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Research report

Elevated depressive symptoms enhance reflexive but not reflective auditory category learning

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ABSTRACT

In vision an extensive literature supports the existence of competitive dual-processing systems of category learning that are grounded in neuroscience and are partially-dissociable. The reflective system is prefrontally-mediated and uses working memory and executive attention to develop and test rules for classifying in an explicit fashion. The reflexive system is striatally-mediated and operates by implicitly associating perception with actions that lead to reinforcement. Although categorization is fundamental to auditory processing, little is known about the learning systems that mediate auditory categorization and even less is known about the effects of individual difference in the relative efficiency of the two learning systems. Previous studies have shown that individuals with elevated depressive symptoms show deficits in reflective processing. We exploit this finding to test critical predictions of the dual-learning systems model in audition. Specifically, we examine the extent to which the two systems are dissociable and competitive. We predicted that elevated depressive symptoms would lead to reflective-optimal learning deficits but reflexive-optimal learning *advantages*. Because natural speech category learning is reflexive in nature, we made the prediction that elevated depressive symptoms would lead to *superior* speech learning. In support of our predictions, individuals with elevated depressive symptoms showed a deficit in reflective-optimal auditory category learning, but an advantage in reflexive-optimal auditory category learning. In addition, individuals with elevated depressive symptoms showed an advantage in learning a non-native speech category structure. Computational modeling suggested that the elevated depressive symptom advantage was due to faster, more accurate, and more frequent use of reflexive category learning strategies in individuals with elevated depressive symptoms. The implications of this work for dual-process approach to auditory learning and depression are discussed.

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1. Introduction

We report the results from a new line of research that merges a dual-learning systems theoretical framework originally developed in vision (Ashby, Alfonso-Reese, Turken, & Waldron, 1998; Ashby & Maddox, 2005, 2010) and recently extended to audition (Chandrasekaran, Yi, & Maddox, 2014; Maddox & Chandrasekaran, in press; Maddox, Chandrasekaran, Smayda, & Yi, 2013) with research that explores the changes in cognitive processing associated with the presence of elevated depressive symptoms (Beevers, 2005; Beevers et al., 2013; Blanco, Otto, Maddox, Beevers, & Love, 2013; Carver, Johnson, & Joormann, 2009; Maddox, Gorlick, Worthy, & Beevers, 2012). Combining these research areas leads to a set of testable predictions regarding auditory and speech learning in individuals with elevated depressive symptoms.

1.1. Dual-processes in visual and auditory speech category learning

The Competition between Verbal and Implicit Systems (COVIS) theory of visual category learning (Ashby et al., 1998; Ashby, Paul, & Maddox, 2011) postulates two learning systems, one reflective and one reflexive.[1] COVIS offers a rich neurobiologically-based framework for understanding the cognitive and neural processes associated with visual (Ashby et al., 1998; Ashby & Maddox, 2005, 2010) and auditory category learning (Chandrasekaran et al., 2014; Maddox & Chandrasekaran, in press; Maddox et al., 2013). In the introduction we focus exclusively on the cognitive processes and explore the neural mechanisms in the General Discussion.

Briefly, the dual-learning systems model postulates that category learning is mediated by a verbalizable reflective system that is under conscious control and relies on working memory and executive attention, and by a non-verbalizable reflexive system that is not under conscious control and does not rely on working memory and executive attention (Ashby et al., 1998; Ashby & Maddox, 2005, 2010). The reflective system selects and tests simple verbalizable hypotheses about category membership. To perform well in reflective-optimal tasks, participants must remember which rules they have already tested and rejected in order to avoid revisiting these failed rules again. The reflexive system involves procedurally learning to associate stimuli lying in different regions of perceptual space with different motor responses. The reflective and reflexive systems interact and compete to generate the response on each trial, and learners have an initial bias toward the reflective system, but switch to the reflexive system with practice when that system is the optimal system for solving the task (Ashby et al., 1998; Ashby et al., 2011).

[1] Recent evidence suggests a third system, referred to as the perceptual-representation system, can also mediate category learning under certain conditions (Casale & Ashby, 2008; Zeithamova et al., 2008).

1.2. Dual-processes in individuals with elevated depressive symptoms

Depression is a common, recurrent, and impairing condition that predicts future suicide attempts, interpersonal problems, unemployment, and substance abuse (Kessler et al., 2003; Kessler & Walters, 1998). Hundreds of millions of individuals currently suffer from depression and many more have elevated depressive symptoms. Furthermore, adults with elevated depressive symptoms, even in the absence of Major Depressive Disorder, have worse physical, social, and role functioning compared to a demographically similar group without a chronic health condition. Indeed, well-being and psychosocial functioning of individuals with elevated depressive symptoms are comparable to people with major chronic medical conditions, such as hypertension, diabetes, and arthritis (Wells et al., 1989).

Individuals with elevated depressives show deficits in tasks that rely on reflective processing, such as problem-solving (Elderkin-Thompson, Mintz, Haroon, Lavretsky, & Kumar, 2006), planning (Rogers et al., 2004), cognitive flexibility (Butters et al., 2004), and decision-making (Beevers et al., 2013; Blanco et al., 2013; Clark Chamberlain, & Sahakian, 2009; Gradin et al., 2011; Maddox et al., 2012; Murphy et al., 2001; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). Much less is known about reflexive processing in individuals with elevated depressive symptoms. However, given the fact that the reflective and reflexive systems compete during learning, we predict that individuals with elevated depressive symptoms will show *enhanced* performance in any category learning task whose learning is mediated by the reflexive system.

To date, category learning has only been explored in individuals with elevated depressive symptoms using the Wisconsin Card Sort Task (Heaton, 1980; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) which is a reflective-optimal category learning task that involves sorting cards into groups based on visually presented features. Individuals with elevated depressive symptoms evidence performance deficits in the Wisconsin Card Sort Task relative to individuals without elevated depressive symptoms (Davis & Nolen-Hoeksema, 2000; Martin, Oren, & Boone, 1991). Auditory category learning has not been explored in individuals with elevated depressive symptoms and thus, the present research represents the first to compare auditory category learning in individuals with and without elevated depressive symptoms in reflective-optimal and reflexive-optimal auditory and speech categories.

1.3. Dual-processes in speech category learning

In a recent paper, Chandrasekaran et al. (2014) provided strong evidence to suggest that non-native speech category learning is reflexive in nature. Adult, native speakers of American English were trained to learn Mandarin tone categories with trial-by-trial feedback and multiple talkers. Mandarin Chinese has four linguistically-relevant tone categories that differ primarily on the basis of pitch pattern (ma^1 'mother' [T1], ma^2 'hemp' [T2], ma^3 'horse' [T3], ma^4 'scold' [T4]), described phonetically as 'high-level', 'low-rising', 'low-dipping', and 'high-falling' pitch patterns, respectively. Two dimensions (pitch height and pitch direction) serve as primary cues in