Safety Science, 16 (1993) 637-654
Elsevier

Behavioral compliance with warnings: effects of voice, context, and location

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Abstract

This research examined the effects of several warning sign variables on compliance behavior. Participants followed a set of printed instructions to perform a chemistry task that involved measuring and mixing disguised (nonhazardous) chemicals. Whether or not participants wore protective equipment as directed by the warning was measured. The environment around the sign was either visually cluttered or uncluttered. In some conditions, pictorials, a voice warning, and/or a flashing strobe light were added. The results showed that compliance was significantly greater when the warning was presented in an uncluttered environment compared to a cluttered environment. The presence of a voice warning produced a strong and reliable increase in compliance compared to conditions without a voice warning. No statistically reliable effects of pictorials or strobe were found though the results did show a trend of greater compliance when they were present. In addition, compliance was positively related to memory of the warning, perception of hazard, and reported carefulness. Experiments 2 and 3 directly compared the effect of a posted-sign warning and a within-instructions warning. Results showed that a warning embedded in a set of task instructions produced significantly greater compliance than a similar, larger warning posted as a sign nearby. Experiment 3 confirmed this finding, but, like Experiment 1, no significant increase in compliance was shown when pictorials were added to either warning.

Résumé

Cette recherche a essayé d'examiner les effets de plusieurs variables de la signalétique sur la volonté des personnes à se conformer aux règles. Les participants ont reçu une série d'instructions imprimées pourqu'ils réalisent une expérience chimique impliquant la pesée et le mélange de plusieurs matières chimiques déguisées (non dangereuses). On a vérifié si les participants portaient oui on non des équipements de protection comme l'indiquait la mise en garde. Le fond sur lequel était inscrite la mise en garde était visuellement encombré ou bien clair. Dans quelques cas des dessins, un avertissement sonore et/ou un flash lumineux étaient rajoutés. Les résultats ont montré que l'observation des mises en garde était considérablement meilleure lorsque l'avertissement était présenté sur un fond non encombré en comparaison à un fond encombré. La présence d'un avertissement sonore a eu pour effet une augmentation importante et fiable du nombre de personnes

0925-7535/93/$06.00

se conformant aux recommandations en comparaison à ce qui se passait quand il n'y avait pas d'avertissement sonore. Le flash lumineux et les dessins n'ont pas eu d'effets statistiquement fiables bien que les résultats aient démontré une tendance à un meilleur respect des règles en leur présence. En outre, l'observation du règlement était positivement liée à la mémorisation de l'avertissement, à la perception du danger et à la prudence. Les expériences 2 et 3 ont permis de comparer les effets d'une mise en garde sous forme d'affiche et d'une mise en garde sous forme d'instructions. Les résultats ont démontré qu'un avertissement livré sous forme d'une série d'instructions à exécuter entraînait un bien meilleur respect de l'avertissement en question qu'un avertissement similaire simplement affiché sur un endroit quelconque. L'expérience 3 a confirmé ce résultat mais, tout comme l'expérience 1, ici non plus on n'a pas pu observer d'amélioration dans le respect des mises en garde lorsque ces dernières étaient accompagnées de dessins.

Zusammenfassung

In dieser Forschungsarbeit wurde untersucht, inwiefern sich die unterschiedlichen Warnschildvariablen auf das Maß, in dem diese Schilder befolgt werden, auswirken. Die Teilnehmer befolgten eine Anzahl gedruckter Anweisungen zur Durchführung einer Chemieaufgabe, bei der getarnte (ungefährliche) Chemikalien gemessen und vermischt werden sollten. Es wurde geprüft, ob die Teilnemer die in der Warnung vorgeschriebene Schutzkleidung trugen. Die Umgebung des Schildes war entweder überladen oder nicht. Unter bestimmten Umständen wurden außerdem noch bildliche sowie mündliche Warnungen und/oder eine blinkende stroboskopische Beleuchtung hinzugefügt. Aus den Ergebnissen wurde ersichtlich, daß die Warnung eher befolgt wurde, wenn die Warnung in einer nicht überladenen Umgebung dargestellt wurde, während sie in einer überladenen Umgebung weiniger schnell befolgt wurde. Die mündliche Warnung führte gegenüber der nichtmündlichen Warnung zu einer erheblichen und zuverlässigen Zunahme in der Befolgung. Im Fall der Anwesenheit bildlicher Warnungen bzw. einer blinkenden stroboskopischen Beleuchtung wurden keine statistisch zuverlässigen Effekte festgestellt, obwohl die Teilnehmer durch die Anwesenheit dieser Medien eher zur Befolgung der Warnung geneigt waren. Weiter gab es einen deutlichen Zusammenhang zwischen der Befolgung der Warnung einerseits und der Erinnerung an die Warnung sowie der Gefahrenerkennung und der gemeldeten Vorsicht andererseits. Im 2. und 3. Experiment wurde der Effekt eines Warnschildes mit dem Effekt einer Warnung in einer Anleitung verglichen. Daraus ergab sich, daß die Warnung in der Anleitung viel schneller befolgt wurde als die ahnliche, in größerer Schrift dargestellte Warnung auf einem in der Nähe befindlichen Schild. Dieser Befund wurde im 3. Experiment bestätigt, aber ähnlich wie beim 1. Experiment wurde auch hier bei der Ergänzung von Bildern zu beiden Warnungen keine deutliche Zunahme in der Befolgung festgestellt.

1. Introduction

A major area of concern in workplace safety programs is the effectiveness of warnings intended to promote the practice of safe behaviors. The following statistics reported in Muchinsky (1990) highlight the need for workplace safety programs: (1) "One American worker dies every eight minutes from an industrial accident." (2) "Approximately 1 million productive person-years are lost annually through work accidents." In addition to the concern over human safety, organizations are also aware of the tremendous economic costs in-

volved. Costs stemming from lost productivity, medical benefits, and workman's compensation claims are estimated to be approximately 100 billion dollars per year (Riggio, 1990). Although the establishment of the Occupational Safety and Health Administration (OSHA) in 1970 has aided in decreasing industrial accidents, dangers inherent in certain types of work continue to pose a potential threat to employees.

Due to the concerns discussed above, warnings are increasingly used as a component of organizational safety programs. The major purposes of warnings are to (a) prevent people from engaging in unsafe behaviors and (b) promote appropriate safety behaviors. As such, they include both informational and behavioral components (Wogalter et al., 1989). Wogalter et al. (1987) further point out that, in general, warnings should have four components: (1) signal word, (2) a hazard description, (3) consequences of non-compliance, and (4) instructions for compliance. The following example illustrates the major components of a warning:

> CAUTION! Skin and Lung Irritant. Improper Mixing May Result in a Compound That Can Burn Skin and Lungs. Wear Rubber Gloves and Mask.

The first part of the message contains the signal word CAUTION and provides information about the hazard. The latter part of the message specifies potential consequences and provides behavioral information on how to reduce the potential for harm.

Before the mid 1980s, the focus of warning effectiveness research was primarily on issues of preference, legibility, and comprehension tests. Although work continues in these areas, the focus of warnings research has shifted to the behavioral compliance paradigm. This methodology places participants in settings that appear hazardous but are actually safe because precautions are taken in advance to ensure that the experimental situation is free from real danger. Compliance is assessed by observing the extent to which participants comply with a warning by performing some specific cautionary behavior (e.g., wearing of protective equipment). Behavioral research has identified a number of factors that influence the effectiveness of warnings, including: warning placement (Wogalter et al., 1987), embedding the warning in other text (Strawbridge, 1986), social influence of others (Wogalter, et al., 1989), severity of the consequences (Wogalter and Barlow, 1990), inclusion of pictorials (Jaynes and Boles, 1990), voice communication (Wogalter and Young, 1991), and effort needed to comply (Wogalter et al., 1989).

Most behavioral compliance research has been conducted in a laboratory situation in which a warning was embedded in a set of written task instructions (e.g., Jaynes and Boles, 1990; Wogalter et al., 1987, 1989). Only a few studies have examined the effects of a posted sign and all of this work has been done with field studies (Laner and Sell, 1960; Saarela, 1989; Wogalter et al., 1987;

Wogalter and Young, 1991). No published research to date has examined the effect of a posted warning sign in a controlled laboratory situation. This was one purpose of the current study.

A second purpose was to examine the influence of the environmental context in which a warning is placed. In many real-world situations, warnings signs are located in cluttered environmental surroundings. Although no previous study has examined the effects of visual clutter on warning compliance, related research indicates that irrelevant visual stimuli reduces detection of target stimuli (Cole and Hughes, 1984; Monk and Brown, 1975; Williams and Hoffmann, 1979). Because posted signs are often located outside the immediate field of view, a sign embedded in visual clutter increases the likelihood that it will be missed, and as a consequence, reduces compliance.

The current study also examined the effects of three other factors that might increase the salience of the sign in visual clutter. The variables were: pictorials, a voice warning, and a flashing strobe light. They were chosen because (a) previous research has shown increased compliance for pictorials and voice, and (b) related research suggests potentially promising effects of a flashing strobe light. Jaynes and Boles (1990) showed greater compliance with a warning when pictorials were present within a set of task instructions than when they were absent. Wogalter and Young (1991) showed greater compliance with a voice warning than a print warning within a set of task instructions.

No previous research has specifically examined the effect of a flashing light on warning compliance, but other research suggests that it might increase warning effectiveness. Guzy et al. (1991) have shown that an amplitude-modulated stoplight increased the detection distance of a stoplight compared to a conventional continuous-on stop light. Moreover, human factors guidelines and general perceptual principles (e.g., Sanders and McCormick, 1993) suggest that a flashing light could be an effective means of gaining attention. Thus, it was expected that the presence of pictorials, a voice warning, and a flashing strobe light would increase the salience of a warning sign in visual clutter, and thereby, reduce any camouflaging effect clutter might have.

These factors were not only studied individually but also in combination (i.e., a multi-modal sign). Simultaneous investigation has certain advantages: (a) it allows the determination of each variable's strength in relation to other variables, and (b) it enables examination of any interaction effects. For example, it is possible that the presence of more than one method of enhancing salience produces a synergistic effect on compliance that is greater than would be predicted by their individual effects.

Twelve conditions (ten experimental conditions and two control conditions) were used to examine the effects of the several factors (context, voice, pictorials, and strobe) on warning compliance. Experiments 2 and 3 were conducted to clarify some of the findings revealed in Experiment 1 and are discussed in further detail later.

2. Experiment 1

2.1. Method

Design. The experiment consisted of the 12 between-subjects conditions shown in Table 1. The primary dependent variable was whether participants complied with the warning by putting on protective gear (i.e., wore mask/gloves).

Participants. Approximately half of the 198 participants were Rensselaer Polytechnic Institute (RPI) undergraduates and half were high school students taking undergraduate courses at RPI. Most of the students that attend RPI are experienced in performing the type of task used in this experiment. That is, they have taken high school and/or college chemistry courses. For their participation in this experiment, they received either credit in their introductory psychology courses or remuneration of $5.00. Participants were assigned randomly to conditions. All conditions had 18 participants except for the two control conditions which had nine each.

Materials and apparatus. The experiment was conducted in an actual chemistry laboratory which included bunsen burner hook-ups, laboratory sinks, etc. In order to avoid demand characteristics, participants were not told that they were participating in an experiment on warnings, rather the study was described as an engineering psychology study dealing with how people perform a chemistry demonstration task. The procedure attempted to lead subjects to

TABLE 1

Mean proportion compliance as a function of warning conditions in Experiment 1

Condition number	Condition description	Proportion compliance
(1)	Control–No warning–No clutter	0.111
(2)	Control–No warning–Clutter	0.000
(3)	Posted sign–No clutter	0.278
(4)	Posted sign–Clutter	0.111
(5)	Posted sign–Pictorials–No clutter	0.444
(6)	Posted sign–Pictorials–Clutter	0.167
(7)	Voice warning only–Clutter	0.611
(8)	Posted sign–Voice warning–Clutter	0.667
(9)	Posted sign–Voice warning–Pictorials–Clutter	0.722
(10)	Posted sign–Strobe–Clutter	0.222
(11)	Posted sign–Pictorials–Strobe–Clutter	0.278
(12)	Posted sign–Voice warning–Pictorials–Strobe–Clutter	0.833

Note. Control conditions 1 and 2 each had 9 participants.
All other conditions had 18 participants.

believe that the primary interest in the study was the outcome and accuracy of their chemical mixing.

The laboratory materials were similar to those described in Wogalter et al. (1987, 1989). Actual chemistry laboratory equipment was used such as a triple-beam balance, beakers, flasks, and graduated cylinders. A large supply of plastic gloves and face masks were also available on a laboratory table next to the equipment. A set of written instructions directed participants to weigh, measure, and mix several substances and solutions in a certain order. The substances and solutions were available in large glass containers and labeled by a letter to disguise their true nature. The chemicals (i.e., food-colored water, cooking oil, and powdered soap) were actually harmless. The basic print warning sign (31×31 cm) appeared in black bold print on a background of bright, highly saturated yellow (ANSI, 1984; FMC, 1985). A signal icon (triangle-exclamation point) was located to the left of the signal word CAUTION on the top of the sign. Signal word letter height was 4 cm and the remaining message had letter heights of 1.5 cm. A pilot study revealed that the pictorials used in this study were understood by participants (i.e., gloves and mask should be worn). In some conditions, this print sign: (1) was present or absent, (2) contained two pictorials illustrating the wearing of mask and gloves immediately below the printed statements, (3) had a strobe light attached to the sign that flashed for 8.25 s at a rate of 8 Hz with a duration of 2.2 ms per flash with a peak illuminance of 200,000 lux at 1.22 m, and/or (4) included a digitized male voice vocalizing the identical message as the printed sign.

The 8.25 s vocal warning was stored on an EPROM chip and was presented at an average sound level of 83 dBA. The apparatus allowed the voice warning and strobe to be activated separately or together. The total dimensions of the sign apparatus were 53 cm high, 31 cm wide, and 16 cm deep. The printed sign was positioned on the front, upper two-thirds of the apparatus. Below was the 15 cm diameter strobe light on the left and a speaker (for the voice) on the right. The entire apparatus was custom built by Accuform, Inc. (Brooksville, Florida). The print warning containing the two pictorials is shown in Fig. 1.

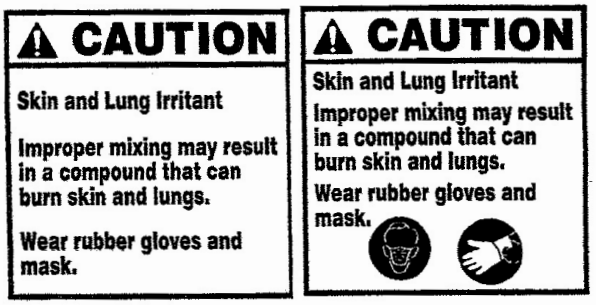


Fig. 1. Pictorial and non-pictorial warnings used in Experiment 1. The non-pictorial warning was also used in Experiment 2.

The area immediately surrounding the laboratory table was either uncluttered (only the warning and the chemistry laboratory materials and equipment) or was cluttered with various kinds of extraneous tools and electronic equipment scattered in front of and on both sides of the laboratory demonstration table.

The strobe and voice were activated when subjects broke an invisible infrared beam as they crossed the area from the doorway entrance to the laboratory table. The warning sign (when present) was always positioned directly facing the doorway. Relative to the front of the laboratory table, the sign was at an angle of 35°. The sign's placement was slightly offset to the right of the participants' forward position, approximately aimed at the participants' left shoulder, and was 1.0 m from the rim of the laboratory table. Table height was 0.95 m. The demonstration area was 1.7 m from the door.

After completing the chemical mixing task, participants were asked to complete a questionnaire. The questionnaire asked whether they: (a) saw masks and gloves, (b) saw or heard warnings of any kind, and (c) if so, what was the specific content of the warning. The questionnaire also requested ratings on the following items: (a) "How *hazardous* were the chemicals?" (b) "How *careful* were you in the task?" and (c) "How *accurate* were you in the task?" All three rating scales were Likert-type 8-point scales verbally anchored at the two ends with (0) "not at all" to (7) "very".

Procedure. Initially, participants were asked to read and sign a consent form which described the study as investigating the procedures and equipment involved in a chemistry laboratory demonstration task. Participants were then asked to wear a white lab coat and shown how to use a triple-beam balance. Next, participants were told that they would be performing the laboratory task in the next room, and that they would be receiving a set of task instructions. Participants were told that they should try to complete the tasks as quickly and as accurately as possible. They were also told that once they began the task they should not ask any questions, and that if any problems arose they should recheck the instructions and do the best that they could. However, since they were supposedly working with dangerous chemicals, they were also informed that if it became necessary, they could ask the experimenter for assistance. This last statement was: (a) required by the Institutional Review Board to prevent students from unnecessary worry in the case that they spilled some of the "chemicals" on themselves and (b) included to add to the realism of the experimental situation.

The experimenter accompanied the participant to the doorway of a second room which contained the chemistry equipment and told the participant to enter the room and begin. In an attempt to reduce experimenter demand characteristics, the experimenter stood in the doorway and recorded whether the participant complied with the warning (wore mask and gloves) before mixing the substances and solutions. After five minutes had elapsed, the participant

was told to stop, was returned to the first room, and was asked to complete the questionnaire. After the questionnaire was completed, participants were debriefed and thanked for their participation.

2.2. Results

Behavioral compliance. The primary dependent variable was whether participants put on and wore protective equipment (mask and gloves) during the demonstration procedure. Participants that put on one piece of protective gear also tended to put on the other piece ($\Phi=0.91$). In the analyses presented below, participants were considered to have complied if they wore at least one piece of protective gear. Analyses considering masks and gloves separately, as well as compliance defined as having put on both pieces of equipment, showed essentially the same pattern of results although the scores were somewhat lower.

Compliance proportion means for the 12 conditions are shown in Table 1. Because there were no differences between the two control conditions ($p>0.05$), in most of the remaining analyses, these two conditions were collapsed into a single No-Warning control condition.

Since our primary interest was in investigating interaction effects, a multifactor analysis of variance (ANOVA) was used. Although it is more typical to use a chi-square test with bivariate data, Cochran (1955) suggested that use of ANOVAs when analyzing this kind of data is appropriate. A one-way between-subjects ANOVA showed a significant effect of conditions, $F(10, 187)=7.12$, $p<0.0001$. As can be seen in Table 2, the structure of the conditions allowed several 2×2 analyses. For example, using conditions 3, 4, 5, and 6 enables one to examine the effects of presence vs. absence of pictorials and clutter and their possible interaction (with the other variables held constant). In this particular analysis, a main effect of visual clutter was found, $F(1, 68)=4.90$, $p<0.05$. The presence of a cluttered environment ($M=0.14$) sig-

TABLE 2

Planned 2×2 tests for Experiment 1

Independent variables	Conditions
Posted sign × Clutter	1, 2, 3, 4
Pictorials × Clutter	3, 4, 5, 6
Posted sign × Voice	2, 4, 7, 8
Pictorials × Voice	4, 6, 8, 9
Pictorials × Strobe	4, 6, 10, 11
Voice × Strobe	6, 10, 9, 12

Note. All 2×2 analyses involved the manipulation of presence vs. absence of the independent variables. Condition numbers refer to the list in Table 1.

nificantly lowered compliance compared to the absence of clutter ($M=0.36$). There was no effect of pictorials, nor was the interaction significant ($ps>0.05$).

Every analysis involving the voice warning showed significant effects ($ps<0.0001$). As can be seen in Table 1, compliance in conditions with the voice warning present was significantly (and substantially) greater than comparable conditions with the voice warning absent. Voice did not interact with the other variables ($ps>0.05$). In addition, no other significant effects were found in the 2×2 analyses ($ps>0.05$). Although the presence of pictorials and strobe appear to show greater compliance compared to their absence, neither produced a significant effect.

Analyses with greater statistical power (χ^2, df$=1$) were also performed to further examine the impact of pictorials, the strobe light, clutter, and voice. The contrasts involved combining conditions to measure the impact of each of these independent variable separately (in terms of presence versus absence). For the pictorials, a contrast compared conditions 5, 6, 9, and 11 (pictorials present) to conditions 3, 4, 8, 10 (pictorials absent). For the strobe, a contrast compared conditions 10, 11, and 12 (strobe present) with conditions 4, 6, and 9 (strobe absent). However, neither contrast showed a significant effect ($ps>0.05$). The contrasts for voice (conditions 2, 4, 6, and 11 versus conditions 7, 8, 9, and 12) and clutter (conditions 1, 3, and 5 versus conditions 2, 4, and 6) were significant ($ps<0.05$).

Questionnaire analysis. Analysis of the questionnaire considered only the data for participants who were in the warning-present conditions ($n=180$). The results showed that if participants complied with the warning, they also reported: (a) seeing the protective equipment ($\Phi=0.45, p<0.0001$), (b) seeing or hearing a warning ($\Phi=0.57, p<0.0001$), (c) believing the situation to be of greater hazard ($\Phi=0.36, p<0.0001$), and (d) being more careful ($\Phi=0.28$, $p<0.0001$). There was no relation between compliance and reported accuracy ($\Phi=0.004, p>0.05$).

Memory for the content of the warning was scored in two ways, strictly and leniently. For the strict criterion, the warning message was divided into idea elements and one point was awarded for each element that was present in an answer. The accumulated points for each participant were then converted to proportion scores. For the lenient criterion, the entire response was scored as correct if there was some indication that a hazard was present or that there was some potential for harm. Both memory measures showed strong positive relations to compliance for the strict, $r=0.59$, $p<0.0001$ and for the lenient criteria, $\Phi=0.55, p<0.0001$. The reliability of the scores was assessed by having another person who was unaware of conditions re-score a random sample of 33% of the responses ($n=59$). Inter-rater agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100. Inter-rater agreement was 94.1% and 98.3% for the strict and lenient scoring, respectively.

TABLE 3

Mean proportions/ratings for questionnaire items as a function of participant compliance in Experiment 1

Questionnaire items	Compliers		Non-compliers	
	M	SD	*M*	SD
See mask/gloves	1.00	0.00	0.64	0.48
See/hear warning	0.91	0.29	0.34	0.48
Strict memory	0.25	0.19	0.04	0.10
Lenient memory	0.71	0.35	0.17	0.38
Hazard rating	2.86	2.15	1.39	1.72
Careful rating	4.26	1.67	3.20	1.86
Accuracy rating	3.91	2.05	3.89	2.05

Note. The first four items are in terms of proportions; the last three items are mean ratings. $N=78$ for compliers; $N=102$ for non-compliers.

A similar pattern was found when participants who complied or did not comply to the warning were separated into two groups. Table 3 shows the mean responses on the questionnaires as a function of participant compliance. All comparisons between compliers and non-compliers were significant ($ps<0.0001$) except for accuracy ($p>0.05$).

Additional analyses, including all subjects, indicated a progressive drop in the mean proportion of persons who reported seeing the protective equipment ($M=0.79$), who reported seeing/hearing a warning ($M=0.59$), and who actually complied with the warning ($M=0.43$).

2.3. Discussion

The results indicated that a warning placed amid visual clutter was less effective in producing behavioral compliance as compared to a warning in a less cluttered environment. These findings are consistent with previous suggestions that warning signs should stand out in order to be noticed (e.g., Cunitz, 1981). The large effect of the voice warning compared to the print warning supports recent research showing that voice warnings can be more effective than print warnings (e.g., Wogalter and Young, 1989).

The failure to show an effect of the flashing light was somewhat surprising because the flash rate (8 Hz) was within the acceptable range of most display guidelines (e.g., Mortimer and Kupec, 1983; Woodson and Conover, 1964). Two possible explanations can be offered. First, the strobe flashed for only a few seconds after being tripped by the participant entering the laboratory room. Second, the light was very intense. Although the on-duration of each flash cycle was very short, its luminance was very high. Most participants looked in

the direction of the sign when it started to flash, but almost immediately turned their head away (presumably because it was annoying and bright). Thus, while the strobe was able to attract attention, it did not hold attention to the sign.

The null effect of pictorials was also somewhat surprising given findings by Jaynes and Boles (1990) who found increased compliance with pictorials. One difference between the two studies is that Jaynes and Boles' warning (and pictorials) was placed in a set of printed instructions whereas it was on a sign in the current study. Results of the questionnaire data indicated that compliance was significantly related to seeing the protective equipment, memory of the warning, perception of hazard, and carefulness. These results indicate that the warning message was received and the means to comply were known. Nevertheless, such awareness did not guarantee compliance by all persons.

The results of Experiment 1 revealed two noteworthy aspects that deserve further study: (1) the overall rate of compliance with posted signs was lower than that obtained in previous research using within-instruction warnings (e.g., Wogalter et al., 1987, 1989), and (2) the addition of pictorials did not result in greater compliance, failing to support the findings of Jaynes and Boles (1990). In order to examine these issues further, two additional experiments were conducted. Experiment 2 directly assessed the effectiveness of warning location. Experiment 3 explored the possibility that the effect of pictorials differ when they are included in a set of instructions versus on a posted sign.

3. Experiment 2

This experiment examined the behavioral effectiveness of a warning placed in two locations (a posted-sign warning versus a within-instructions warning).

3.1. Method

Design and participants. The experiment consisted of four between-subjects conditions: (1) no warning (control), (2) posted-sign warning, (3) warning inserted within a set of task instructions, and (4) both posted-sign and within-instructions warnings. Behavioral compliance was measured by the wearing of protective gear (both mask and gloves) as directed by the warning. Forty-eight undergraduate students participated and were assigned randomly to each of the four conditions (12 per condition).

Materials and procedure. The materials and procedure were similar to that used in the first experiment. The posted-warning sign, when present, was the same as the pictorial-absent warning in Experiment 1. The within-instructions warning, when present, was located in the middle of the chemistry task instruction sheet and was 4% the size (6×6 cm) of the posted sign. It was otherwise identical to the sign except it had a white background. The posted-sign warn-

TABLE 4

Compliance frequencies and percentages of conditions in Experiment 2

Condition	Compliance		Non-compliance	
	n	%	*n*	%
No warning (control)	0	0%	12	100%
Posted-sign warning	4	33%	8	67%
Within-instructions warning	11	92%	1	8%
Posted-sign and within instructions warning	9	75%	3	25%

Note. $n=12$ for all conditions ($N=48$).

ing, when present, was located so it could be seen from the doorway upon entering the laboratory room and was positioned facing the participants 1.0 m away at the chemistry table. The task instructions were available to participants on the laboratory table in the next room and included the within-instructions warning in some conditions.

3.2. Results

Compliance frequencies and percentages are shown in Table 4. The overall Chi-square test was significant, χ^2 (3, $N=48$) $=24.67$, $p<0.0001$. As can be seen in this table, greatest compliance was found when the within-instructions warning was present. Specific paired comparisons, using a χ^2 test with one degree of freedom, among the individual conditions showed that all differences were significant ($ps<0.05$), except between the two within-instruction warning conditions (within-instruction warning only and posted-sign plus within-instructions warning conditions).

3.3. Discussion

Although all warning conditions produced greater compliance than the control condition, the within-instructions warning produced greater compliance than the posted-sign warning. This difference was found despite the fact that the within-instructions warning was much smaller and lacked the bright yellow background of the sign. These findings are consistent with the informal observation of lower compliance to a posted-sign in Experiment 1, than to within-instructions warnings used in previous research. The levels of compliance obtained in the within-instruction conditions were also comparable to those reported in previous research (Wogalter et al., 1987, 1989).

4. Experiment 3

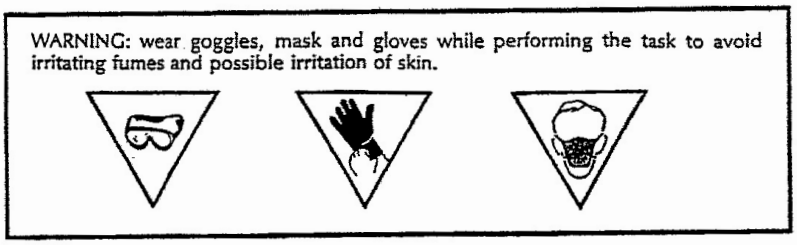
This experiment reexamined the effect of location and also examined the influence of warning pictorials added to the warnings on behavioral compliance.

4.1. Method

Design. The experiment consisted of five conditions: (1) no warning (control), (2) posted sign, (3) posted sign with pictorials, (4) within-instructions warning, and (5) within-instructions warning with pictorials.

Participants. Eighty undergraduates were assigned randomly to each of the five conditions in equal proportions (16 per condition).

Materials and procedure. The materials and procedure were similar to Experiments 1 and 2 except several changes were made to closely replicate the conditions of an earlier study by Jaynes and Boles (1990) that examined the effects of pictorials in a set of written instructions. The exact within-instructions warning (3.5×14.5 cm), pictorials, and protective equipment employed by Jaynes and Boles (1990) were used. The print warning stated: "Warning: Wear goggles, mask and gloves while performing the task to avoid irritating fumes and possible irritation of skin." The three pictorials depicted in Fig. 2 (when present) were previously evaluated and shown to be understood by lay persons (Collins et al., 1982). The posted-sign warning was identical to the within-instruction warning except its area was approximately 10 times larger (11×45.5 cm). When present, it was located 68 cm away from the rim of the laboratory table with the bottom edge 13 cm above the table directly in front of participants' standing position at the table.



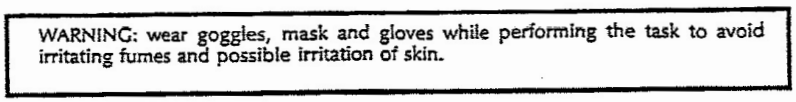


Fig. 2. Pictorial and non-pictorial warning used in Experiment 3.

TABLE 5

Compliance frequencies and percentages of conditions in Experiment 3

Condition	Compliance		Non-compliance	
	n	%	*n*	%
No warning (control)	1	6%	15	94%
Posted-sign warning	3	19%	13	81%
Posted-sign and pictorial warning	3	19%	13	81%
Within-instructions warning	11	69%	5	31%
Within-instructions and pictorial warning	13	81%	3	19%

Note. $n=16$ for all conditions. ($N=80$).

4.2. Results

Compliance frequencies and percentages are shown in Table 5. The overall Chi-square test was significant, χ^2 (4, $N=80$) $=30.76$, $p<0.0001$. As can be seen in the table, the within-instruction warning conditions produced the highest levels of compliance. Paired comparisons among conditions, using a χ^2 test with one degree of freedom, showed that all differences were significant ($ps<0.05$) except among the control and the two posted-sign conditions, and between the two within-instruction conditions.

4.3. Discussion

This experiment confirmed Experiment 2's finding that a posted sign produces a lower rate of behavioral compliance compared to the same warning appearing in a set of task instructions. The results are similar to those reported in previous research (Wogalter et al., 1987, 1989). The study failed to find a significant benefit of pictorials, although there was a positive trend of greater compliance for the presence of pictorials when they appeared in the within-instructions warnings (69% versus 81% for absence versus presence of pictorials, respectively).

5. General discussion

This research showed that a warning appearing in a set of task instructions is more effective in producing behavioral compliance than one on a nearby posted sign. Two explanations can be offered. First, although the sign was near the participant, their visual attention was presumably focused on the task instructions and chemistry materials and not on the surrounding environment. Therefore, it is possible that the warning information presented on the posted

sign was less accessible to participants because it was not within their primary visual field. Second, it is possible that the within-instructions warning might have appeared more relevant to the task at hand than a separate posted warning more distant from the main task material. Thus, subjects may have perceived the warning to be a more important component of the overall set of task instructions than participants in the posted-sign conditions. Since participants were required to read the instructions in order to perform the task, and thus were more likely to see and read the warning, one might conclude that the within-instruction effect was due to demand characteristics. However, it is not difficult to imagine a student performing a chemistry task for a class project or an employee required to perform a chemical mixing or some other task for which using a set of task instructions is necessary. In these cases, and other similar situations, including the warnings within the instructions should be more effective in producing compliance than a posted warning sign.

Interestingly, no effect of pictorials was seen in Experiments 1 and 3. Though it does not confirm Jaynes and Boles' (1990) finding, there was a slight trend of higher compliance when pictorials were included. Nevertheless, the failure to find an effect of pictorials should not be taken as evidence against the use of pictorials in warnings. Indeed, pictorials may have an important function in communicating to populations unable to read verbal commands (e.g., the illiterate, children). Moreover, Young and Wogalter (1990) have found that pictorials in instruction manuals facilitate memory and comprehension of the warning although behavioral effectiveness was not examined in that study.

The failure to show an effect of the flashing light in Experiment 1 was also somewhat surprising because the flash rate (8 Hz) was within the acceptable range of most display guidelines (e.g., Mortimer and Kupec, 1983; Woodson and Conover, 1964). Although the strobe was able to attract attention, it did not hold attention to the sign. Future research varying light luminance and duration times might be useful in determining optimum ranges for promoting compliance.

Results also indicated that a warning sign placed in surrounding visual clutter is complied with less often than the same sign in a less cluttered surrounding (Experiment 1). This result supports a previously untested assumption that the surrounding environment has an influence on behavioral compliance. This effect is undoubtedly due to the sign's greater noticeability in a surrounding environment that is free from potentially distracting stimuli. Another way to increase noticeability is to increase the salience of the sign itself. As we have seen, however, in these experiments, enhancements such as the addition of pictorials and a strobe light had no beneficial effects. Nevertheless, other research (e.g., Wogalter et al., 1987) has found an enhanced sign to be more effective than an unenhanced sign.

The most striking finding from Experiment 1 was the large effect of the voice warning. Its power to influence compliance relative to the other variables in-

dicates that voice warnings may be a very effective means of gaining behavioral compliance. This result supports the finding of Wogalter and Young (1991) showing greater compliance for voice warnings than comparable print warnings.

One implication of this research is that work instruction sheets given to employees should include warnings relevant to the task and environment in which the work is performed. Within-instruction warnings might be particularly useful for less experienced employees following specific task directions and whose attention is likely to be focused on the instructions and tasks, and not on other aspects of the surroundings. Signs, however, could act as occasional reminders for experienced workers who no longer need written task instructions, and would be particularly effective if placed in an uncluttered environment. Additionally, there may be no other available way to inform visitors of work area hazards other than through signage.

Given the strong effect of the voice warning, the potential advantages and disadvantages of such warnings should be mentioned. The two foremost advantages are its attention-getting and omnidirectional qualities. Both are important considerations when visual attention is occupied and focused on other objects or tasks, as was the case in the current study. In addition, reception of a voice warning does not necessarily require reorientation of attention away from a visual task as would be the case for a visually-presented warning. In addition, voice warnings can provide, in a direct manner, specific hazard information (unlike simple nonverbal auditory warnings). Although complex nonverbal auditory warnings can inform, effective communication requires extensive training (Patterson and Milroy, 1980). Voice warnings do not require such training because they take advantage of inherent verbal capabilities and preexisting knowledge. Voice warnings can also benefit certain populations who have difficulty with printed language such as the blind and illiterate.

However, there are some potential problems with the use of voice warnings: (a) voice warnings are not appropriate for very long messages because of the time needed for transmission; (b) voice warnings could be masked in an environment with high levels of ambient noise; and (c) voice warnings would not be appropriate for hearing impaired personnel. In the latter two cases, it is apparent that modality redundancy is necessary to communicate the message in varied contexts and populations. Moreover, in situations where multiple voice warnings could be activated, simultaneous presentation could interfere with message reception. Despite potential disadvantages, improvements in voice recognition and synthesis technology in recent years has made voice warnings more feasible. Development of voice generation chips and digitized sound processors together with a growing number of sophisticated tripping devices to initiate a warning (perhaps a personalized message) voice warnings may be an effective means of gaining compliance in situations where a printed warning alone is inadequate.

Acknowledgement

Faculty support for this research was provided by a grant to the first author from the Paul Beer Trust, Rensselaer Polytechnic Institute.

Portions of this research were presented at the 35th and 36th Annual Meetings of the Human Factors Society.

The authors would like to thank Richard Frei, Raheel Rashid, and Steven Clarke for their help in this research.

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