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# What are close calls? A proposed taxonomy to inform risk communication research

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ABSTRACT

Technology designers and researchers view *close calls* as an actionable source of information that can be leveraged to increase safety. Organizational representatives responsible for safety examine close call trends to understand their impact on human cognition and to improve risk communication. The relatively few published theoretical investigations of close calls have lacked focus. Attempts to relate close calls to Signal Detection Theory have often neglected the human judgment of event feedback. Furthermore, close call effects can be considered from a variety of perspectives, illustrating the enormity of the problem space. An important first step is to develop a taxonomy and framework that reflects close call impacts, severity, and potential for risk communication. The current article distinguishes close calls from false alarms, specifies a proposed framework for their definition, and demonstrates differences in severity within task domains. The article concludes with a proposed research agenda.



## 1. Introduction

Due to a legal propensity to warn about unsafe conditions and proactive attitudes toward safety espoused by management, unsafe events in many applied task environments are relatively rare (Scerbo and Mouloua, 1999, p. 66). Unsafe events that *do* occur are often anticipated by fixed physical warnings or precipitated by transient alert or alarm signals. However, researchers have documented many ways in which the presence or absence of signals has led to inefficient, inaccurate, untimely, or inappropriate reactions (see Breznitz, 1984; Wogalter, 2006; Xiao and Seagull, 1999). Much of the existing research on signals targets conditions that fit neatly into the matrix depicted in Table 1, which characterizes the relationship between the existence of an environmental event (danger) and the presentation of a signal that indicates the danger (Green and Swets, 1966).

Signals should activate when real-world events (presence of a danger) appropriately trigger them (hit), but should not activate in their absence (correct rejection). Unfortunately, signals sometimes activate when no event exists (false alarm) or fail to activate when an event occurs (miss).

For many reasons, the four cells comprising Table 1 do not fully capture the complexity of emergency signaling situations. For example, sensors that detect airborne chemicals may be conservatively set to detect only the most dangerous concentrations, and as a result, lesser concentrations may go undetected. Therefore, what constitutes a "hit" may vary according to characteristics of the detector and the concentration criterion. To account for these factors, Parasuraman et al. (2000) combined elements of Fuzzy Set Theory with Signal Detection Theory to characterize situations in which a stimulus may be interpreted as present or absent, depending upon the criteria that are used to make the determination. Subsequently, many researchers have used Fuzzy Signal Detection Theory to quantify or describe stimulus detection performance when the stimulus domain itself, or the criteria used for qualification of a stimulus as present or absent, is open to interpretation (Masalonis and Parasuraman, 2003; Wallace and Horswill, 2007).

When a signal is generated by an automated system, human operators must judge whether the signal truly indicates danger or not. The performance of automated or human detection and response systems can be characterized by comparing the rate of hits to the rate of false alarms, and plotting that relationship as a Receiver Operating Characteristic curve. Fuzzy and Crisp Signal Detection Theory models are well accepted, intuitive, and sensitive to many signaling situations. Because of their popularity, some researchers have attempted to associate close call events with terms common to Crisp (or Fuzzy) Signal Detection Theory (see Rhatigan et al., 2003). However, the application of such terms to close calls is misleading. By definition, any variant of Signal Detection Theory is sensitive only to predicted or actual response behavior. In contrast, characterizing an event as a "close call" necessarily

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requires knowledge of the future consequences of response behavior. Therefore, any determination of close call existence, frequency or severity must be made retrospectively. This is why Saveland (2005, p. 11) discussed Signal Detection Theory as a "portal into expanded and deeper causal models in investigations."

Consequences must be allowed to play out before one can characterize a situation as a "close call." In similar fashion, investigating close calls for the goal of predicting them is a fruitless endeavor because events subsequent to an operator's response decision are often variable. A better approach is to study the occurrence of close calls by combining traditional Signal Detection Theory with elements of Bayesian estimation, so they can be explained more comprehensively and so that training and design decisions can be made to improve safety. A possible approach to accomplish this is suggested by Birnbaum (1983), who analyzed the classic "cab problem" using a combination of Signal Detection Theory to investigate signal detection behavior and Bayesian estimation to account for the effects of human judgment colored by consequences or feedback.

Many industries have recognized the potential benefits of studying close calls. As noted previously, researchers have successfully used Bayesian analysis to investigate the human judgment and decision-making process in relation to close call events. Dillon and Tinsley (2008), for example, investigated how decision makers use close call data. In their analysis, they noted that human decision makers often treat close calls as "successes," which serves to lower the perceived risk associated with similar events. Importantly, perceived risk is not equivalent to statistical risk. As a result, decision makers often miss opportunities to learn from close call events.

Dillon and Tinsley (2008) and others have aptly noted that studying close calls is challenging. There are a wide variety of situations that might be considered "close calls," rendering the problem space enormous. Furthermore, there are limited theoretical structures and tools to guide interpretation of close call data. An important first step is to define the term and bound the problem space. In the next section, we distinguish among situations that could be considered close calls. Following that, we focus on one subset of close calls: those that are preceded by signals to the operator. We then discuss a number of research questions that call for attention by safety researchers.

## 2. Definition of "Close Call" or "Near Miss"

A close call, sometimes referred to as a near miss, is defined differently by the applied and research communities, depending upon the task domain of interest and geographic location. In 2010, the State of Nevada's Near Miss Study Group evaluated definitions adopted by different states and medical agencies (Near Miss Study Group, 2010). They reported, for example, that the Agency for Health Care Research and Quality (AHRQ) defines near misses as "patient safety events that did not reach the patient." In contrast, The World Health Organization (WHO) defines a near miss as a "serious error or mishap that has the potential to cause an adverse event, but fails to do so by chance or because it was intercepted" (World Health Organization, 2005, p. 9).

From these examples, it is clear that a close call event may actually represent one of many possible scenarios. For that reason, and because of the possibility of variability in human behavior resulting from close calls, we believe it is important to distinguish among types of close call situations. An important premise we adopt is that close calls are not necessarily the same as "false alarms," though some researchers have historically presented the terms as equivalent or closely related (c.f., Rhatigan et al., 2003). The rationale for this distinction is simple: False alarms, as defined within Signal Detection Theory, occur when a dangerous environmental event is not present, but a signal is presented. However, close calls often occur when the environmental event *is possible*, but ultimately poses little to no danger to the task operator.

An important aspect of close calls is that they can happen regardless of whether an emergency signal has been presented, detected, and acknowledged. To account for such possibilities, we propose the following taxonomy of close call terms.

### 2.1. Signaled Close Calls (SCCs)

SCCs are close call events that occur because of the specific properties of an emergency signal. For example, researchers (e.g., Wickens et al., 2009) have noted that close calls may happen when a signal indicates imminent danger. However, if the sensor that controls the activation of the signal is set liberally, the signal may occur but the danger does not ultimately materialize. Such SCCs may occur, for example, in the context of aviation when traffic collision avoidance system signals activate. Because there is some tolerance in the sensor activation threshold, certain signaled events do not materialize.

### 2.2. Un-signaled Close Calls (UCCs)

In some cases, no signal is detected prior to a close call event, so there is no way for operators to anticipate the dangerous event. UCC's may occur because no signal was presented prior to the event (for example, if the sensor was set too conservatively) or because the signal that was presented was not detected by the operator. Perhaps the signal was not salient enough, the operator was overloaded, or the operator did not recognize the signal. Because the operator did not detect a signal, the utility or training benefit of UCC's may not be obvious. However, it is possible that UCC's in many situations could indicate a lack of Level 3 situation awareness, defined by Endsley (1995) as enhanced appreciation of how stimuli may change in the future.

### 2.3. Event-Driven Close Calls (ECCs)

Regardless of whether a signal was presented and detected, some close call situations may unfold due to a complex progression of event consequences. In such cases, a potential dangerous event does not occur because the event unfolds in a manner that was not anticipated. For example, the presence and trajectory of a hurricane may trigger an alert by a weather forecasting service. However, the hurricane may ultimately cease to be a threat because the subsequent path of the hurricane leads away from populated areas (Janis, 1962).

### 2.4. Vicarious Close Calls (VCCs)

VCCs occur when a task operator witnesses someone else suffering negative consequences. Such situations occur frequently. For example, news reports often depict crimes or accidents that happen to friends or neighbors. A common reaction by listeners is to become more vigilant or careful so that similar events do not affect them. VCC situations have unfolded in the domains of aviation, air traffic control, medicine, and other high-consequence task environments. VCCs occur in a wide variety of situations, because people learn vicariously from many sources such as firsthand observation, cognitive visualization, simulation, or anecdotal reporting (Dekker and Laursen, 2007).

The preceding four categories of close calls share a common feature: all involve situations in which any emergency signal could retrospectively be considered "false" because the receiver did not suffer negative consequences. By contrast, the following two