Loomis,
Dumas-Hines, & Dweck, 1997; Rudolph, Abaied, Flynn, Sugimura, &
Agoston, 2011; Rudolph & Bohn, 2014; Rudolph, Caldwell, & Conley,
2005; Ryan & Shim, 2008). The interaction between social approach
and avoidance motivation is thus critical for understanding social
outcomes. For example, relatively higher levels of social approach may
lead to either aggressive or prosocial behavior depending on levels of
social avoidance. Similarly, Carver et al. (2008) have proposed that
certain mental health problems can result from self-regulatory deficits
that are determined by the approach-avoidance system. Effortful self-
regulation (i.e., top-down executive control) is critical both for re-
straining inappropriate approach impulses and for overriding in-
appropriate avoidance impulses in social contexts. A sensitive reactive
approach or an insensitive reactive avoidance system may be reflected
in the impulsive pursuit of social incentives, while a sensitive reactive
avoidance or an insensitive reactive approach system may be reflected
in cognitive perseveration, "reflexive freezing", and diminished social
goal pursuit. In applying these models to understanding social moti-
vation in schizophrenia, a testable hypothesis is that social impairment
in the disorder could at least partly stem from an underactive approach
and/or overactive social avoidance sensitivity in combination with di-
minished effortful control.

Research on tendencies toward approach and avoidance in social
contexts are informative for understanding social impairment in psy-
chopathology. This research can provide a framework for under-
standing the paradox of expressed need for affiliation, on the one hand,
and lack of drive or effortful striving toward social connection on the
other hand, in schizophrenia. For example, while expressed need for
affiliation could reflect high social approach tendencies, fear of rejec-
tion associated with high social avoidance tendencies could override
this need and limit engagement in social interaction. For another
person, low social approach tendencies may limit the extent to which
they perceive and remember rewarding aspects of an interaction, even
if their sensitivity to punishment is in the normal range. While in-
formative, the above theories do not tell us much about the temporal
nature of social interactions, such as how relative approach and
avoidance sensitivities might influence drive to engage in or maintain
these interactions, or how they might influence interpretations of ex-
perienced interactions. Importantly, studies to date have not utilized
paradigms that measure the simultaneous interaction between social
reward and punishment in social contexts. In our framework, we sug-
gest that tendencies toward social approach and avoidance may interact
with each other to interfere with initiating social interactions, facil-
itating communication during interactions, and interpreting outcomes
following interactions (see Fig. 1). Studies combining measurement of

social approach and avoidance before, during, and after social inter-
actions will allow us to better understand the interactive contributions
of these qualities to social motivation in schizophrenia.

2.7. Social motivation in schizophrenia

Our goal in this review is to emphasize that social motivation can be
distinguished from social cognition and social skills on the basis of
observable exertion of effort needed to form and maintain social bonds.
Social motivation, in our view, is more specific than individual differ-
ences in *tendencies* toward or away from affiliation, and should include
behaviors in the service of approaching and avoiding social interaction.
Indeed, effective social functioning relies on the ability to optimally
move away from social rejection and move toward social reward. While
social motivation has received considerably less research attention than
social skills and social cognition, there is a long history of examining
social affiliation broadly in schizophrenia. Asociality, defined as "lack
of involvement in social relationships of various kinds" (Andreasen,
1989, p. 56), is a core feature of schizophrenia. Nonetheless, the limited
social engagement observed in schizophrenia may not necessarily re-
flect psychopathology-based deficits in the desire to have relationships
(i.e., lack of social involvement as a negative symptom), at least in full.
For example, people with schizophrenia are less likely to have intact
families or the socioeconomic resources to participate in social activ-
ities, limiting opportunities for social connection (Corrigan & Phelan,
2004). Thus, our definition of social functioning as an outcome, in-
cluding the quantity and quality of social exchanges and relationships,
allows us to consider diminished social motivation (viz., self-initiated
social interaction; Messinger et al., 2011) as a key contributor to social
impairment in schizophrenia.

2.8. Self-report and behavioral findings

While research on social motivation, as defined above, is sparse,
there is a large body of work on social anhedonia in schizophrenia.
Social anhedonia is a deficit in the experience of pleasure in the social
domain. Studies investigating social anhedonia have mostly used self-
report measures, such as the Chapman Social Anhedonia Scale (SAS;
Chapman, Chapman, & Raulin, 1976). These studies support the idea
that people with schizophrenia endorse deficits in the ability to ex-
perience pleasure from interpersonal relationships (Blanchard, Mueser,
& Bellack, 1998; Blanchard, Horan, & Brown, 2001; Granholm, Ben-
Zeev, & Link, 2009), consistent with findings of self-reported general
anhedonia outside of the context of positive stimuli (Cho et al., 2017;
Horan, Blanchard, Clark, & Green, 2008). It remains unclear, however,
whether people with schizophrenia show a deficit in anticipatory, but
not consummatory, social pleasure, which would be consistent with
findings in the nonsocial reward literature. While the Anticipatory and
Consummatory Interpersonal Pleasure Scale (ACIPS; Gooding & Pflum,
2014, 2016) has been developed to assess both consummatory and
anticipatory components of social pleasure, to our knowledge, the scale
has not been examined in schizophrenia.

The challenge in interpreting findings of social anhedonia is that
items on self-report questionnaires depend on the presence of recent
interactions and ongoing relationships, which are both consistently low
in schizophrenia. Even among studies using a modified version of the
SAS designed to capture drive for social affiliation, as opposed to di-
minished social pleasure, items include "I don't really feel very close to
my friends" and "I like to make long distance phone calls to friends and
relatives" (Brown, Silvia, Myin-Germeys, & Kwapil, 2007; Granholm
et al., 2009). These items may be more reflective of levels of social
contact and presence of relationships than drive or desire for affiliation.
As such, findings regarding social anhedonia in schizophrenia more
likely reflect the absence of meaningful interaction, rather than social
motivation, or the objectively-observed drive to form and maintain
social relationships.

There have been comparatively fewer behavioral studies of social pleasure in people with schizophrenia. Compared to healthy controls, people with schizophrenia report less anticipated pleasure about being included in social interactions (Engel, Fritzsche, & Lincoln, 2016). They also report less pleasure in response to social interactions with smiling partners (Campellone & Kring, 2018) and those resulting in positive social outcomes (Campellone, Truong, Gard, and Schlosser, 2018). These findings suggest that, unlike in the context of nonsocial reward (e.g., monetary gain), people with schizophrenia may show diminished anticipatory and consummatory social pleasure, even in the context of positive social experiences. Interestingly, anticipated displeasure, or predicting a lack of pleasure from social exclusion or interactions with negative outcomes, appears to be intact (Campellone and Kring, 2018; Campellone et al., 2018; Engel et al., 2016).

As reported above, in spite of findings from laboratory studies suggesting lower pleasure in relation to social interaction, people with schizophrenia report a normative need for social affiliation (Gard et al., 2014; Trémeau, Goldman, Antonius, & Javitt, 2013). They also report greater positive and less negative affect when in the company of others than when alone (Oorschot et al., 2013; Delespaul & deVries, 1987), even when, on the whole, they report higher overall negative affect and lower positive affect in their day-to-day experiences (Cho et al., 2017). In addition, positive affect associated with past social interactions predicts engagement in future interactions when measured in daily life (Granholm, Ben-Zeev, Fulford, & Swendsen, 2013). There is even recent evidence that social connection may serve to protect patient motivation in recovery from a first episode of psychosis (Fulford, Piskulic, et al., 2018). Thus, findings suggest that interpersonal emotional experience of people with schizophrenia may be highly dependent on both how and where it is assessed (e.g., whether in the context of a computer task-based social manipulation or as measured in daily life). It may be that interactions with familiar others—those likely to occur in the context of experience sampling studies—are more likely to result in positive outcomes (e.g., social pleasure, motivation) than interactions with unfamiliar others, as often occur in laboratory simulations. Future research should test this hypothesis by comparing reports of pleasure in the context of familiar and unfamiliar others.

2.9. Neurobiological findings

In light of the work covered on the neurobiology of social motivation above, there is evidence that the anticipation and receipt of social and nonsocial rewards and punishments may be represented by distinct neural signatures based on timing of reward and participant gender (Montague & Berns, 2002; Rademacher et al., 2010; Ruff & Fehr, 2014; Spreckelmeyer et al., 2009). Nonetheless, how these brain regions are implicated in measurable drive to approach or avoid social interactions is relatively unknown.

The literature on the neurobiology of social motivation in schizophrenia is similarly limited. In one study, Gromann et al. (2013) examined the neural correlates of cooperation and trust in 20 people with psychotic disorder and 20 healthy controls. A primary finding was that controls showed stronger reward-related activation (caudate nucleus) while participating in a cooperative economic game than did people with schizophrenia, while there were no differences in activation during a deceptive game. Reduced activation among people with psychosis was also associated with more paranoia. This finding suggests that, consistent with the broader reward literature, at least one contributor to diminished social motivation in schizophrenia may be reduced sensitivity to social reward.

Our argument is that motivation for social interaction is significantly influenced by not only the possibility of reward but the high potential for punishment. Thus, while there may be at least some neurobiological overlap in the experience of social and nonsocial rewards, effort exertion in the service of forming and maintaining social bonds undoubtedly requires integrative functioning of highly complex broad-based neural networks that weigh costs and benefits of such connection. Indeed, as we covered in the literature above on neurobiology of social reward, there is emerging evidence that neural correlates of reward anticipation and receipt are distinct from those representing punishment. As such, research is needed that simultaneously measures and integrates individual differences in sensitivity to reward and punishment in the social domain.

2.10. Experimental studies examining social approach and avoidance motivation

Early theories about social impairment in schizophrenia suggested a 'praise decrement', or a maladaptive defensive reaction to a censorious interpersonal environment in the patient's formative past; in other words, praise was considered discordant with the person's low self-esteem (see Fischer & Hoch, 1966). This theory was partially supported by experimental findings suggesting people with schizophrenia performed *worse* while receiving praise in lab tasks (Berkowitz, 1964; Cavanaugh, Cohen, & Lang, 1960; Irwin & Renner, 1969), but other studies showed that people with schizophrenia responded to verbal praise as much as healthy people (D'Alessio & Spence, 1963; Goodstein, Guertin, & Blackburn, 1961). This area has since been largely neglected in the experimental literature.

Three recent studies have examined social approach and avoidance behaviors in schizophrenia. Radke, Pfersmann, and Derntl (2015) developed a task to measure the impact of social reward (pictures of faces) on approach and avoidance tendencies. Participants were asked to imagine standing face-to-face with the person in the picture and rate their tendency to approach or avoid him/her as the number of steps they would make toward (+) or away (−) from him/her on a scale from −4 to +4. Those with schizophrenia were less likely to endorse both approaching happy faces and avoiding angry faces than were healthy controls. Importantly, emotion recognition accuracy was not tied to approach/avoidance tendencies, which suggests this component of social cognition is not directly related to social motivation. De la Asuncion et al. (2015) developed a similar task to assess response tendencies toward images of happy and angry faces that included both direct and averted gaze, as well as a personal space test to objectively measure approach-avoidance behaviors. People with schizophrenia showed faster avoidance responses to the happy faces with averted gaze than did healthy controls. In addition, people with schizophrenia approached the experimenter less than healthy controls did in the personal space test, and less approach behavior was associated with higher positive symptoms. Most recently, Fulford, Treadway, and Woolley (2018) developed a task to measure effort in the context of social encouragement. People with schizophrenia and a healthy comparison group completed a vigorous key pressing task in which the goal was to earn as many points as possible across a series of trials. In half of the trials, a research assistant delivered live positive encouragement. A primary finding was that both people with schizophrenia and healthy controls increased their effort in the context of encouragement, suggesting no praise decrement in schizophrenia. Among those with schizophrenia, however, higher apathetic social withdrawal (as measured by the Positive and Negative Syndrome Scale) was associated with significantly lower effort across social and nonsocial conditions.

Taken together, findings from these studies suggest that individual difference variables are important to consider in understanding social motivation in schizophrenia. On the whole, people with schizophrenia report a need for affiliation, and recent findings suggest that they exert effort in the context of social reward. It seems, however, that both sensitivity to social rejection and heightened social withdrawal in schizophrenia may result in diminished approach and heightened avoidance behaviors in laboratory tasks assessing social motivation. What is still relatively unknown is the extent to which sensitivity to punishment or rejection might interact with social approach tendencies to predict short- and long-term engagement in social interaction.

2.11. Roadmap for future research in social motivation in schizophrenia

In this review we covered emerging research in the area of reward learning, hedonic components of reward, and effort-based decision-making, and discussed the application of these motivation components to understanding social motivation and functioning in schizophrenia. We identified gaps in how this research has been applied to our understanding of social motivation in schizophrenia, and how this application has failed to capture the dynamic nature of social interactions. Indeed, the inputs used to guide effort in the service of forming and maintaining social bonds before and during an interaction—as well as the outputs following an interaction (e.g., memory formation, interpretation)—are fluid, making granular, ecologically valid methods of assessment essential for capturing the forces that influence social motivation. Below, we provide suggestions for how emerging mobile technologies can be leveraged to improve our understanding of the complex nature of social motivation in schizophrenia.

3. Active mobile data collection: Ecological Momentary Assessment and virtual reality

The near ubiquity of mobile devices (e.g., smartphones, tablets) allows for remote data collection in real-world settings. The major benefit of naturalistic data collection is increased ecological validity by allowing for the assessment of social behavior in the context of daily life. The most common method of active mobile assessment is Ecological Momentary Assessment (EMA; Stone & Shiffman, 1994), or Experience Sampling Methodology. Compared to laboratory-based investigations of social behavior, EMA offers greater ecological validity (Moskowitz & Young, 2006) by assessing social behavior in the context of daily life. In these studies, participants are prompted multiple times a day for several consecutive days to answer a set of questions. This allows for not only an understanding of how social behavior changes across contexts, but also how ratings at one time point might predict ratings at a later time point.

The increasing ubiquity of smartphone ownership among people with schizophrenia and other psychotic disorders (40–60% ownership according to a recent meta-analysis by Firth et al., 2016) has increased the feasibility of mobile assessment and intervention. For example, EMA has been used to assess anticipated pleasure (Gard et al., 2007; Gard et al., 2014), effort expenditure (Gard et al., 2014), and appraisal of social interactions (Granholm et al., 2013) in people with schizophrenia.

3.1. Virtual environments

Another rapidly growing approach for the assessment of social motivation and behavior is the use of virtual environments (for reviews, see Bombari, Mast, Canadas, & Bachmann, 2015; Gillath, McCall, Shaver, & Blascovich, 2008), which combines the control of laboratory-based studies with greater ecological validity (Blascovich et al., 2002; Gillath et al., 2008). In healthy people, virtual environments have been used to study motivation by measuring movements of an avatar toward (approach) or away (avoidance) from other avatars displaying certain emotions (Kim, Geiger, Herr, & Rosenthal, 2010; Kwanguk Kim et al., 2015), social behaviors (interpersonal distance, eye contact) during interactions with virtual homosexual and heterosexual people with HIV (Toppenberg, Bos, Ruiter, Wigboldus, & Pryor, 2015), as well as interactions with a disadvantaged other ("virtual beggar"; Gillath et al., 2008). While comparatively less utilized in people with schizophrenia and other psychotic disorders, virtual environments have shown promise as tools for assessing and treating paranoia (Freeman et al., 2016) and measuring functional outcomes (Keefe et al., 2016). Further, a recent study in people at clinical high risk for psychosis demonstrated the feasibility of using virtual environments as a tool for assessing aspects of social interaction, such as regulation of interpersonal distance

(Geraets et al., 2017). Taken together, these findings underscore the promise of virtual environments for assessing social motivation in schizophrenia.

3.2. Passive mobile data collection: Social sensing

The majority of mobile devices available today come with built-in sensors that allow for mobile data collection that is passive. This means that data collection can happen in the absence of participant responding, making it easier to capture ecologically valid data while removing subjective bias. Indeed, sensors such as an accelerometer, gyroscope, GPS, microphone, and camera can provide researchers with participant location data, physical activity, ambient sound and speech, and eye tracking data such as gaze fixation (for reviews, see Harari et al., 2016; Miller, 2012). Recent work has established the feasibility of passive data collection in people with schizophrenia (e.g. Ben-Zeev et al., 2015; Kerz et al., 2016), but this is an area in need of additional investigation.

These same sensors can also be used to passively capture participant social behavior, a process known as social sensing (Mast, Gatica-Perez, Frauendorfer, Nguyen, & Choudhury, 2015). Social sensing captures participant non-verbal (e.g., posture, gesturing, facial expressivity) and verbal (e.g., speech rate, prosody) social behavior and can be conducted with mobile-based (e.g., smartphone) or stationary sensors (e.g., video camera, Microsoft Kinect). Social sensing data channels can be integrated (e.g., Rachuri et al., 2010; Lu et al., 2012; LiKamWa, Liu, Lane, & Zhong, 2013) to facilitate "digital phenotyping", or individualized profiles of real-world behavior as captured by mobile devices (Torous, Staples, & Onnela, 2015). Digital phenotyping also represents a critical step in advancing the precision of medical and mental health interventions for targeting specific behaviors, such as social motivation (e.g. Onnela & Rauch, 2016). Passive data collection and digital phenotyping have the potential to disrupt the current approaches to diagnosis, assessment, and intervention through the unobtrusive collection of behavior "in the wild", or in the context of users' daily life. Further, passive approaches can be used in tandem with active methods of assessments like EMA and used to inform "just-in-time" interventions that can provide users with resources they need at the precise moment that they might need them. For example, passive collection of physical activity (GPS, accelerometer) and social activity (text and call activity) data along with self-reported mood and loneliness can be used to deliver a personalized intervention to promote social engagement. Over time, data collection could be used to create and refine that user's digital phenotype, allowing for the prediction of changes in symptoms and functioning based on passive sensing data.

Measuring the dynamics of social behavior by looking at the simultaneous interaction of social approach and avoidance in the real world is an exciting possibility for mobile sensing. For example, in the moment reports of a desire to connect with others, coupled with reports of feeling uneasy around the prospect of being in public, could supplement sensing data showing the user staying at home over an extended period (as assessed by GPS), or lack of conversing with others (as assessed by passively recorded microphone data). Or, automatic coding of emotion in social conversation could tell us about the real-time dynamics of approach and avoidance affect in the social context. These and other unique opportunities afforded to us by extant and emerging technologies will give us the tools to vastly improve our understanding of social approach and avoidance as key components of social motivation and functioning in schizophrenia.

Taken together, mobile technology provides the capability for granular, ecological assessment of the dynamic nature of social interaction. Implementing mobile-based assessment, both active and passive, can provide insight into the complex interaction between acceptance and rejection and how these forces shape social motivation tendencies. Furthermore, improved assessment of social motivation in schizophrenia can yield more precise targets for intervention, including

the potential for the delivery of real-time support. While we are proposing the use of these methods to better understand impairment in schizophrenia, these methods have a broader transdiagnostic utility as means for assessing social motivation.

4. Conclusions

Our primary goal in this review was to summarize the current state of knowledge surrounding social motivation in schizophrenia, paying particular attention to how research on reward informs, and limits, our understanding of behaviors in the service of social connection. We began by covering recent work on reward and its potential contributions toward understanding the temporal nature of forming and maintaining social bonds. We then discussed the primary limitations of this work in understanding social motivation in schizophrenia—that much of it has failed to integrate the critical influence of punishment (e.g., avoidance, threat, anxiety). After covering the broader research on social motivation, we argued for real-time measurement approaches to provide ecologically valid assessment of social reward and punishment interactions.

A topic such as social motivation is immense and impossible to cover fully. As such, this review leaves us with as many questions as it does answers. Nonetheless, we hope readers can take away a few key points for consideration. For one, the burgeoning research on basic reward processes conducted in recent years provides us with a framework for understanding the multifaceted nature of human motivation across a variety of domains, from anticipating the experience of pleasure, to experiencing pleasure in the moment, to exerting the effort necessary to attain a desired outcome. Because social interaction is rewarding, at least at times, there is clear applicability of this work to motivation in the social domain. To better understand social functioning in schizophrenia, for example, we may choose to measure enjoyment of interactions in the moment (self-reported social liking), anticipated enjoyment of social interaction (self-reported social wanting and/or its neurobiological correlates), and/or the amount of work one is willing to engage in to have an interaction in the future (observed effort in the social domain).

Nonetheless, as Gable and Prok (2012) so clearly assert in the quote that opens this review, with the potential for rewards comes the simultaneous potential for threats when it comes to social interaction. Our second key point, then, is that we must consider the influence of uncertainty with which one approaches a given social interaction on one's willingness to socially engage. For a person with schizophrenia, who often has experienced a long history of social challenges, understanding contributors to this impairment is not as simple as knowing the extent to which they experience or anticipate rewarding outcomes. In this review, we argued that we must also know the extent to which sensitivity to punishment or rejection (social avoidance tendencies) might interact with approach tendencies to influence social engagement.

Our third key point is that the simultaneous measurement of social approach and avoidance, ideally across the temporal nature of social interactions, will provide useful insights into social motivation and associated impairment in schizophrenia. We believe the use of mobile technologies and other advances in ecological measurement provide exciting opportunities for accomplishing these goals.

Examination of the interactive nature of social reward and punishment is a research area ripe for testing several different hypotheses about social functioning in schizophrenia. Using various models and methodologies, studying behavior both in the laboratory and out in daily life, we can work toward identifying a clearer target for assessing and intervening in social motivation and behavior. It may be the case that instead of identifying a characteristic pattern of impairment, this research will reveal within-group heterogeneity that will inform more personalized approaches to treatment. We may also find evidence that people with schizophrenia are more commonly in environments that do

not support social interaction (e.g., those in which social rejection is the standard). Research incorporating a clearer understanding of social contexts, such as what can be provided by mobile sensing technology, will help answer these and other important questions. Ultimately, multi-method studies that combine lab and field-based assessment will help us narrow down mechanisms of social motivation most relevant for daily life.

Contributors

Dr. Fulford, Dr. Campellone, and Dr. Gard all participated in the conceptualization of the review, conducted literature searches, and drafted the manuscript. All authors contributed to and have approved the final manuscript.

Conflicts of interest

None.

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