Schizotypy is associated with reduced mnemonic precision in visual working memory

Weizhen Xie a,⁎, Marcus Cappiello a, Hyung-Bum Park a, Patricia Deldin b, Raymond C.K. Chan c,d, Weiwei Zhang a,⁎

⁎ Corresponding authors at: Department of Psychology, UC Riverside, 900 University Ave., Riverside, CA 92521, USA.
E-mail addresses: weizhen.xie@email.ucr.edu (W. Xie), wewei.zhang@ucr.edu (W. Zhang).

A R T I C L E   I N F O
Article history:
Received 8 May 2017
Received in revised form 21 July 2017
Accepted 23 July 2017
Available online xxxx

Keywords:
Working memory
Sensory memory
Capacity
Precision
Schizotypy
Depression

A B S T R A C T
Background: Working memory (WM) maintains a limited amount of information over a short period of time at the service of other ongoing mental activities. Deficits in this function are often observed in schizophrenia spectrum disorders. The present study examined whether self-report schizotypy was associated with the qualitative, quantitative, or both aspects of visual WM and whether these impairments could be accounted for by sensory memory deficits and/or depressed mood in a group of non-clinical, medication-naive participants.

Method: Visual WM and sensory memory were assessed in 164 medication-naive college students using delayed and immediate color estimation tasks, respectively. Self-report measures of schizotypy and depressed mood were also collected.

Results: Individuals with more schizotypal features retained less precise representations in visual WM, without a significant reduction in the number of retained WM representations (i.e., capacity). In contrast, there was no significant correlation between sensory memory precision and schizotypy, suggesting that schizotypy-related imprecision in visual WM was unlikely a result of imprecise sensory memory. Furthermore, opposite patterns of WM deficits were observed for depressed mood in that it was negatively associated with WM capacity, but not with WM precision.

Conclusion: Together, the present findings demonstrated dissociable WM deficits in schizotypy and depressed mood, providing strong evidence for unstable mental representations in schizotypy and reduced cognitive resource in depressed mood.

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1. Introduction

Working memory (WM) maintains a limited amount of information over a short period of time at the service of other ongoing mental activities (Baddeley, 2012; Cowan, 2001). Impairments in this function are often observed in schizophrenia spectrum disorders, including schizophrenia patients (Park and Gooding, 2014), their first-degree relatives (R. Zhang et al., 2016), and individuals with schizotypal features (Park et al., 1995; Park and McTigue, 1997; Rosell et al., 2014; but see Kane et al., 2016; Matsui et al., 2007; Xie et al., 2014). The present study aims to examine whether self-report schizotypy is associated with the qualitative, quantitative, or both aspects of visual WM in a group of non-clinical, medication-naive participants.

Schizotypy is often referred to as a multidimensional personality organization of subclinical schizophrenia-like traits, ranging from ordinary dissociative, imaginative states to more extreme states associated with schizophrenia pathology (Kwapil and Barrantes-Vidal, 2015; Meehl, 1962, 1990). It may be a manifestation of inherited genetic diathesis and adverse environmental experiences (Meehl, 1962, 1990). Schizotypal features, such as affective flattening and social disinterest (i.e., negative schizotypy) as well as odd beliefs and unusual perceptual experiences (i.e., positive schizotypy), can be captured by self-report checklists or psychometric inventories (J. P. Chapman et al., 1995; L. J. Chapman et al., 1978, 1976, 1980; Eckblad and Chapman, 1983; Raine, 1991; Winterstein et al., 2011b). The current study focuses on this subclinical stage of schizophrenia spectrum disorders for three specific reasons. First, although individuals with schizotypal features have increased risks of developing full psychosis (Cannon, 2015), they seldom take anti-psychotic medication. This allows examination of memory impairments potentially associated with schizophrenia-related symptoms without confounds of antipsychotic medication. Second, intermediate...
schizophrenia-spectrum phenotypes, such as schizotypy, may originate from shared genetic roots with schizophrenia (Nicolson et al., 2003; Torngersen, 1985). Consequently, individuals with schizotypal features often demonstrate neuroanatomical (Modinos et al., 2009) and neuropsychological (Chan et al., 2016b) impairments that largely overlap with those in schizophrenia patients, including deficits in WM (Hazlett et al., 2014; Park et al., 1995; Park and McIntighe, 1997; Roitman et al., 2000). Third, assessment of WM impairments in a subclinical stage of schizophrenia spectrum disorders could potentially facilitate early diagnosis and intervention of the disease by using cognitive impairments as target features to capture schizophrenia-related deficits (e.g., Germaine and Hooker, 2010).

Impairments in visual WM have been reported in schizotypy (e.g., Farmer et al., 2000; Mitropoulou et al., 2005; Roitman et al., 2000). However, effects on the compound measures of visual WM performance, such as accuracy, could have been driven by a reduction in the quantitative (i.e., how many stimuli are remembered, capacity), qualitative (i.e., how precise is the retained memory), or both aspects of retained WM representations (Xie and Zhang, 2017a, 2017b, 2016; W. Zhang and Luck, 2011, 2008). Recent studies assessing WM impairments associated with schizotypy have focused on the quantitative aspect of WM (i.e., capacity) and yielded mixed findings (e.g., Kane et al., 2016; Matsui et al., 2007; Xie et al., 2014). It is thus possible that visual WM impairments associated with schizotypal features could reflect a reduction in the precision, instead of the number, of retained WM representations (e.g., Bates, 2005).

To independently and simultaneously measure the quantitative and qualitative aspects of visual WM, the current study used an established delayed estimation paradigm and analytical approach (Gold et al., 2010; W. Zhang and Luck, 2008). In this task, participants memorized distinctive colors of briefly presented colored squares on a computer screen and then, after a 1-second blank delay, estimated the color of a randomly picked square from memory by matching it to a color on a continuous color wheel. Participants’ performance can be fitted with Zhang and Luck’s (2008) mixture model, yielding independent estimates of the likelihood of correct recall and mnemonic precision. Specifically, the likelihood of correct recall (multiplied by the total number of to-be-remembered colors yielding the number of remembered colors) is inversely related to the proportion of non-guessing responses and memory precision is the inverse of performance variability (W. Zhang and Luck, 2011, 2009, 2008).

To isolate the deficits in visual WM from potential deficits in perceptual and/or sensory processing (Coleman et al., 2012), a sensory memory task was also included (also see Gold et al., 2010). In this task, to-be-remembered colored squares were briefly presented (100 ms), and observers estimated the color of a randomly picked square immediately following the offset of the memory array. This task thus captures sensory memory representations available for up to a few hundred milliseconds after the offset of briefly presented visual stimuli (Sperling, 1960). These sensory memory representations are fundamentally different from WM representations in several ways. For instance, they are fragile and easily disrupted by masking procedures (Vogel et al., 2006). In addition, sensory memory has an exceedingly large capacity in contrast to the limited storage capacity in WM (Sperling, 1960). Furthermore, a recent study suggests that observers’ performance in sensory memory tasks may be conjointly supported by two internal representations, namely a fine-grained representation and a coarse-grained representation (see Cappiello and Zhang, 2016 for details). Between these two, the fine-grained representation is more likely to be transferred into WM (Cappiello and Zhang, 2016). In the current study, if individuals with more schizotypal features also demonstrate more deficits in sensory memory (especially the fine-grained trace), then the observed deficits in WM performance could potentially result from impairments in perceptual and/or sensory processing instead of WM (Tek et al., 2002). Furthermore, given the large co-occurrence of schizotypy (especially positive schizotypy) and mood-related symptoms in the general population (Lewandowski et al., 2006), it is important to examine whether the pattern of compromised visual WM representations can be accounted for by mood-related symptoms, such as depressed mood. Specifically, a growing literature suggests reduced WM capacity as one of the critical cognitive impairments associated with depressed mood (Adams et al., 2001; Arnett et al., 1999; Hubbard et al., 2015). There may even be a causal relationship between these two because interventions that alleviate depressed mood can also improve WM capacity (e.g., Klein and Boals, 2001). The current study thus assessed and used depressed mood as a control variable when examining the relationship between schizotypy and WM to reveal whether depressed mood could account for WM deficits associated with schizotypy, if WM deficits in schizotypy were more related to capacity instead of precision.

In summary, the current study used an individual-differences approach to assess whether self-report schizotypy and depressed mood were associated with different impairments in visual WM.

2. Method

2.1. Participants

One-hundred-and-sixty-four typical college students (19.30 ± 1.16 [Mean ± std.] years old, 85 female) voluntarily participated this study for course credits at University of California, Riverside. All participants reported normal (or corrected-to-normal) visual acuity and normal color vision. No participant reported use of antipsychotic medication. Written informed consent was given by all participants at the beginning of the study. The Institutional Review Board at University of California, Riverside approved the study prior to data collection.

2.2. Procedure

Participants performed the visual WM and sensory memory tasks sequentially with the order counterbalanced across subjects. In both tasks, all stimuli were presented on a 60 Hz LCD monitor (calibrated using an X-Rite i1Pro spectrophotometer) on a gray background (6.1 cd/m²) at a viewing distance of 57 cm. Participants also completed questionnaires assessing general demographic information, schizotypal features, and depressed mood.

2.2.1. Visual WM task

In the visual WM task (Fig. 1a), participants were instructed to memorize a memory array with 5 color squares simultaneously presented on the screen for 400 ms. These colors were randomly chosen from 180 colors evenly distributed in the Commission Internationale de l’Eclairage Lab color space (see W. Zhang and Luck, 2008 for details). Locations of the color squares were randomly selected from a set of eight possible locations that were equally spaced on an invisible circle (5.5° radius). After a short delay of 1000 ms with a blank screen, an arrow cue was presented pointing to the location of a randomly selected memory item, along with a continuous color wheel with all the 180 colors. Participants were required to report the color at the cued location using a computer mouse to click on the color wheel. Immediately afterwards, an arrow was drawn outside of the color wheel pointing to the correct color for 1000 ms as a feedback. All participants completed 3 blocks of 50 trials, yielding 150 trials in total.

2.2.2. Sensory memory task

The sensory memory task was comparable to the visual WM task with the following modifications to allow effective measurement of sensory memory (Fig. 1b). First, the duration of memory array was reduced to 100 ms. Second, the delay interval was reduced to 17 ms to test sensory memory. Third, the continuous color wheel was presented throughout the trial to avoid potential disruption of sensory memory...
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