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## A suicidal mind tends to maintain less negative information in visual working memory

Weizhen Xie<sup>a,b,\*</sup>, Huanhuan Li<sup>b,\*\*</sup>, Yingmin Zou<sup>b,c</sup>, Xuemei Sun<sup>b</sup>, Chuan Shi<sup>d</sup>

<sup>a</sup> Department of Psychology, University of California, Riverside, CA, USA

<sup>b</sup> Department of Psychology, Renmin University of China, Beijing, China

<sup>c</sup> Neuropsychology and Applied Cognitive Neuroscience Laboratory, Key Laboratory of Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, China

<sup>d</sup> Peking University Sixth Hospital, Beijing, China

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### ABSTRACT

The motivation to avoid psychological pain may characterize a suicidal mindset. This study examines how this motivational manifestation of suicidal ideation modulates the maintenance of affective information in visual working memory (WM). Fifty-five outpatients with major depressive disorder (MDD) and twenty-five healthy participants performed visual WM change localization tasks with emotional (e.g., positive or negative schematic facial expressions) and non-emotional (e.g., colors) stimuli. The number of items that participants retained in WM (i.e., capacity) for each of those stimuli was measured. Based on the Beck Scale for Suicide Ideation, MDD patients were categorized into high and low suicidal ideation groups. These two groups had comparable depression levels. In addition to showing a smaller overall WM capacity for emotionally neutral information (colors), MDD patients with high suicidal ideation retained fewer negative schematic facial stimuli in WM. This disproportional reduction in the amount of negative information held in visual WM was correlated with levels of suicidal ideation and psychological pain across participants. Together, these results reveal the impact of pain avoidance motivation on information processing in WM and provide a novel perspective to understand aberrant cognitive patterns that are potentially driven by maladaptive affective processing in individuals with higher suicide risk.

### 1. Introduction

Worldwide, over 800,000 people die because of suicide every year (World Health Organization, 2014). Although no single explanation can account for suicidal behaviors (de Leon et al., 2015), suicidal ideation and prior suicide attempt remain two of the most important predictors of suicide in the general population (Glenn and Nock, 2014; World Health Organization, 2014). Both factors are closely associated with higher levels of *psychological pain*, which is often referred to as the introspective experience of negative emotions such as dread, despair, fear, grief, shame, guilt, frustrated love, loneliness, and loss, etc. (Shneidman, 1998, 1999). These painful feelings can reliably predict suicidal ideation and/or suicide attempt in various populations, including college students (e.g., Troister et al., 2015; Troister and Holden, 2010), patients with major depressive disorder (MDD, e.g., Li et al., 2014), and homeless people (e.g., Patterson and Holden, 2012).

Recent research has highlighted the motivation component of psychological pain (i.e., the tendency to avoid or escape from

psychological pain, hereafter referred to as *pain avoidance*) in driving suicidal behaviors (Baumeister, 1990; Li et al., 2014; Meerwijk et al., 2013; Orbach et al., 2003; Williams, 2014). That is, suicide may be a behavioral consequence of a high motivation to escape from emotional sufferings under elevated psychological pain (i.e., *pain avoidance account of suicidality*, Li et al., 2014; Orbach et al., 2003; Williams, 2014). Supporting this hypothesis, MDD patients with a history of suicidal act reported much higher levels of pain avoidance compared to those with no prior suicidal act in a recent study (Li et al., 2014). The increased level of pain avoidance during a major depressive episode could further manifest as a behavioral tendency to exert more efforts to avoid negative feedback (Xie et al., 2014). Most importantly, disputing the cognitive bias of pain avoidance and replacing it with adaptive coping skills could decrease suicide risk after an 8-week therapy intervention (Zou et al., 2017). These findings were consistent with observations that individuals with a higher suicide or self-injury desire generally showed a worse capability to experience negative psychological states (known as *distress tolerance*, Anestis et al., 2011, 2013; Anestis and

\* Corresponding author at: Department of Psychology, University of California, Riverside, 900 University Ave., Riverside, CA 92521, USA.

\*\* Correspondence to: Department of Psychology, Renmin University of China, 1004 10th Floor, Suite D Huixian Building, No. 59 Zhongguancun St., Beijing 100872, China.  
E-mail addresses: [weizhen.xie@email.ucr.edu](mailto:weizhen.xie@email.ucr.edu) (W. Xie), [psylh@ruc.edu.cn](mailto:psylh@ruc.edu.cn) (H. Li).

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Joiner, 2012; Nock and Mendes, 2008) and a higher tendency to act rashly to reduce negative feelings (known as *negative urgency*, Anestis and Joiner, 2011; Riley et al., 2015). Although these converging findings suggest profound impacts of pain (or negativity) avoidance on affective processes associated with suicidality, little is known whether and how this motivational tendency modulates the cognitive building blocks leading to a suicidal mindset. For example, does suicide ideation influence the ability to maintain affective information in working memory (WM)?

WM is a capacity-limited memory system (Cowan, 2001; Luck and Vogel, 1997; Miller, 1956; Zhang and Luck, 2008) that actively maintains information over a short time period at the service of other ongoing mental activities (Baddeley, 2012a). Its capacity limitation constrains a range of cognitive and affective functions, including attentional allocation (Kane et al., 2006), fluid intelligence (Conway et al., 2002), optimal processing of affective information (Lynn et al., 2016; Xie et al., 2016), and emotional regulation (Schmeichel et al., 2008). Given its central role in human cognition (Cowan, 2001), WM is often considered as an information processing system that integrates both bottom-up (stimuli-driven) and top-down (motivation and cognitive control) mental processes (Baddeley, 2012a; Cowan, 2001; Miyake and Shah, 1999). For example, stimulus-level object features (e.g., object complexity of the memory items) may alter the number of items one could simultaneously retain in visual WM (Alvarez and Cavanagh, 2004; but see Jackson et al., 2015). In addition, irrespective of bottom-up stimulus-level features, motivational salience of memory items, introduced either by material rewards (e.g., money, food, and liquid, Gong and Li, 2014; Infanti et al., 2015; Wallis et al., 2014) or by social signals (e.g., attractive faces or happy expressions, Kajimura et al., 2014; Pe et al., 2013), can exert top-down influences on the information encoded into and maintained in WM (Baddeley, 2012b; Baddeley et al., 2012; Xie et al., 2016; Xie and Zhang, 2016). It is thus possible that pain avoidance motivation associated with suicidal ideation (e.g., Anestis et al., 2011, 2013; Anestis and Joiner, 2011, 2012; Hayes and Gifford, 1997; Li et al., 2014; Nock and Mendes, 2008; Xie et al., 2014) can modulate the encoding/maintenance of affective information in visual WM. However, this speculation remains to be tested.

Two possibilities can be expected. On the one hand, because high suicidal ideation is often accompanied with severe depression, suicidal ideation may simply reduce the capacity for any WM content regardless of its emotional valence (i.e., *overall dysfunction hypothesis*), due to the overall reduction in cognitive resource caused by depression (Hertel and Hardin, 1990; Hertel and Rude, 1991; Xie et al., 2017). This overall dysfunction hypothesis is in line with previous research on neuropsychological deficits of WM capacity in depressed individuals in general (e.g., Arnett et al., 1999a, 1999b; Hubbard et al., 2015; Kizilbash et al., 2002; Rose and Ebmeier, 2006) and in suicide attempters in specific (Keilp et al., 2001, 2013). On the other hand, individuals with high suicidal ideation may possibly maintain less negative information in visual WM (i.e., *disproportional dysfunction hypothesis*) due to the impact of pain avoidance motivation on various stages of information processing. For example, it is possible that a strong motivation to avoid negative affect associated with high suicidal ideation can modulate attentional allocation (Adams et al., 2001), which subsequently filters out (either consciously or unconsciously) negative information from one's mind. Furthermore, the affective values of retained WM representations may be detected and labeled during WM maintenance (Baddeley, 2007, 2012b; Baddeley et al., 2012; Xie et al., 2016). Through the mechanism of selective rehearsal (or refreshing, Johnson et al., 2007; Miller et al., 2008; Raye et al., 2007) or inhibitory control (Munakata et al., 2011), these labeled WM representations may be further highlighted or suppressed, resulting in different amounts of information retained in WM for different types of emotional content.

Although both the overall dysfunction hypothesis and the disproportional dysfunction hypothesis are plausible, it was difficult to

differentiate these two possibilities because most previous studies showing a reduction in WM capacity due to mood disorders did not measure suicidal ideation, depressive symptoms, and the affective bias in WM at the same time (e.g., Arnett et al., 1999a, 1999b; Hubbard et al., 2015; Kizilbash et al., 2002; Rose and Ebmeier, 2006). To test these two hypotheses, the current study thus used a visual WM change localization paradigm (Gold et al., 2006; see Method for details) to quantify WM capacity for stimuli with different affective values, and assessed suicidal ideation and depressive symptoms in both MDD patients and healthy controls. If there is an overall dysfunction of visual WM capacity in MDD regardless of suicidal ideation, MDD patients should show a general decrease in WM capacity regardless of the emotional valence of task stimuli. However, if pain avoidance impacts information processing in visual WM, there should be a reduction in WM capacity for negative information only in MDD patients with high suicidal ideation but not in those with low suicidal ideation. The former result would support the overall dysfunction hypothesis, whereas the latter result would support the disproportional dysfunction hypothesis.

## 2. Method

### 2.1. Participants

Fifty-five outpatients with major depressive episodes were recruited from local psychiatric clinics/hospitals through referral. Inclusion criteria for these outpatients were: (a) diagnosis of MDD without concurrent or recent manic episodes by certified psychiatrists based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV, American Psychiatric Association, 2000)<sup>a</sup>; (b) aged 18–60 years; (c) first episode or a short (< 1 year) medication period; (d) > 9 years of education; (e) no comorbid physical disease or other mental disorder, such as schizophrenia, anxiety disorders, or personality disorders. These outpatients were further categorized into high suicide ideation (HSI;  $n = 25$ ,  $24.52 \pm 7.56$  [Mean  $\pm$  SD], actual range = 18–30, 14 males) and low suicide ideation (LSI;  $n = 20$ ,  $25.70 \pm 7.07$ , actual range = 18–40, 8 males) groups, based on scores of the Beck Scales for Suicide Ideation (BSS, Beck and Steer, 1991; see the Procedure section for details). Specifically, the HSI group included participants with BSS-C (suicide ideation in the past week) scores greater than 2 and BSS-W (suicide ideation at one's worst point) scores greater than 16 (Beck and Steer, 1991; Xie et al., 2014). Clinical interview records indicated that 56% of participants in the HSI group had a history of suicidal attempt. In contrast, only 10% of the participants in the LSI group had past suicidal attempt ( $p = 0.0017$ , Fisher's exact test).

Twenty-five healthy control participants ( $23.04 \pm 2.16$ , actual range = 18–47, 12 males) were recruited from a local community via flyers. All participants filled out a prescreening survey to determine eligibility. Participants were eligible for inclusion if they (a) aged 18–60 years, (b) had a BDI-I (Beck Depression Inventory I) score  $\leq 10$  (Beck et al., 1979b, 1988), (c) scored 0 for both item 4 and item 5 in the BSS (Beck and Steer, 1991; Xie et al., 2014), (d) and had no self-report history of major physical diseases (such as cancer, diabetes, or brain trauma, etc.) or mental disorders (such as mood disorders, schizophrenia, anxiety disorders, or personality disorders, etc.). However, these healthy control participants had a higher level of education as compared to outpatients in the clinical groups (see Table 1). Thus, education level (number of years) was further treated as covariates in data analyses.

All participants received monetary compensation and provided written informed consent before the study. Local ethics committees of participating institutes/hospitals approved the study before data collection.

<sup>a</sup> The current study was designed prior to the publication of DSM-5.

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