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The role of alarm signal duration as a cue for alarm validity

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Abstract

Researchers have isolated several variables that moderate the degrading effects of alarm mistrust on alarm reactions. We examined how alarm duration influences reactions to alarms of varying true alarm rates. In Experiment one, 45 psychology students performed a complex psychomotor task while reacting to an alarm system generating short- and long-duration signals. We predicted that participants would consider long-duration alarms more valid and would respond more to them despite the true alarm rate. Results supported both expectations. In addition to these findings, participants believed that true alarm rate influenced their response decisions more than duration even though true alarm rate did not affect actual response frequency. In Experiment two, 40 students reacted to short- and long-duration alarms originating from unique systems. Results showed some participants relied on duration, whereas others used true alarm rate, responded extremely, or combined strategies. Overall, results suggest signal duration is an important influence, but that increased task complexity may lead operators to adopt other reaction strategies.

Keywords: Alarm; Duration; Heuristic; False; Trust; Warning; Alert; Reaction

1. Experiment one introduction

Many modern alarm systems generate enough false alarms to cause a reduction in responding known as the cry-wolf effect (Bliss, 1993; Breznitz, 1984). Researchers have examined variables that may moderate the relationship between true alarm rate and performance. Such variables have included the urgency of the alarm (Bliss, 1993), the availability of hearsay information about true alarm rate (Bliss et al., 1995), and the modality of the alarm signal (Bliss and Kilpatrick, 2000). One common factor that may underlie these strategies is the match between alarm stimuli and operators' mental conceptualizations of a valid signal. Guillaume et al. (2003) suggested that mental representations of alarm signals stored in long-term memory might affect operators' perceptions of incoming stimuli.

The influence of mental representations of true and false signals is intuitively appealing. For example, many people have learned that automobile theft alarms are often false (Friedman et al., 2003). Therefore, when they hear one, they may disregard it because they have mentally conceptualized the automobile theft alarm stimulus as unreliable. The same might be said for building fire alarms or home burglar alarms.

Human reliance on mental representations when making alarm reaction decisions is demonstrated by strategies such as the representativeness heuristic (Kahneman and Tversky, 1973). According to this heuristic, people often diagnose an event based on the match between perceptual information from the event and their knowledge of similar events from the past (Wickens and Hollands, 2000). For example, people are likely to consider an alarm to be valid if their perception of the signal matches their mental representation of a true alarm constructed from past experiences. Research has shown that the representativeness heuristic is robust to many other variables that may affect decisions, including the overall probability of a dangerous event (Fischoff and Bar-Hillel, 1984).

There are many variables that may act as cues for representativeness. As suggested by Edworthy and Stanton (1995), auditory parameters may be manipulated to create compelling and meaningful signals that represent

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real-world events. One parameter that is a feature of all signals is duration, from stimulus onset to offset.

Signal duration varies in the real world for a variety of reasons. In some cases, signal duration is a natural by-product of the type of signal. For example, a verbal alarm may be lengthy because it requires time to annunciate its message. In other cases, the logic driving the signal may dictate its length. Many medical alarms sound continuously until they are silenced. A third reason for variation of signal duration involves interruption by other stimuli. Many residential smoke alarms will stop annunciating if the presence of smoke particles is interrupted.

Because human operators encounter signals of varying duration, within and across signaling systems, they may develop cognitive associative strategies to categorize them. In operational settings, alarms of short duration often turn out to be false. For example, Bliss (2003a), in a review of alarm-related activities in the US Army Safety Center database, found anecdotal examples where helicopter pilots had assumed that some alarms were false because they were shorter than expected. Because variations in signal duration are common, it is important to determine whether duration can moderate the relationship between alarm mistrust and reaction performance.

The current study was designed to examine the impact of alarm signal duration on responses to alarms of different true alarm rates. We wanted to examine how participants respond to alarm stimuli from systems with varying true alarm rates, when those stimuli varied in duration. Based on the strength of the representativeness heuristic (Fischoff and Bar-Hillel, 1984), we believed that participants would ignore true alarm rates and base their reactions solely on how well the stimuli matched their mental representation of a valid signal. We predicted that participants would use the representativeness heuristic to make their reactions, ignoring short-duration signals and responding to the long-duration alarm signals (Fischoff and Bar-Hillel, 1984; Guillaume et al., 2003).

2. Experiment one method

The first experiment was conducted using a $2 \times 3 \times 2$ mixed design. Alarm stimulus duration was a within-subjects variable with two levels, short (1 s duration) and long (4 s duration). A second independent variable, experimental session, was manipulated within groups; participants completed three experimental sessions. True alarm rate, manipulated between subjects, consisted of two levels: 60% and 80% true alarms. Participants in the 60% group were told that 60% of the alarms in each session would be true. Those in the 80% group were told that the system would generate true alarms 80% of the time. The dependent variables in this study were response frequency to the alarm system, reaction time in seconds from the start of each alarm, primary task tracking and gauge monitoring performances, and subjective perceptions of alarm signal validity.

2.1. Participants

A power analysis revealed that testing 40 participants would enable statistical power of 0.80 at $p = .05$. The researchers collected data from 45 Old Dominion University psychology students. Thirteen males and 32 females were randomly assigned to a high (80%) or low (60%) true alarm rate group. Twenty-one participants were in the low group (six males, 15 females) and 24 (seven males, 17 females) were in the high. Participants ranged from 18 to 38 years old, with an average age of approximately 21 years. No participants reported problems with hearing or vision.

2.2. Materials

Gauge monitoring and tracking sub-tasks from the Multi-Attribute Task (MAT) Battery program were used as the primary task, hosted on an IBM-compatible computer with a Pentium IV processor and a 17-in color monitor (Comstock and Arnegard, 1992). A Macintosh computer hosting a secondary alarm response program (SuperCard 2.5) displayed alarm signals on a 15-in color monitor to the right of the participant at a 90° angle to the primary task workstation. All tasks have been used in previous research (Bliss, 1993; Bliss and Kilpatrick, 2000). The signal was a Boeing 757 overspeed siren presented for 1 or 4 s at approximately 65 dB(A) (background noise was at 45 dB(A)). The alarm also included a visual component. When an alarm occurred the signal word "Warning" was presented on the alarm response computer screen for the entire duration of the auditory signal. Participants performed the primary tracking task with a standard mouse and responded to moving gauges by pressing buttons on a keyboard.

Participants also completed background and opinion questionnaires. The background questionnaire was designed to obtain background information such as participants' hearing and computer experience. The opinion questionnaire contained five-point Likert scale items designed to assess how alarm duration and true alarm rate affected each participant's perception of alarm signal validity. For example, participants rated how much the two independent variables (duration and true alarm rate) influenced their alarm reaction decisions. Participants also rated how much they believed short- and long-duration sounds matched their perception of a true alarm. Specifically, one question asked, "To what extent did the short duration signals match how you believe a true alarm 'should' sound?" The possible answers included "The short duration signals were a very good [or good, or fair, or poor, or did not] match." A similar question addressed long signals.

2.3. Procedure

Participants first received an informed consent form to read and sign. Next, they completed a background