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Research Paper

# The impact of reward on attention in schizophrenia

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ABSTRACT

Traditionally, attention was thought to be directed by either top-down goals or bottom-up salience. Recent studies have shown that the reward history of a stimulus feature also acts as a powerful attentional cue. This is particularly relevant in schizophrenia, which is characterized by motivational and attentional deficits. Here, we examine the impact of reward on selective attention.

Forty-eight people with schizophrenia (PSZ) and 34 non-psychiatric control subject (NCS) discriminated the location of a target dot appearing inside a left circle or right circle. The circles were different colors, one of which was associated with reward via pre-training. In the first 2 blocks, targets were equally likely to appear in the left or right circle. In the last 4 blocks, the target was 75% likely on one side, thus allowing us to separately examine how attention was impacted by reward (color) and probability (location).

PSZ had slower overall reaction times (RTs) than NCS. Both groups showed robust effects of spatial probability and reward history, with faster RTs for the rewarded color and for the more probable location. These effects were similar in PSZ and NCS. Negative symptom severity correlated with overall RT slowing, but there were no correlations between symptoms and reward-associated biasing of attention.

PSZ demonstrated RT slowing but normal reward history and spatial probability-driven RT facilitation. These results are conceptually similar to prior findings showing intact implicit reward effects on response bias, and suggest that implicit processing of reward and probability is intact in PSZ.

## 1. Introduction

Since the earliest accounts of Kraepelin et al. (1919) and Bleuler (1950), abnormalities of attention and motivation have been considered to be central features of schizophrenia. Motivational impairments are implicated in the disability associated with the disorder because difficulties initiating and sustaining goal-directed behavior can undermine educational, vocational, and recreational activities. The psychological and neural processes implicated in motivational impairment remain to be determined. Anhedonia is one candidate mechanism given that people with schizophrenia typically report reductions in pleasure on measures such as the Chapman Social and Physical Anhedonia scales (e.g. Horan et al., 2006). However, despite self-reports of low positive affect and pleasurable experience, people with schizophrenia (PSZ) typically show normative affective ratings when actually experiencing positively valenced stimuli under controlled conditions (e.g. Kring and Moran, 2008; Cohen and Minor, 2010). However, for reasons that remain to be fully understood, it seems that the apparently normal hedonic responses at the subjective level fail to have the expected impact on behavior in PSZ. That is, despite evidence of intact in-the-moment reward experience, PSZ typically show reductions in effortful reward-seeking behavior (e.g. Gard et al., 2014).

A possible mechanism by which past reward history may impact future behavior is by influencing selective attention. One central function of selective attention is to reduce the information overload from a rich sensory environment, by prioritizing relevant sensory inputs for further processing.

Traditionally, it has been thought that this prioritization and selection occurs due to either top-down goals or bottom-up sensory salience (e.g. Corbetta and Shulman, 2002). In studies of schizophrenia, selective attention driven by bottom-up information is often unimpaired, whereas deficits in goal-driven control of attention are more frequently reported (Gold et al., 2007; Luck and Gold, 2008). Recent research has reported a hybrid form of attentional control that may be

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of special clinical relevance: stimulus selection history (Awh et al., 2012). Stimulus features that become associated with the receipt of rewards in one context may automatically receive preferential processing in a different context where no rewards are available (Anderson et al., 2011; Hickey and van Zoest, 2013). This serves an important adaptive function by facilitating approach behavior towards stimuli that have a prior history of being rewarding. People also demonstrate attentional biases based on probabilistic information, even if they are unaware of the probabilities. For example, if a target appears more often at one of multiple potential locations, an attentional bias is likely to develop towards the more frequent location (Geng and Behrmann, 2005; Walthew and Gilchrist, 2006; Jiang et al., 2013a). Like reward history effects, spatial probabilities are learned quickly, are persistent (Geng et al., 2013; Jiang et al., 2013a; Jiang et al., 2013b) and are typically implicit (Geng and Behrmann, 2005). These effects are top-down insofar as they reflect learning (Gaspelin and Luck, submitted), but they are fast, involuntary, and unconscious, just like bottom-up effects (Theeuwes, 2018).

In order to investigate how attentional control may be differentially impacted in PSZ, we examined the consequences of attentional capture by known reward associations when an implicit spatial probability was introduced. In doing so, we explored the possibility that that PSZ would show reductions in reward history effects as a function of motivational deficits. Although previous studies have exclusively examined aspects of reward processing and spatial allocation of attention in PSZ, it has yet to be understood how multiple sources of selection history interact when presented simultaneously. For example, it may be easier to attend to something associated with pleasure if it is also situated in a predictable location. Outside the laboratory, a reduction in the bias to attend to features and cues associated with past rewards might undermine the initiation of volitional, reward-seeking behavior. This would also be consistent with the idea that PSZ have intact in-the-moment experiences of rewards but that these experiences do not impact the later initiation of reward-seeking behavior (Gold et al., 2009). Alternatively, based on prior studies showing intact implicit reward processing and selective attention in schizophrenia (Erickson et al., 2014; Heerey et al., 2008; Gold et al., 2009; Elshaikh et al., 2015; Barch et al., 2017), another possibility is that PSZ could manifest intact sensitivity to rewards in this task. Under this hypothesis, we expected that PSZ would show intact spatial probability effects because they often show normal levels of benefit from precues that are reliably predictive of target location. In terms of the interplay between the forms of attentional bias, we speculated that if PSZ were impaired at using reward to control attention but unimpaired at using probability, then probability should win when placed in competition with low reward. The paradigm we adapted from Stankevich and Geng (2014), allowed us to examine the relationship between these two factors, and to ascertain our speculations about reward modulation in PSZ.

## 2. Methods

### 2.1. Participants

Demographic information is provided in Table 1. Forty-eight PSZ were recruited through the Outpatient Research Program at the Maryland Psychiatric Research Center and evaluated during a period of clinical stability (defined as no change in medication type or dosage for four weeks or longer). Consensus diagnosis was established via detailed psychiatric history and interviews, confirmed using the Structured Clinical Interview for DSM-IV (SCID) (First, 1995). In PSZ, symptom

**Table 1**
Participant characteristics.

| | HCS (*N* = 34) | PSZ (*N* = 48) | Statistic | *P* value |
|---|---|---|---|---|
| Age | 38.53 (11.44) | 38.38 (9.58) | t = 0.07 | 0.95 |
| Gender (M \| F) | 19 \| 15 | 30 \| 18 | φ = 0.36 | 0.55 |
| Race (African American \| Caucasian \| Other) | 14 \| 18 \| 2 | 16 \| 28 \| 4 | φ = 0.60 | 0.74 |
| Participant education | 14.88 (2.06) | 13.21 (2.44) | t = 3.27 | 0.002 |
| Maternal education | 14.21 (2.56) | 14.21 (2.84) | t = −0.004 | 0.99 |
| Paternal education | 15.03 (3.92) | 14.82 (3.59) | t = 0.87 | 0.39 |
| Neurocognitive test results | | | | |
| WASI-II IQ | 109.44 (11.23) | 92.54 (28.7) | t = 3.25 | < 0.001 |
| WRAT 4 | 108.65 (14.1) | 93.54 (29.74) | t = 2.74 | 0.01 |
| WTAR | 110.68 (13.45) | 94.17 (30.73) | t = 2.93 | < 0.001 |
| MD processing speed | 52.09 (11.66) | 42.76 (11.41) | t = 3.58 | < 0.001 |
| md attention vigilance | 50.68 (10.54) | 42.26 (12.18) | t = 3.23 | < 0.001 |
| MD working memory | 50.71 (10.61) | 41.85 (11.18) | t = 3.58 | < 0.001 |
| MD verbal learning | 49.35 (8.41) | 38.5 (8.28) | t = 5.76 | < 0.001 |
| MD visual learning | 44.97 (11.02) | 38.85 (10.39) | t = 2.54 | 0.01 |
| MD reasoning | 50.91 (9.93) | 44.02 (10.02) | t = 3.05 | < 0.001 |
| MD social cognition | 55.26 (6.59) | 42.74 (11.16) | t = 5.83 | < 0.001 |
| MCT overall | 50.5 (9.92) | 36.11 (12.18) | t = 5.64 | < 0.001 |
| Antipsychotic medication | | | | |
| Total CPZ | | 510.76 (290.21) | | |
| Total haloperidol | | 10.73 (6.53) | | |
| Clinical ratings | | | | |
| BPRS positive | | 2.05 (1.16) | | |
| BPRS negative | | 1.87 (0.61) | | |
| BPRS disorganization | | 1.25 (0.32) | | |
| BPRS total | | 33.39 (11.26) | | |
| SANS AA | | 21.03 (8.55) | | |
| SANS EE | | 13.7 (8.62) | | |
| SANS total | | 27.15 (10.94) | | |

WASI = Wechsler Abbreviated Scale of Intelligence; WRAT = Wide Range Achievement Test; WTAR = Wechsler Test of Adult Reading; MD = MCCB (MATRICS Consensus Cognitive Battery) Cognitive Domain; MCT = MCCB Composite Total; CPZ = Chlorpromazine equivalent; BPRS = Brief Psychiatric Rating Scale; SANS = Scale for the Assessment of Negative Symptoms; AA = Apathy-Avolition; EE = Emotional Expressivity.