Connoted Hazard of Voiced Warning Signal Words: An Examination of Auditory Components

Todd D. Hollander and Michael S. Wogalter

Department of Psychology
North Carolina State University
Raleigh, North Carolina 27695-7801

ABSTRACT

Signal words, such as DANGER and WARNING have been used in print (visual) warnings with the intention of evoking different levels of perceived hazard. However, there is limited research on whether auditory presentation of these words connote different levels of perceived hazard. In the present study, five voiced signal words were used to produce sound clips each composed of the words spoken three times and were manipulated according to the following factors: speaker gender, word unit duration (fast, slow), inter-word interval, (short, long), with the sound level held constant. Results indicate that the sound clips with short word unit duration were given higher carefulness ratings than long word unit duration ($ps < .01$). The results showed a similar pattern of ratings for the signal words as shown in research using print presentations. Implications for the design of voiced warnings are described.

INTRODUCTION

Research on warnings has increased in the last two decades. The focus has mainly involved print (visual) warnings. Research has identified some of the components of print warnings that facilitate communication of hazards (Chapanis, 1994; Edworthy & Adams, 1996; Wogalter, Kalsher, Frederick, Magurno, & Brewster, 1998). For example, Chapanis (1994) found that the signal word DANGER is best associated with the color red. However, print may not be the best medium to communicate safety. Auditory warnings might be useful in workplaces when the visual processing system is overloaded such as in cluttered environments like system control rooms and aircraft cockpits. These environments involve tasks with high visual workloads that can dominate visual attention and decrease the likelihood that a visually presented warning will be seen.

Most of the research addressing signal words have focused on printed warnings. However, two recent studies have examined issues associated with signal words in auditory warnings. Edworthy, Clift-Matthews, and Crowther (1998) found that voiced warning signal words spoken in an appropriate manner were perceived to be more urgent than those spoken in an inappropriate manner. Barzegar and Wogalter (1998) found that spoken signal words are perceived to be more urgent when spoken by female voices as opposed to male voices. They also found that emotional voicings produced greater precautionary intentions than monotone voicings. Since the same words were used in both voicing conditions, the effects found between conditions must be due to the physical characteristics of the sounds.

Other research and applications of auditory warnings have involved nonverbal warnings. Recent research has evaluated the characteristics of nonverbal components that enhance perceived urgency (e.g., Edworthy & Adams, 1996; Haas & Casali, 1995). Edworthy and Adams (1996) found that changing pitch and speed affected perceived urgency. Furthermore, Haas and Casali (1995) demonstrated that shorter inter-pulse intervals were perceived to be more urgent than longer ones.

Recently, voice chips have enabled spoken warnings to become technologically feasible which has increased the need for research on the effects of paralinguistic components of spoken warnings (i.e., pitch, intensity and duration) on perceived urgency.

Although there is research on non-verbal auditory sounds with those manipulations, no one has physically manipulated the components of the same spoken signal word sound unit.

Wogalter and Silver (1990, 1995) had participants rate how careful they would be to a set of signal words. Results indicated that participants rated DEADLY higher than DANGER which was in turn rated higher than WARNING and CAUTION. The latter two words did not differ. Furthermore, all of these terms were rated higher than NOTICE. Other studies have found similar results.

Given the relative lack of research on verbal warnings, the present study focused on two characteristics that have been previously shown to affect perceived carefulness of nonverbal warnings. Voiced signal words were manipulated with respect to word unit duration and inter-word interval (IWI) for a three word clip. A word clip consists of three repetitions of the same signal word. The words were spoken by three male and three female speakers. Intended carefulness ratings were measured for each signal word presentation.

METHOD

Participants

Twenty North Carolina State University (NCSU) undergraduates (11 males and 9 females, mean age of 21.3 years, SD = 4.9) participated for research credit in their Introductory Psychology courses. The ethnic/racial composition as reported by participants was 75% Caucasian; 10% African-American; 10% Asian and 5% other. In addition, three female and three male Caucasian NCSU students were employed to speak the signal word stimuli.

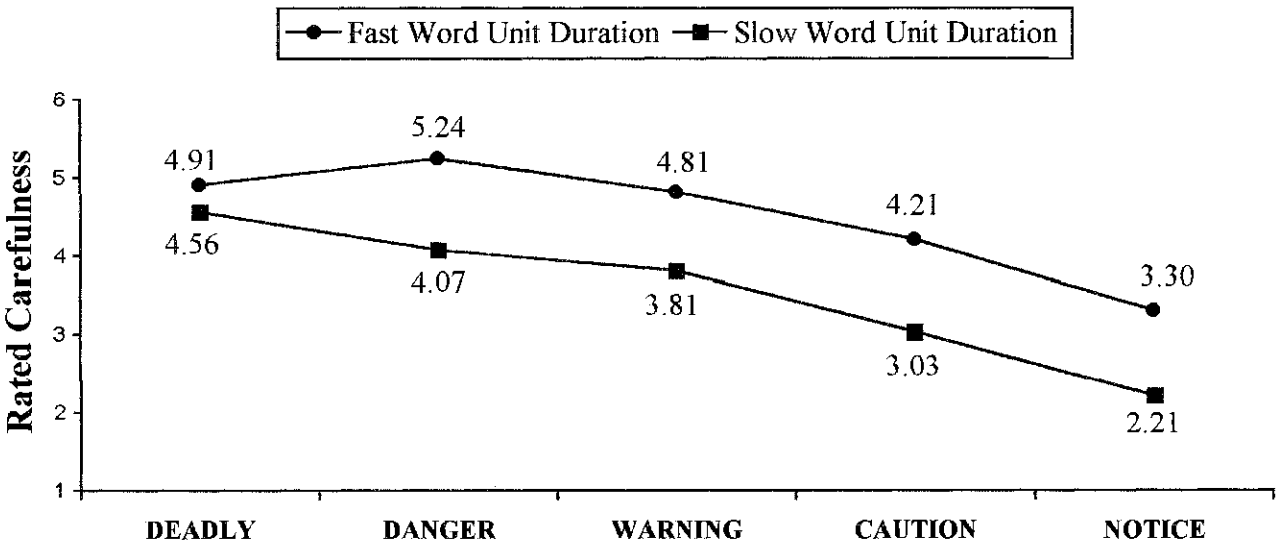
Materials & Equipment

The spoken words used as stimuli were produced by having the six speakers individually speak each of the five signal words once into a microphone connected to an Apple Macintosh computer. The words were recorded, digitized, and manipulated using Macromedia's Soundedit 16 software. Each recorded term was placed into a sequence of three repetitions (e.g., "Warning—Warning—Warning"), which was considered a single sound clip. The sound clips were manipulated by altering word unit duration (fast vs. slow) and inter-word interval (short vs. long) from all six speakers for all five words resulting in a total of 120 sound clips.

Word unit duration was manipulated by changing the speed of each word within the sound clip. From the onset to the end of each of the three words within each sound clip, the speech rate was either increased by 50% (fast rate) or decreased by 50% (slow rate). Inter-word interval (IWI) was manipulated by adding silence in between each of the three repetitions of the sound clip. For each sound clip (e.g., "Warning-Warning-Warning") there were two gaps that were either .25 or .50 seconds of silence, which produced the IWI manipulation (short vs. long, respectively). Pitch level was held constant for all 120 sound clips by using a sound level meter placed at the participants listening position. The 120 sound clips were each separated by 6.0 seconds of silence.

Procedure

Participants read written instructions that included the information to rate the following sound clips according to how careful they would be if they heard that particular sound. These instructions were also presented verbally by the experimenter. The sound clips were presented by an Apple Macintosh computer to participants in one of three random orders. During the silent period between clips, participants wrote down their ratings on a single sheet of paper that had a numbered list of 120 blank spaces. Participants were told to rate each sound clip even if they did not understand the sound clip fully. Participants made judgements for all 120 sound clips on a 9-point Likert scale from 0 to 8. This scale was provided on a sheet of paper with the even-numbered anchors having terms: (0) Not at all careful, (2) Slightly Careful, (4) Careful, (6) Very Careful, and (8) Extremely Careful.



RESULTS

The data were examined using a 2 (Participant gender: male vs. female) X 2 (Speaker gender: male vs. female) X 3 (Speakers per gender) X 5 (Signal Words: DEADLY vs. DANGER vs. WARNING vs. CAUTION vs. NOTICE) X 2 (Word unit duration: fast vs. slow) X 2 (Inter-word Interval: short vs. long) mixed-model design analysis of variance (ANOVA). All except the first variable were within-subjects variables.

The ANOVA showed a significant main effect for speaker gender, $F(1, 18) = 13.06$, $p < .01$. Female speakers ($M = 4.2$) produced higher carefulness ratings than male speakers ($M = 3.9$).

The ANOVA showed a significant main effect for signal words, $F(4, 72) = 34.2$, $p < .001$. Post hoc Tukey HSD test indicated that the signal words DEADLY ($M = 4.7$), DANGER ($M = 4.6$), and WARNING ($M = 4.3$) were rated significantly higher than the signal words CAUTION ($M = 3.6$) and NOTICE ($M = 2.8$), $ps < .05$. Also, CAUTION was rated significantly higher than NOTICE, $p < .05$.

There was no significant difference between short ($M = 4.1$) and long ($M = 4.0$) IWI, $F(1, 18) = 1.6$, $p > .05$.

The ANOVA also indicated the presence of a significant interaction between signal word and spoken duration, $F(4, 72) = 5.4$, $p < .01$. Figure 1 shows the means for this effect. Examination of this figure shows the same basic pattern of the signal words as described in the signal word main effect. Simple effects analysis showed that for all words, except for the word DEADLY, the difference between Fast and Slow word unit duration was significant, $ps < .05$.

DISCUSSION

The present study supported the results of earlier work by Barzegar and Wogalter (1998) and Edworthy et al. (1998) showing that a female voice elicits higher carefulness ratings than male voices.

This study also supports earlier work on the connoted hazard of printed signal words. Similar to studies using printed signal words, the present results indicated a general trend of high to low carefulness ratings from DEADLY to NOTICE.

However, the pattern of significant differences was somewhat different from past research. Most research has found significant differences between DEADLY and DANGER, and between DANGER and WARNING with no difference between

WARNING and CAUTION. The present results did not show a significant difference between DEADLY and DANGER and DANGER and WARNING but did show a significant difference between WARNING and CAUTION. The reason for the dissimilarity of the present findings with past research may be due to methodological differences between studies. The present study used voice presentation while earlier signal word research used visual presentation. Further research in this area will assist in determining if there is a consistent difference between visual and auditory signal word presentations.

The present study also manipulated two physical components of spoken signal words: Word unit duration and IWI. Voice clips with the shorter word unit duration produced higher carefulness ratings than voice clips with the longer word unit duration. The fast and slow word unit duration effect was consistently different across all signal words except for the word DEADLY. One possible explanation for this finding is that the sound parameters comprising the word DEADLY were less intelligible at the faster (shorter) duration. However, the general finding is that the word-unit duration corresponds with nonverbal auditory warning research showing that faster sound rates produce greater levels of perceived urgency (Edworthy & Adams, 1996; Haas & Casali, 1995).

The results also show that physical modification of voiced stimuli can affect their impact. This research is an initial step toward producing effective auditory warnings. The present study examined only a few of the many components that could be examined. Further investigations might explore features such as frequency, phonetic composition and repetition effects. With the additional information that research can provide, construction of spoken auditory warnings can be produced to effectively warn individuals of hazards.

ACKNOWLEDGEMENTS

We thank Kevin McKenna for his assistance with production of auditory stimuli and data collection.

REFERENCES

ANSI (1998). *Accredited Standard on Safety Signs and Colors, Z535.5.* Arlington, VA: National Electrical Manufacturers Association.

Barzegar, R. S., & Wogalter, M. S. (1998). Inteuded carefulness for voiced warning signal words. *In Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting,* 1068 – 1072.

Barzegar, R. S. & Wogalter, M.S. (1998). Effect of auditorily-presented warning signal words on intended carefulness. *Contemporary Ergonomics 1998* (pp. 311-315). London, UK: Ergonomics Society.

Chapanis, A. (1994). Hazards associated with three signal words and four colours on warning signs. *Ergonomics, 37,* 265 – 275.

Edworthy, J., Clift-Matthews, W., & Crowther, M. (1998). Listeners' understanding of warning signal words. *Contemporary Ergonomics 1998* (pp. 316 – 320). London, UK: Ergonomics Society.

Edworthy, J., & Adams, A. (1996). Speech warnings. In Edworthy, J. and Adams, A. (1996). *Warning Design: A Research Prospective,* (pp. 179 - 198). London: Taylor and Francis.

Haas, E. C. & Casali, J. G. (1995). Perceived urgency of and response time to multi-tone and frequency-modulated warning signals in broadband noise. *Ergonomics, 38,* 2313 – 2326.

Wogalter, M. S., Kalsher, M. J., Frederick, L. J., Magurno, A. B., & Brewster, B. M. (1998). Hazard level perceptions of warning components and configurations. *International Journal of Cognitive Ergonomics, 2,* 123 – 143.

Wogalter, M.S., & Silver, N.C. (1990). Arousal strength of signal words. *Forensic Reports, 3,* 407-420.

Wogalter, M.S., & Silver, N.C. (1995). Warning signal words: connoted strength and understandability by children, elders, and non-native English speakers. *Ergonomics, 38,* 2188-2206.