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Signal Words and Signal Icons in Application Control and Information Technology Exception Messages – Hazard Matching and Habituation Effects

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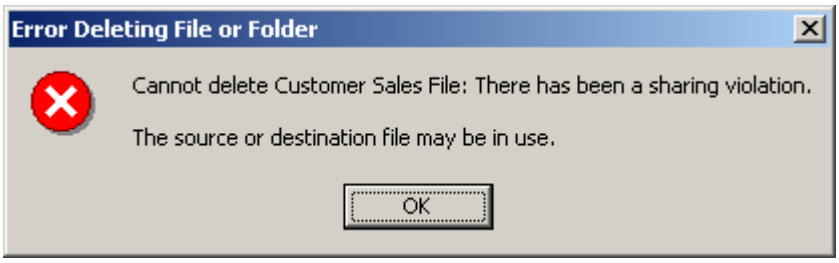
T.S. Amer and J.B. Maris

I. Introduction

People often encounter warnings in various life situations. For example, warnings may be posted or displayed to those handling potentially harmful chemicals, entering potentially hazardous environments, or using various pieces of equipment. These warnings take various forms but typically include a variety and combination of phrases (e.g., "warning," "caution," and "danger") and icons (e.g., a stop sign). For example, potentially dangerous chemicals may be labeled with the phrase "Deadly" and the skull and cross-bones icon. These phrases and icons are often referred to as "signal words" and "signal icons" because they are used to signal a possible hazard to a person encountering a potentially harmful situation or making a decision with potentially negative consequences.

Users of information technology (IT) frequently encounter such signal words and icons in so-called "exception messages" (a.k.a. "error messages"). Exception messages appear on computer screens, typically in a secondary window (Windows XP Design Team 2001), when the user performs an unexpected action or if a condition could arise that may result in a negative occurrence. For example, a computer user may encounter the following exception message if they are about to erase important data:



Note the use of the signal word "Error" in combination with a signal icon in the form of a red circle containing an "X." As with other life situations, the signal words and icons in exception messages are used to catch the attention of the user in a manner to warn of potential hazard if certain actions are taken or conditions occur.

Application Controls

An important function of signal words and signal icons within exception messages is in the context of accounting application controls. Accounting application controls deal with exposures within specific computer application programs such as payroll, sales processing, and cash disbursements (Hall 2006; Weber 1999). Application controls can be programmed in to the computerized application program itself. For instance, validation input controls are intended to detect errors in transaction data before the data is processed by the system. An example of this type of control would be a missing data check whereby the computer application would examine the contents of data input for blank spaces or empty fields. When the program detects a blank during data entry where it expects data, an exception message would be displayed with a signal word and signal icon warning the data input clerk that data is missing. Program execution is also halted until the user corrects the error.

Hazard Matching

There are different levels of "hazardous" outcomes associated with different actions that may be taken by a user when interacting with computerized applications. For example, attempting to enter an incorrect field during data input is arguably a less hazardous occurrence than accidentally erasing an entire file containing customer credit sales data. Accordingly, exception messages within application controls should communicate different levels of hazard in order to achieve so called "hazard matching." Hazard matching occurs when the severity of the hazard that is implied by the signal word and icon within the application control exception message matches the level of hazard faced by the user (Hellier et al. 2000). In this way, highly hazardous situations can be indicated by signal words and icons that are perceived by users as indicating high levels of hazard and vice-versa. Hazard matching is widely recommended as a desirable result in that it improves the informativeness of warnings (Edworthy and Adams

1996; Edworthy 1998; Hellier et al. 2000; Hellier and Edworthy 2006; Momtahan and Tansley 1989; Wogalter and Silver 1990).

In order to carry out hazard matching systems designers must understand how the users of a system perceive the severity of hazard communicated by the various parameters (e.g., signal words used, signal icons used, color, size, etc.) of application control and IT exception messages. The severity of hazard communicated by a warning is referred to as the "arousal strength" of the warning. Once the arousal strength of various parameters is determined, these parameters can be manipulated to effect variations in the perceived hazard of the application control exception message. This allows the exception message to be matched to the appropriate hazardous situation or condition (Hellier et al. 2000). Among these parameters is, of course, the arousal strength of the signal words and icons contained in the exception message.

A very limited set of prescriptions and standards exists in both the academic IT literature and professional IT literature related to the parameters that should be included in exception messages. While studies have been conducted in psychology to examine the arousal strength of various signal words and signal icons in relation to consumer products and equipment (e.g., chemicals, cigarettes, tools, etc.), there is virtually no empirical data available upon which to establish recommendations for systems developers as to the form and content of application control and IT exception messages.

To address this void, the first experiment reported in this paper collected data from 316 participants who viewed exception messages containing combinations of signal words and signal icons. They provided their perception on a 10-point Likert-type scale of the severity of hazard associated with each exception message. The signal words and signal icons examined were those commonly used in Microsoft products. The results indicate that the different combinations of signal words and icons possess different levels of arousal strength and that signal words in combination with signal icons increases the arousal strength of an exception message. This data will allow systems designers to accomplish hazard matching by aligning an exception message containing the appropriate signal word and icon with a computing or application control or IT related hazard. In addition, systems designers can select an appropriate signal word and icon to design an exception message to address potential problems that occur as a result of contextual factors or situations. One important contextual factor that has received relatively little research consideration is that of "habituation" (Thorley; Hellier, and Edworthy 2001, Wogalter et al. 2002, Wogalter and Mayhorn 2006).

Habituation

People may be less likely to attend to the information contained in the warning after repeated exposure. The desensitizing result of habituation can lead to problems whereby compliance with the warning may decrease. In addition, if warnings look or sound about the same then they may not be attended to at the same level over time (Wogalter and Vigilante 2006). For example, if IT exception messages look the same across two different hazardous situations, the desensitizing effect of habituation could be transferred across the two situations resulting ultimately in non-compliance or inappropriate action.

In response, the systems designer can alter the parameters of the exception message (e.g., content or appearance) to reduce redundancy effects (Wogalter et al. 2002, Wogalter and Mayhorn, 2006). In this way, the systems designer can develop application control exception messages tailored to the context. In fact, manipulating warnings to match contextual characteristics could be accomplished relatively easily in IT environments when compared to other situations (e.g., consumer product warning labels) given the ability to easily alter the display of information on a computer screen. Very little research addressing habituation has been reported.

Accordingly, the second experiment reported in this manuscript investigated the factor of habituation and if the negative results of habituation can be overcome through the design of exception messages. Participants were randomly assigned across treatment conditions to determine if they habituated to an exception message. In addition, and using data from the first experiment, further treatment conditions were structured to determine if the results of habituation could be mitigated through the design of the exception message. A strong habituation effect was found to exist and the effect was also found to be mitigated by strengthening the arousal level of the signal word and icon contained in an exception message.

Addressing both the issues of hazard matching and habituation contributes to practice and the academic literature. The data reported will allow systems designers to accomplish hazard matching by aligning an exception message containing the appropriate signal word and icon with a computing or application control or IT related hazard. In addition, this is among only a few studies to examine habituation and the mitigation of the associated negative effects. Overall, this study constitutes the first step in a process that will increase the overall

informativeness of exception messages used in computing environments, including application control environments.

The next section of this paper contains a discussion of prior literature and outlines the research question of interest related to the first experiment carried out. The first experiment addressed the issue of the arousal strength of signal words and signal icons. The third section describes the second experiment carried out to examine the matter of habituation. The paper concludes by highlighting key results and discussing the implications for practice.

II. Hazard Matching – Experiment 1

The logical first step in understanding the role and use of signal words and signal icons in the context of application control and IT exception messages is to determine how the users of IT perceive the severity of hazard associated with these words and icons. That is, to determine and quantify the arousal strength of signal words and signal icons in this context. Determining a quantitative rating (e.g., a numerical equivalent) for these words and icons will provide system designers a reference point for matching the appropriate exception message with an underlying system hazard or application control hazard.

Prior Literature – Numerical Equivalents

Prior research in both psychology and accounting has investigated the numerical interpretation of various qualitative expressions and words. The most developed area of this research involved determining the numerical equivalents of probability phrases such as "likely," "probable," "remote," and "reasonably possible" (AICPA 2000; Amer et al. 1994, 1995; Chesley 1986, 1979; Harrison and Tomassini 1989; Jiambalvo and Wilner 1985; Raghunandan et al. 1991; Reimers 1992; Schultz and Reckers 1981, 1992). The focus of this prior work was primarily on determining the average numerical interpretation of the probability phrases.

A few studies have also examined the numerical equivalents of qualitative expressions other than probability phrases. For example, the interpretation of expressions of amount, such as "a few," "some" or "several," have been studied (e.g., Borges and Sawyers 1974; Cohen et al. 1958; Horman 1983), as well as the interpretations of expressions of frequency, such as "sometimes" and "very often" (e.g., Newstead and Collis 1987; Wallsten et al. 1986; Pepper 1981), and finally qualitative expressions of magnitude, such as "minimal," "moderate" or "sizable," that are used to describe the size of a concept or the change in size of a concept (Amer and Drake 2005; Amer and Maris 2003).

Signal Words and Signal Icons

The role of signal words such as "warning," "caution," and "danger," and signal icons such as the skull and the exclamation point in the context of consumer products and equipment has been the focus of a considerable amount of research in the psychology literature (Edworthy 1998; Hellier, et al. 2000; Wogalter 2002, 2006). Among this work has been the examination of the "arousal strength" of such expressions and icons in non-business and non-IT contexts (Hellier, et al. 2000; Wogalter, et al. 1998, Wogalter and Laughery 1996, and Wogalter and Silver 1990). The results have provided design knowledge that can be used to improve the informativeness of warnings for consumer products and equipment and to facilitate hazard matching.

For example, Wogalter and Silver (1990) examined 84 potential signal words in a contextually neutral setting on dimensions such as the severity of arousal strength, severity of implied injury, and the likelihood of implied injury. Their motivation stemmed from the fact that the standards and guidelines promulgating the use of signal words were not based upon empirical research. They found that there is a clear ordering of arousal strength of signal words with "deadly" communicating the highest level of hazard and "note" communicating the lowest level.

Wogalter et al. (1998) expanded the set of signals to include both signal words and signal icons. They conducted three experiments in which varied participant groups (undergraduate students and community volunteers) provided estimates of the extent of hazard they associated with various words, icons, colors, and configurations. A key finding was that not all the warning design guidelines in the professional standards held. For example, the standards indicate that the signal word "warning" is to communicate a higher level of hazard than "caution." Wogalter et al. did not find this to be the case.

Hellier et al. (2000) expanded the findings of prior work by demonstrating a high level of agreement in the arousal strength values of signal words across participant groups. Additionally, Hellier et al. note that the arousal strength scales of signal words are robust. That is, word ratings are unaffected by scaling methodology used to elicit the perceptions of participants.

Combining signal words and signal icons together has not been as thoroughly investigated. However, research in psychology found that including signal icons (pictorials) in textual warning labels of consumer products and equipment increases the salience of the warning to consumers and the likelihood of the warning being noticed (Kalsher et al. 1996; Laughery and Young 1991; Sojourner and Wogalter 1998; Young and Wogalter 1988). Additionally, including pictorials in a textual warning facilitates warning comprehension (Dewer 1999) and has been shown to enhance memory of a warning (Young and Wogalter 1988).

Signal Words and Signal Icons in the IT Professional Guidelines

Within the IT professional design guidelines exception messages (a.k.a., error messages), similar to non-IT warnings, are generally thought of as notifying the user that an unusual event has occurred. Cooper (1995) views these messages as being rude, but if one must use an exception message, Cooper advises that a well-formed exception message box should be polite, illuminating, and helpful. This advice corresponds to that noted above by psychologists who strive to increase the "informativeness" of warnings. However, Cooper does not discuss the use of signal words or icons to indicate the severity of the problem indicated by the exception message.

Booch (1987 and 1991) notes that a programmer or designer should explicitly recognize that exceptions or errors will occur in an IT application and should plan for them. His advice focuses on informing the user of the actions to be taken in response to the exception message. No guidance, however, is offered as to the content or appearance of exception message, including how to use signal words and signal icons.

Apple Corporation (1989) notes that some icons have "standard accepted uses" (p.115). These icons are "right and left arrows, return arrow, About box balloon, check box, radio button, and the house icon" (p.115). However, only ambiguous advice is given as to how icons should be used: "Any button in one of these shapes must conform to the expected use, or users will be confused" (p.115). No guidance is offered with respect to signal words or signal icons.

Microsoft, in ***The Official Guidelines for User Interface Developers and Designers*** (***UI Guidelines:*** Windows XP Design Team 2001) contains more specific guidance for the components of what they term "message boxes." The UI Guidelines provide recommendations for the following components of message boxes: (1) title bar text, (2) use of icons, and (3) message box text. The general view of Microsoft UI Guidelines is that the title bar identifies the source of the message, the icon identifies the type of message, and the text presents the message. As with Apple, no specific guidance with respect to the arousal strength of signal words and signal icons and hazard matching is provided.

Research Question – Experiment 1

The research in psychology and the IT professional guidelines noted above raises interesting questions with regard to the use of signal words and signal icons in application control and IT exception messages. First, it is useful to examine the arousal strength of the signal words and signal icons that are common to IT exception messages because, to date, they have been unexamined. Second, the IT professional design guidelines provide little advice as to how and when a given signal word or signal icon should be utilized, especially with respect to the severity of an IT related hazard communicated by such words and icons. Accordingly, much may be contributed toward the goal of hazard matching in IT environments. Third, the guidance that is offered in the IT professional design guidelines is, apparently, not supported by empirical findings. This situation is similar that noted above by Wogalter and Silver (1990) and Wogalter et al. (1998) with regard to the professional guidelines for warnings associated with consumer products and equipment.

Following the work in psychology, the first experiment carried out sought to determine how users perceive the severity of an IT related hazard associated with combinations of signal words and signal icons. The results will allow systems designers to accomplish hazard matching by aligning an application control exception message with the appropriate signal word and icon with an application control related hazard, and the ability to increase the overall informativeness of exception messages:

R1: How do IT users perceive the severity of an IT related hazard associated with signal words and signal icons contained in IT exception messages?

Methodology

The data collection was accomplished using a Web-based, computerized data collection program and followed the approach used by Amer and Drake (2005). The data collection involved asking participants to provide

a numerical rating on a ten-point scale of various signal words and signal icons within the context of an IT exception message displayed on a computer screen. A fully randomized design was incorporated such that each participant viewed every combination of signal word and signal icon in random order and provided their perception as to the severity of hazard communicated by the message.

Participants

The authors recruited 316 students from a large university to complete the elicitation exercise. The participants were comprised of upper division undergraduate business students and MBA students. Table 1 provides descriptive statistics of key information related to these participants. Data from Table 1 indicates that the participants were younger rather than older but have used computers to a large extent.

Table 1
Descriptive Statistics of Data Related to the Participants In The First Experiment

Panel A – Participant Age

18 to 25 years	76%
26 to 35 years	16%
36 to 45 years	5%
46 to 55 years	2%
56 to 65 years	1%
Over 65 years	0%

Panel B – Participant Gender

Male	56%
Female	44%

Panel C – Participants' Hour(s) of Daily Computer Use

Less than an hour	8%
1 hour	11%
2 hours	25%
3 hours	17%
4 hours	12%
More than 4 hours	28%

Procedure and Task

The task was administered using a Web-based, computerized data collection program.[1] The programmed instrument was accessed individually by each participant through the internet at their convenience. The participants completed the task in its entirety during one sitting whenever they had a sufficient block of time within a window of three to four days. The program randomly assigned the order of each exception message viewed by each participant. Therefore, each combination of signal word and signal icon was presented in a random order to each participant, thus avoiding order effects in the measures collected.

At the start of the exercise, the participants were instructed that the purpose of the study was to determine how people use and understand expressions such as "warning." Next, the participants read through a scenario that described a hypothetical computerized interaction. After reading the scenario, the participants answered three multiple choice questions about the scenario. The multiple choice questions were designed to ensure that the participants had attended to the context presented in the scenario. The participants were not able to continue the exercise until they had answered the scenario-related questions correctly. Ninety-three percent of the multiple choice questions were answered correctly on the first attempt indicating that the participants attended to the scenario.

The scenario described a situation in which the participant was interacting with a computer network. A generic, yet vary common scenario was presented to the participants to provide a reasonable context within which to assess the arousal strength of the signal words and signal icons. Responses were not identifiable to any participant,

but the participants' completion of the exercise was recorded by the system in order to provide each participant with extra-credit course points. The extra-credit points were offered as an incentive for the participant's to complete the exercise.

The participant's provided a rating on a 10-point scale of the severity of hazard associated with 29 different IT exception messages, each containing a different combination of signal word and signal icon. A sample of the elicitation question is as follows:

As you are typing on your keyboard you receive the following exception message on your computer screen:

Please indicate on the following scale the degree of SEVERITY of the computer problem implied by the above exception message:

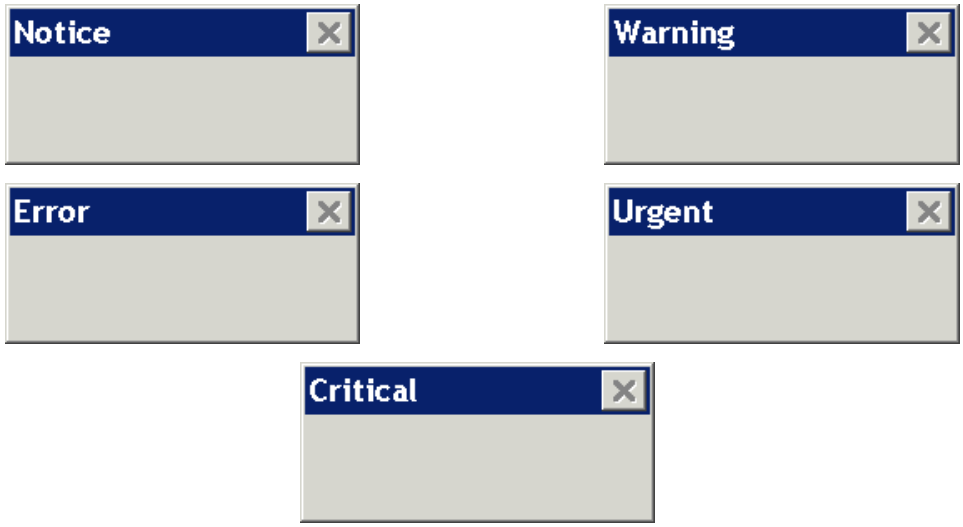
Not at all Severe		Slightly Severe			Very Severe		Extremely Severe		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Signal Word and Signal Icons Used

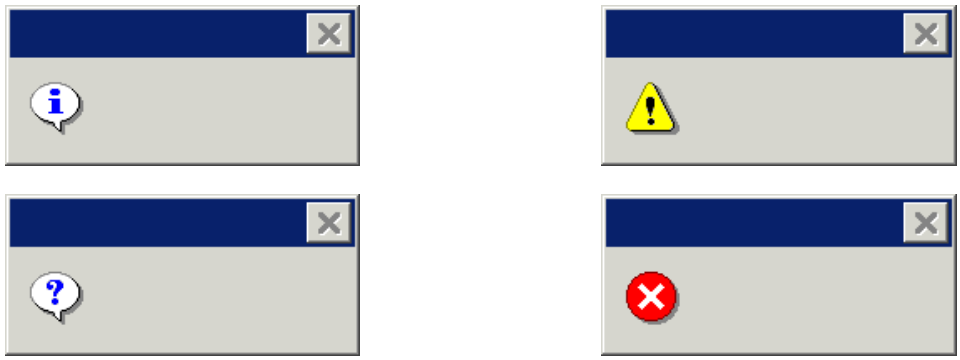
The signal words and signal icons used in the study were selected from Microsoft development manuals, published both in hard copy and on-line (Windows XP Design Team 2001), and from prior literature in psychology (Hellier et al. 2000). The Microsoft development manuals are used by application programmers as a reference for programming when developing products to be Microsoft compliant. Accordingly, the signal words and icons chosen from these sources are those a user would encounter in an IT exception message when using Microsoft products. The signal words and signal icons used are shown in Table 2.

Table 2.
Signal Words and Signal Icons Used

Signal Words Used



Signal Icons Used



To avoid order effects in the data collected, each participant provided a rating as to the severity of hazard communicated by every combination of signal word and signal icon presented in a random order. In addition, each participant provided a rating for each signal word and signal icon alone. As a result, each participant viewed a total of 29 exception messages (no rating was provided for a "blank" exception message that did not contain either a signal word or signal icon). Pilot testing and previous research (Amer et al. 1994) showed that participants began to experience fatigue after about 25 to 30 evaluations.

Dependent Variable

The measure collected during the elicitation exercise was each participant's perception as to the severity of an IT related hazard communicated by the warning contained in the exception message. As noted above, each participant provided this rating on a 10-point scale, which provided a measure of the arousal strength of each exception message warning. The elicitation question and response metric itself was consistent with those used in prior research (Wogalter and Silver 1990, Wogalter et al. 1998; Hellier et al. 2000).

Results – Experiment 1

Table 3 provides the mean values and standard deviations of the data collected for each signal word and signal icon. The top row of Table 3 shows the mean values for the signal icons alone, that is without an accompanying signal word. The left column shows the mean values for the signal words alone, without an

accompanying signal icon. The other cells in the table display the mean values for combinations of signal words and signal icons.

Table 3
Mean Values (Standard Deviations) of the Perceived Severity of the Computer Problem Communicated by Signal Words and Signal Icons

	Icon*				
Word	**Blank**	**i**	**?**	**!**	**x**
Blank		***2.00*** ***(1.43)***	***2.18*** ***(1.73)***	***3.74*** ***(1.98)***	***5.30*** ***(2.29)***
Notice	***2.23*** ***(1.63)***	***2.64*** ***(1.76)***	***2.52*** ***(1.67)***	***3.89*** ***(1.99)***	***5.19*** ***(2.35)***
Error	***3.84*** ***(2.19)***	***3.85*** ***(1.90)***	***3.73*** ***(1.92)***	***4.97*** ***(2.20)***	***6.24*** ***(2.37)***
Warning	***4.06*** ***(2.10)***	***4.09*** ***(2.03)***	***3.91*** ***(1.96)***	***5.41*** ***(2.08)***	***6.65*** ***(2.20)***
Urgent	***4.09*** ***(2.31)***	***4.15*** ***(2.14)***	***3.97*** ***(2.13)***	***5.34*** ***(2.29)***	***6.54*** ***(2.37)***
Critical	***5.11*** ***(2.49)***	***4.82*** ***(2.42)***	***4.74*** ***(2.21)***	***6.01*** ***(2.26)***	***7.38*** ***(2.22)***

*** Icons Represented in the Table ("Blank" is the absence of a word or icon):**

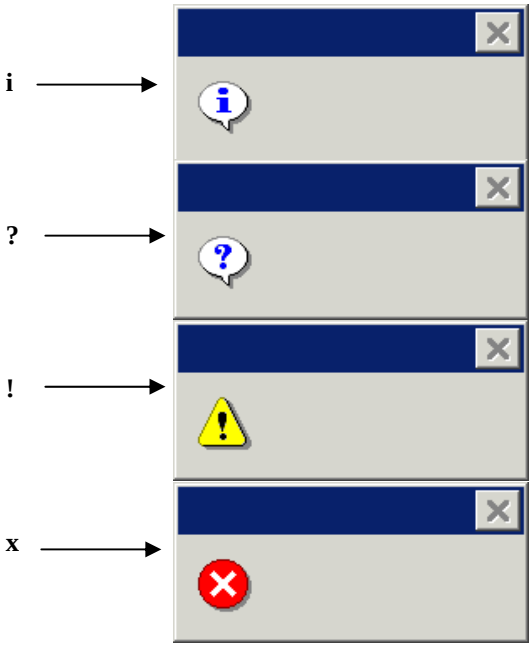
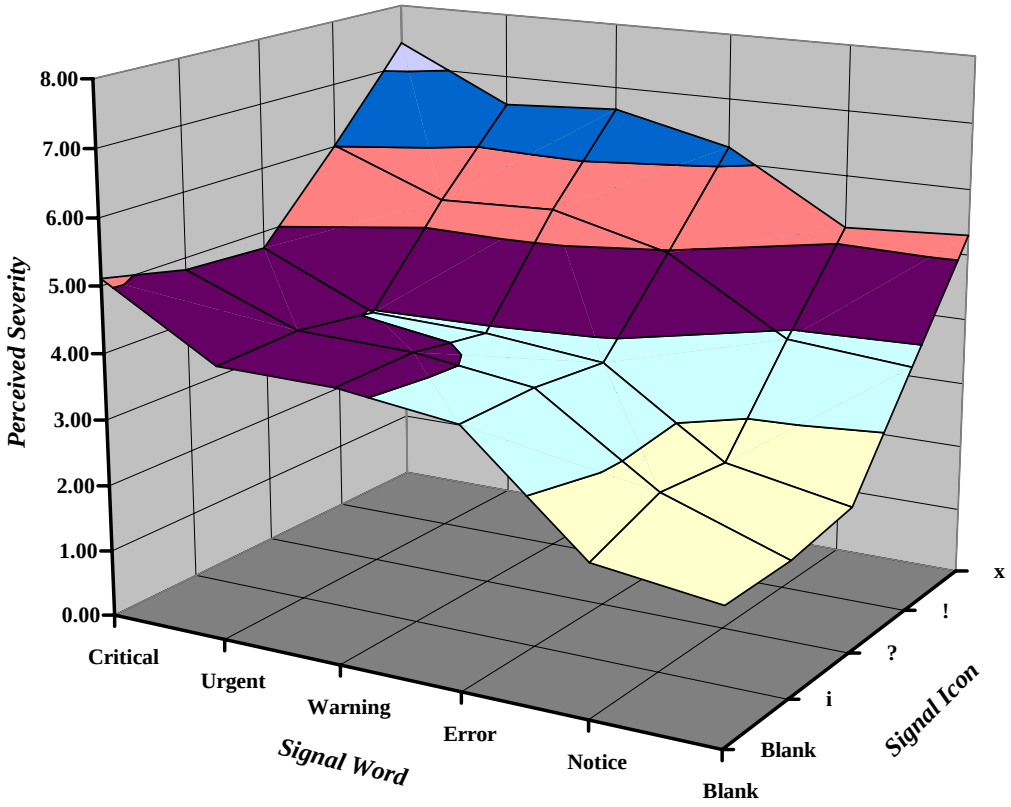


Figure 1
Plot of the Mean Values of Perceived Severity of the Computer Problem Communicated by Signal Words and Signal Icons



Icons Represented in the Graph ("Blank" is the absence of an icon):

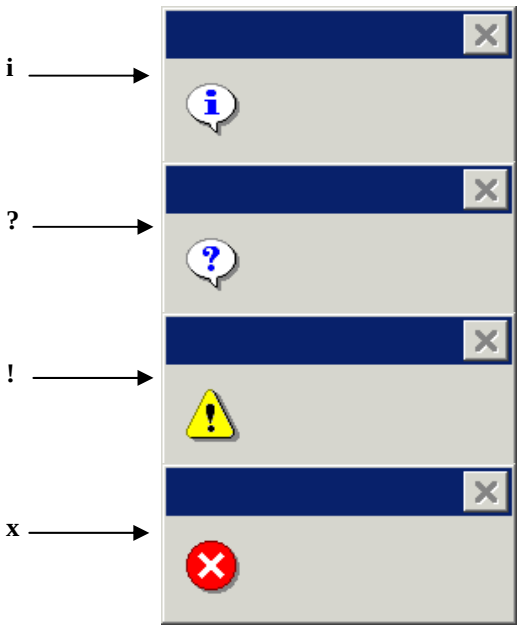


Figure 1 displays the data from Table 3 in graphical form. An examination of the mean values indicates that there are different levels of arousal strength associated with different signal words and signal icons alone, as well as in combinations. The top row of Table 3 and the "Signal Icon" axis in Figure 1 illustrates an increase in the perceived severity of the hazard associated with each of the four signal icons alone, with apparently very little difference between the icons "i" and "?." Likewise, an examination of the left column of Table 3 and the "Signal Word" axis of Figure 1 indicated an increase in the perceived severity of hazard associated with each of the five signal words alone, with apparently very little difference between the words "Warning" and "Urgent." Finally, the data in the lower right section of Table 3 and the back portion of Figure 1 indicates that a combination of signal words and signal icons results in the highest level of perceived severity of hazard. Observing the data as displayed in Figure 1 indicates an interactive effect resulting from combining signal words and signal icons. That is, the two factors together result in higher levels of perceived hazard.

Using this data, system designers can better achieve hazard matching by determining the severity of a potential situation faced by an IT user and then choosing the signal word and icon to appropriately warn the user. In this way, highly hazardous situations can be indicated by signal words and icons that are perceived as indicating high levels of hazard and vice-versa.

ANOVA – Main Effects for Signal Word and Signal Icon

Each participant viewed every possible combination of signal word and signal icon during the elicitation exercise. Accordingly, a repeated measures ANOVA was carried out to determine if the signal word factor and signal icon factor were both statistically significant. The main effect for the signal word factor was statistically significant: $F(5, 271) = 104.9$; $p < .0001$. Likewise, the main effect for the signal icon factor was also statistically significant: $F(4, 271) = 165.4$; $p < .0001$. These results indicate that there are clear differences in the mean values presented in Table 3. There is also a significant interaction between the factors of signal word and signal icon ($F(20, 271) = 3.14$; $p < .0001$)) indicating that combinations of signal words and signal icons result in higher levels of perceived hazard. This result is clearly seen in Table 3 and Figure 1 as higher levels of perceived severity of hazard result when signal words and signal icons are used together.

Pairwise comparisons revealed no difference between the signal words "Warning" and "Urgent:" $p = .829$. Comparing the data in Table 3 from row labeled "Warning" and the row labeled "Urgent" reveals very little difference in the mean values of these two signal words. The differences between all other signal words were statistically significant at .05. This result suggests that, with respect to perceived hazard, these two signal words can be used interchangeably.[2]

Signal Words and Signal Icons Together

An examination of the data in Table 3 and Figure 1 indicates that the mean values of perceived severity for the combination of signal words and signal icons are higher than for the signal words and signal icons alone. The analysis revealed a significant interaction between the factors of signal word and signal icon ($F(20, 271) = 3.14$; $p < .0001$)). To further examine the interaction pairwise comparisons between the combinations of signal words and signal icons are examined. These tests revealed significant results ($p < .05$) for the following combinations:

Signal Word	Signal Icon
Critical	x
Critical	!
Urgent	x
Urgent	!
Warning	x
Warning	!
Error	x
Error	!
Notice	x
Notice	!

In all these cases, the signal icons "x" and "!" increased the perceived severity of warning for the corresponding signal words. Accordingly, one can combine signal words and signal icons in an exception message to communicate a statistically significant higher level of perceived hazard than by using signal words and signal icons alone.[3]

An examination of the data in the "i" column and the "?" column of Table 3 indicates relatively minor differences in the mean values between these columns, that is, between the two signal icons. For example, for signal word "Notice" the mean values are 2.64 and 2.52 for the signal icons "i" and "?" respectively. Likewise, for the signal word "Error" the mean values are 3.85 and 3.73 for the signal icon "i" and "?" respectively. This pattern is similar for the remaining cells in these two columns. Pairwise analysis revealed that there is not a statistically significant difference between perceived severity of hazard communicated by the question mark icon ("?") and the perceived severity of hazard communicated by the information icon ("i"): $p = .065$. The differences between all other signal icons were statistically significant at .05.

III. Habituation Effects – Experiment 2

The data provided by Experiment 1 and reported in Table 3 allows systems designers to select the appropriate signal word and icon to design an appropriate exception message for a given context or situation. As noted earlier, manipulating warnings to match contextual characteristics could be accomplished relatively easily in IT environments when compared to other situations (e.g., consumer product warning labels) given the ability to easily alter the display of information on a computer screen. One important contextual factor that has received relatively little research attention is that of habituation (Thorley; Hellier, and Edworthy 2001, Wogalter et al. 2002, Wogalter and Mayhorn 2006). The desensitizing result of repeated exposure to a warning, including an IT exception message, can lead to problems whereby compliance with the warning may decrease.

There are two habituation related issues facing the designers of warning and exception messages: (1) the desensitizing effect of repeated exposure to the ***same*** warning/exception message, and (2) the case where different warnings or exception messages look or sound about the same across ***different*** situations (Wogalter and Vigilante 2006). In both cases the warnings may not be attended to. A warning that is noticed but fails to maintain the attention of the user long enough for its content to be encoded is of little direct value. What is required is referred to as "attention maintenance" (Wogalter, 2006) whereby attention to the warning/exception message is maintained long enough for the user to extract meaning from the information contained in the message. Habituation occurs when the user encodes the contents of the message in memory and upon subsequent exposures there is a decline in attention to the message to the point where no further processing occurs (Thorley, Hellier and Edworthy 2001, Wogalter and Mayhorn 2006).

In response, the systems designer can alter the parameters of the exception message (e.g., alter the content or appearance) to reduce redundancy effects and mitigate the negative results of habituation (Wogalter et al. 2002, Wogalter and Mayhorn, 2006). In this way, the systems designer can develop application control exception messages tailored to the context.

Very few studies in psychology have addressed the factor of habituation and how to mitigate the resulting desensitizing effects. All have focused upon warnings in the context of consumer product or equipment related hazards. Gardner-Bonneau, Kabbara, Hwang, Bean, Gantt, Hartshorn, Howell, and Spence (1989) report that exposure to multiple simultaneously-presented cigarette warnings leads to a greater range of hazard information recalled than a single, repeated warning. Wogalter and Brelsford (1994) determined that rotating different warnings on alcoholic beverages are a better means of communicating facts and hazards than a single repeated warning of limited content, as measured by test scores of recall. Thorley, Hellier and Edworthy (2001) found that warning compliance behavior decreased as a function of time following repeated exposure to a visual warning.[4] This supported the notion that participants habituated to visual warnings. Changing the warning in appearance, but not intensity, unexpectedly decreased compliant behavior. However, Thorley et al. note confounds in their experiment in that the familiarity of the surrounding environment and social influence may have affected the results.

The paucity of psychological research targeted on habituation effects leaves open the door for significant contributions to both the academic and applied literature. This study examines both habituation issues noted above. First, we investigate how repeated exposure to the ***same*** exception same results in a desensitization and a resulting lack of attention. Second, we investigate the case where different exception messages looks about the same across ***different situations***. We then alter the signal words and icons contained in the exception messages to mitigate the negative results of habituation.

Hypothesis – Repeated Exposure to the Same Exception Message

In this situation a user of an application is repeatedly exposed to identical exception messages. As an example, a user may be exposed to the same IT exception message every time they select a given menu command. The habituation effect results in reduced attention maintenance:

H1: Attention maintenance (as measured by time) declines over repeated exposure to the ***same*** exception message.

Hypothesis – Similar Exception Messages Across Different Situations

In this situation a user of an application may encounter exception messages that look the same across two different hazardous situations. The desensitizing effect of habituation could be transferred across the two situations resulting in non-compliance or perhaps an inappropriate action:

H2: Behavioral compliance to an exception message in a ***new*** situation is impaired by the repeated exposure to a ***similar*** exception message in a prior situation.

Mitigating Habituation Effects

Can the negative results of habituation be mitigated by altering the design of the exception message? As noted above, researchers in psychology found that rotating warnings of alternative appearance leads to a greater range of hazard communication and information recall (Gardner-Bonneau, et al. 1989, Wogalter and Brelsford 1994). These researchers did not examine compliance directly. In addition, Thorley et al. (2001) found that warning compliance behavior decreased as a function of time (a habituation effect) following repeated exposure but that changing the warning in appearance unexpectedly ***decreased*** compliant behavior and the results were subject to confounding variables.

In this study we address actual behavioral compliance (not just user recall) and control for the confounds noted by Thorley et al. (2001). In addition, we alter the intensity of signal words and signal icons that appear in the exception message in an attempt to overcome the desensitization resulting from habituation and thereby increase behavioral compliance.

As noted by Thorley et al. (2001) post habituation compliance should increase if there is some form of reinforcement stimulation added to the content of a warning/exception message that had previously been repeated. This reinforcement stimulation can take a variety of forms, but in the current study the signal word and signal icon are altered to affect a change in the appearance of the exception message. First, simply changing the signal word and icon to alter the appearance of the message is examined:

H3: Behavioral compliance to an exception message in a ***new*** situation increases by altering the appearance of the signal word and signal icon of the exception message.

Additionally, and using the data from Experiment 1, increasing the intensity (i.e., the arousal strength) of the signal word and signal icon that are used in the exception message should further stimulate the user to attend to the message and comply:

H4: Behavioral compliance to an exception message in a ***new*** situation increases by strengthening the intensity (arousal strength) of the signal word and signal icon of the exception message.

Methodology

A second experiment was carried out to examine the effects of habituation as set forth in hypotheses **H1** through **H4**. In this experiment, participants were randomly assigned across treatment conditions to determine if they habituated to an exception message. In addition, further treatment conditions were structured to determine if the habituation effect could be mitigated through the design of the exception message. The participants completed a simple yet relevant accounting data entry task that required the entry of sales order information using an on-line sales order data entry screen.

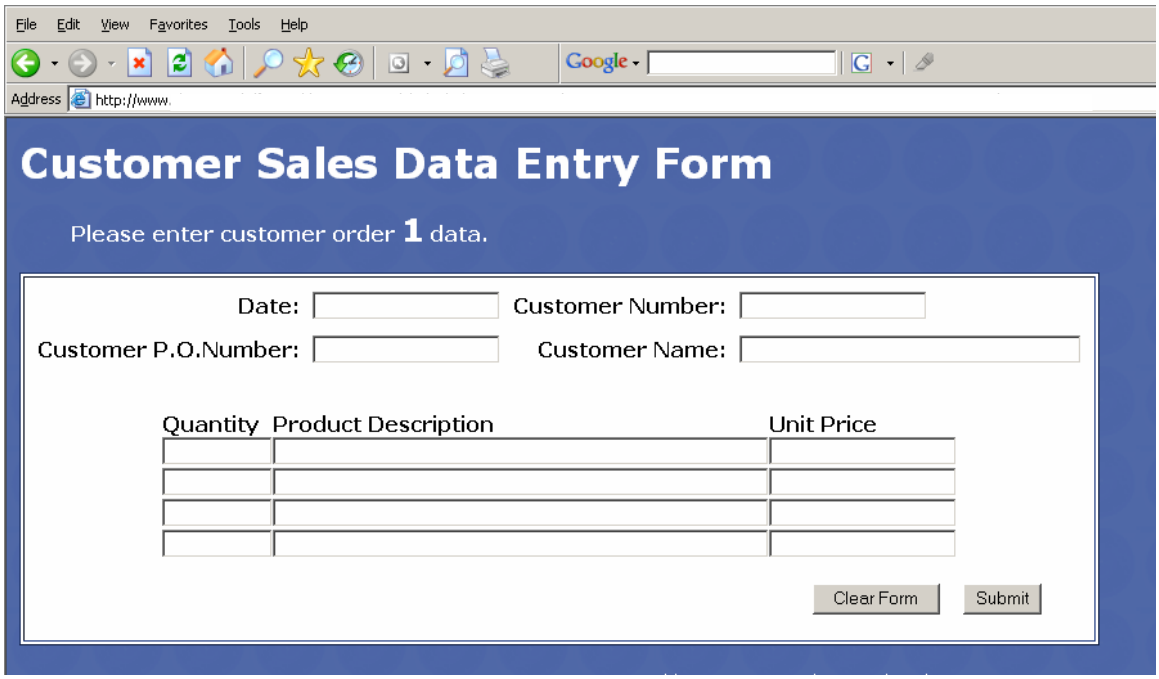
Participants

The authors recruited upper division business students to complete the task. All participants had completed two accounting courses and other business coursework. As such, a group of participants with this background would reasonably be expected to complete the data entry task utilized in the experiment (described below) in an actual working environment. Each participant was awarded extra credit course points if they successfully and accurately completed the task.

Procedure and Task

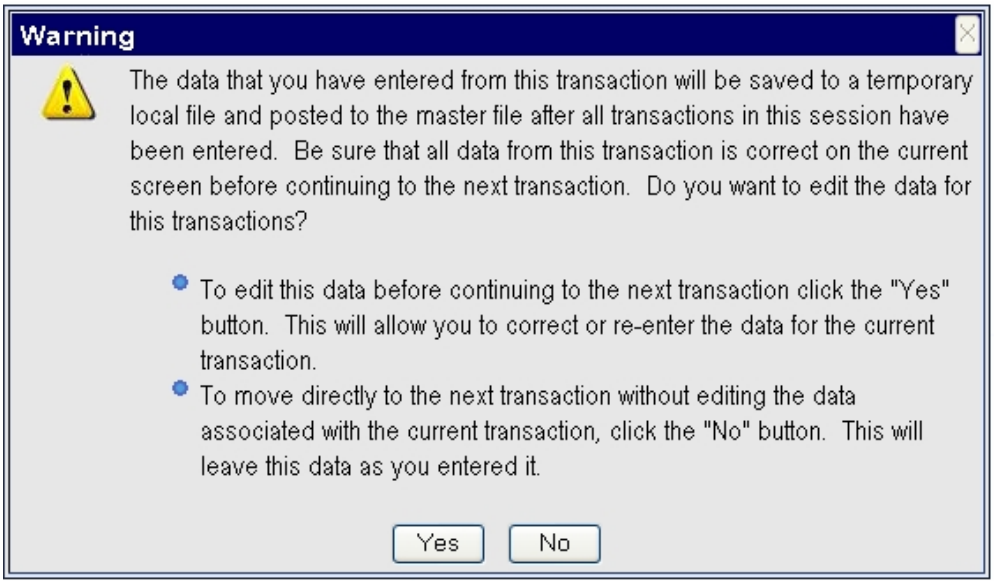
As with Experiment 1, the task was administered using a Web-based computerized data collection program and was accessed individually by each participant through the internet at their convenience. The participants completed the task in its entirety during one sitting and were randomly assigned to each treatment condition.

At the start of the exercise, the participants were instructed that the purpose of the study was to carry out a short system test by entering data from several sales transactions for a hypothetical wholesale distributor of sporting goods.[5] The data from each transaction was provided to the participants in document form. Each participant then entered the data on a separate data input screen. The data entry task was modeled after the on-demand software model whereby computer applications are hosted and maintained by a software vendor – not an internal IT staff – and then delivered over the Web like a service (Lacy, 2006).[6] These systems are growing in popularity and are structured as a client-server topology (see www.everestsoftwareinc.com, www.act.com, www.netsuite.com, www.oequickbooks.com, and www.redwingsoftware.com for examples). A sample of the data entry screen is as follows:



Treatment Conditions and Dependent Variable – H1

To examine **H1**, the decline in attention maintenance (as measured by time) associated with repeated exposure to the ***same*** exception message, the participants entered the data from each of the sales transactions on a separate data entry screen. After entering the data for each of the sales transactions the following exception message, the "edit request" exception message, appeared on the screen asking if the user would like to edit the data before submitting the transaction:

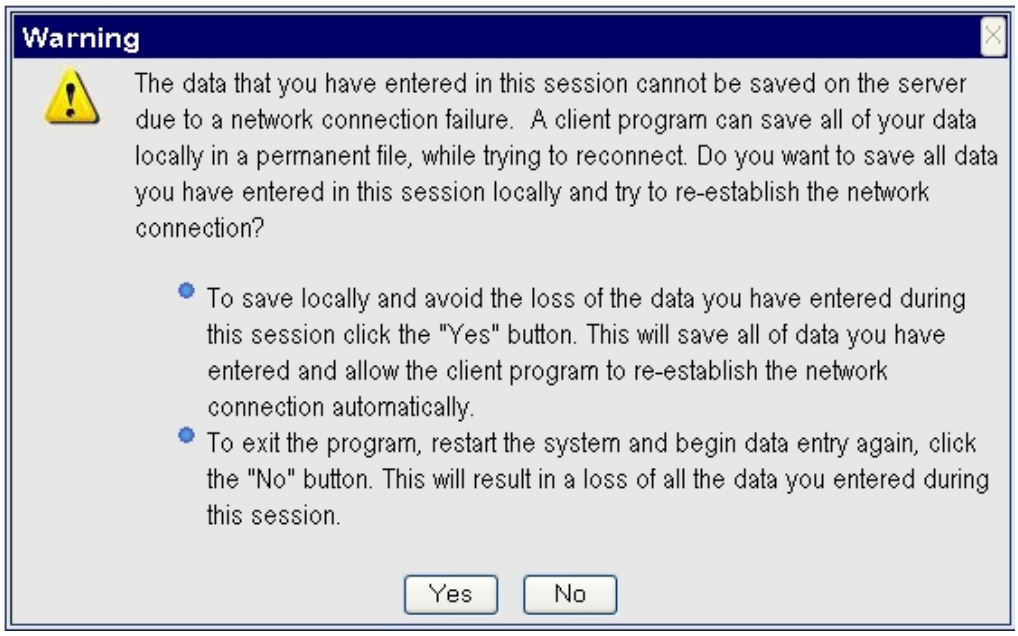


The general form and content of this exception message was modeled after two Microsoft exception messages – an Excel exception message for potential data loss, and a Word exception message for format conversion. The most common response to this message would be "No" as the participants would have to select the "No" button before continuing to enter the data for the next transaction. The signal word (Warning) and icon (exclamation point) combination displayed in the message was chosen based upon the data from Experiment 1. As can be seen from the data in Table 3 the perceived severity of this combination of signal word and icon is 5.41, reasonably close to the midpoint of the data in Table 2.

To measure the decline in attention maintenance, the time in seconds that the edit request message was displayed on each participant's screen was captured and recorded by the data collection program. This measure of time ("display time") began when the message was sent from the server to the participant's screen and ended at the point when the server received the participant's response from their selection of a button at the bottom of the exception message.[7] A decline in attention maintenance can be tracked by examining the display times on each of the repeated displays of the exception message – one after the entry of each transaction.

Treatment Conditions and Dependent Variable – H2 Through H4

To examine the behavioral compliance predictions of **H2** through **H4**, a different hazardous situation and exception message were developed. The exception message was similar in appearance to the first but the context required a different action to be taken. After each participant entered the data for a ninth transaction, a simulated network connection failure occurred. The participants were informed of the connection failure by the following "network connection failure" exception message that notified them that all data would be lost if they did not save it to a local file:



Note that this network failure exception message looks similar to the edit request message that each participant would have seen eight times prior, but that the action required is "Yes" not "No". That is, each participant would have been habituated to respond "No" to the edit request exception message before encountering the network failure exception message. If a "No" response was selected in the later case, each participant would suffer the loss of all the data they had entered to that point in the exercise, a clearly undesirable occurrence.

The predictions of **H2** regarding the impairment of behavioral compliance to an exception message in a ***new*** situation by the repeated exposure to a ***similar*** exception message in a prior situation can be examined by measuring the "hit rate" of the participants on the network connection failure exception message. That is, the percentage that each participant takes the desirable action (selecting "Yes") in response to the network connection failure exception message. This is the case because the action required to avoid the loss of data in the network connection failure message is opposite to the habituated action required in response to the edit request exception message.

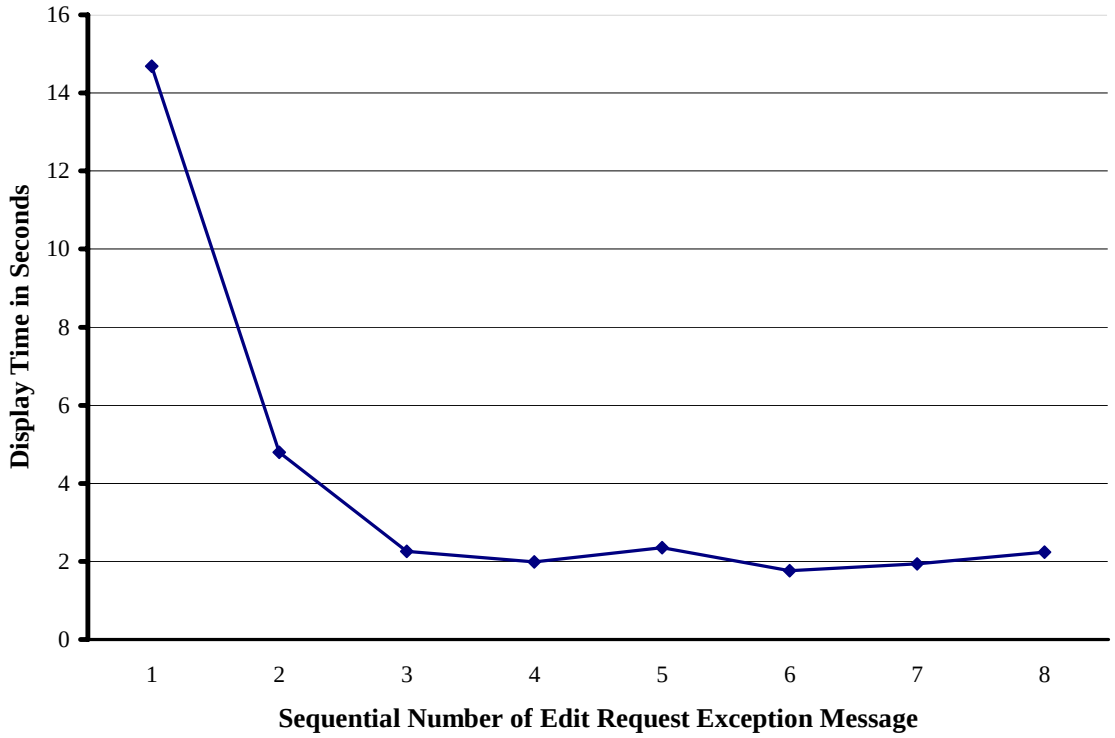
As will be described below, the predictions of **H3** and **H4** can be examined by changing the signal word and icon combinations in the network connection failure exception message and measuring the associated changes in hit rates. Under both hypotheses the hit rate in response to the network connection exception message should increase when the signal words and signal icons in the message change from those in the edit request exception message.

Results – H1

Eighty-eight participants completed the sales data entry. After entering the data for each of the sales transactions the edit request exception message was displayed to habituate the participants. Figure 2 presents the average display time in seconds for each of the eight exposures of the edit request exception message. The data in Figure 2 indicates that the participants' attention maintenance to the edit request exception message declines rapidly from about 15 seconds to two seconds. After just three exposures the display time levels off at two seconds. This is

about the time it would take for a user to move the cursor on a computing screen and select an action button in the exception message without attending to the contents of the message. These results clearly indicate that the participants habituated quickly to the repeated exposure to the ***same*** exception message, and spent less time attending to the contents of the message.

Figure 2
Plot of the Mean Values of Display Time for Each of the First Eight Edit Request Exception Messages



Results – H2 Through H4

All eighty-eight participants completed the same data entry task through the first eight transactions. Accordingly, they were all habituated by the repeated exposure to the same edit request exception message. At the point after the ninth transaction all participants encountered the simulated network connection failure and associated exception message. The participants were randomly assigned to three treatment conditions that varied the signal word and signal icon combinations displayed as part of the network connection failure exception message: (1) A signal word and icon combination identical to that of the edit request exception message ("Warning" and the "!" icon), (2) the signal word "Notice" and the information "i" icon, and (3) the signal word "Critical" and "x" icon.

The signal words and icons chosen for each treatment condition were selected based upon the data from Experiment 1. As can be seen from the data in Table 3 the perceived severity of these three combinations of signal word and icon are 2.64, 5.41, and 7.38 respectively. These three combinations represent a reasonable range of arousal strength to test the hypotheses. In addition, the difference in the arousal strength is about the same between the three combinations.

The first treatment condition with the identical signal word icon to that of the habituated edit request message combination was designed to examine the prediction of **H2**. The second treatment condition used a signal word and signal icon combination with a relatively low perceived severity to examine the prediction of **H3,** by simply changing the signal word and icon combination. The third treatment condition used a signal word and icon combination with the highest perceived severity to examine **H4**.

Table 4 provides an inventory of the hit rates across each of the three treatment conditions. As seen, there is an increase in the hit rates across all three treatment conditions. The lowest hit rate of 11% corresponds to the exception message that contained a signal word and icon combination that was identical to the habituated edit request exception message. The highest hit rate of 39% corresponds to the exception message with a higher

intensity (arousal strength) signal word and icon combination. Simply changing the signal word and icon combination (treatment condition 2) increases the hit rate to 20%.

Table 4
Mean Values of the Hit Rates for the Alternative Network Connection Failure Exception Messages

Treatment Condition		Hit Rate
1.	Signal word icon combination identical to that of the habituated edit request message	11%
2.	Signal word and signal icon combination that was ***different*** (lower perceived severity) to that of the habituated edit request message.	20%
3.	Signal word and signal icon combination with ***higher perceived severity*** to that of the habituated edit request message.	39%

A Chi Square goodness of fit statistical analysis was carried out to examine the differences in the hit rates across treatment conditions. The hit rates between the first and second treatment conditions were not statistically significantly different from one another ($p = .358$) thus indicating that simply changing the signal word and icon combination will not increase behavioral compliance after subjects are habituated. This statistical result occurred despite the fact that the hit rate almost doubled from 11% to 20% across the treatment conditions. The data and statistical analysis indicates that low behavioral compliance (as measured by hit rate) occurs for participants in response to an exception message in a ***new*** situation after repeated exposure to a ***similar*** exception message in a prior situation providing support for **H2**. The prediction of **H3**, however, is not supported in that behavioral compliance to an exception message in a new situation does not increase by simply altering the signal word and signal icon included in the exception message.

The hit rate of the third treatment condition was statistically significantly different from the hit rates of the first two treatment conditions: $p < .05$. This indicates that increasing the intensity (arousal strength) of the signal word and icon combination included in the message increases the behavioral compliance of users who are habituated to a similar exception message thus supporting **H4**.

Control Treatment – Non-habituation Group to Further Examine H2

Additional data was collected to further examine the prediction of **H2** that behavioral compliance to an exception message in a ***new*** situation is impaired by the repeated exposure to a ***similar*** exception message in a prior situation. A control group of 33 new participants of similar background and experience completed the same data entry exercise. For this task, however, no edit request exception message appeared after each data entry screen. That is, the participants were not habituated to an exception message before the simulated network connection failure that occurred after the entry of the ninth transaction. At that point, the participants were exposed to the network connection failure exception message that contained the signal word "Warning" and the exclamation icon ("!"). This was the same network connection exception displayed to the participants in the first treatment condition.

The hit rate of the non-habituated control group was 97% and was statistically significantly greater than the hit rates of the other three treatment conditions ($p < .0001$). The relatively high behavioral compliance of the non-habituated control group supports **H2** in that behavioral compliance was only 11% for those exposed to an exception message in a ***new*** situation after repeated exposure to a ***similar*** exception message in a prior situation.

IV. Discussion and Conclusions

The results of two experiments are reported in this paper. The first examined and measured the arousal strength associated with the signal words and signal icons that are commonly used in application control and IT exception messages. An elicitation exercise was completed by 316 participants, in which each participant viewed exception messages containing combinations of signal words and signal icons. One objective of this research was to provide system designers with data that will allow them to improve the informativeness of application and IT

exception messages by achieving hazard matching. The data in Table 3 can be used in this way such that highly hazardous IT related situations can be indicated by signal words and icons that are perceived as indicating high levels of hazard and vice-versa.

For example, suppose a computer clerk who, while interacting with a sales order processing system, executes a series of commands that may inadvertently delete a file containing customer credit sales data. This relatively hazardous result could be signaled to the clerk in an application control exception message containing the signal word "Critical" and the signal icon "x". As seen from the data in Table 3, this combination of signal word and icon is associated with the highest arousal strength. This level of arousal strength may be appropriate to warn the clerk in this situation.

Other Guidance

The results of the second experiment focused on the issue of habituation and how the negative effects of this factor can be mitigated. The results related to **H1** through **H4** indicate that users can become habituated after only a few exposures to the same exception message. This habituation results in decreased attention maintenance and the potential for reduced behavioral compliance. Using the results from the first experiment related to the relative arousal strength of alternative signal word signal icon combinations, behavioral compliance can be increased by designing exception messages that contain signal words and icons of high arousal strength.

Future Research

This study constitutes the first step in a process that will increase the overall informativeness of exception messages used in computing environments including application control environments. Future research can examine how other important individual and contextual factors may affect the arousal strength of various IT exception message parameters. For example, do individual characteristics such as gender, risk tolerance, and tolerance for ambiguity affect the arousal strength communicated by the warnings contained in exception messages? Another rich area for investigation involves the assessment of alternative features of IT exception messages such as an audio component. In addition, IT environments allow the implementation of dynamic exception messages that change during periods of use. Such dynamic exception messages may be used to address issues of habituation and to increase behavioral compliance. Addressing these factors may allow systems designers to tailor specific exception message parameters to individual users, thus customizing and improving the nature of the user interaction.

Endnotes

[1] Amer et al. (1994) and Amer and Drake (2005) note that this data-capturing approach provides several advantages: (1) preventing participants from changing previous responses as they were not allowed to review prior responses, (2) controlling order effects through complete randomization of trials, (3) alleviating problems of non-responses (the computer program required the participants to respond to every prompt before continuing), and (4) ensuring participants' complete understanding of the instructions by requiring them to correctly answer multiple choice questions about the context.

[2] Although not a focus of the current research, it is interesting to note that Microsoft in the ***UI Guidelines*** that systems designers should not use the question mark icon in exception messages because users can confuse the question mark icon with the help information icon. While Microsoft's recommendation does not address the relative arousal strength of these two icons directly, the data presented here indicates that there are no difference s in the perceived severity of hazard associated with these two icons.

[3] Again, although not a focus of the current research, it is interesting to note that Microsoft in the ***UI Guidelines*** implies that no additional information is communicated by combining signal words and signal icons. In the context of arousal strength this implication seems to be false.

[4] The context was the participants' use of doors posted with a warning sign reading **"DEFECTIVE DOORS, PLEASE USE OTHER DOORS."**

[5] The order of the transactions was randomized across the participants to avoid an order effect on the measures collected.

[6] Alternatively, the participants could have completed a task using a product such as Microsoft Word or Excel. However, the treatment conditions required to be manipulated in the experiment would not be those commonly seen in these products. Accordingly, the participants may have been confused by seeing exception messages not encountered in their prior experience.

[7] The recording of the times on the server was selected for consistency across all participants in that the same system clock tracked all times.

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