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A developmental analysis of threat/safety learning and extinction recall during middle childhood

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ABSTRACT

The current study examined developmental changes in fear learning and generalization in 54 healthy 5–10-year old children using a novel fear conditioning paradigm. In this task, the conditioned stimuli (CS+/CS−) were two blue and yellow colored cartoon bells, and the unconditioned stimulus was an unpleasant loud alarm sound presented with a red cartoon bell. Physiological and subjective data were acquired. Three weeks after conditioning, 48 of these participants viewed the CS−, CS+, and morphed images resembling the CS+. Participants made threat–safety discriminations while appraising threat and remembering the CS+. Although no age-related differences in fear learning emerged, patterns of generalization were qualified by child age. Older children demonstrated better discrimination between the CS+ and CS morphs than younger age groups and also reported more fear to stimuli resembling the CS+ than younger children. Clinical implications and future directions are discussed.

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Introduction

Middle childhood is a crucial period for studying fear learning given age-related changes in memory abilities (Ofen, 2012; Riggins, 2014), brain structures that support fear learning and extinction (Gee et al., 2013; Ghetti & Bunge, 2012; Gogtay et al., 2004), and prevalence of fear-based internalizing disorders such as social anxiety disorder (Kessler, Berglund, Demler, Jin, & Walters, 2005). Although classic studies suggest that human infants manifest relatively mature capacities for fear learning by conditioning (Watson & Rayner, 1920), more recent work in humans (see Shechner, Hong, Britton, Pine, & Fox, 2014, for a review) and animals (e.g., Kim & Richardson, 2010; Rudy, 1993) finds that this capacity may change subtly throughout development. However, given methodological difficulties in studying fear learning among children, relatively little is known about how fear conditioning develops during middle childhood. Even less is known about fear extinction and recall of extinguished fears during this period. To address these difficulties, we developed a novel paradigm designed to assess the development of fear conditioning, extinction, and extinction recall in young children.

The literature on human fear learning corroborates findings in animals of the early emergence of the acquisition of fear (Pattwell et al., 2012), although relatively little is known about the development of this process, particularly in young children. The few available developmental studies of human fear conditioning indicate that children as young as 3 years show evidence of fear acquisition (Gao, Raine, Venables, Dawson, & Mednick, 2010), with discrimination between an aversively conditioned stimulus and a neutral stimulus (CS+ > CS−) gradually improving with age (Gao et al., 2010; Glenn et al., 2012). This increased discrimination ability with age continues into adulthood and is associated with distinct developmental patterns of neural activity during fear learning (Lau et al., 2011).

Although learned fear memories are persistent, their expression can be inhibited through new learning that a threatening stimulus in the past is now safe. Experimentally, this process of extinction learning is modeled by repeatedly presenting the CS+ without the aversive unconditioned stimulus (UCS) so that it no longer elicits a fear response. Developmental changes in fear extinction learning have also been observed across species. In particular, fear extinction in both humans and rodents is selectively attenuated during adolescence relative to children and adults (Pattwell et al., 2012). Based on these few studies, findings support that young children are capable of fear learning processes (e.g., fear conditioning and extinction), threat and safety cue discrimination improves with age, and adolescents show attenuated extinction learning compared with adults. Taken together, age-related differences in fear and safety learning seem to emerge as more complex forms of learning continue to mature and interact with changes in neural circuitry.

The capacity for remembering and maintaining threat–safety discrimination also improves with age. Extinction recall, the retention of extinction over time, quantifies this more complex form of discrimination, although work in young children remains limited. Recent work suggests two possible means for detecting developmental change in fear learning during extinction recall. First, Lau and colleagues (2011) assessed participants' awareness of danger and found that adolescents showed reduced discrimination of threat and safety cues when rating fear during conditioning compared with adults. Second, extending this work, two studies combined a focus on awareness and on subtle discrimination by creating a generalization gradient using morphs that mixed features of the extinguished CS+ and CS− cues (i.e., generalization stimuli, GS) at extinction recall. These two studies demonstrated age differences in generalization (Britton et al., 2013; Glenn et al., 2012). However, across these three studies, the youngest participants were 8 years old. Prominent theories suggest that fear conditioning contributes to individual differences in anxiety because individuals differ in the extent to which they experience fear generalization (LeDoux, 1998; Lissek et al., 2014). Thus, there is a need for research that uses these methods in younger children. The aim of the current study was to test whether generalization gradients observed in older children differ in younger children.

Few studies have focused on fear generalization processes during middle childhood due to methodological limitations (i.e., UCS stimulus selection). Because it provides the strongest learning, most research in adults uses electric shock as a UCS, which is inappropriate for use in pediatric populations (Pine, Helfinstein, Bar-Haim, Nelson, & Fox, 2009). Some work with children has attempted to use milder aversive stimuli, such as a mildly aversive sound UCS (Gao et al., 2010; Neumann, Waters, & Westbury,