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Clarifying the nature of startle habituation using latent curve modeling

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ABSTRACT

Startle habituation is present in all startle studies, whether as a dependent variable, discarded habituation block, or ignored nuisance. However, there is still much that remains unknown about startle habituation, including the following: (1) what is the nature of the startle habituation curve?; (2) at what point does startle habituation approach an asymptote?; and (3) are there gender differences in startle habituation? The present study investigated these three questions in a sample of 94 undergraduates using both traditional means-based statistical methods and latent curve modeling. Results provided new information about the nature of the startle habituation curve, indicated that the optimal number of habituation trials with a 100 dB startle stimulus is 13, and showed that females display greater startle reactivity but habituate toward the same level as males.

1. Introduction

The acoustic startle eyeblink response is a defensive reflex that occurs in reaction to an intense and sudden stimulus (Blumenthal et al., 2005; Koch, 1999; Landis and Hunt, 1939; Yeomans et al., 2002). Thousands of studies have used startle modulation to investigate both basic and applied processes. For example, affective-valence modulation paradigms involve measuring startle reactivity in the context of an emotionally evocative foreground (e.g., a picture of food or a spider). This paradigm has provided unique insight into emotional abnormalities in internalizing, externalizing, psychotic, and autism spectrum disorders (Dichter et al., 2010; Patrick et al., 1993; Vaidyanathan et al., 2009a, 2009b; Yee et al., 2010). Similarly, prepulse inhibition of startle has been employed extensively to investigate information processing in a range of disorders (Braff et al., 1992; Swerdlow et al., 2008).

1.1. Group differences in startle habituation

Several studies have employed a third form of startle modulation, startle habituation. In learning and memory research, habituation has been defined as a "behavioral response decrement that results from repeated stimulation and that does not involve sensory adaptation/sensory fatigue or motor fatigue" (p. 136, Rankin et al., 2009; see also Thompson, 2009). Additionally, Thompson and colleagues described several specific characteristics that connote habituation (Rankin et al., 2009; Thompson, 2009). Despite decades of startle habituation research, we note that few of these habituation characteristics have been specifically examined in startle research and few studies have controlled for the potential contributions of sensory and motor fatigue to startle reactivity decrements across stimulus presentations. Nevertheless, startle habituation traditionally has been conceptualized as an index of sensorimotor gating in psychiatric populations (see Braff and Geyer, 1990). For example, studies have found diminished habituation in association with schizophrenia (Braff et al., 1992; Ludewig et al., 2003; Meincke et al., 2004), schizotypal personality disorder (Cadenhead et al., 1993), bipolar depressive disorder (Perry et al., 2001), posttraumatic stress disorder (Kozaric-Kovacic et al., 2011), panic disorder (Ludewig et al., 2005), and children with a parental history of alcoholism (Grillon et al., 1997). On the other end of the spectrum, LaRowe et al. (2006) found that faster habituation was associated with extraversion. In contrast to these studies, several investigations have failed to find diminished habituation in association with schizophrenia (Hasenkamp et al., 2010; Perry et al., 2002), attention-deficit hyperactivity disorder (Ornitz et al., 1997), suicidality and major depressive disorder (Quednow et al., 2006), bipolar disorder (Rich et al., 2005), or anxiety disorders (Ross et al., 1989; Hoenig et al., 2005).

One potential explanation for these discrepancies is the limitations of the methods used to quantify startle habituation. Many of these studies measured small blocks of startle-alone trials (i.e., between two and six trials) before and after large blocks of prepulse inhibition trials (i.e., 18 to 36 trials). Other studies measured startle-alone trials that were embedded in prepulse inhibition blocks (e.g., Cadenhead et al., 1993; Rich et al., 2005). A minority of studies examined only startle-alone reactivity over the course of several trials (LaRowe et al., 2006; Ornitz et al., 1996, 1997; Ross et al., 1989; Schicatano and Blumenthal, 1995, 1998). Regardless of the habituation method, most studies condensed several individual startle trials into blocks and a mean was calculated for each block. T-tests or analyses of variance (ANOVAs) were then performed to determine if

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startle reactivity was significantly lower in later blocks compared to earlier blocks. If there was a significant difference, then startle habituation was said to have occurred.

These means-based analyses have three major limitations that make it difficult to describe or find significant differences in startle habituation. First, these methods often artificially condense startle habituation (e.g., the mean of the first six trials is compared to the mean of the second six trials). Important changes may happen during startle habituation from trial to trial; condensing several trials into a single block accordingly discards potentially important information (cf. MacCallum et al., 2002). Groups may differ on startle habituation in important but subtle ways that condensation into means may mask.

Second, a closely related limitation is that traditional methods for evaluating mean differences are not well-equipped to describe startle habituation in detail. Specifically, these methods may be able to detect that habituation has occurred, but they are less able to describe specific rates of habituation or how rates of habituation change across trials or individuals. The minority of studies that employ long blocks of startle habituation trials (e.g., Ornitz et al., 1996; Ross et al., 1989; Schicatano and Blumenthal, 1998) may be able to overcome this limitation with post hoc tests that can describe patterns of data. However, these contrasts often have restrictive assumptions (Maxwell and Delaney, 2004) that startle habituation data may not always meet. Moreover, although such contrasts can detect if a specific pattern exists (e.g., linear, quadratic), they are less able to describe the specific nature of that contrast (e.g., what type of quadratic pattern). For example, it could be possible that individuals high and low in trait fear would both show a quadratic startle habituation pattern; however, low fear individuals might display a substantial drop in startle reactivity across the first few trials, whereas high fear individuals might display a much more gradual (though still quadratic) pattern. An ANOVA would describe these patterns as essentially the same (i.e., significant habituation with a quadratic slope), but latent curve modeling (LCM) would be more likely to detect the important differences between these two groups. Thus, a more detailed account of startle habituation with a more appropriate statistical technique would provide more insight into the nature of group differences in startle habituation.

Third, means-based techniques that artificially group startle trials into blocks may confound differences in startle habituation (i.e., slope) with differences in initial startle reactivity (i.e., intercept). Individuals who display higher initial startle reactivity may have farther to fall to reach a startle reactivity asymptote. This would result in a steeper startle habituation curve that is an artifact of initial startle reactivity. More fine-grained statistical methods may be able to more effectively model this slope/intercept relationship and to avoid this potential confound.

1.2. Latent curve modeling

To address the limitations of means-based analyses, we will utilize a more recently developed method of analysis known as latent curve modeling. This is an advanced structural equation modeling approach based on the assumption that there is an underlying (i.e., latent) trajectory for a variable and that repeated measurements allow for the estimation of that trajectory (Bollen and Curran, 2006; Meredith and Tisak, 1984, 1990). For startle habituation data, this technique would establish a latent habituation trajectory that allows for a continuous model of startle habituation. Latent curve modeling would also provide statistical information on the nature of habituation (e.g., rate of change throughout the trajectory) and how exogenous variables affect habituation (e.g., gender). In sum, latent curve modeling overcomes the limitations of means-based techniques noted above. Moreover, latent curve modeling has additional advantages over means-based methods, including the following: (a) allowing continuous exogenous variables; (b) separating intercept and various slope factors; (c) permitting the prediction of the habituation trajectory with exogenous variables; and (d) including participants who are missing data on one or more habituation trials.

1.3. Startle habituation blocks

The majority of startle studies present a startle habituation block designed to have participants approach a startle reactivity asymptote before the experimental portion of the study (e.g., affective-valence startle modulation or prepulse inhibition blocks). The major goal of these blocks is to reduce variance in the data caused by startle habituation rather than the independent variables (cf. Blumenthal, 1997). There is a wide range in the number of trials in startle habituation blocks across studies. Some studies do not report a habituation block, but others have reported habituation blocks consisting of one (Braff et al., 1992; Cadenhead et al., 1993; Hoenig et al., 2005; Grillon et al., 1997), three (e.g., Csomor et al., 2006, 2008; Franklin et al., 2009a, 2010), four (e.g., Glenn et al., 2011), six (e.g., Schachinger et al., 2008), nine (e.g., Grillon and Charney, 2011), or ten (e.g., Grillon and Morgan, 1999) startle stimuli. The wide range of startle habituation block trials demonstrates a lack of empirically-based number of trials for habituation blocks. It is possible that one trial is sufficient to reach an asymptote, but it is also possible that a block of ten trials is insufficient to reach an asymptote. In the present study we will examine this question with a variety of statistical techniques. Our specific focus will be demonstrating the strengths of the latent curve model, as we believe the latent curve model better corresponds the process of habituation.

1.4. The present study

We pursued three major goals in the present study. The first was to utilize latent curve modeling to provide new information about the nature of startle habituation. We aimed to address basic questions such as: How does initial startle reactivity (i.e., intercept) covary with the trajectory (i.e., slope) of startle habituation? Is there a substantial amount of individual variability in startle habituation or does everyone follow a very similar pattern? What exactly does startle habituation look like from trial to trial? The second goal was to employ both means-based and latent curve modeling techniques to establish an empirical basis for the number of trials that should be used to have most individuals reach a startle reactivity asymptote.

Our final goal was to examine potential gender differences in startle habituation. There is some evidence that females display higher startle reactivity compared to males (e.g., Blumenthal and Gescheider, 1987; Della Casa et al., 1998; Kofler et al., 2001 [though note that this study did not find differences for reactivity measured from the orbicularis oculi]); however, many studies have not found gender differences for startle reactivity or startle habituation (e.g., Ludewig et al., 2003; Quednow et al., 2006; Swerdlow et al., 1993). It is possible that there are no gender differences in startle reactivity, but it is also possible that these differences have been too subtle for traditional methods to detect. Overall, the present study has the potential to provide new insights into a phenomenon present in all startle studies — startle habituation.

2. Method

2.1. Participants

The participants were 96 undergraduate introductory psychology students who participated in order to partially fulfill a class research requirement. Data from two participants were discarded because their average startle magnitude level was more than three standard deviations above the mean. The final sample size was 94, with 51 males and 43 females. The age range was 18–21 years, with a mean of 18.74 years. Ethnically, 69.6% of the participants self-identified as