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Background noise decreases both prepulse elicitation and inhibition of acoustic startle blink responding

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Abstract

Prepulse inhibition of startle (PPI) has proved to be useful in distinguishing between schizophrenia patients and normal controls, although not all studies in this area find such group differences. One reason for this inconsistency may be the fact that some research labs present the startle eliciting and inhibiting stimuli over a steady background noise (70 dB), whereas others present stimuli in ambient noise conditions (30–56 dB). The present study tested the impact of background noise (30, 50, and 70 dB) on PPI in normal college adults, with prepulses at intensities of 75, 80, and 85 dB, and with prepulse rise times of 1 or 10 ms. Background noise decreased the amount of PPI caused by the prepulses, and also decreased the ability of the prepulses to themselves elicit blink responses. We conclude that background noise interferes with the processing of the prepulse, attenuating its effect as both an elicitor and inhibitor of the startle reflex. By elevating the difficulty of prepulse processing, this attenuation may be a necessary condition for observing differences in PPI between patient and control groups.

Keywords: Startle; Blink; Background noise; PPI

Prepulse inhibition of the startle response (PPI) has been found to be a useful measure in the study of a variety of disorders, including schizophrenia, obsessive-compulsive disorder, tourette's, and post-traumatic stress disorder (Cadenhead and Braff, 1999; Braff et al., 2001). PPI is often found to be less pronounced in patients than in healthy control participants. However, some studies fail to find such a difference, and Wynn et al. (2004) have suggested that differences in background noise may underlie some of the inconsistencies in studies investigating PPI deficits in schizophrenic patients. The present paper is an attempt to evaluate the impact of a specific methodological difference that exists between clinical and nonclinical studies of PPI, the issue of background noise during the testing session.

The startle response is a rapid defensive reaction that can be elicited by sudden acoustic, visual, tactile, or electrical stimuli, and is usually measured by quantifying limb extension in rats or eyeblink electromyographic (EMG) responding in humans (Yeomans et al., 2002; Blumenthal et al., 2005). This response can be inhibited by a stimulus presented before the eliciting stimulus (at lead intervals of 15–500 ms for acoustic prepulses preceding acoustic startle stimuli), an effect referred to as prepulse inhibition of startle (PPI) (Blumenthal, 1999; Graham, 1975). This prepulse can be in any sensory modality, and need only be above detection threshold to have an effect. Discrete prepulses, which begin and end before the startle stimulus begins, are more effective inhibitors than are continuous prepulses, which begin before the startle stimulus and stay on until or after startle stimulus onset (Blumenthal and Levey, 1989; Braff et al., 2001b; Putnam and Vanman, 1999; Wynn et al., 2000). Prepulses that are initiated at the same time as the startle stimulus have been shown to increased startle reactivity (prepulse facilitation), probably due to temporal summation (Boelhouwer et al., 1991; Sarno et al., 1997).

In studies that compare PPI in human schizophrenic patients and controls, the prepulse and startle stimuli are usually presented above a continuous background noise in the 60–75 dB range (most often 70 dB). Background noise is on throughout the testing session, unlike continuous prepulses, which are initiated either before or at startle stimulus onset on each trial, with a silent period between trials. Background noise was originally used in animal startle research by Hoffman and Fleshler (1963) to mask unpredictable environmental sounds and thereby reduce variability in startle responding.

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However, Hoffman discovered that this background noise increased startle reactivity in the rat, a finding that has been replicated many times (see Hoffman, 1999, for historical context). Further, Palmer et al. (2000) showed that PPI in rats was impaired to a greater extent when background noise was present than when background noise was absent. Miyazato et al. (1999) also showed that PPI in the rat was reduced when background noise was increased from 50 to 60 dB.

Studies in which PPI deficits are found in schizophrenia patients generally use background noise at an intensity of 70 dB (Braff et al., 2001a). In the absence of this background noise, PPI deficits are generally not seen in patients unless the prepulse is a target in an attention task (Filion et al., 1993). In this situation, PPI to ignored prepulses is equivalent in schizophrenia patients and controls, and PPI is more pronounced to target prepulses in controls, but not in patients. It may be that the attentional task increases prepulse processing, and the background noise impairs prepulse processing, leading to less effective processing for ignored prepulses or prepulse embedded in background noise, in all participants. This increased difficulty may have more of an impact in schizophrenic patients and, thereby, relatively less PPI is seen in schizophrenia patients than in normal controls in these situations.

Given that animal studies have clearly shown that background noise can facilitate startle and impair PPI, and given that hundreds of PPI studies have been conducted with humans, some using background noise and others not, it is noteworthy that no reports investigating the impact of background noise on human startle and PPI had been published until very recently (Flaten et al., 2005; Hsieh et al., 2005). Flaten et al. presented a 70 dB pure tone prepulse before a 94 dB noise startle stimulus, in the presence of background noise intensities of 28 dB (ambient), 40, and 60 dB, and found that increasing background noise from 28 to 40 dB increased startle reactivity. Increasing background noise from 40 to 60 dB resulted in reduced PPI, an effect that Flaten et al. attribute to a reduction in the signal-to-noise ratio (the intensity of the prepulse relative to the intensity of the startle stimulus). That is, as background noise level increased, the difference between background noise intensity and prepulse intensity (signal) decreased, making prepulse detectability more difficult. Hsieh et al. (2005) found that increasing background noise from 54 dB (ambient) to 70 dB resulted in reduced PPI, similar to the finding of Flaten et al. (2005). Hsieh et al. also conclude that the important parameter in determining PPI is signal-to-noise ratio between the prepulse and the background. This signal-to-noise explanation was also proposed by Gewirtz and Davis (1995) to explain reduced PPI in the presence of background noise in rats.

In a second experiment, Flaten et al. (2005) used an airpuff prepulse to the hand, stating that the signal-to-noise explanation should not apply when the prepulse and background noise are in different sensory modalities. In support of their hypothesis, the background noise level had no impact on PPI caused by the tactile prepulse. In a third experiment, Flaten et al. used an acoustic prepulse and a tactile startle stimulus, an airpuff directed to the temple. PPI was seen when 28 dB (ambient) background noise was used, but no PPI was seen when background noise was 60 dB, showing that the background noise effect could be seen even when the prepulse and startle stimulus were not in the same modality, as long as the prepulse and background noise are in the same modality. This supports the conclusion that using background noise and acoustic prepulses can reduce the signal-to-noise ratio of those prepulses enough to impair PPI. An interesting test of this hypothesis (not included in the present paper) would be the use of prepulses and ‘‘background noise’’ in a non-auditory modality.

The present study extends the findings of Flaten et al. (2005) and Hsieh et al. (2005) in several ways. Whereas the highest background noise intensity used by Flaten et al. was 60 dB, and the lowest used by Hsieh et al. was 54 dB, the present study used background noise intensities of 30, 50, and 70 dB, with 70 dB being the level most often used in schizophrenia—PPI research (Braff et al., 2001a). The present study also used prepulses at three intensities, to further evaluate the impact of signal-to-noise ratio at the background noise level most often used in the clinical research in this area. Finally, the signal-to-noise hypothesis was tested in a second manner in this study, by evaluating the ability of the prepulses themselves to elicit blink reflexes (Blumenthal and Goode, 1991). If decreased PPI in the presence of background noise is due to a lowering of the signal-to-noise ratio, then prepulses presented in the context of background noise should also be less able to elicit blinks themselves. These two effects would converge on the conclusion that background noise interferes with the processing of the prepulse, decreasing its effectiveness as both an elicitor and an inhibitor of the blink response. To increase the information available in this study, prepulses with rise times of either <1 or 10 ms were used, since prepulse rise times within this range should affect the ability of the prepulse to elicit a blink response without affecting the PPI caused by these prepulses (Reilly and Hammond, 2001; Blumenthal and Goode, 1991; Blumenthal and Levey, 1989).

1. Methods

1.1. Participants

Participants were randomly selected from a group of introductory psychology students earning extra credit. All participants responded to the startle stimulus in each background noise condition, but two participants were excluded due to equipment problems, leaving a sample of 45 participants, 33 females and 12 males, ranging from 18 to 21 years of age. All participants reported no hearing loss or psychiatric disorders. All procedures in this study were approved by the Institutional Review Board of Wake Forest University.

1.2. Stimuli

Startle stimuli were 105 dB (A) broadband noise (20 Hz–20 KHz), with a 50 ms duration and a rise/fall time of <1 ms. Background noise was 30, 50, and 70 dB (A) broadband noise. Prepulses were 75, 80, and 85 dB (A) broadband noise, with a duration of 40 ms. Participants were tested in two groups according to the rise/fall time of the prepulses, either <1 ms ($N = 21$) or 10 ms ($N = 24$). All stimuli were generated by Coulbourn noise generators, gated through Coulbourn rise/fall gates, amplified by Coulbourn audio mixer amplifiers, and presented to the participant via headphones. Stimulus intensities