Using a Computer Simulated World to Study Behavioral Compliance with Warnings: Effects of Salience and Gender

Barbara L. Glover and Michael S. Wogalter
Department of Psychology
North Carolina State University
Raleigh, NC 27695-7801

ABSTRACT

Warning signs are intended to alert persons to potential dangers in the environment. Despite its importance, empirical studies measuring behavioral compliance with warnings are limited due to methodological difficulties and ethical considerations in conducting the research. The present study used a computer simulated world as a new method for studying behavioral compliance. Such simulations can be constructed to appear realistic, thus maintaining ecological validity, while allowing control over experimental conditions. Three factors (time stress, salience, and sign type) were manipulated to determine their effects on a simulated egress task from an underground mine. Gender was also introduced as an additional independent variable. Results indicated signs with salient features increased compliance compared to signs without those features. Time stress and sign type failed to show significant effects. In general, women complied more frequently than men. Use of computer simulated worlds in warning compliance research is discussed.

INTRODUCTION

Warnings are placed on products and in workplaces to ultimately invoke safe behavior. To be effective in producing compliance behavior, the warning message must successfully be processed in a series of information processing stages (McGuire, 1980; Lehto & Miller, 1988; Wogalter & Laughery, 1996). These stages include attention, comprehension, attitudes/beliefs and motivation. Most research on warnings has used subjective preference and memory methods to assess processing at the intermediate stages prior to behavior. Some studies have assessed behavioral intentions which are subjective measures that are presumably related to behavior. However, relatively few studies have evaluated actual behavioral compliance with warnings. The reason there are so few studies of this type is that the research is difficult to do. Empirical evaluation of compliance requires behavioral observation which is frequently time and labor intensive since the critical events such as accidents occur infrequently and unpredictably (Wogalter, Godfrey, Fontenelle, Desaulniers, Rothstein, and Laughery, 1987; Wogalter & Dingus, in press). Just as important is the fact that exposing persons to potentially dangerous situations is unethical, except perhaps in special circumstances. Moreover, time and limited research budgets frequently prohibit such data collection efforts.

A possible alternative method is to measure behavior in a computer simulated environment. To date, simulation methodology has not been employed in warnings research. Under controlled conditions this methodology could permit cause and effect inferences to be drawn, while not exposing participants to any "real" danger. Such simulated worlds might be useful in testing the effectiveness of variants of signs under more realistic conditions than methods employing subjective judgments via questionnaires.

The purpose of the present research was to determine whether the use of a computer simulated world could be used to test warnings. The simulated world was an underground coal mine with many tunnels, alternate routes, and intersections. The scenario was a mine evacuation (egress). Three factors were examined: sign salience (presence vs. absence), time stress (low vs. high), and sign type (workplace vs. directional).

Numerous studies in the warnings literature indicate that features that enhance the salience (e.g., color, pictorials) of a warning can also increase compliance behavior (e.g., see Laughery, Wogalter, & Young, 1995 for a collection of articles). These features include color (e.g., Braun & Silver, 1995), the presence of pictorials (Jaynes & Boles, 1990), among others (e.g., sign size). Also, Magurno and Wogalter (1994) and Wogalter and Rashid (1997) have found that greater time stress reduced compliance compared to lower time stress. Sign type was considered because workplace and directional (arrow) signs are used in actual coal mines (Safety Sign Company, 1995). It was expected that signs with more salient features would promote higher levels of behavioral compliance than signs with less salient features, that higher time stress would decrease behavioral compliance compared to lower time stress. Also investigated was whether there might be an interaction between these two factors. Other research has indicated that time pressure produces a decrement in performance (Moray, Dessouky, Kijowski, & Adapathya, 1991). At high levels of arousal (e.g., under time pressure), attentional resources become more restricted causing a decrement in the ability to discriminate between

stimuli (Ben Zur & Breznitz, 1980; Zakay & Wooler, 1984). Thus, greater time stress combined with signs of lower salience might dramatically reduce compliance (more than would be expected by the linear addition of the two individual effects).

Arrow signs were expected to produce greater compliance due to their simplicity of design and instruction than more complex workplace signs. In research by Collins and Lerner (1981), people comprehended an arrow pictorial at higher levels than a set of more complex fire-safety symbols. Finally, gender was also examined because in a review of research literature, Laughery and Brelsford (1991) reported that in general women tended to comply with warnings more often than men.

METHOD

Participants

Eighty undergraduates enrolled in introductory psychology courses at North Carolina State University participated for research credit (mean age = 20.8 years, SD = 3.6 years). Half were female. Participants were assigned to experimental conditions randomly with the constraint that equal number of male and female participants appeared in each condition.

Design

A 2 (salience: low vs. high) x 2 (time stress: low vs. high) x 2 (type of sign: workplace vs. directional) x 2 (gender) design was used. Type of sign was a within-subjects variable, whereas salience, time stress, and gender were between subjects variables.

Representations of the types of signs used in this study are shown in Figure 1. For the workplace signs, greater warning salience was defined as the presence of a header, large bold high contrast print, and larger overall sign size.

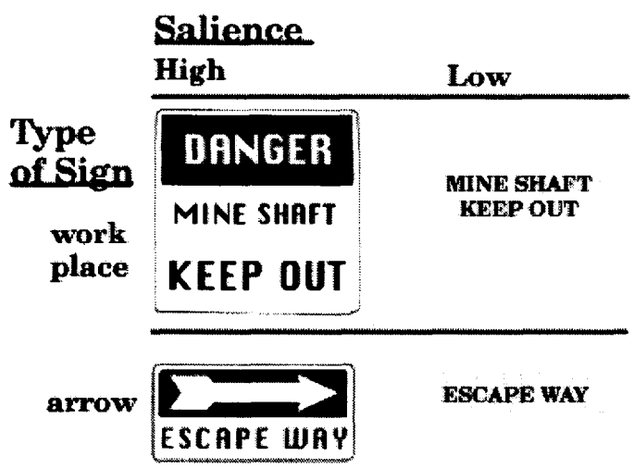

Figure 1. *Sign Representations as a Function of Salience Level and Sign Type*

The header consisted of the signal word "DANGER" set in a red oval on a black background (as specified in ANSI, Z535.2, 1991; OSHA 1926.200, 1993; OSHA 1910.145, 1996). Lower workplace warning salience was defined as the absence of a header with smaller, non bold plain text on a gray background that produced lower contrast. The more salient directional signs, included a white arrow on a red background and the text "escape way" printed in red on a white background. The less salient directional signs had only the text "escape way" printed in smaller non bold plain text on a gray background. Both sign types were based on actual coal mine signs in the Safety Sign Company (1995) catalog.

Participants in the high time stress condition were told they must exit the mine very quickly because there was a fire. Participants in the low time stress condition were told the purpose of leaving the mine was to go to lunch.

All participants was exposed to six different work place safety signs having the following messages:

(a) UNSUPPORTED ROOF KEEP OUT
(b) CONFINED SPACE KEEP OUT
(c) MINE SHAFT KEEP OUT
(d) HIGH VOLTAGE KEEP OUT
(e) EXPLOSIVE LOADED HOLES KEEP OUT
(f) LETHAL GAS KEEP OUT

The participants were also exposed to six directional (arrow) signs that were identical except for the arrow direction. All signs that a given participant viewed were of the same salience level (low or high). There were a total of 24 intersections in the mine. Twelve intersections had warning signs and 12 had distracter signs (e.g., "May is mine history month"). Signs were randomly assigned to intersections, and 5 different random orders of signs were used.

The main dependent variable was behavioral compliance, which was defined as the extent to which the participant adhered to the experimental signs. For each of the workplace signs, a participant complied if he/she did not enter the dead-end hallway located adjacent to the sign. For each of the directional signs, a participant complied if he/she went in the direction indicated by the sign.

Materials

The entire virtual world was created and rendered using Virtus Walkthrough Pro 2.5.1 (Virtus, Inc. Cary, North Carolina), and displayed on a 14 inch (35 cm) color monitor connected to an Apple Power Macintosh computer. An example view is shown in Figure 2. The Virtus software recorded a video record of each participant's path. The simulated coal mine consisted of a series of connected tunnels in a maze-like pattern with many choice points where the participant had to decide which way to go. At each choice point, a safety sign indicated whether or not to take a particular route or not. The tunnels were rock face with dirt on the floor. The lighting throughout the tunnel was dim. All participants started and exited at the same points. There was only one exit in the mine and no looping tunnels.

Figure 2. *View of Coal Mine*

There were three different types of intersections in the VR coal mine: Obvious-T, Blind-T, and Standard-T. An Obvious-T intersection had a long dead-end tunnel straight ahead of the direction the participant was traveling, and another hallway where he/she could turn. A Blind-T intersection occurred when the hallway the participant was traveling through ended and he/she could turn either left or right (one of these directions was always a dead-end). A Standard intersection occurred along a long hallway where the participant could either keep going straight or turn off (the turn off was always a dead end). A map of the coal mine layout with descriptions of the intersection types is shown in Figure 3.

A questionnaire asking demographic (e.g., age, gender) and computer-experience information was also used.

Procedure

Pre-experimental training. The participant was first asked to sign a consent form. After receiving preliminary instructions, each participant was trained on how to navigate through a virtual world. The training used a virtual world resembling a museum that was different in appearance from the coal mine. The purpose of the training was to make the participant comfortable with using the mouse to navigate in a virtual world. Participants had practice moving the mouse around corners and down long hallways. The training lasted approximately 10 minutes.

Experimental session. The experimenter started the coal mine program and placed the participant at the starting point in the mine. The experimenter then told the participant their mission which was either (a) to leave the mine to go to lunch and there was no need to rush, or (b) to escape from the mine as quickly as they could because of fire (participant needed to rush). All participants were run individually and each person had up to one hour to exit the mine.

RESULTS

In the main analysis, there were two compliance scores for each participant, one for the workplace signs and one for the directional signs. For each type of sign, compliance was the proportion complied out of a total of 6 signs.

To determine the reliability of the scoring, a random sample of 30 (out of a total of 80) of the participants' virtual walks was re-evaluated by a second independent judge. The inter-rater reliability was 96% (number of agreements on compliance divided by total number of agreements and disagreements). The few disagreements mainly occurred in the high time stress, low salience condition.

Performance Data Analysis

A 2 (time stress) X 2 (sign type) X 2 (salience) X 2 (gender) mixed-model analysis of variance (ANOVA) was conducted on the proportion compliance scores. Type of sign was a within-subjects factor; the remainder were between-

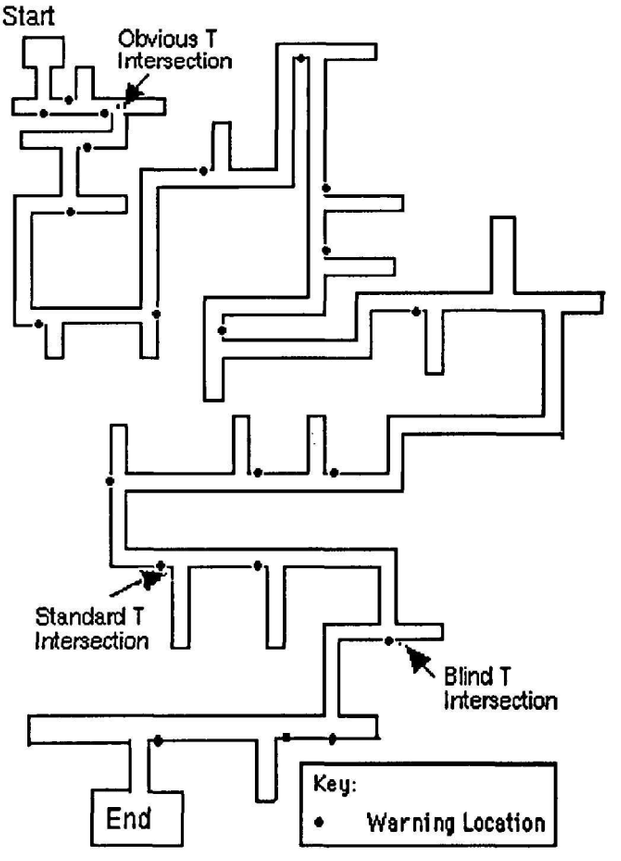

Figure 3. *Layout of the Coal Mine*

subjects factors. There was a main effect of salience, $F(1, 72) = 54.80$, $p < .0001$, and a main effect of gender, $F(1, 72) = 5.59$, $p < .02$. Participants exposed to high salience signs ($M = .84$) were significantly more likely to comply than participants exposed to the low salience signs ($M = .44$). Females ($M = .70$) were significantly more likely to comply than males ($M = .57$). There were no other significant effects (main effects or interactions).

Type of Intersection Analysis

A separate ANOVA examined intersection type (Obvious-T, Standard-T, and Blind-T), as a within-subjects variable instead of type of sign. Type of sign was not included because only escape way signs were located at all three types of intersections. Workplace signs were only located at standard intersections. Sixteen data points were excluded from the analysis because one of the 5 random sign orders had no escapeway signs at an Obvious-T intersection. As in the other analysis, both salience, $F(1, 112) = 101.05$, $p < .0001$ and gender, $F(1, 112) = 8.71$, $p < .01$ produced significant main effects. Also, there was a significant main effect for type of intersection, $F(1, 112) = 5.04$, $p < .01$. A comparison of means revealed that Obvious-T intersections ($M = .82$) produced a significantly higher compliance than the Standard ($M = .66$) or Blind-T intersections ($M = .65$).

The ANOVA also showed a significant interaction of salience and intersection type, $F(1, 112) = 8.91$, $p < .0003$. The means for this interaction are shown in Figure 4. With high salience signs there was no difference in compliance between the intersection types, but with low salience signs, compliance was significantly greater for Obvious-T intersections than for either the Standard-T or the Blind-T.

Other analyses involving various measures of computer experience as an independent variable failed to show significant and/or readily interpretable results.

DISCUSSION

Compliance for high salience signs was greater than low salience signs for both workplace and directional signs. This effect of salience supports previous behavioral compliance research. In earlier research, color, size of print, bold facing, size of warning, and presence of a header have been shown to facilitate sign noticeability and to increase compliance to warnings (Laughery et al., 1993; Wogalter et al., 1987; Young et al., 1995). Most studies though, have manipulated each of these components separately. The present study is one of the few to examine their combined effect on overall warning salience. Nevertheless, future research might manipulate the components separately in a single study to determine which components have stronger effects.

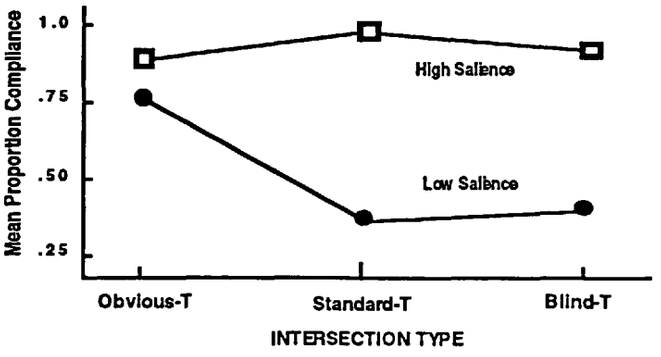

Figure 4. *Mean Proportion Compliance as a Function of Intersection Type and Salience.*

The results also showed an effect of gender. Females complied more often than males. This finding supports previous research (Laughery & Brelsford, 1991).

It had been expected that high time stress would decrease warning compliance compared to low time stress based on recent behavioral research (Magurno & Wogalter, 1994; Wogalter & Rashid, 1997) However, no effect of time stress (main effect or interaction) was found. The failure to find an effect of time stress could be due to its weak manipulation. Time stress in this study was actually perceived time stress since no actual time limit was imposed. Future research might impose real time limits. For example, a count down clock could be displayed on the screen as a participant navigated. Another potential change would be to ensure that the instructions in the low and high time stress conditions are sufficiently powerful to evoke different levels of arousal.

The results also showed no effect of sign type. Although no behavioral research on this variable has previously been conducted, Collins and Lerner (1982) demonstrated higher comprehension for an arrow pictorial compared to a set of other fire-safety symbols. The discrepancy between that study and the present one might be due to methodological differences, but it also suggests that additional research on the effects of sign complexity is needed.

Thus, there are mixed results with respect to the use of computer simulated worlds as a method for studying behavioral compliance with warnings. Two main effects, salience and gender, support findings from other behavior research studies, but the failure to find an effect of time stress did not. Sign type has not been investigated in previous behavioral compliance research, although previous research suggested that they might also differ in compliance. These are only a few of many factors that could influence compliance. There is a need for research on other warning-related factors in the virtual world environment.

Effects of intersection type were examined to determine whether the three types of mine intersections would affect compliance with directional signs. An interaction of salience and intersection type was shown. In general, Obvious-T intersections had greater compliance rates than the other two intersection types. When approaching the obvious-T intersections it is apparent which way to turn because it is

visible which hallways are dead ends without having to look at the warning sign. These intersections were included because they are frequently used in mines to reduce decision-making and facilitate navigation during evacuations. When approaching the Standard-T and Blind-T intersections, one cannot tell which hallway is a dead end. With greater sign salience, compliance at the Standard and Blind-T intersections was as high as that of the Obvious-T intersection, but with lower sign salience, compliance at Standard and Blind-T intersections dropped significantly.

It is possible that some of the participants regarded the simulated coal mine task as a computer adventure game. All of the participants were college students who tend to have extensive experience playing computer and video games. This participant group is also not likely to have experience in real coal mines. Consequently, they might have been less serious in performing the task than other individuals who have more domain specific knowledge such as actual or prospective coal miners. Coal miners might regard the task as a relevant simulation, and if so, it could be used in training exercises for an emergency evacuation.

There are advantages and disadvantages of using the virtual-world method to study warning compliance. Some of the advantages include: (a) external validity by virtue of the setting's appearance, (b) relative ease of world construction and modification, (c) cost-effectiveness of using modifiable software compared to full-scale physical simulators, (d) internal validity because control can be maintained over most extraneous factors, and (e) ability to simulate emergency situations without exposing the participants to danger. Some of the disadvantages include: (a) participants not treating the simulated world seriously, viewing it as a computer game, (b) cost of software and hardware, and (c) potential extraneous effects of computer experience that could produce navigational difficulties for persons less familiar with using a mouse or joy stick. The advantages, however, seem to outweigh the disadvantages.

Future research could employ the virtual world to study more complex decision-making and navigational strategies using intersections with more than two choice points, or using looping hallways. Also, the environment within the virtual coal mine could be made more representative of a fire emergency by, for example, simulating smoke. Future studies could also examine warnings in immersive, three-dimensional worlds which could produce more realistic involvement if the system is capable of producing multi-modal sensations.

Overall, the outcome of this research is generally encouraging, and suggests that the computer-simulated world methodology could be a promising technique for studying behavioral compliance with warnings.

ACKNOWLEDGEMENTS

The authors would like to thank Amy B. Magurno for scoring a sample of the compliance data and for commenting on an earlier version of this article.

REFERENCES

American National Standards Institute (1991). *Sign, color and symbol standards. Z535.1-5.* Arlington, VA: National Electrical Manufacturers Association.

Ben Zur, H., & Breznitz, S. J. (1981). The effect of time pressure on risky choice behavior. *Acta Psychologica, 47,* 89-104.

Braun, C. C., & Silver, N. C. (1995). Interaction of signal word and colour on warning labels: Differences in perceived hazard and behavioural compliance. *Ergonomics, 38,* 2207-2220.

Jaynes, L.S., & Boles, D.B. (1990). The effect of symbols on warning compliance. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 984-987). Santa Monica, CA: Human Factors Society.

Collins, B. L., & Lerner, N. D. (1982). Assessment of fire-safety symbols. *Human Factors, 24,* 75-84.

Cox, E. P., Hoyer, W. D., & Krshna, K. (1995). The behavior effectiveness of on-product warnings in low hazard conditions. *Marketing and Public Policy Conference Proceedings* (pp. 1-10). American Marketing Association.

Laughery, K. R., & Brelsford, J. W. (1991). Receiver characteristics in safety communications. *Proceedings of the Human Factors Society 35th Annual Meeting* (pp. 1068-1072). Santa Monica, CA: Human Factors Society.

Laughery, K. R., Wogalter, M. S., & Young, S. L., Eds. (1994). *Human Factors Perspectives on Warnings: Selections from Human Factors and Ergonomics Society Annual Meetings 1980 - 1993.* Santa Monica: Human Factors and Ergonomics Society.

Laughery, K.R., Young, S. L., Vaubel, K. P., & Brelsford, J. W. (1993). The noticeability of warnings on alcoholic beverage containers. *Journal of Public Policy & Marketing, 12,* 38-56.

Lehto, M. R. & Miller, J. M. (1988). The effectiveness of warning labels. *Journal of Products Liability, 11,* 225-270.

Magurno, A. B., & Wogalter, M. S. (1994). Behavioral compliance with warnings: Effects of stress and placement. *Proceedings of the Human Factor and Ergonomics Society 38th Annual Meeting* (pp. 826-830). Santa Monica, CA: Human Factors and Ergonomics Society.

McGuire, W. J. (1980). The communication-persuasion model and health risk labeling (pp. 99-122). In L. A. Morris, M. B. Mazis, & I. Barofsky (Eds.), *Banbury Report 6: Product Labeling and Health Risks.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory.

Moray, N., Dessouky, M. I., Kijowski, B. A., & Adapathya, R. (1991). Strategic behavior, workload, and performance in task scheduling. *Human Factors, 33,* 607-629.

Occupational Safety and Health Administration (1993). *Accident prevention signs and tags, 1926.200.* Washington, DC: U.S. Department of Labor, OSHA.

Occupational Safety and Health Administration (1996). *Specifications for accident prevention signs and tags, 1910.145.* Washington, DC: U.S. Department of Labor, OSHA.

Safety Sign Company (1995). *Signs & markers: safety signs - labels - decals - markers - tapes, numbers - letters & other identification products.* Cleveland, OH: Safety Sign Company, 82.

Strawbridge, J. A. (1986). The influence of position, highlighting, and imbedding on warning effectiveness. *Proceedings of the Human Factors Society 30th Annual Meeting* (pp. 716-720). Santa Monica, CA: Human Factors Society.

Wogalter, M. S. & Dingus, T. A. (in press). Chapter 4: Methodological techniques of evaluating behavioral intentions and compliance/adherence. In M.S.Wogalter, D.M. DeJoy & K.R. Laughery (Eds.) *Warnings and Risk Communication,* London: Taylor & Francis.

Wogalter, M. S., Godfrey, S. S., Fontenelle, G. A., Desaulniers, D. R., Rothstein, P. R., & Laughery, K. R. (1987). Effectiveness of warnings. *Human Factors, 29,* 599-612.

Wogalter, M. S., & Rashid, R. (1997). Effects of time stress and social monitoring on warning compliance. Presented at the American Psychological Association Annual Meeting, Chicago, IL.

Young, S. L., Wogalter, M. S., Laughery, K. R., Magurno, A. B., & Lovvoll, D. (1995). Relative order and space allocation of message components in hazard warning signs (pp. 969-973). *Proceedings of the Human Factor and Ergonomics Society 39th Annual Meeting,* Santa Monica, CA: Human Factors and Ergonomics Society.

Zakay, D., & Wooler, S. (1984). Time pressure, training, and decision effectiveness. *Ergonomics, 27,* 273-284.