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Respiratory sinus arrhythmia, shyness, and effortful control in preschool-age children

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ABSTRACT

Resting respiratory sinus arrhythmia (RSA) and shyness were examined as predictors of effortful control (EC) in a sample of 101 preschool-age children. Resting RSA was calculated from respiration and heart rate data collected during a neutral film; shyness was measured using parents', preschool teachers', and classroom observers' reports; and EC was measured using four laboratory tasks in addition to questionnaire measures. Principal components analysis was used to create composite measures of EC and shyness. The relation between RSA and EC was moderated by shyness, such that RSA was positively related to EC only for children high in shyness. This interaction suggests that emotional reactivity affects the degree to which RSA can be considered a correlate of EC. This study also draws attention to the need to consider the measurement context when assessing resting psychophysiology measures; shy individuals may not exhibit true baseline RSA responding in an unfamiliar laboratory setting.

1. Introduction

Measures of autonomic nervous system function are valuable because they may provide additional information about internal states that are difficult to assess reliably using observation or self-report measures (Kagan, 1998), and can provide evidence for the underlying physiological mechanisms that support individual differences in temperament and adjustment (e.g., Beauchaine et al., 2008). The sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) both exert influence on the heart, with opposing effects: the sympathetic nervous system is involved in metabolically costly fight/flight responding, whereas the PNS slows heart rate, and has been conceptualized as a "brake" on heart rate (Porges et al., 1996). Respiratory sinus arrhythmia (RSA)—referred to as vagal tone by some investigators because its effects are largely mediated by the vagus nerve (Porges, 2007)—is considered a measure of PNS influence on the heart. Resting RSA is a stable individual difference variable (Doussard-Roosevelt et al., 2003; El-Sheikh, 2005) that has been studied extensively as a correlate of two aspects of temperament, effortful control (EC) and shyness/behavioral inhibition. To our knowledge, however, no researchers have attempted to understand how RSA is related to both of these aspects of temperament in the same individuals even though EC and shyness are believed to be largely orthogonal constructs (Rothbart et al., 2001). In this study, we examine shyness as a moderator of the relations between RSA and EC.

1.1. Effortful control

Effortful control has been defined as "the efficiency of executive attention—including the ability to inhibit a dominant response and/or to activate a subdominant response, to plan, and to detect errors" (Rothbart and Bates, 2006, p. 129). There are conceptual similarities between RSA and both EC. High RSA is thought to index emotion regulation (e.g., Beauchaine et al., 2007; Fabes and Eisenberg, 1997; Gyurak and Ayduk, 2008). Similarly, EC is believed to underlie effective emotion regulation (Eisenberg et al., in press; Rothbart and Bates, 2006), and would therefore be expected to relate positively to RSA. Neuroscience research also supports a link between RSA and EC, as the anterior cingulate cortex is believed to provide the neural basis for EC (Fan et al., 2003; Posner and Rothbart, 1998), and activity in the anterior cingulate cortex also is associated with PNS function (Gianaros et al., 2004; Matthews et al., 2004).

Positive relations between attentional control—an important component of EC—and resting RSA have sometimes been documented in the literature. For fourth and fifth graders and for adults, performance on a continuous performance task (a measure of attentional control) was found to be positively associated with resting RSA (Hansen et al., 2003; Suess et al., 1994). In a sample of children and adolescents ranging from eight to 17 years old, resting

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RSA was positively related to parents' reports of EC (Chapman et al., 2010).

Studies also show that resting RSA is positively related to performance on complex cognitive tasks involving executive functioning (EF)—a capacity that has considerable conceptual overlap with EC (Zhou et al., 2012)—across the lifespan. In a study of 3.5-year-old children, resting RSA was positively related to performance on two EC/EF tasks (Marcovitch et al., 2010), and in school-age children resting RSA was found to be positively related to EF and processing speed, but unrelated to more general measures of cognitive ability (Staton et al., 2009). Similarly, resting RSA was negatively related to adults' processing time during a Stroop task (Mathewson et al., 2010). Finally, RSA was found to correlate with a composite measure of EC/EF in a sample consisting mostly of boys, half of whom had emotional or behavioral disorders (Mezzacappa et al., 1998).

In contrast to this evidence, some researchers have failed to document significant relations between baseline RSA and EC/EF. For example, performance on two behavioral EC measures was unrelated to resting RSA in sample of low-income preschoolers enrolled in Head Start (Blair and Peters, 2003). Null relations between resting RSA and a cognitive signal detection task also were observed for college students (Duschek et al., 2009). Nonetheless, the literature suggests that resting RSA is positively related to EC in school-age children and adults, although few investigators have examined these relations in preschool-age children.

1.2. Shyness and behavioral inhibition

Coplan and Rubin (2010, p. 9) defined shyness as "(temperamental) wariness in the face of social novelty or self-conscious behavior in situations of perceived social evaluation." Behavioral inhibition, in contrast, is a dimension of temperament characterized by high emotional reactivity to the unfamiliar (Snidman et al., 1995). According to Fox and colleagues (Fox et al., 2001, p. 2), "Reticence [i.e., shyness] is conceptually related to behavioral inhibition based on the common underlying motivation to avoid novelty due to the negative affect elicited by novel stimuli." Behavioral inhibition is characterized by emotional reactivity to unfamiliar situations in general, whereas shyness is specific to social situations and may also involve fear of being evaluated in addition to emotional reactivity to the unfamiliar (Xu et al., 2009). As might be expected based on the overlap between these constructs, shyness and behavioral inhibition have been found to be positively correlated (Xu et al., 2009). Furthermore, shyness and behavioral inhibition have both been reported to predict the development of anxiety problems (e.g., Prior et al., 2000).

High resting RSA is believed to index the ability to engage with the environment (Porges, 2007), as well as flexibility in responding (Thayer and Lane, 2000). Because shyness and behavioral inhibition are characterized as relatively inflexible emotional responses to novelty, these constructs would be expected to relate negatively to RSA. In addition, there appears to be a shared neural basis for shyness and RSA, with activity in the insula associated with both shyness (Beaton et al., 2010) and PNS function (Gianaros et al., 2004; Lane et al., 2009).

The standard deviation of heart period, a measure of heart rate variability that is strongly correlated with RSA (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996), has been found to relate negatively to behavioral inhibition in some studies. For example, children classified as behaviorally inhibited at 21 months of age had a smaller heart period *SD* across a battery of tasks at age 4 relative to children who were not inhibited (Kagan et al., 1984). Some investigators also have observed a negative relation between children's behavioral inhibition and RSA (Fox, 1989; Putnam, 2000; Rubin et al., 1997) or between parental ratings of shyness and RSA (Doussard-Roosevelt et al., 2003; Kagan et al., 1988). In addition, RSA has been found to relate negatively to infants' social fear (Stifter and Jain, 1996) and to preschoolers' social reticence (Henderson et al., 2004). Although some researchers have failed to find significant relations between RSA and behavioral inhibition (Burgess et al., 2003; Marshall and Stevenson-Hinde, 1998) or shyness (Dietrich et al., 2009; Schmidt et al., 1999), overall the evidence suggests that baseline RSA is negatively related to these constructs.

1.3. The present investigation

As discussed, a number of investigators have attempted to examine the direct relations between baseline RSA and temperamental characteristics such as EC and shyness. To our knowledge, however, moderators of the relation between RSA and EC have not been examined. In this study, we attempt to predict EC from the interaction between baseline RSA and shyness. RSA was expected to relate more strongly to EC under conditions that require effective emotional self-regulation (cf., Krypotos et al., 2011), and the experimental situation was expected to be more arousing for children high in shyness than for children low in shyness. Thus, we hypothesized that RSA would be more strongly related to EC for those children high in shyness because shy children with greater attentional resources, compared to shy children with low attentional regulation, should be better able to regulate their emotional arousal in an unfamiliar setting.

2. Method

The study consisted of three components: (1) a laboratory visit in which heart rate and respiration were recorded during a baseline film, and in which children completed three tasks assessing EC; (2) a second, shorter laboratory session in which children completed a continuous performance task (another behavioral measure of EC); and (3) questionnaires measures of children's shyness and EC that were completed by parents, preschool teachers, and classroom observers.

2.1. Participants

Participants were 106 children (42 girls) attending any of the three research preschools at a southwestern university campus who gave assent for physiological recording. All subsequent analyses include data for the 101 children (40 girls) who had complete physiological data for a baseline film. Physiological data were missing for five children due to problems with the recording of respiration (e.g., improper placement of the respiration bellows). Age ranged from 3.31 to 5.88 years ($M = 4.49$; $SD = 0.63$).

Parents of eighty-three children in the current study returned questionnaires that included demographic information. Education was reported on a 7-point scale (1 = did not graduate high school; 7 = Ph.D. or professional degree). The median level of parental education averaged across both parents was 4-year college graduate. Annual family income was also reported on a seven-point scale (1 = <$10,000; 7 = more than $100,000). Median family income was $75,000–$100,000. Six percent of children were from single-parent families. Children's racial composition, as reported by parents, was as follows: 73% Caucasian; 2% African American; 9% Asian; 4% Native American; 12% other/multiracial. Eighteen percent of parents reported that their children were Mexican American/Hispanic in ethnicity.

2.2. Laboratory procedure

Prior to the laboratory session, we employed several methods to familiarize children with the experimenters and the physiological hook-up procedures. Experimenters spent some time playing with children in their classroom so that the children would be somewhat familiar with them. In addition, experimenters demonstrated the physiological hook-up procedure in the classroom during group instructional time and allowed children to try putting on the respiration bellows and the electrodes. To make the electrodes more appealing, we placed animal stickers on them.

Each laboratory session was administered by one experimenter and one camera person, both of whom were trained undergraduate or graduate research assistants. There were a total of 24 experimenters/camera people (14 females, 10 males) across three semesters of data collection.[1] Undergraduate research assistants were

[1] We dummy coded four variables: (1) the sex of the experimenter; (2) the sex of the camera person; (3) whether the sex of experimenter matched the sex of the