ATHABASCA UNIVERSITY

PREPULSE INHIBITION AND CALL ALERTING IN EMERGENCY MEDICAL SERVICES

BY

SCOTT HEATHCOTE

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF COUNSELLING

FACULTY OF HEALTH DISCIPLINES
ATHABASCA, ALBERTA
FEBRUARY, 2023

Approval of Thesis

The undersigned certify that they have read the thesis entitled

PREPULSE INHIBITION AND CALL ALERTING IN EMERGENCY MEDICAL SERVICES

Submitted by

Scott Heathcote

In partial fulfillment of the requirements for the degree of

Master of Counselling

The thesis examination committee certifies that the thesis
and the oral examination is approved

Co-Supervisors:
Dr. Tammy O'Rourke
Athabasca University

Dr. Jeff Chang
Athabasca University

Committee Member:
Dr. Patricia Kostouros
Athabasca University

External Examiner:
Dr. Tony Carlsen
University of Ottawa

April 4, 2023

Dedication

To my fellow paramedics.

Acknowledgements

My research has benefited from the help and guidance of an extraordinary number of people. Without their generosity and tolerance, I would not have been able to complete this research or my studies. Dr. Tammy O'Rourke chaired my thesis committee and provided guidance and support while allowing me the freedom to take the project where I thought it needed to go. Dr. Patricia Kostouros has been a constant supporter from my first days in the program. She pushed me to attempt the thesis route when I was questioning it. Dr. Jeff Chang, my long-suffering program mentor, helped me navigate the transition from an overly direct paramedic to a more careful communicator.

The topic I chose for my research is unusual. I was fortunate to find specialists willing to share their time and long experience with me. Dr. Neal Swerdlow spent hours helping me understand his field's concepts and gently correcting and encouraging me. Many of the contours of this research are of his design. He pushed this study to be what it is. I thank Dr. Terry Blumenthal for his dedication to sound science and his strong encouragement for me to follow his example.

I received generous support from the University of Calgary Human Performance Lab. Dr. Timothy Leonard allowed me to use the department's EMG machine, recording equipment, taught me how to use them and understand the data I collected. Dr. Ian Smith helped develop the first PP+Tone call alert and advised me on the fundamental components of the study design. Franziska Onasch helped me understand the operation of the EMG data recording system and provided technical support when I created disasters. Andrzej Stano created the powered microphone that synchronized the call alert to the EMG recording – a crucial element of my project. Hoa Nguyen provided information technology support and created a novice researcher-resistant template for the EMG recording.

I benefited from the ongoing support of the AHS EMS Research department. Dr. Ian Blanchard helped secure institutional support that allowed me to research my fellow paramedic in the EMS environment and guided me through the operational review process. Ryan Lee supplied ongoing enthusiasm and shared his technical knowledge of AHS and Stryker Canada's data recording system interface.

Jason Henderson of Stryker Canada generously loaned the project an LP-15 heart monitor that allowed the integration of heart rate data. Vaughn Parshotam facilitated a classroom for testing at the University of Calgary Medical School. Dr. Cherisse Seaton rescued me from statistical purgatory in moments of deep despair.

I am grateful for the collaboration of my fellow paramedics, who gave their time to participate in my experiment. Many paramedics find the call alert aversive, so their willingness to endure the testing is a testament to their generosity. I also owe gratitude to the paramedic supervisors who made allowances for crews to participate in the testing while maintaining ambulance capacity to serve the citizens of Alberta.

Finally, and most importantly, I continue to be thankful for the tolerance of my wife Greta and children Callum and Duncan. They have allowed me the time away from my family responsibilities to pursue this project. They participated as stand-ins during the design phase and offered advice, support, and encouragement. With the completion of this project, I can begin repaying the debt I owe you.

Abstract

The present study determined if the current AHS EMS call alert was startling to paramedics and if a prepulse moderated the magnitude of the startle response. Fifty paramedics were exposed to four call alerts (two with and two without a prepulse) in counterbalanced order. Participants' responses were measured using EMG blink magnitude, heart rate, perceived signal intensity, and perceived dislike. Paramedics responded to the call alert with a significant magnitude startle reflex blink and an increase in heart rate. Adding a prepulse caused a significant reduction in the magnitude of the startle blink, perceived sound intensity, and perception of dislike of the call alert. This study demonstrates that the call alert is startling to paramedics and that adding a prepulse can moderate the response.

Keywords: acoustic startle response, call alert, prepulse, paramedic, startle

Table of Contents

List of Figures

List of Symbols, Nomenclature, or Abbreviations

AHS EMS	Alberta Health Services Emergency Medical Services
ANOVA	Analysis of variance
ASR	Acoustic startle response
bpm	Heart beats per minute
dB	Decibel
dB(A)	A-weighted decibel
ECG	Electrocardiogram
EMG	Electromyography
EMS	Emergency medical services
min	Minute
ms	Millisecond
mV	Milivolt
PPI	Prepulse inhibition of startle
PPIPSI	Prepulse inhibition of perception of startle intensity
s	Seconds
VAS	Visual analog scale

Chapter 1. Significance of the Problem

In emergency medical services (EMS), paramedics are most often informed of an emergency call by an audible alarm called the call alert. While the nature of the call alert varies between agencies, it is consistently loud (Diel, 2001; Patel & Clarke, 2019) and often achieves full volume almost immediately (MacNeal et al., 2016). In Alberta Health Services Emergency Medical Services (AHS EMS), the call alert consists of three 106 dB(A), 50 ms tones that repeat every 5 s until manually silenced (Patel & Clarke, 2019).

Loud and sudden sounds, like the call alert, cause physical and psychological responses in humans. Physical responses include a characteristic whole-body pattern of skeletal and facial muscular contractions (including a short-latency blink) called the acoustic startle response (ASR) and rapid changes in heart rate caused by the cardiac startle response and the cardiac defence response (Barnard & Duncan, 1975; Eder et al., 2009; Graham, 1979; Karlsson et al., 2011; Ramirez et al., 2005). Barnard and Duncan (1975) linked frequent exposure to the call alert with an increased risk of heart disease, while Kales et al. (2007) and Smith et al. (2013) have associated the call alert with sudden cardiac death.

The psychological responses to startling sounds include changes in perception of sound intensity (Peak, 1939; Swerdlow et al., 2007) and the call alert, specifically, has been associated with anxiety (Barnard & Duncan, 1975). First responders also dislike the call alert (MacNeal et al., 2016; Paterson et al., 2016). Several researchers have identified the call alert as a significant source of occupational stress in first responders (Barnard & Duncan, 1975; Hall et al., 2016; Karlsson et al., 2011).

While more than 40 years of research have demonstrated that call alerting has detrimental physical and psychological effects on paramedics and other first responders, only two mitigation strategies have been proposed and investigated. Barnard and Duncan (1975) advocated for a reduction of the use of startling call alerts. MacNeal et al. (1975) examined the effect of reduced use of call alerts, along with a second mitigation strategy, extending the rise time of the call alert known as a ramp-up call alert. While MacNeal et al. (2016) found both interventions cause a small but significant reduction in heart rate changes, the call alert remains a substantial source of stress for paramedics (Karlsson et al., 2011).

Addressing sources of occupational stress in paramedics has become increasingly important. The demands of the Covid-19 pandemic on Alberta's already strained ambulance service have resulted in a crisis. Situations in which no ambulances are available to respond to emergency calls were once rare in Alberta (Le, 2022). But since 2018, they have occurred with growing frequency (Francis, 2022). For example, in January 2020, there were 18 occurrences in which no ambulances were available to respond; in January 2022, there were 1,223 such occurrences (Bartko, 2022). AHS EMS managers stated the ongoing problem is caused chiefly by staff shortages; union leaders and front-line paramedics reported that the staffing shortage results from exhaustion and stress (Anderson, 2022; Ross, 2022). While some stressful aspects of a paramedic's job are unavoidable, such as caring for acutely ill and injured patients, others, like the call alert, can be mitigated. An important step to address the current crisis in AHS EMS is to search out and manage occupational stressors, so more paramedics are available to care for patients.

The present study assesses if adding prepulses to the existing call alert can make the call alert less aversive. The research begins with a scoping review of the literature related to the call alert and methods of measuring psychophysiological responses in paramedics using Athabasca University's library search engine, Google Scholar, exploring the citations in relevant research and consultation with subject matter experts. Barnard and Duncan (1975) conducted seminal research in the field.

Chapter 2. Literature Review

Research on the effect of the call alert on first responders is a relatively small field of study and is, therefore, replete with research opportunities. Motivated by a concern about the disproportionate rates of heart disease and sudden cardiac deaths in firefighters (Smith et al., 2013), early researchers primarily focused on the cardiac effects of the call alert (Barnard & Duncan, 1975). While they brought attention to the call alert as a source of occupational stress for first responders, only two practical solutions (reducing the number of call alerts and 'ramp-up' call alerts) have been proposed to date (Barnard & Duncan, 1975). The sole research paper that has tested these solutions found they had a small but significant effect (MacNeil et al., 2016). With one notable exception (Hall et al., 2016), the field of study remains primarily focused, even siloed, within a cardiology perspective. Other limitations in the existing research include difficulty isolating the effects of the call alert from those of mobilization, limited or absent descriptions of the call alert studied, a lack of statistical analysis of findings, and a lack of consilience (Wilson, 2014) with other fields of study.

This current investigation intends to address some of the shortcomings of previous research by applying additional measures to the study of the call alert and evaluating a novel mitigation strategy. First, the existing research on the call alert was reviewed along with its limitations. Second, the literature on the acoustic startle response and prepulse inhibition of startle (PPI) and perceived stimulus intensity (PPIPSI) was reviewed as a basis for an empirical investigation of a novel strategy for mitigating the adverse effects of call alerts, prepulse inhibition of dislike (PPID).

Discovery of the Call Alert

The impact of the call alert on first responders was initially discovered by chance in the early 1970s. Barnard et al. (1975) were investigating the curious finding that the most frequent reason for a Los Angeles firefighter to receive a disability pension was heart disease – at more than twice the rates of police officers. To understand why this was the case, the authors tested 90 firefighters. Each firefighter was medically assessed, and their heart rates and ECGs were measured during near-maximal treadmill testing. These measurements were compared to those of a group of insurance underwriters. Even though firefighters were in slightly better health and had lower risk factors for heart disease than the underwriters, the firefighters had higher rates of ischemic changes in their ECG, predictive of heart attacks. Other contemporary research (Barnard et al., 1973) found similar ECG patterns in participants when they quickly transition from inactivity to near-maximal physical response. Barnard et al. (1973) speculated that abrupt changes in physical activity that firefighters experience while responding to an emergency call might cause the higher rates of heart disease they found in firefighters.

Next, Barnard and Duncan (1975) tested the theory that sudden strenuous exercise caused ischemic ECG changes and increased heart rate by studying another group of Los Angeles firefighters. They monitored their ECGs during their 24-hour workday, expecting to find changes when the firefighters began physically demanding tasks. Instead, they discovered an increased heart rate and ECG changes immediately after the call alert, well before the firefighters began significant physical exertion. To isolate the cause of these changes, Barnard and Duncan assessed firefighters moving an equivalent distance and putting on jackets under laboratory conditions. The firefighters demonstrated less change in heart rate in the laboratory compared to call alerts in the fire hall. Barnard and Duncan attributed this unexplained difference to anxiety caused by the call alert. For the first time, the call alert had been linked to a psychophysiological effect on first responders.

Mitigation Strategies

Barnard and Duncan (1975) were the first to identify the call alert as a source of occupational stress for first responders and were the first to propose mitigation strategies. In the final sentences of their discussion, they acknowledge that the call alert is a source of anxiety for firefighters. They also expressed concern that many fire departments send call alerts to all stations, including those that do not need to respond, and recommended the discontinuation of this practice in order to avoid unnecessary stress on firefighters. They also questioned whether the characteristics of the call alert may differentially affect firefighters (Barnard & Duncan, 1975).

In the subsequent forty years, research on the call alert fell quiet. However, there was a growing awareness of the risk of heart disease and sudden cardiac death among firefighters (Fahy, 2005; Fahy et al., 2012; Smith et al., 2013). MacNeal et al. (2016) investigated the effect of Barnard and Duncan's (1975) suggestion to only send call alerts to stations required to respond (station-specific call alerting). MacNeal et al. also evaluated the effect of a call alert with a prolonged rise time (2 s). They then monitored the heart rate of firefighters throughout their shifts over three months. Predictably, they found that when station-specific call alerting was instituted, firefighters who did not receive a call alert experienced no increase in heart rate. Moreover, firefighters' heart rates increased by an average of 7 bpm in response to the standard call alert vs. 5 bpm in response to the ramp-up call alert; this difference was statistically significant (MacNeal et al.).

The qualitative data provided a more granular description of the participants' experience with ramp-up tones, e.g.:

> "Whatever you choose to do…please keep the ramp up. The jolt on the heart is what we are trying to avoid. The current tones are so much more easy on us no matter how many times we have to hear them. Thank you for caring!!" (p. 869)

This investigation by MacNeal et al. (2016) is the only available peer-reviewed study on the effects of modulating the characteristics of call alerting in humans. Interestingly, an investigation of the acoustic startle response in grey seals (Götz & Janik, 2011) reported that short-rise sounds caused an ASR, while long-rise sounds of the same volume did not. While the seals were not responding to emergencies, the findings from this study provide helpful insight. Götz and Janik concluded that "repeated long-term exposure of humans to short-rise pulsed noise may be problematic, and acoustic startle should be considered as a potential contributing factor in the context of posttraumatic stress disorder" (Conclusion, para. 1).

Limitations of The Existing Call Alert Research

Descriptions of the Call Alert

Descriptions of the call alert in the existing literature are limited, incomplete, or absent. Barnard and Duncan (1975) described the call alert only as “a tone system” (p. 248). Kuorinka and Korhonen (1981) described the call alert as a gong, announcement, and tone. The call alert Diel (2001) worked with was reported to have an intensity of 95 dB through the interior klaxon and 103 dB for an alarm on the exterior of the fire hall, but they provided no other characteristics. MacNeal et al. (2016) described the call alert as “startling” (p. 867) and reported a rise time as “near-instant” (p. 867) but do not report the volume. Patel and Clarke (2019) reported two volume measurements of the call alert used by AHS EMS as 103.8 and 107.7

dB(A). Despite the vagueness of many descriptions of the call alert by other studies, the available evidence suggests that call alerts tend to have a short rise time and high sound intensity.

Isolating the Effect of the Call Alert

Most studies of call alert effects on first responder heart do not differentiate between the two subcomponents of the call alert sound and the subsequent mobilization (Hall et al., 2016; Karlsson et al., 2011; MacNeal et al., 2016; Smith et al., 2013). Only a few studies have attempted to measure the effects of the call alert separately from the effects of mobilization (Barnard & Duncan, 1975; Kuorinka & Korhonen, 1981). Others, such as Karlsson et al. (2011), stated that they evaluate the call alert separately, but their data collection methodology (average heart rate over 15 s) and the operational necessity of immediate mobilization made complete isolation unlikely. As a result, it is unclear whether the observed increase in heart rate during the response to an emergency call was caused by the call alert sound, the physical effort of moving to the response vehicles, or a combination of these events.

Barnard and Duncan (1975) attempted to differentiate the effects on heart rate of the call alert versus mobilization (see Discovery of the Call Alert), but their findings were challenged. Kuorinka and Korhonen (1981) conducted a study similar to that of Barnard and Duncan (1975), but also included an assessment of firefighters in the station who heard the call alert but were not required to mobilize. While the heart rates of responding firefighters increased, the heart rates of non-responding firefighters did not change. Kuorinka and Korhonen (1981) concluded that the call alert alone did not directly affect firefighters' heart rates. It is possible that other factors, such as environmental cues or expectancy, could account for the differences detected by Barnard and

Duncan (1975) between firefighter heart rates during genuine responses versus mobilization under laboratory conditions.

Statistical Analysis

Studies investigating first responder heart rates often have not subjected their findings to statistical analysis (Barnard & Duncan, 1975; Kuorinka & Korhonen, 1981). Hall et al. (2016) criticized the study designs of Barnard and Duncan (1975) and Kuorinka and Korhonen (1981) because they did not assess the statistical significance of their findings. Karlsson and collaborators (2011) confirmed that the combined call alert and mobilization significantly ($p < .05$) increased paramedic heart rates. Additionally, they found that paramedics who received a call alert while returning to the station from a previous call had an increase in heart rate similar to that which they experienced as a result of the call alert in the station. As these paramedics were already seated in the ambulance and no physical effort was involved in responding, this observation suggested that the heart rate change was due only to the call alert. However, this observation was not subjected to statistical analysis.

A Lack of Theoretical Framework

While heart rate appears as the primary, and often only, physiological measure of the effect of the call alert on first responders in such research, the mechanism that links loud and startling sounds to heart rate is not described and, therefore, must be inferred. Building on existing work on attention and heart rate, Graham and Clifton (1966) first suggested that an initial acceleration in heart rate in response to loud and sudden sounds may be part of a startle reflex. In subsequent research, Hatton et al. (1970) found that when they exposed participants to 90 dB sound with a rise time of five microseconds [*sic*], the participants immediately experienced an increased heart rate that persisted for 5 s. In contrast, when they exposed the same participants to 90 dB sound with a rise time of 300 ms, the participants demonstrated a decrease in heart rate, confirming Graham and Clifton's findings that rise time is an important predictor of cardiac response. In 1979 Graham refined the definition of the cardiac startle response as an immediate increase in heart rate due to exposure to a high-intensity sound with a short rise time. Turpin et al. (1999) confirmed that loud sounds with fast rise times cause an increased heart rate 4 s after exposure. These findings provide a mechanism by which the call alert could cause an increase in heart rate in first responders.

However, subsequent findings about the cardiac response to loud and sudden sounds complicates the situation. Turpin (1986) found evidence of a second rise in heart rate 35 s after the onset of the startling sound that endured for 40 to 60 s. Vila and Fernandez (1989) identified decelerative components after each acceleration, which were confirmed by Ramirez et al. (2005). The existence of accelerative and decelerative components of heart rate response in close temporal proximity raises the possibly of the two effects nullify each other, resulting in no change in heart rate in an averaged heart rate. It is also possible to find an increase or a decrease in heart rate, depending what time window is assessed.

With the nuanced cardiac response to startling sounds in mind, the methodology of call alert studies can be evaluated. Barnard and Duncan (1975) measured participant heart rates using portable ECG machines. They reported that movement artifact complicated some measurements of the ECG, but they could identify R waves in each cardiac cycle. They determined participant heart rates by averaging the number of R waves in six-second intervals. They then reported their findings for 15 to 30 s after the call alert. While an overall trend can be inferred from their findings, the use of 6 s intervals may not provide optimal sensitivity to detect the early cardiac response. Kuorinka and Korhonen (1981) recorded participants' ECGs and measured their heart rates by calculating the time between beats but reported findings in 30 s averages. Hall et al. (2016) used a heart monitor that reported an average heart rate over 5 s, and MacNeal et al. (2016) used watches that recorded an average heart rate over 1 min.

It is therefore possible that the heart rate findings of researcher investigating the physiological effects of the call alert suffered from significant limitations. While a general correlation between the call alert (all be it conflated by the effects of mobilization) and an increased heart rate has been found (Barnard & Duncan, 1975; Hall et al., 2016; Kuorinka and Korhonen, 1981; MacNeal et al., 2016) these findings must be considered with caution. Likewise, Kuorinka and Korhonen's findings that the call alert in isolation from mobilization does not cause an increase in heart rate may be better understood as not necessarily contradicting the findings Barnard and Duncan.

The Acoustic Startle Response

Researchers have noted that the call alert is startling (MacNeal et al., 2016), sudden (Hall et al., 2016), and loud (Patel & Clarke, 2019). These characteristics suggest that the call alert is likely to cause an ASR in first responders. Because the ASR occurs in fractions of a second, it might be an ideal response to assess the physiological effects of the call alert separately from those of mobilization. However, an extensive search of the literature did not identify any studies in which the ASR was used to measure the effect of the call alert on first responders.

In 1929, Strauss (as cited by Hunt, 1936) reported that participants adopted a stereotyped posture and facial expression response to an abrupt, intense sound – in this case, a pistol shot. Hunt and Landis (1936) later confirmed Strauss's results and expanded on them. They described the response as "... shutting of the eyes, a characteristic distortion of the features, forward movement of the head, raising and drawing forward of the shoulders, abduction of the upper arms...” (p. 207, Hunt, 1936) and theorized that this response reduced an individual’s vulnerability to harm from attack. Landis and Hunt (1939) found this response pattern in varying degrees in almost all participants. In particular, in every trial, participants blinked at the sound of the pistol shot. They described this pattern of behaviour as “the startle pattern” (p. 4).

Further research (Berg, 1973; Blumenthal & Berg, 1986) had demonstrated that the startle pattern response, which came to be known as the ASR, can be elicited by a great diversity of sounds that are sudden and loud, such as the call alert. In humans, as with most mammals, the ASR is triggered by a sound with an intensity greater than 80-93 dB and with a rise time of less than 5 ms (Davis, 1984; Landis & Hunt, 1936; Götz & Janik, 2011; Ramirez-Moreno & Sejnowski, 2012). Additionally, the sound must be significantly more intense than any background noise so that the background noise does not mask the startle sound (Blumenthal, 1999; N. Swerdlow, personal communication, December 13, 2022). ASR magnitude increases as sound intensities increase (Blumenthal, 1988; Blumenthal & Berg, 1986). Loudness and suddenness are necessary to elicit an ASR, but neither is sufficient in isolation. For example, Davis (1984) found that even a 140 dB sound will not elect an ASR in rats if the rise time is greater than 12 ms. The likelihood of a sound causing an ASR is increased if the sound is broadband noise rather than a pure tone (Blumenthal et al., 2005) if it is louder (Blumenthal, 1996; Blumenthal & Berg, 1986), if the tone is longer (up to 50 ms; Berg, 1973), and when the rise time is shorter (Blumenthal & Berg, 1986; Blumenthal & Goode, 1991).

Measuring the ASR

Davis (1984) described the characteristics of acoustic startle that make it an informative measure for studying behaviour. Among these, startle is robust, reliable, easily quantified, can be studied across species to clarify mechanisms, is under tight stimulus control to enable parametric manipulations and displays several forms of plasticity. While the ASR causes an array of measurable physical responses in humans, eye blink is most-often measured, chiefly because it is the most consistent ASR component (Brown et al., 1991; Landis & Hunt, 1936). It is also preferred because it is the last component of the ASR to habituate (Brown et al., 1991), is relatively easy to measure, can be measured across the life span (Blumenthal et al., 2005), and is sensitive to small changes in stimuli (Blumenthal & Goode, 1991). Because the blink response is used most frequently, it is most easily compared across reports in the literature (Blumenthal et al., 2005; De Pascalis et al., 2013). For these reasons, the blink component of the startle response is an ideal candidate to determine if the call alert activates a physiological component of the startle response in first responders. However, this approach has yet to be explored in call alert research.

Despite, or perhaps because, the ASR is one of the most comprehensively studied mammalian reflexes, debate about its definition exists. Brown et al. (1991) and Carlsen et al. (2011) argued that because the eye blink persists when other measurable reactions (such as muscular contractions of the trapezius muscle) have habituated to the startle probe, the eye blink may constitute an independent reflex that utilizes different neural circuitry. Further, most studies of the ASR identify a significant number of individuals, termed ‘non-responders,’ who do not manifest a measurable ASR when presented with an appropriate startle probe (Blumenthal et al., 2005; Götz et al., 2011). For the present purposes, the eye blink will be used as a sensitive measure of human reactions to loud and sudden sounds, regardless of whether it represents a reflex that is somehow distinct from the ASR.

The startle reflex is most often measured using surface electromyography (EMG (Blumenthal, 2005; Brown et al., 1991). Two electrodes are placed below the eye, on the orbital portion of the orbicularis oculi muscle to measure its electrical activity (Blumenthal, 2005; Brown et al., 1991; Landis & Hunt, 1936). The blink electromyographic signal requires amplification to be appreciated (Blumenthal et al., 2005). The EMG data is then filtered to reduce the influence of extraneous sources of artifact, such as large muscle movement and electrical interference (Blumenthal, 2005).

Measuring the EMG signal is only one step in identifying if an ASR blink has occurred. Multiple approaches exist to identify the presence of an ASR blink within an EMG signal (Blumenthal, 2005). One method, signal averaging, involves comparing the average EMG signal within a response 'window' during which an ASR blink could have occurred, to a 'baseline' time period in which no startling sounds were presented (Blumenthal, 2005). Blinks caused by an ASR response in humans begin between 25-59 ms after the onset of a startling sound and last for 63.3 - 149.2 ms (Brown et al., 1991). Therefore, by evaluating the EMG in a response window of 21 to 150 ms after a potentially startling sound is presented, the electrical signal of a blink produced by the ASR can be captured. The baseline is established by assessing the EMG signal in a period when a startle blink should not occur, such as 0 to 50 ms before (Blumenthal et al., 2005) or 0 to 20 ms after (Graham, 1979) the startling sound is presented. If the sound causes a startle blink, the EMG signal will be elevated during the response window compared to baseline. The signal can also be applied sample groups by averaging the EMG signals for all participants under the same conditions (baseline and response window). The significance of differences in EMG signal (e.g., under different stimulus conditions, or across different cohorts) can be established by applying statistical tools to compare the participant responses (Blumenthal, 2005). This approach is particularly useful in situations when the ASR-generated blinks that are too low to be detected above the oscillations in the signal that can occur in typical recordings (Blumenthal, 2005)

Careful attention to the properties of the EMG signal can improve the fidelity of measurements of eye blink startle. For example, the blink reflex signal can be 'contaminated' by non-reflexive blinks, which might be either voluntary or spontaneous. Compared to involuntary blink reflexes, voluntary blinks have a much longer latency, averaging 225 ms (Thomas & Irwin, 2006); a response window of 150 ms will thus prevent contamination of startle measurements by voluntary blinks. Spontaneous blinks – e.g., those elicited in response to eye dryness or irritation – occur without relation to the startling sound and, therefore, are not found more frequently in either the baseline or the response window.

Prepulse Inhibition

Prepulse inhibition (PPI) is the reduction in the magnitude of a startle response that occurs when a weaker sound (prepulse), is presented shortly before the startling sound (pulse; De la Casa et al., 2016; Graham, 1975; Hoffman & Flesher, 1963; Hoffman & Searle, 1968; Peak, 1939). Depending on other stimulus conditions, PPI in humans typically occurs when the interval between prepulse onset and startle stimulus onset is 20-800 ms (Graham et al., 1975). Conceptually, while the brain processes the prepulse, the response to the startling stimulus is inhibited. While researchers often use PPI as a measurement of brain function, in the present study, it is being considered as an intervention to reduce the ASR in first responders. The efficacy of PPI is influenced, in part, by the prepulse-pulse interval, prepulse duration and prepulse intensity.

In their 1963 paper, Hoffman and Fleshler presented sound analogous to a gunshot (pulse) to rats under several conditions and measured the rats' startle reaction. When they repeated the experiment but over a background noise of that alternated 0.5 s of silence followed by 0.5 s of 85 dB noise, the rats exhibited almost no physiological response (Hoffman & Flesher, 1963). Subsequent investigations in humans found that the time interval between the prepulse and pulse modulates the magnitude of the resulting ASR. Intervals of 20-800 ms inhibit the ASR (Graham, 1975); however, when the prepulse-pulse interval is extended beyond 240 ms, the inhibitory effect starts to decay, eventually crossing over from ASR inhibition to ASR facilitation at approximately 800 ms prepulse-pulse interval (Bloch, 1972 as cited in Graham, 1975; De la Casa, 2016; Graham, 1975).

The duration of the prepulse also affects PPI. Historically, tones lasting 50 ms were used (Berg, 1973; Graham, 1975; Peak, 1939). Graham and Murray (1977) found that increasing the length of the prepulse beyond 20 ms did not increase the magnitude of PPI and many studies use 20 ms prepulses (Blumenthal & Goode, 1991; Braff, 1992). In 1995, Blumenthal established that under specific stimulus conditions, 50 ms and even 100 ms prepulses result in greater PPI than 20 ms prepulses, and for this reason, some studies use longer prepulse durations (Gómez-Nieto et al., 2020). In some studies, prepulses are used as continuous stimuli, such that there is no prepulse offset (return to baseline) prior to startle stimulus onset (Braff et al., 1978); other studies (Ludewig et al., 2003) use a discrete prepulse that resulted in a return to sound baseline prior to startle stimulus onset. Importantly, because PPI is under tight stimulus control, different stimulus configurations can be selected in order to study specific reflex phenomena.

PPI generally increases with increasing prepulse intensity. Some literature defines PPI as a phenomenon elicited by a non-startling prepulse (Duncan et al., 2003). However, Blumenthal and Goode (1991) reported that, under conditions of low background noise, prepulses of 50-70 dB intensity can elicit an ASR in some participants; louder prepulses generate more inhibition of the ASR (Franklin et al., 2007), though prepulses that independently elicit startle ultimately become less effective at inhibiting the response to the second startling noise (Swerdlow et al., 2007a, 2007b). Studies of prepulse effects on blink magnitude occur in laboratory settings that allow precise control of background and prepulse noise levels. By contrast, ambient noise levels at a time of a call alert can be highly variable; Patel and Clark (2019) found that typical ambient noise levels in a running ambulance were 68-72 dB(A). An effective prepulse must be more intense than the ambient noise level, but not so intense as to independently elicit a robust startle response.

ASR and PPI Sex Differences

PPI levels vary across a number of different physiological conditions, including subject age, sex and several different neurologic and psychiatric conditions. While a full description of these patterns is beyond the scope of this thesis, sex differences in PPI are relevant to the use of PPI to modify the effects of the call alert. Males generally exhibit more PPI of acoustic startle than do females (Swerdlow et al. 1993, 1999b, 2007a; Kumari et al., 2010). Sex differences are least pronounced during the follicular menstrual phase (Swerdlow et al., 1997; Jovanovic et al., 2004), though more PPI among males than females has been noted as early as eight years of age (Ornitz et al., 1991), predating cyclic hormonal changes. Researchers often control or account for this sex difference in their methodology or reporting. Ludewig et al. (2003) controlled for sex differences by assessing female participants early in their follicular phase and found no sex differences in startle magnitude or PPI. However, the magnitude of sex differences in PPI is often robust enough to produce identifiable group differences when not accounting for individual subject menstrual phase (Swerdlow et al. 1993, 2007a; Kumari et al., 2005).

Prepulse Inhibition of Perceived Stimulus Intensity

Prepulses inhibit not only the magnitude of the blink reflex response to the startling noise, but can also alter conscious perception of the sound such as intensity – a process described as prepulse inhibition of perceived stimulus intensity (PPIPSI; Peak, 1939; Swerdlow et al., 2005). Generally, PPIPSI is studied by asking participants to rate the loudness of a stimulus that either includes a startling pulse alone, or the same pulse preceded by a weak prepulse (Swerdlow et al., 2007a). Swerdlow et al. (2005, 2007a) established that maximal PPIPSI can be achieved using stimulus conditions similar to those that produce maximal PPI. The magnitude of startle reflex inhibition is typically much greater than perceptual inhibition, for example, under conditions that produce complete blink suppression, perceived stimulus intensity is reduced by only 20% (Swerdlow et al., 2005).

As a measure of the physiological impact of prepulses on sensory processing, the advantages of PPIPSI are that it is technologically simple, reliable, is not affected by differences in sex, menstrual phase, or personality characteristics, and is not complicated by subjects who are 'non-responders,' as is typically seen in measures of the startle reflex (Swerdlow et al., 2005, 2007a). It is also possible to simultaneously measure PPIPSI and startle reflex magnitude (Swerdlow et al., 2005, 2007a), and thereby assess prepulse effects on both motor and perceptual responses. There are challenges to the use of PPIPSI as an experimental measure, including the inherently subjective nature of the assessment which allows for response biases. PPIPSI also requires focused attention on the participants' part, which may not be feasible in certain study cohorts, and which may complicate comparisons with PPI studies that do not engage attentional resources (Braff et al., 2001). Blumenthal et al. (1996) also argued that PPIPSI results rely on participants understanding the instructions and consistently executing them. Martin et al. (2016)

reported that startling stimuli can impede decision-making for up to 30 s; therefore, the accuracy of participant judgements of loudness intensity may be compromised.

Finally, relatively little is known regarding prepulse effects on the affective experience of the startling stimulus. In other words, studies that assess prepulse effects on *perceived stimulus intensity* have not generally inquired about changes in the subjective experience of the *aversive or otherwise unpleasant qualities* of the intense startling noise. In one related line of inquiry (Blumenthal et al., 2001), weak cutaneous electrical prepulses reduced the amount of pain experienced in response to an intense electrical shock. Whether a prepulse can reduce the perceived aversiveness of an intense noise – like a call alert – has not yet been studied.

Literature Review Summary

The existing literature about the call alert suggests that the call alert signal triggers a cardiac response in first responders, involving increases in heart rate, but this research suffers from inconsistent methodologies and overreliance on a single measurement. The addition of the ASR paradigm to both the conceptualization and analysis of the call alert response could significantly strengthen the field of research. Measurements of both eyeblink EMG and of perceived stimulus intensity would allow for a more nuanced and deeper understanding of how the call alert impacts first responders, as well as potential approaches to mitigating this impact.

Chapter 3. Theoretical Framework

This study assesses two hypotheses: 1) The call alert used by AHS EMS is startling, and 2) The addition of a prepulse to the call alert reduces the magnitude of the startle response in paramedics. These hypotheses are based on theories developed in three separate but related research areas about the effect of sounds on humans. Studies of the call alert have demonstrated that the process of responding to an emergency call results in an increase in heart rate. Separate research into the effects of starling sounds has found an array of short-latency muscular responses (Blumenthal et al., 2005; Graham, 1979; Landis & Hunt, 1939) and an impact on higher-order perception (Peak, 1939; Swerdlow et al., 2007a). Because these fields have evolved, to greater and lesser degrees separately, there are differences in perspective and terminology. Therefore, the following section presents a unified theoretical framework and standardizes essential terms.

Effects of the Call Alert

Barnard and Duncan (1975) established a relationship between the call alert and an increased heart rate that has endured. Subsequent research viewed the call alert as an occupational stress and primarily measured the physiological effect on first responders by assessing increases in heart rate (Hall et al., 2016; Karlsson et al., 2011; Kuorinka & Korhonen, 1981; MacNeal et al., 2016; Smith et al., 2013). While the call alert is often not clearly defined, the descriptions and conclusions in the existing research suggested the call alert is likely to be startling because it is both sudden and loud (Barnard & Duncan, 1975; Hall et al., 2016; Karlsson et al., 2011; Kuorinka & Korhonen, 1981; MacNeal et al., 2016; Smith et al., 2013). How the call alert causes an increase in heart rate is often not reported but can be inferred from other research.

Several researchers have reported that high-intensity sounds with a short rise time cause an increase in heart rate within six seconds of presentation (Graham,1975, 1979; Turpin et al., 1999). A long latency (<30 s) heart rate increase (Graham, 1979, Turpin, 1986) and discrete decelerative components following each acceleration (Vila & Fernandez, 1989) have also been identified as part of the cardiac response to high intensity. Researchers (Graham, 1979; Turpin et al., 1999) have divided these responses into cardiac startle and cardiac defence responses. However, for the purposes of the current study, both the cardiac startle and cardiac defence responses demonstrate a measurable cardiac response of the participant to the call alert. Therefore, this study defines the *cardiac response* as an increased heart rate in the first six seconds due to exposure to a startling sound.

Sound Induced Short Latency Musculature Responses

Landis and Hunt (1939) carefully documented the array of short-latency muscular responses participants demonstrated in the aftermath of loud and sudden sounds (often a pistol shot) which came to be known as the ASR (Davis, 1984). Subsequent research indicated that the blink response accurately measures the startle response (Blumenthal, 2005; Graham, 1975, 1979). It was also discovered that the ASR could be influenced by several factors, such as the addition of prepulse, which can reduce the blink magnitude (Blumenthal et al., 2005; Graham, 1975; Hoffman & Searle, 1968).

Sound and Higher Order Cognition

In 1939, Peak found that the perception of the intensity of a loud, sudden sound could be reduced by adding prepulse. This modulation of judgement demonstrated that prepulses also affects participants' conscious experience. Subsequent confirmatory research established the principle that prepulses decreased the negative effect of startling sounds (Swerdlow et al., 1999a, 2007).

MacNeal et al. (2016) investigated the effect of increasing the rise time of the call alert. Participants expressed a preference for the call alert with a long rise time, and some commented that they found it less aversive (MacNeal et al.), thus demonstrating that perception of the call alert can be influenced by its characteristics. As this relationship has not been fully elucidated, broader emotional valance terms (such as dislike) are likely to be more sensitive measures than terms specific to particular emotions (such as anger or rage). General terms may also reduce the potential of priming bias in participant responses (Podsakoff et al., 2003).

Summary Application

From these theories and empirical results, both the current hypotheses and methods of testing were drawn. The first hypothesis, as shown in figure 1, is that the Tone Only call alert is startling because it is both intense and sudden. Therefore, it should induce an ASR blink and a cardiac response in participants.

The second hypothesis, as shown in figure 2, is that adding a prepulse to the Tone Only call alert to create the PP+Tone call alert will be less startling than the Tone Only call alert. The PP+Tone call alert should result in lower magnitude ASR blinks and less cardiac acceleration. Compared to the Tone Only call alert, participants should also judge the PP+Tone call alert as less intense and report lower scores of dislike.

Figure 1

Tone-Only Causes Startle Theoretical Framework

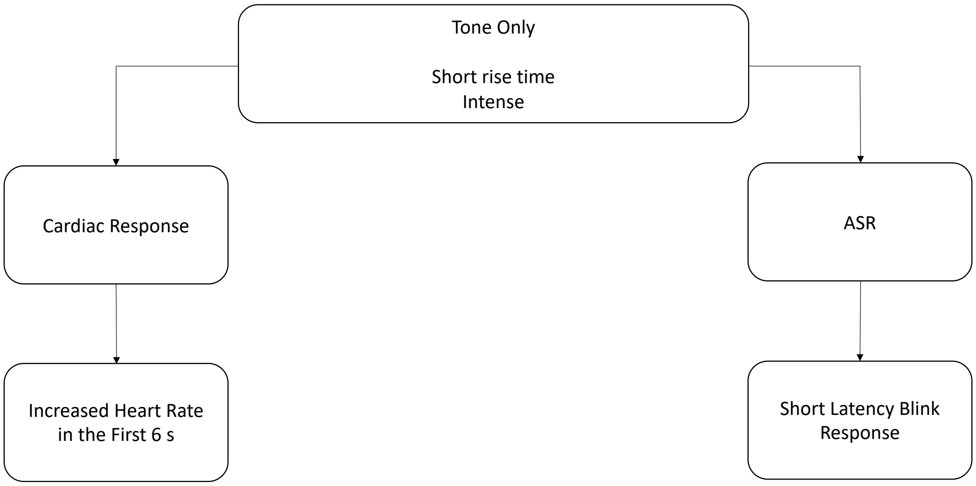
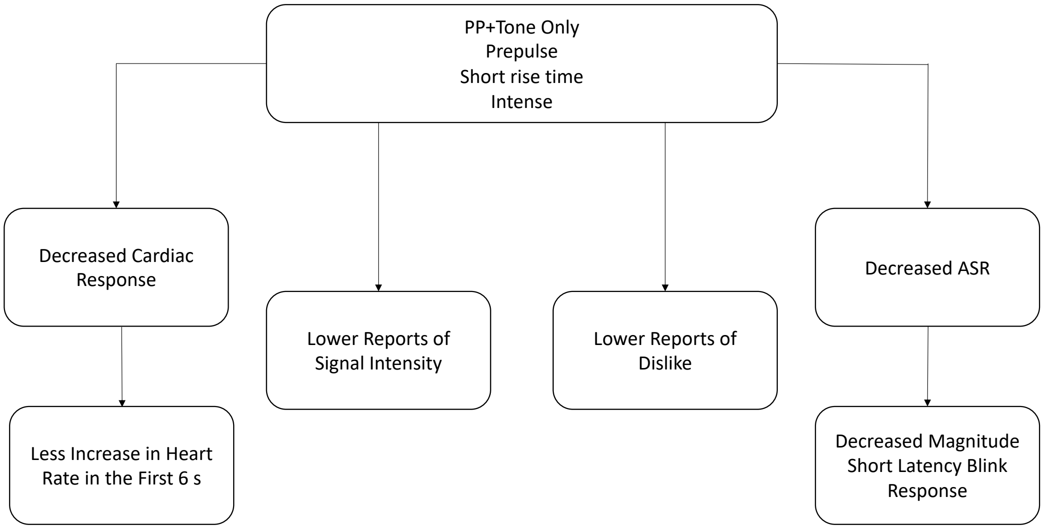


Figure 2

PP+Tone Reduces Responses Theoretical Framework



Note. Differences reported are relative to Tone Only call alert responses.

Chapter 4. Methodology

The intention of this study is to assess the effect of the call alert on paramedics in the EMS environment. Participant recruitment and selection have been designed to create a sample population reflective of front-line paramedics in AHS EMS. The stimuli and testing conditions are meant to be faithful to the work setting of paramedics. A rigorous data analysis procedure has been chosen because the results of this study may inform practices that affect the daily experience of paramedics.

Participants

Fifty paramedics (13 female, 34 male, and three who did not report their sex, participants' ages were not recorded) were recruited and participated in testing. Participants were only recruited if they met the inclusion criteria. Before testing began, each participant completed the consent documentation and provided informed consent for research compliance. The protocols were approved by the University of Alberta Health Research Ethics Board (Pro00117392).

Participant Recruitment and Selection

Participants were made aware of the study by an email and advertising postcards. AHS EMS sent paramedics an email informing them of the study. The email contained the purpose of the study, inclusion criteria, expected outcomes, a description of the testing protocol and the researcher's contact information. Postcard advertisements for the study were placed in communal areas of ambulance stations and the EMS areas of one hospital. Participants could enroll by email or on a walk-up basis during testing. AHS EMS allowed paramedics to participate in testing on duty or on their time off. No compensation was provided to participants.

Inclusion Criteria

Inclusion criteria were defined by occupation, experience, and employer. Because an individual's response to the call alert may be in part the result of conditioning, participants were required to be front line Advanced Care Paramedics, Primary Care Paramedics, or Emergency Medical Responders as defined by the Paramedics Profession Regulation (2016; collectively referred to as paramedics in this paper) who provide patient care. A minimum of one year of experience was also required to ensure all participants were accustomed to the call alert. To assess the effects of the call alert and prepulses on a representative sample of paramedics, no other exclusion criteria were employed.

Stimuli

Tone Only Call Alert

The call alert currently used by AHS EMS is the Tone Only call alert in the present study. The call alert was recorded using a first-generation iphone SE and downloaded into version 3.0.0 of Audacity recording and editing software (Audacity Team, 2021). The call alert consisted of three 50 ms, 1672 Hz sound bursts, separated by 50 ms of silence. The rise time of the sound bursts was 5 ms. The signal intensity was measured at 106 dB(A) using the Decibel X application (Thanh & Thang, 2020) on the same first-generation iphone SE. These findings were consistent with the results of Patel and Clarke (2019), who measured the call alert at 103.8 and 107.7 dB(A).

PP+Tone Call Alert

The PP+Tone call alert was created by adding a prepulse component to the existing Tone Only call alert. Using Audacity software (2021), one of the 50 ms, 1672 Hz sound bursts from the Tone Only call alert was copied and placed 120 ms before the onset of the Tone Only segment. The magnitude of the prepulse component was adjusted to 61% of the Tone Only component so that when the recording was played at a maximum intensity of 106 dB., the prepulse component was 65 dB. While the prepulse noise burst had a rise time of 5 ms before it was modified to 61%, no rise time could be identified after the reduction (i.e., it was < 5 ms).

Data Collection

Setting

Contextual factors such as ambient sound, situation, lighting, clothing (uniform) and expectancy can influence the magnitude of individuals' ASR and the efficacy of prepulses (Grillion et al., 1998). Therefore, participants were tested in a room adjacent to their usual work areas. Testing took place in meeting rooms in two ambulance stations and a classroom near the emergency department in one hospital. All participants were in uniform, and the majority were on duty at the time of testing. No attempt was made to mask the ambient background noise to maintain fidelity with normal working conditions in the ambulance station or hospital. The ambient sound was measured and found to be 58.30 dB(A) (*SD* = 2.59).

Research Design

The research study was designed to allow for the on-duty assessment of paramedics. Because AHS EMS is a busy ambulance service, operational approval was contingent on short trials so that the present study would not impact ambulance service. Therefore, trials were designed to be 10 minutes in duration.

Apparatus

Call alerts were produced with the Audacity software (2021) on a 2016 MacBook pro and amplified using a KLIQ Sonus electric guitar amplifier without distortion. The call alert intensity was calibrated before each testing session using a Smart Sensor ST9604 digital sound level meter placed 10 cm from the speaker, approximating the position of the participant’s left ear during testing. The amplifier's volume was adjusted to achieve a consistent intensity of 106 dB, +/- 2 dB.

Each trial was video and audio recorded using a password-protected I-phone SE second generation. The phone was mounted on a tripod approximately 5 m from the participant so that the participant's entire body and the researcher's procedure could be recorded. Adhesive tape with the number of each trial was placed on the amplifier visible in each recording. Participants' names were not used during the video and audio recordings. After each testing day, the recordings were transferred to an encrypted and password-protected external hard drive accessible only to the primary investigator. The recordings on the phone were erased.

Heart rate was recorded using a Physio Control Lifepak 15 using a 4-lead ECG. Modified limb lead placement was primarily used to reduce movement artifact, but classic limb lead positioning was used when requested by the participant. Participants' heart activity was recorded as individual files stored internally on the heart monitor and identified only by time and date. Batches of files were manually uploaded to AHS EMS's encrypted server and reviewed using Codestat software. PDFs of each file were stored on an encrypted and password-protected external hard drive accessible only to the primary investigator.

Participants' blink response was measured with a Biovision EMG. The EMG amplifier gain was adjusted to 1,000, and the sampling rate was of 1000 Hz. Two Biopac 4 mm Ag-AgCl reusable snap electrodes with electrode gel were placed immediately below the participant's lower left eyelid over the orbicularis oculi muscle, and a 3M Red Dot ground electrode was placed in the middle of the participant's forehead according to the process described by Blumenthal et al. (2005). The electrode were connected to the EMG with Biovision EMG amplifying electrodes. Signals were recorded with Windaq Data Acquisition software on Asus R541N Vivobook Max laptop PC. A custom-made powered microphone provided a precise time stamp of the call alert presentation time on the EMG record. Each trial was recorded as a separate file marked only with their participant number and stored on a password-protected external hard drive accessible only to the primary investigator.

Participants' ratings of perceived intensity and dislike of each call alert were recorded on a combined visual analog scale (VAS; see Appendix A.) The VAS was a letter-size sheet of paper containing a 100 mm horizontal lines on either side of the page. Participants reported their perception of the intensity of the call alert on the line on the left of the page and their dislike of the call alert on the line on the right of the page. In the center of the page was a 5 cm square photo of an ambulance. One VAS was used for each call alert and was marked only with the participant's study identification number. Completed VASs were stored in a locked filing cabinet accessible only to the primary investigator.

Procedure

At the onset of each session, the researcher verbally informed participants about the nature of the study, their right to withdraw, and the risks involved in participation. The audio and video recording were started as participants entered the testing room. Each participant was seated in a chair with the audio amplifier positioned 10 cm behind their head. They completed the consent form and were given a link to an online demographic survey if it had not already been completed.

Participants were then connected to the recording devices. 3M Red Dot electrodes were applied to participants to record 4-lead ECG activity during the trial. The participant's lower left eyelid was cleaned with an isopropyl alcohol swab and allowed to dry. Two microelectrodes were placed, one midline below the pupil and the second 1 cm lateral to the first. The ground electrode was connected to the middle of the forehead using a single-use disposable 3M Red Dot electrode. The leads were tucked over the participant's left ear to alleviate the weight of the cables. Micropore tape was used to stabilize the lead placement when needed.

Participants were directed to hold a clipboard holding four copies of the combined visual analog scale (see Appendix A.) They were instructed to look at the image of an ambulance in the center of the page while holding the clipboard comfortably to minimize movement artifact in the EMG and ECG. After each call alert, they were instructed to make a vertical pen mark across the horizontal axis of both the loudness and dislike scales. Marks towards the left of the axis indicated quiet and like, respectively, and marks towards the right meant loud and dislike. After each call alert, they were directed to drop the page to the floor and use the following page to record their assessment of the following call alert.

The researcher sat at a table immediately behind the participant, so that the participant could not discern when a call alert was about to be presented. Each trial was approximately seven minutes in duration. After an initial acclimatization period of 70 s, four call alerts, two of each type, were presented over the balance of the trial. The researcher monitored the EMG display and attempted to present the call alert approximately 2 s after a voluntary blink. The call alert was triggered by depressing the trackpad of a 2016 MacBook pro. Sound measurements at the participants' position found that pushing the trackpad resulted in no discernable sound reading above background noise. The call type was counterbalanced so that 25 participants were exposed to the Tone Only call alert first, and 25 were exposed to the PP+Tone call alert first. Call alerts were presented in an alternating pattern; presentations were separated by 70 s of silence. ECG and EMG signals continued to be recorded for at least 30 s after the last call alert. Participants were then disconnected from the instruments and excused.

Data Analysis

Blink Response

The raw EMG waveforms were amplified, filtered, and integrated, as described by Blumenthal et al. (2005). The EMG signals for each participant were imported into LabCharts data analysis software (ADInstruments, 2022), band pass filtered (40 – 400 Hz), notch filtered (60 Hz), and rectified. As the signal level was not centred on zero, the average unrectified signal amplitude during the baseline period was subtracted from each data point. Despite these treatments, many trials still included significant artifact that obscured some components of the blink response signal. Therefore, the signal-averaging approach described by Blumenthal et al. (2005) was used; the average signal in the 50 ms period before the call alert was statistically compared to the average signal of 21 to 150 ms after the call alert (see statistical analysis).

Assessment of Perceived Intensity and Dislike

The VASs were scored by measuring the distance from the left origin of the axis to the intersection of the pen mark made by the participant using ECG callipers. The calliper spread was then compared to a steel ruler. The findings were rounded down when the resulting measurement fell between mm gradients. Each VAS was scored blind to response conditions by the same investigator.

Heart Rate

Participants' heart rates were measured before and after the call alert. Discharge of the call alert was not electronically coordinated with the heart monitor, nor were the electronic clocks of the heart monitor and computer recording the ECG synchronized. Therefore, the video recording of each testing session was reviewed, and the LP15's power on chime was used to synchronize the EMG and ECG records. Participants' heart rates 30 s before and 6 s after the call alert were measured by counting the R waves within each epoch. A pre-call alert period of 30 s was used to identify a representative baseline heart rate. The 6 s post call alert epoch was used, consistent with published reports assessing heart rate increase associated with the cardiac startle and the short latency element of the cardiac defence responses (Graham, 1979). A longer post call alert period was not used because the normal decelerative component at 6 -30 s (Vila & Fernandez, 1989) might obscure the initial acceleration.

Statistical Analysis

Each measure provided a data array of approximately 200 measurements, 100 in response to the Tone Only call alert and 100 in response to the PP+Tone call alert. ANOVAs and *t*-tests were used to measure the statistical significance of findings and compare the group means. The data was assessed and redressed according to the requirements of the statistical test applied.

Outliers, Normalcy, and Homogeneity. The raw measurements were assessed for outliers, the data set's normalcy and variance homogeneity. Within each data set, a *z* score was produced for each data point, and those with *z* values +/-3.29 were defined as outliers. Each outlier (*n* = 12 of 774 data points) was verified and Winsorized to the maximal non-outlier value. Twenty-six data points were not collected for various technical reasons (e.g. participants forgot to complete the VAS, the EMG recording was started late). As a consequence, the number of data points was less than the 800 that would be predicted by the study design.

From the Winsorized data sets average response values to Tone Only and PP+Tone call alerts were created. These average response values and separate values for each call alert exposure were subjected to a Shapiro-Wilk's test to assess if the data was normally distributed, and Levene's test was used to evaluate the homogeneity of variances between groups. In each case the normality and homogeneity of the averaged scores and individual scores were in concordance and therefore they were managed in the same way (e.g., if the individual scores were treated with a logarithmic transformation, the averaged responses were also treated with a logarithmic transformation). In data sets to be assessed with an ANOVA, those with a non-normal distribution were addressed with transformations. When transformations successfully rectified abnormalities, the transformed values were used to calculate the statistical significance of the findings. When transformations did not correct abnormalities in distribution, the unmodified data was used. As there were two factors in each within-subject level of the three-way ANOVA, sphericity assumptions were irrelevant and were therefore not reported. Data sets assessed using a *t*-test containing non-normal or non-homogenous variances were managed with a bootstrapped *t*-test.

Assessments of Statistical Significance. Four statistical tests were used to assess the significance of the findings. A three-way repeated measures ANOVA was used to measure the significance of differences in the means of measures after each call alert exposure. The within-subject factors were the call alert type and the call alert number. The between-subject factor was the participants' sex. A two-way ANOVA was applied to the %PPI findings as the calculation of %PPI subsumes the call alert type variable. The call alert number and participants' sex remained as the within and between subject factors, respectively. A paired t-test was used to assess whether the participants' mean heart rates differed before and after the first call alert presentation, irrespective of call alert type. An independent t-test was used to compare the heart rate change between participants whose first exposure was to the Tone Only call alert or the PP+Tone call alert.

Comparison of Means. For clarity, the untransformed Winsorized data was used to calculate the group means and degree of inhibition. The degree of inhibition was calculated by dividing the difference between the Tone Only value and the PP+Tone value over Tone Only value. The quotient was then multiplied by 100 and expressed in percent. The same statistical test was used to assess the statistical significance to compare the means. In some cases, the lack of need for a transformation, or the inability of a transformation to correct normalcy or homogeneity, resulted in the same test being used for assessments of significance and comparison of the means.

Chapter 5. Results

The findings of this study are presented according to the established order of blink magnitude, PPIPSI, PPID, and then heart rate. The figures in this section reflect the untransformed mean responses under each condition. Only statistically significant findings have been reported.

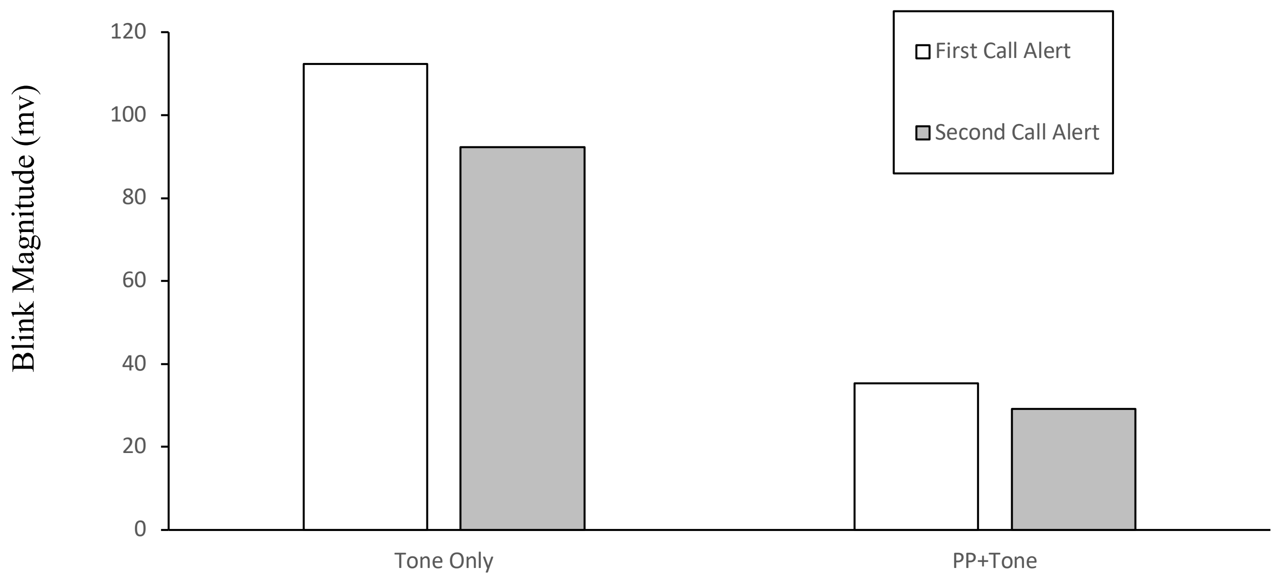
Blink Magnitude

Five outliers were identified in the raw data of participants' blink responses to the call alert. These outliers were Winsorized. Most participants had small magnitude blink responses, while a smaller number had much larger magnitude responses. As a result, there was a positive skew in responses (both individual and averaged) which was corrected with a logarithmic transformation. Participants' blink responses to each call type varied roughly equally around each mean, so the assumption of homogeneity of variances was met.

Statistically significant main effects of call alert type, $F(1,44) = 33.388$, $p < .001$, and call alert number, $F(1,44) = 6.795$, $p = .012$, were found and are illustrated in figure 3. There was a two-way interaction between call alert type and sex, $F(1,44) = 5.282$, $p = .026$. No other main or interaction effects reached statistical significance. Participants' average blink responses were greater to the tone-only call alert ($M = 100.705$ mV) than the PP+Tone call alert ($M = 38.103$ mV), partial eta square = .190. They demonstrated larger magnitude startle blinks to the first call alert of each type ($M = 76.112$ mV) than the second ($M = 62.696$ mV), partial eta square = .099 (Figure. 3). Females (71.503 mV) had greater magnitude blink response than males (67.304 mV) partial eta square = .001. ANOVA of PPI revealed a significant effect of sex (M>F; $F(1, 44) = 4.595$, $p = .038$). The overall %PPI was 44.556, male %PPI was 53.489, and female was 21.879, partial eta square = .121.

Figure 3

Startle Blink Magnitude



Note: The main effect of call alert type, *F*(1,44) = 33.388, *p* < .001.

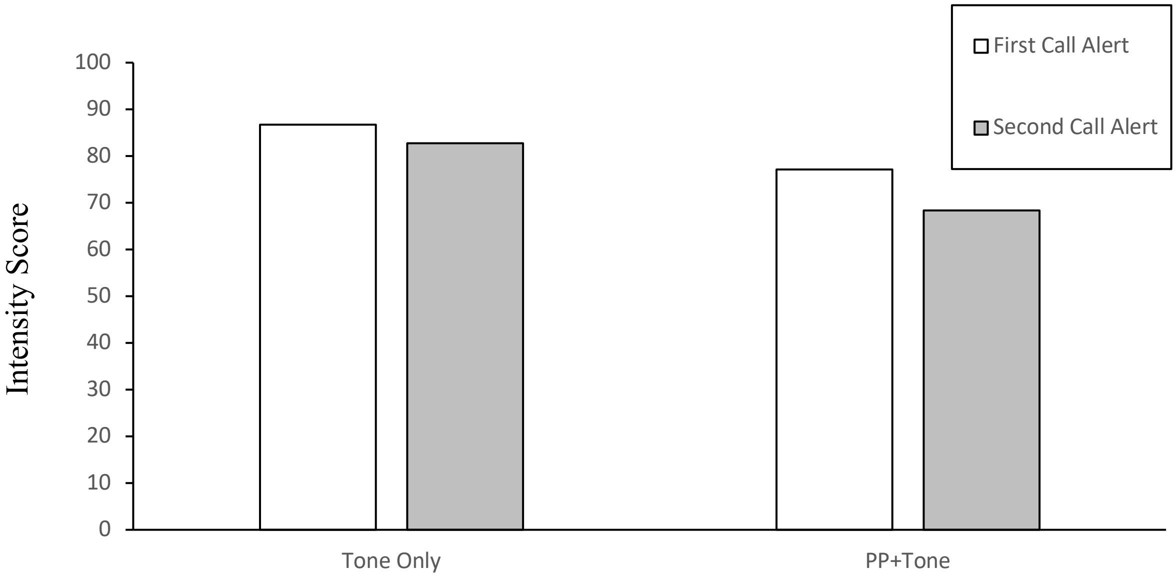
Perception of Stimulus Intensity

Stimulus intensity reports included three outliers which were Winsorized. In each trial, most participants found the call alerts intense, and therefore their responses were not normally distributed (Shapiro-Wilk test *p* < .05). A reflect square root transformation was applied, which resulted in a normal distribution of the data set, but for the first PP+Tone in male participants (*p* = .047). There was more diversity in scores of sound intensity of the PP+Tone call alert than the Tone Only call alert. Therefore, the assumption of homogeneity of variances was violated (Levene's test *p* > .05).

There was a statistically significant main effect of call alert type, *F*(1,44) = 15.879, *p* < .001, and call alert number, *F*(1,44) = 5.108, *p* = .029 and is illustrated in figure 4. No other statistically significant main or interaction effects were found. Participants perceived tone-only call alerts as louder (*M* = 82.557) than the PP+Tone call alert (*M* = 72.762), partial eta square = .220 (figure 4). Participants also rated the first call alert as louder (*M* = 81.221) than the second (*M* = 74.098), partial eta square = .137 (figure 4). An ANOVA of %PPIPSI revealed no significant effect of sex, *F*(1,44) = .142, *p* = 0.708). The overall %PPIPSI was 12.853% while male %PPIPSI was 16.844% and female %PPIPSI was 2.723%, partial eta square = .088.

Figure 4

Perception of Intensity



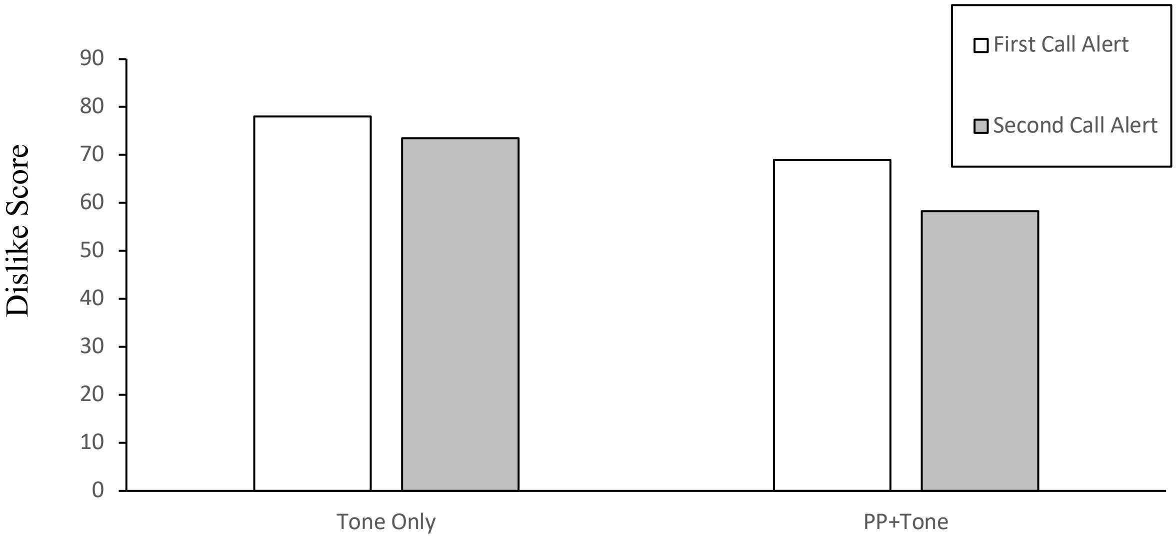
Perception of Dislike

There were no outliers in this data set. Participants' responses were not normally distributed because while most participants reported a significant amount of dislike for the call alert of either type, a number reported lower scores (Shapiro-Wilk test $p < .05$). A reflect and square root transformation was applied to the data, which normalized the distribution but for the response of male participants to the first PP+Tone call alert ($p = .047$). The variance was homogeneous (Levene's test $p > .05$).

A statistically significant main effect was found for call alert type, *F*(1,44) = 30.329, *p* < .001 and call alert number, *F*(1,44) = 5.289, *p* = .026. These findings are illustrated in figure 5. No other main or interaction effects reached significance. Participants disliked tone-only call alerts more (*M* = 72.297) than the PP+Tone call alert (*M* = 62.159), partial eta square = .289 (higher values represent greater dislike of the call alert). Participants also disliked the first call alert more (*M* = 70.995) than the second (*M* = 63.460), partial eta square = .087 (figure 5). ANOVA of %PPID did not demonstrate a significant effect of sex, *F*(1,44) = .815, p = 0.371). The overall %PPID was 14.753%, male %PPID was 16.314%, and female %PPID was 10.791%, partial eta square = .014.

Figure 5

Dislike



Note. Higher scores reflect greater dislike.

Heart Rate

Three statistical tests were performed to assess the change in participants' heart rates in response to the call alert. A three-way ANOVA was performed to evaluate the difference in participants' heart rates subsequent to each call alert exposure. An independent T-test was conducted to determine if the first call alert of the trial (of either type) caused a significant change in participants' heart rates, and a paired T-test was used to determine if there was a significant difference between the heart rate changes due to the type of call alert.

One outlier in the heart rate data was identified and Winsorized. A small but influential number of participants demonstrated marked decreases in heart rate to the second PP+Tone call alert which resulted in the assumption of normality being violated (Shapiro-Wilk test $p < .05$). Attempts were made to normalize the data using square root, logarithmic, and inverse transformations for the three-way ANOVA. While these transformations increased the p values slightly, none decreased the number of significant results ($p < .05$) or made a substantive difference in the results of the ANOVA. Therefore, results have been presented using the Winsorized data without transformations. Data for each response was approximately equally distributed around each mean; therefore, the assumption of homogeneity was met ($p > .05$).

The three-way ANOVA found no statistically significant main effects of call alert type, $F(1,42) = .973$, $p = .330$, call alert number, $F(1,42) = 0.228$, $p = .636$ or participants' sex, $F(1, 42) = .366$, $p = .548$. There was a significant interaction between call alert number and participants' sex, $F(1,42) = 6.773$, $p = .013$. No other main effects or interactions reached significance. Because no main effects were found, the means were not compared.

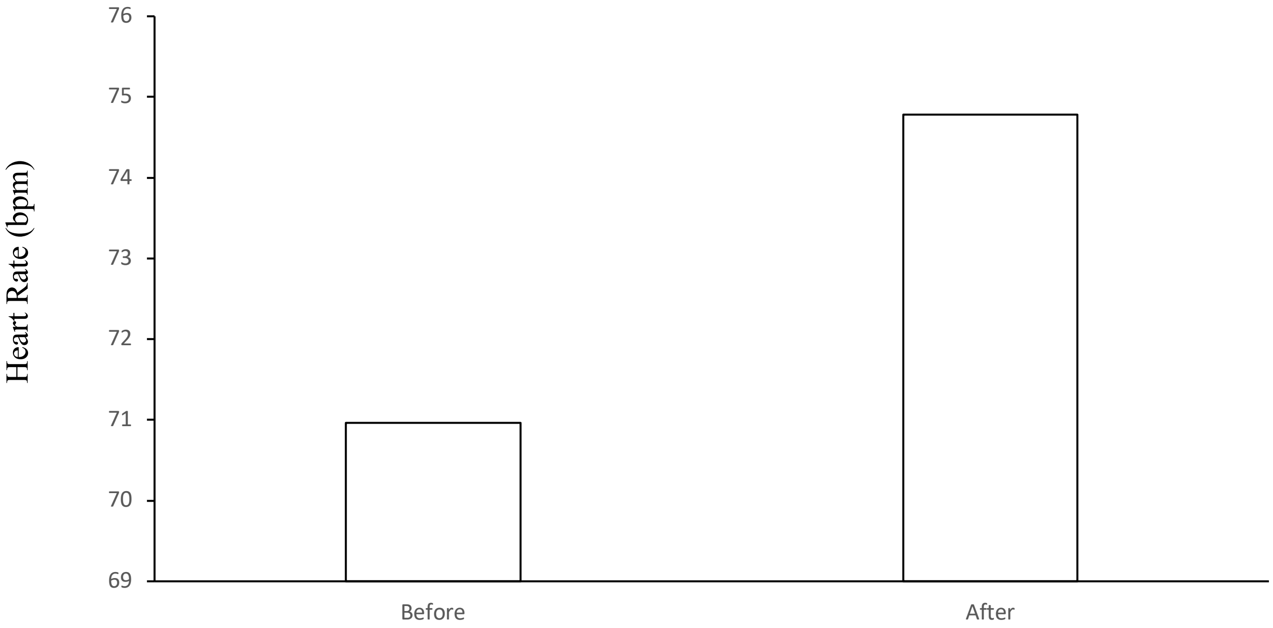
When considered in isolation, the assumption of normality was violated because a small number of participants demonstrated significant increases in heart rate (Shapiro-Wilk test $p < .44$). This was addressed using a bootstrapped statistical test. The variance in the sample was homogeneous ($p > .05$).

A paired T-test was used to assess the effect of the first call alert (without regard to type) on participants' heart rates. The paired sample T-test demonstrated that participants had higher heart rates after the call alert (*M* = 74.78 bpm, *SD* = 12.788) than before (*M* = 70.96 bpm, *SD* = 11.097) and is illustrated in figure 6. The call alert caused an average increase in heart rate of 3.826 bpm, 95% CI [2.610, 5.216], $t(45) = 5.646$, $p < .001$. The effect size was large ($d = .832$).

An independent T-test was used to determine if the call alert type differentially affected participants' heart rates on first exposure. No significant difference was found between the increases in response to each call alert type, $t(44) = 1.457$, $p = .152$. The %PPI of heart rate for call alert type was not calculated because no significant result was found.

Figure 6

Heart Rate Before and After the First Call Alert



Note. Heart rate was calculated 30 s before and 6 s after each call alert.

Chapter 6. Discussion

Summary of Findings

This study found that the call alert used by AHS EMS is startling to paramedics as evidenced by an ASR blink response to the call alert and a statistically significant increase in heart rate. The addition of a prepulse to the call alert was associated with three changes in the call alert response: a statistically significant reduction in startle magnitude, a significant reduction in the perceived intensity of the call alert signal, and a significant reduction in the degree to which paramedics disliked the call alert signal. Given the potential physiological and psychological benefits to paramedics of a blunted call alert response, these findings warrant careful consideration.

Interpretations

The Call Alert is Startling

As this study has found, the presence of an ASR blink and cardiac responses in the moments after the presentation of the call alert provides solid evidence that the call alert is startling. When presented with a call alert (of either type), participants responded with a short latency blink and increased heart rate. The blink (as identified by an increase in EMG signal magnitude compared to the baseline) occurred during the characteristic latency window of an ASR blink (21 – 150 ms). The blink was accompanied by a sudden increase in heart rate during the first six seconds after the call alert, indicative of a neuronally mediated cardiac startle and cardiac defence response (Graham, 1979; Turpin et al., 1999).

These present findings align with the findings of other studies on the effects of the call alert. Barnard and Duncan (1975) found that firefighters' heart rates increased eleven beats per minute more than could be explained by the physical response involved in moving to the fire truck and concluded that the difference was caused by the call alert. Karlsson et al. (2011) found that paramedics experienced an increase in heart rate in response to the call alert when seated in the ambulance, thereby removing the physical exertion of mobilization as a potential cause of this cardiac response. In contrast, Kuorinka and Korhonen (1981) found no increase in the heart rate of firefighters who heard the call alert but were not required to respond to the emergency. This negative finding may reflect the method used to measure heart rate, which was ill-suited to identify the rapid fluctuations between accelerative and decelerative components of the cardiac startle and cardiac defence responses (Graham, 1979; Turpin et al., 1999).

The present study's findings also are consistent with those of Blumenthal and Berg (1986), who measured the effect of a similar startle probe. They found that a 50 ms burst of 1000 Hz pure tone at an intensity of 102 dB with a rise time of 5 ms resulted in a very high (~95%) likelihood of measurable ASR blinks. Because broadband noises have been found to evoke an ASR more consistently than pure tones (Blumenthal, 2005), few studies using pure tones are available for comparison with this current research.

Prepulse Effects the Call Alert Response

The present study demonstrated that the addition of a prepulse to the call alert signal was associated with reductions in three aspects of the call alert response: the magnitude of ASR blinks; the perceived intensity of the call alert signal; and the amount to which paramedics disliked the call alert signal. As the most enduring element of the startle response, the ASR blink is a valid measure of startle (Blumenthal, 2005). Therefore, the marked reduction in blink magnitude to call alerts with prepulse in the present study suggests that this is an effective method of diminishing the motor reflex response to call alerts. The significant reduction in participants' reports of perceived call alert intensity on PP+Tone trials is consistent with previous reports (Peak, 1939; Swerdlow et al., 2005); that in addition to reducing the motoric response, prepulses blunt the perceptual impact of a startling noise. The present findings also suggest that prepulses can diminish the aversive quality of intense noises, detected here as a decrease in the degree of ‘dislike’ noted by participants on PP+Tone trials versus Tone-Only trials.

The effect of the prepulse on participant’s responses to the call alert aligns with more than 80 years of startle response research (cf., Peak, 1936, 1939; Graham, 1979; Blumenthal, 2005). Like the present study, Grillion et al. (1998) reported that prepulses consistently reduce the startle response in the presence of contextual cues and expectancy. However, the present study used pure tones whereas most other studies use broadband or white noise (Blumenthal et al., 2005); this was done to recreate the acoustic properties of the call alert signal. Nonetheless, the motor- and perceptual-inhibition detected with the present choice of stimuli is consistent with much of the published literature, suggesting that the observed effects generalize across these stimulus characteristics.

While much less frequently investigated, the present study's findings of prepulse effects on perceived stimulus intensity are generally consistent with previous reports. For example, Peak (1939) reported that – in addition to reduced blink magnitude - perceived stimulus ‘loudness’ was reduced by 25% using paired tone stimuli. Swerdlow et al. (2005) reported that prepulses that reduced startle magnitude by more than 80% reduced perceived loudness by roughly 20%. Therefore, the present research finding of 11.865% PPIPSI is modest; however, given the sensitivity of prepulse effects to subtle changes in stimulus parameters, it is likely that different magnitudes of PPIPSI across studies reflects differences in methodology, such as startle stimulus intensity and the difference in intensity between the prepulse and background noise. For example, Swerdlow et al. achieved their highest PPIPSI using a 118 dB noise burst and a prepulse of 16 dB over background noise. In contrast, this present study used a 105 dB pure tone with a prepulse of approximately 7 dB over background noise. The present finding that there was no significant difference in response between male and female participants is consistent with previous research (Swerdlow et al., 2005).

The present finding that prepulses reduce the degree to which participants ‘dislike’ the call alert signal is novel; a review was unable to identify clear examples of similar reports in the published literature. Grillion and Baas (2003) reported that a participant's affective state can influence the magnitude of the startle response, and other studies provide anecdotal reports from first responders that they dislike the call alert (Barnard & Duncan, 1975; Hall et al., 2016). Moreover, a small number of reports suggested that prepulses can diminish the pain associated with a noxious electrocutaneous shocks (Blumenthal et al. 2001). The present findings extend these observations by suggesting that prepulses can blunt the aversive experience associated with the call alert stimulus. To the degree that the aversive experience of the call alert is associated with adverse physiological or psychological consequences of call alert exposure, these new findings suggest the possibility that a modified call alert signal – via the addition of prepulses - might reduce the likelihood or intensity of such outcomes.

Implications

This study is a unique and practical application of prepulse inhibition to mitigate the adverse effects of the call alert for paramedics and other first responders. The findings herein confirm and extend the work of a substantial body of literature related to startle and its modification by lead stimuli. While the focus of this study is narrow by design, broader implications can be drawn. Clearly, the nature of the interface between a paramedic and their radio has a measurable effect and can be modified. Therefore, operational decisions, such as the nature of the call alert, might consider the use of a modified call alert signal to enhance well-being among paramedics. Certainly, any modification of the call alert signal must also consider the effectiveness of that stimulus in mobilizing a paramedic's response to an emergency call.

Limitations

While the present study provided statistically significant results using multiple indices, the findings should be considered along with their limitations. In conducting the present experiments, the operational requirements of an ambulance service were balanced with the benefit of in situ research. As a result, the study design involved brief assessment of participants and a limited number of call alert exposures. Because participants experienced only four call alerts (two of each type), the findings may be limited. However, in support of this design, the 'real-life' response in a paramedic is generated by a single call alert event; for this reason, traditional designs of startle studies, using dozens of trial presentations, may be less relevant to operational conditions experiences by paramedics. Other trial parameters in this study may not optimally capture the physiological responses to the call alert; for example, because the period between call alerts averaged 70 s, it is unknown whether participants returned to a baseline state after the first call alert, particularly with regards to cardiac influences.

The testing environment - rooms adjacent to typical work environments, rather than a separate laboratory facility – also represented a compromise. Using four measurements benefited the research but also caused practical limitations. Only simulated call alerts could be used; therefore, they were not the antecedent to potentially traumatic exposures. Participants thus may not have had the same psychological context – e.g., sense of expectancy - that they would in response to a genuine emergency call. The background noise in the testing environment was not representative of the variable background levels typical of the paramedic work environment. For example, the controlled environment of the testing rooms lacks many of the stimulus features experienced when paramedics get a call alert while in a moving ambulance.

A significant limitation in assessing the cardiac response to the call alert and prepulse was a lack of precise synchronization between the ECG and EMG records and the onset of the call alert. Given the short timeframes of the initial phases of the cardiac startle and cardiac defence responses, some accuracy was undoubtedly lost. Coordination of records to the millisecond level may have improved the precision of the findings.

Further Research

The present research is a starting point for many other avenues of inquiry. Parametric studies can be used to identify prepulse characteristics that maximally blunt call alert startle and its associated aversive properties. Modifications of the call alert tone might be used in concert with variations in prepulse characteristics, as a way to diminish undesirable properties of the call alert. Once stimulus parameters are optimized, it would be important to test their efficacy when applied to genuine emergency calls. Such research would likely require using fewer measurement methods and more compact and portable equipment. Previous research on the call alert has focused on heart rate data, and the literature would benefit from using more diverse operational measures of startle. For example, it might be possible to use wireless EMG of skeletal musculature to assess the ASR in paramedics in response to standard versus modified call alerts under real work conditions.

The effect of the call alert and the use of prepulses could be assessed beyond immediate responses. If a prepulse can reduce the magnitude of the startle response and the aversive experience associated with a call alert, perhaps this reduction can also have a more enduring effect. For example, the present research demonstrated that participants dislike the call alert. It is unknown how long that negative affective state persists and what impact it has on other tasks such as interpersonal interactions with patients and coworkers, emergency response driving, the care paramedics provide patients and ultimately the psychological well-being of the paramedic. It may well be that a non-startling call alert results in improved patient care and greater emotional resiliency to stress.

In the first study of the call alert, Barnard and Duncan (1975) proposed that the call alert was partially responsible for firefighters' disproportionately high rates of heart disease. Future research could investigate the link between the call alert and occupational stress diseases. Given the purported role of stress in reducing the operational readiness of AHS EMS, determining if there is a link between the call alert experience and paramedic mental health could be of vital importance to ambulances services and the populations they serve.

Chapter 7. Conclusion

This thesis began with the observation that occupational stress experienced by paramedics is a significant factor in the current acute shortage of paramedics (Ross, 2022). Previous research has demonstrated that the call alert is an important source of physiological and psychological risk for paramedics and other first responders (Kales et al., 2007; Karlsson et al., 2011). The call alert is associated with adverse effects in first responders, such as sudden increases in heart rate (Barnard & Duncan, 1975; Karlsson et al., 2011) and increased occurrences of sudden cardiac death (Smith et al., 2013); Patterson et al., 2016). Several researchers have hypothesized that the call alert's loud and sudden nature may explain its adverse effects (Barnard & Duncan, 1975; MacNeal et al., 2016).

Therefore, the current study sought to determine if the call alert currently used by AHS EMS causes a physiological startle response and if adding a prepulse to the call alert could moderate the startle in paramedics. The call alert was found to cause an increase in heart rate and an ASR blink response consistent with a startle response. Adding a prepulse to the call alert resulted in decreased magnitude of ASR blinks, reduced perceptions of sound intensity, and lower levels of dislike for the call alert. These findings confirm the hypotheses that the call alert is startling and that prepulse inhibition can moderate the startle response caused by the call alert.

This research's findings demonstrate that the call alert's characteristics determine how it affects paramedics. Therefore, ambulance service leaders should make informed decisions about call alerting. Leaders who want to reduce occupational stress and protect paramedics' mental and physical health should consider using a call alert that includes a prepulse.

References

ADInstruments. (2022). *LabCharts* (7.1). https://www.adinstruments.com/

Anderson, D. (2020, October 20). "It's destroying me as a person": Calgary paramedics say job is taking toll on mental health. *CBC News*. https://www.cbc.ca/news/canada/calgary/ems-mental-health-calgary-1.5768163

Audacity Team (2021). *Audacity: Free audio editor and recorder* (3.0.0). Muse Group. https://audacityteam.org/

Barnard, R., & Duncan, H. (1975). Heart rate and ECG responses of fire fighters. *Journal of Occupational Medicine, 17*(4), 247-250. https://journals.lww.com/joem/pages/default.aspx

Barnard, R. J., Gardner, G. W., Diaco, N. V., & Kattus, A. A. (1975). Near-maximal ECG stress testing and CHD risk factor analysis in Los Angeles City firemen. *Journal of Occupational Medicine*, *17*(11), 693-695.

Barnard, R. J., MacAlpin, R., Kattus, A. A., & Buckberg, G. D. (1973). Ischemic response to sudden strenuous exercise in healthy men. *Circulation*, *48*(5), 936–942. https://doi.org/10.1161/01.cir.48.5.936

Bartko, K. (2022, July 18). Frequent code reds, high levels of ambulance strain in Edmonton region: AHS data. *Global News*. https://globalnews.ca/news/8999767/alberta-health-services-ambulance-code-red-edmonton/

Berg, K. M. (1973). *Elicitation of acoustic startle in the human* [Unpublished doctoral dissertation] University of Wisconsin– Madison. *Dissertation Abstracts International, 34*, 5217B–5218B.

Blumenthal, T. D. (1988). The startle response to acoustic stimuli near startle threshold: Effects of stimulus rise and fall time, duration, and intensity. *Psychophysiology*, *25*(5), 607–611. https://doi.org/10.1111/j.1469-8986.1988.tb01897.x

Blumenthal, T. D. (1995). Prepulse inhibition of the startle eyeblink as an indicator of temporal summation. Perception and Psychophysics, 57(4), 487–494. https://doi.org/10.3758/bf03213074

Blumenthal, T. D. (1996). Inhibition of the human startle response is affected by both prepulse intensity and eliciting stimulus intensity. *Biological Psychology*, *44*(2), 85–104. https://doi.org/10.1016/0301-0511(96)05214-3

Blumenthal, T. D. (1999). Short lead interval startle modification. In M. E. Dawson, A. M. Schell, & A. H. Böhmelt (Eds.), *Startle modification: Implications for neuroscience, cognitive science, and clinical science* (pp. 51–71). Cambridge University Press. https://doi.org/10.1017/CBO9780511665523.005

Blumenthal, T. D., & Berg, W. K. (1986). The startle response as an indicator of temporal summation. *Perception and Psychophysics*, *40*(1), 62–68. https://doi.org/10.3758/bf03207595

Blumenthal, T. D., Burnett, T. T., & Swerdlow, C. D. (2001). Prepulses reduce the pain of cutaneous electrical shocks. *Psychosomatic Medicine*, *63*(2), 275–281. https://doi.org/10.1097/00006842-200103000-00012

Blumenthal, T. D., Cuthbert, B. N., Filion, D. L., Hackley, S., Lipp, O. V., & Van Boxtel, A. (2005). Committee report: Guidelines for human startle eyeblink electromyographic studies. *Psychophysiology*, *42*(1), 1–15. https://doi.org/10.1111/j.1469-8986.2005.00271.x

Blumenthal, T. D., & Goode, C. T. (1991). The startle eyeblink response to low intensity acoustic stimuli. *Psychophysiology*, *28*(3), 296–306. https://doi.org/10.1111/j.1469-8986.1991.tb02198.x

Blumenthal, T. D., Schicatano, E. J., Chapman, J. G., Norris, C. M., & Ergenzinger, E. R. (1996). Prepulse effects on magnitude estimation of startle-eliciting stimuli and startle responses. *Perception and Psychophysics*, *58*(1), 73–80. https://doi.org/10.3758/bf03205477

Braff, D. L., Geyer, M. A., & Swerdlow, N. R. (2001). Human studies of prepulse inhibition of startle: Normal subjects, patient groups, and pharmacological studies. *Psychopharmacology*, *156*(2–3), 234–258. https://doi.org/10.1007/s002130100810

Braff, D. L., Stone, C., Callaway, E., Geyer, M. A., Glick, I. D., & Bali, L. (1978). Prestimulus effects on human startle reflex in normals and schizophrenics. *Psychophysiology*, *15*(4), 339–343. https://doi.org/10.1111/j.1469-8986.1978.tb01390.x

Brown, P., Rothwell, J. C., Thompson, P. D., Britton, T. C., Day, B. L., & Marsden, C. D., (1991). New observations on the normal auditory startle reflex in man. *Brain*, *114*, 1891–1902. https://doi.org/10.1093/brain/114.4.1891

Carlsen, A. N., Maslovat, D., Lam, M. Y., Chua, R., & Franks, I. M. (2011). Considerations for the use of a startling acoustic stimulus in studies of motor preparation in humans. *Neuroscience & Biobehavioral Reviews, 35*(3), 366–376. https://doi.org/10.1016/j.neubiorev.2010.04.009

Davis, M. (1984). The mammalian startle response. In: Eaton, R.C. (ed.) *Neural mechanisms of startle behavior* (pp. 287–342). *Springer*, Boston, MA. https://doi.org/10.1007/978-1-4899-2286-1_10

De la Casa, L. G., Mena, A., & Ruiz-Salas, J. C. (2016). Effect of stress and attention on startle response and prepulse inhibition. *Psychology and Behaviour 165*, 179-186. http://dx.doi.org/10.1016/j.physbeh.2016.07.022

De Pascalis, V., Cozzuto, G., & Russo, E. (2013). Effects of personality traits emotionality on acoustic startle response and prepulse inhibition including N100 and P200 event related potential. *Clinical Neurophysiology, 124*(2), 292-305. http://dx.doi.org/10.1016/j.clinph.2012.07.018

Diel C. (2001). Noise exposure in the fire department. *Independent Studies and Capstones:* 2001. (pp. 1-25). Washington University School of Medicine https://core.ac.uk/download/pdf/70376613.pdf

Duncan, E., Szilágyi, S. M., Efferen, T. R., Schwartz, M. P., Parwani, A., Chakravorty, S., Madonick, S., Kunzova, A., Harmon, J. V., Angrist, B., Gonzenbach, S., & Rotrosen, J. (2003). Effect of treatment status on prepulse inhibition of acoustic startle in schizophrenia. *Psychopharmacology*. https://doi.org/10.1007/s00213-002-1372-z

Fahy, R. F. (2005). *US firefighter fatalities due to sudden cardiac death, 1995-2004* (pp. 1-9). Quincy, MA: National Fire Protection Association.

Fahy, R. F., LeBlanc, P. R., & Molis, J. L. (2012). *Firefighter fatalities in the United States-2011*. Emmitsburg, MD: NFPA.

Francis, G. (2022, March 23). ‘12 years of frustration’ Paramedics speak out about systemic ambulance issues. *The Toronto Star.* https://www.thestar.com/news/canada/2022/03/23/12-years-of-frustration-paramedics-speak-out-about-systemic-ambulance-issues.html

Franklin, J. C., Moretti, N. A., & Blumenthal, T. D. (2007). Impact of stimulus signal-to-noise ratio on prepulse inhibition of acoustic startle. *Psychophysiology*, *44*(2), 339–342. https://doi.org/10.1111/j.1469-8986.2007.00498.x

Gómez-Nieto, R., Hormigo, S., & López, D. E. (2020). Prepulse inhibition of the auditory Startle reflex assessment as a hallmark of brainstem sensorimotor gating mechanisms. *Brain Sciences*, *10*(9), 639. https://doi.org/10.3390/brainsci10090639

Götz, T., & Janik, V. M. (2011). Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. *BioMed Central Neuroscience, 12*(30). https://doi.org/10.1186/1471-2202-12-30

Graham, F. K. (1975). The more or less startling effects of weak prestimulation. *Psychophysiology*, *12*(3), 238–248. https://doi.org/10.1111/j.1469-8986.1975.tb01284.x

Graham, F. K. (1979). Distinguishing among orienting, defense, and startle reflexes. In H.D. Kimmel, E. H. van Olst & J.F. Orlebeke (Eds.), *The Orienting Reflex in Humans.* (pp. 137–167). Routledge.

Graham, F. K., & Clifton, R. K. (1966). Heart-rate change as a component of the orienting response. *Psychological Bulletin*, *65*(5), 305–320.https://doi.org/10.1037/h0023258

Graham, F. K., & Murray, G. M. (1977). Discordant effects of weak prestimulation on magnitude and latency of the reflex blink. *Physiological Psychology*, 5(1), 108–114. https://doi.org/10.3758/bf03335308

Graham, F. K., Putnam, L. E., & Leavitt, L. A. (1975). Lead-stimulation effects on human cardiac orienting and blink reflexes. *Journal of Experimental Psychology: Human Perception and Performance*, *1*(2), 161–169. https://doi.org/10.1037/0096-1523.1.2.161

Grillon, C., & Baas, J. (2003). A review of the modulation of the startle reflex by affective states and its application in psychiatry. *Clinical Neurophysiology*, *114*(9), 1557–1579. https://doi.org/10.1016/s1388-2457(03)00202-5

Grillon, C., Morgan, C. A., Davis, M., & Southwick, S. M. (1998). Effects of experimental context and explicit threat cues on acoustic startle in Vietnam veterans with posttraumatic stress disorder. *Biological Psychiatry*, *44*(10), 1027–1036. https://doi.org/10.1016/s0006-3223(98)00034-1

Hall, S. J., Aisbett, B., Tait, J. L., Turner, A. I., Ferguson, S. A., & Main, L. C. (2016). The acute physiological stress response to an emergency alarm and mobilization during the day and at night. *Noise & Health, 18*(82), 150-156. https://doi.org/10.4103/1463-1741.181998

Hatton, H. M., Berg, W. K., & Graham, F. K. (1970). Effects of acoustic rise time on heart rate response. *Psychonomic Science*, *19*(2), 101–103. https://doi.org/10.3758/bf03337442

Hoffman, H. S., & Fleshler, M. (1963). Startle reaction: Modification by background acoustic stimulation. *Science, 141*(3584). 928-930. https://doi.org/10.1126/science.141.3584.928

Hoffman, H. S., & Searle, J. L. (1968). Acoustic and temporal factors in the evocation of startle. *The Journal of the Acoustical Society of America*, *43*(2), 269–282. https://doi.org/10.1121/1.1910776

Hunt, W. A. (1936). Studies of the startle pattern: II. Bodily pattern. *The Journal of Psychology*, *2*(1), 207–213. https://doi.org/10.1080/00223980.1936.9917453

Jovanovic, T., Szilagyi, S., Chakravorty, S., Fiallos, A. M., Lewison, B. J., Parwani, A., Schwartz, M. P., Gonzenbach, S., Rotrosen, J. P., & Duncan, E. J. (2004). Menstrual cycle phase effects on prepulse inhibition of acoustic startle. *Psychophysiology*, *41*(3), 401–406. https://doi.org/10.1111/1469-8986.2004.00166.x

Kales, S. N., Soteriades, E. S., Christophi, C. A., & Christiani, D. C. (2007). Emergency duties and deaths from heart disease among firefighters in the United States. *New England Journal of Medicine*, *356*(12), 1207–1215. https://doi.org/10.1056/nejmoa060357

Karlsson, K., Niemela, P., & Jonsson, A. (2011). Heart rate as a marker of stress in ambulance personnel: A pilot study of the body's response to the ambulance alarm. *Prehospital and Disaster Medicine, 26*(1), 21-6. https://doi.org/10.1017/s1049023x10000129

Kumari, V., Antonova, E., Zachariah, E., Galea, A., Aasen, I., Ettinger, U., Mitterschiffthaler, M. T., & Sharma, T. (2005). Structural brain correlates of prepulse inhibition of the acoustic startle response in healthy humans. *NeuroImage*, *26*(4), 1052–1058. https://doi.org/10.1016/j.neuroimage.2005.03.002

Kumari, V., Konstantinou, J., Papadopoulos, A., Aasen, I., Poon, L., Halari, R., & Cleare, A. J. (2010). Evidence for a role of progesterone in menstrual cycle-related variability in prepulse inhibition in healthy young women. *Neuropsychopharmacology*, *35*(4), 929–937. https://doi.org/10.1038/npp.2009.195

Kuorinka, I., & Korhonen, O. (1981). Firefighters reaction to alarm, an ECG and heart rate study. *Journal of Occupational and Environmental Medicine, 23*(11), 762–766. https://doi.org/10.1097/00043764-198111000-00010

Landis, C., & Hunt, W. A. (1936). Studies of the startle pattern: III. Facial pattern. *The Journal of Psychology*, *2*(1), 215–219. https://doi.org/10.1080/00223980.1936.9917454

Landis, C. & Hunt, W. A. (1939). *The startle pattern*. Farrar & Rinehart, Incorporated.

Le, K. (2022, October 11). Part 1: Many stories of the system's failure. *CVT News*. https://calgary.ctvnews.ca/part-1-many-stories-of-the-system-s-failure-1.6099239

Ludewig, K., Ludewig, S., Seitz, A., Obrist, M., Geyer, M. A., & Vollenweider, F. X. (2003). The acoustic startle reflex and its modulation: effects of age and gender in humans. *Biological Psychology*, *63*(3), 311–323. https://doi.org/10.1016/s0301-0511(03)00074-7

MacNeal, J. J., Cone, D. C., & Wistrom, C. L. (2016). Effect of station-specific alerting and ramp-up tones on firefighters' alarm time heart rates. *Journal of Occupational & Environmental Hygiene, 13*(11), 866-870. https://doi.org/10.1080/15459624.2016.1183018

Martin, W. L., Murray, P. S., Bates, P. R., & Lee, P. S. (2016). A flight simulator study of the impairment effects of startle on pilots during unexpected critical events. *Aviation Psychology and Applied Human Factors*, *6*(1), 24–32. https://doi.org/10.1027/2192-0923/a000092

Ornitz, E. M., Guthrie, D., Sadeghpour, M., & Sugiyama, T. (1991). Maturation of prestimulation-induced startle modulation in girls. *Psychophysiology*, *28*(1), 11–20. https://doi.org/10.1111/j.1469-8986.1991.tb03381.x

Paramedics Profession Regulation. (2016). AB Reg 151/16. https://www.canlii.org/en/ab/laws/regu/alta-reg-151-2016/latest/alta-reg-151-2016.html

Patel, B., & Clarke, D. (2019). Occupational noise survey of Alberta Health Services EMS Calgary's paramedic rapid response units report. *EHS Training & Consulting Services*.

Paterson, J. L., Aisbett, B., & Ferguson, S. A. (2016). Sound the alarm: Health and safety risks associated with alarm response for salaried and retained metropolitan firefighters. *Safety Science, 82*, 174-181. https://doi.org/10.1016/j.ssci.2015.09.024

Peak, H. (1936). Inhibition as a function of stimulus intensity. *Psychological Monographs*, *47*(2), 135–147. https://doi.org/10.1037/h0093410

Peak, H. (1939). Time order error in successive judgments and in reflexes. I. Inhibition of the judgment and the reflex. *Journal of Experimental Psychology, 25*(6), 535–565. https://doi.org/10.1037/h0063056

Podsakoff, P. M., MacKenzie, S. B., Lee, J. M., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Quednow, B. B., Kühn, K. U., Beckmann, K., Westheide, J., Maier, W., & Wagner, M. (2006). Attenuation of the prepulse inhibition of the acoustic startle response within and between sessions. *Biological Psychology*, *71*(3), 256–263. https://doi.org/10.1016/j.biopsycho.2005.05.001

Ramirez, I., Sanchez, M. B., Fernandez, M. C., Lipp, O. V., & Vila, J. (2005). Differentiation between protective reflexes: Cardiac defense and startle. *Psychophysiology*, *42*(6), 732–739. https://doi.org/10.1111/j.1469-8986.2005.00362.x

Ramirez-Moreno, D. F., & Sejnowski, T. J. (2012). A computational model for the modulation of the prepulse inhibition of the acoustic startle reflex. *Biological Cybernetics 106*(3), 169-176. https://doi.org/10.1007/s00422-012-0485-7

Ross, T. (2022, July 6). New ambulances won't fix bigger problems, says paramedics' union. *CBC News*. https://www.cbc.ca/news/canada/calgary/alberta-paramedics-ambulance-1.6512414

Smith, D. L., Barr, A. B., & Kales, S. N. (2013). Extreme sacrifice: Sudden cardiac death in the US fire service. *Extreme Physiology & Medicine, 2*(6). https://doi.org/10.1186/2046-7648-2-6

Swerdlow, N. R., Auerbach, P., Monroe, S. M., Hartston, H., Geyer, M. A., & Braff, D. L. (1993). Men are more inhibited than women by weak prepulses. *Biological Psychiatry*, *34*(4), 253–260. https://doi.org/10.1016/0006-3223(93)90079-s

Swerdlow, N. R., Blumenthal, T. D., Sutherland, A. N., Weber, E., & Talledo, J. A. (2007a). Effects of prepulse intensity, duration, and bandwidth on perceived intensity of startling acoustic stimuli. *Biological Psychology*, *74*(3), 389–395. https://doi.org/10.1016/j.biopsycho.2006.10.001

Swerdlow, N. R., Geyer, M. A., Blumenthal, T. D., & Hartman, P. L. (1999a). Effects of discrete acoustic prestimuli on perceived intensity and behavioral responses to startling acoustic and tactile stimuli. *Psychobiology*, *27*(4), 547–556. https://doi.org/10.3758/bf03332152

Swerdlow, N. R., Geyer, M. A., Hartman, P. L., Sprock, J., Auerbach, P. P., Cadenhead, K., Perry, W., & Braff, D. L. (1999b). Sex differences in sensorimotor gating of the human startle reflex: All smoke? *Psychopharmacology*, *146*(2), 228–232. https://doi.org/10.1007/s002130051111

Swerdlow, N. R., Hartman, P. L., & Auerbach, P. P. (1997). Changes in sensorimotor inhibition across the menstrual cycle: Implications for neuropsychiatric disorders. *Biological Psychiatry*, *41*(4), 452–460. https://doi.org/10.1016/s0006-3223(96)00065-0

Swerdlow, N. R., Sprock, J., Light, G. A., Cadenhead, K., Calkins, M. E., Dobie, D. J., Freedman, R., Green, M. F., Greenwood, T. A., Gur, R. E., Mintz, J., Olincy, A., Nuechterlein, K. H., Radant, A. D., Schork, N. J., Seidman, L. J., Siever, L. J., Silverman, J. M., Stone, W. S., . . . Braff, D. L. (2007b). Multi-site studies of acoustic startle and prepulse inhibition in humans: Initial experience and methodological considerations based on studies by the Consortium on the Genetics of Schizophrenia. *Schizophrenia Research*, *92*(1–3), 237–251. https://doi.org/10.1016/j.schres.2007.01.012

Swerdlow, N. R., Talledo, J. A., & Braff, D. L. (2005). Startle modulation in Caucasian-Americans and Asian-Americans: A prelude to genetic/endophenotypic studies across the Pacific Rim. *Psychiatric Genetics*, *15*(1), 61–65. https://doi.org/10.1097/00041444-200503000-00010

Thanh, D., & Thang, L. (2020). Decible X [Software]. In *Mobile app* (9.2.0). SkyPaw. https://skypaw.com/

Thomas, L. E., & Irwin, D. E. (2006). Voluntary eyeblinks disrupt iconic memory. *Perception and Psychophysics*, *68*(3), 475–488. https://doi.org/10.3758/bf03193691

Turpin, G. (1986). Effects of stimulus intensity on autonomic responding: the problem of differentiating orienting and defense reflexes. *Psychophysiology*, *23*(1), 1–14. https://doi.org/10.1111/j.1469-8986.1986.tb00583.x

Turpin, G., Schaefer, F., & Boucsein, W. (1999). Effects of stimulus intensity, risetime, and duration on autonomic and behavioral responding: Implications for the differentiation of orienting, startle, and defense responses. *Psychophysiology*, *36*(4), 453–463. https://doi.org/10.1111/1469-8986.3640453

Vila, J., & Fernández, M. C. (1989). The cardiac defense response in humans: Effects of predictability and adaptation period. *Journal of Psychophysiology, 3*(3), 245–258.

Wilson, E. O. (2014). *Letters to a young scientist* (Reprint). Liveright.

Appendix A: Visual Analog Scale

Participant ID: Trial:

Quiet Loud Like Dislike

Version: June 16, 2022 Ethics ID: Pro000117392

Appendix B: Data Cleaning Log

Data Type	Participant	Remedy	Initial Value	Corrected value
Dislike Tone only 2 (1-100 score)	2	Winsorized	9	31
Dislike Tone only 2 (1-100 score)	37	Winsorized	13	32
Dislike (1-100 Score)	15	Winsorized	18	44
EMG PP+Tone 2 (mv)	2	Winsorized	149.64	128.67
EMG Tone Only 1 (mv)	8	Winsorized	702.90	599.51
EMG Tone Only 2 (mv)	8	Winsorized	719.70	555.54
EMG PP+Tone 1 (mv)	22	Removed	0.00	-
EMG PP+Tone 1 (mv)	41	Winsorized	255.52	187.62
EMG PP+Tone 2 (mv)	41	Winsorized	171.31	128.67
Perceived Intensity Tone Only 2 (1-100 Score)	2	Winsorized	9	33
Perceived Intensity PP+Tone 1 (1-100 Score)	15	Winsorized	18	43
Perceived Intensity PP+Tone 1 (1-100 Score)	37	Winsorized	13	33
Heart Rate PP+Tone 2	26	Winsorized	-10	-2

Appendix C: Certificate of Ethical Approval

Athabasca University
RESEARCH CENTRE

CERTIFICATION OF ETHICAL APPROVAL

The Athabasca University Research Ethics Board (REB) has reviewed and approved the research project noted below as approved by the University of Alberta Health Research Ethics Board – Health Panel through formal agreement between the institutions. The REB is constituted and operates in accordance with the current version of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2) and Athabasca University Policy and Procedures.

Ethics File No.: 24781

Principal Investigator:
Mr. Scott Heathcote, Graduate Student
Faculty of Health Disciplines\Master of Counselling

Supervisor:
Dr. Jeff Chang (Co-Supervisor)
Dr. Tammy O'Rourke (Co-Supervisor)

Project Title:
Prepulse Inhibition and Call Alerting in Emergency Medical Services

Effective Date: April 18, 2022 **Expiry Date**: April 17, 2023

Restrictions:

Any modification or amendment to the approved research must be submitted to the AUREB for approval.

Ethical approval is valid *for a period of one year*. An annual request for renewal must be submitted and approved by the above expiry date if a project is ongoing beyond one year.

A Project Completion (Final) Report must be submitted when the research is complete *(i.e. all participant contact and data collection is concluded, no follow-up with participants is anticipated and findings have been made available/provided to participants (if applicable))* or the research is terminated.

Approved by: **Date: April 21, 2022**

Carolyn Greene, Chair
Athabasca University Research Ethics Board

Athabasca University Research Ethics Board
University Research Services, Research Centre
1 University Drive, Athabasca AB Canada T9S 3A3
E-mail rebsec@athabascau.ca
Telephone: 780.213.2033