# A Personalized Speech Warning Facilitates Compliance in an Immersive Virtual Environment

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The effect of a personalized technology-based warning on compliance was assessed using an immersive virtual environment (IVE). Sixty university students performed an end-of-day routine security check in the IVE. Participants were asked to search for and activate safety-related devices, which involved entering several rooms. Just prior to abandoning the first room, participants were incidentally exposed to a posted warning (mandatory to disconnect the music generator) consisting of either a personal warning (i.e., a speech message with the participant's first name) or an impersonal warning (i.e., a auditory beep signal). Compliance was determined by observing whether or not the participants pressed the button-switch as directed by the warning. Results reveal that compliance rate was significantly greater when the warning was personalized. No significant gender differences were found. Implications of these results are discussed in terms of the benefits of effective warnings.

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## INTRODUCTION

Warning people about potential hazards can be an effective method of hazard control and for preventing of injury and property damage. Methods of improving warnings effectiveness are needed.

Technology has been suggested as a way to improve warnings (Wogalter & Conzola, 2002). Technology for warnings includes sensors and integrated circuits to improve detection of persons and/or of a hazard. Also, technology facilitates dynamic and/or multimodal warnings, in which design features and message content are changed in electronic displays. The technology-based warnings can be tailored to the situation and user characteristics, which can aid warning effectiveness by: improving information accessibility, increasing noticeability, reducing habituation, conveying an appropriate perceived hazard level and providing cognitive support to users (Wogalter & Mayhorn, 2005).

Previous research has shown that multimodal warnings produce greater compliance than those that are only unimodal (e.g., only visual). Some research shows that voice warnings, alone, also produce greater compliance than printed, static, traditional warnings (e.g., Wogalter & Young, 1991). However, some other studies show otherwise (e.g., Barlow & Wogalter, 1993, Cohen, Cohen, Mendat & Wogalter, 2006).

Auditory warnings are particularly useful when the users' attention is focused on other aspects of the environment or the task at hand. Moreover, auditory, particularly speech warnings have the potential not only to alert but also to inform. Furthermore, warnings incorporating human speech have the advantage of not being dependent on the users' previous knowledge of the meaning of the sounds to be correctly understood (for a review about auditory warnings see Edworthy & Hellier, 2006; Haas & Edworthy, 2006).

Previous studies have already tested some technological solutions for warnings. For example, an infrared photoelectric detection system, used to initiate a warning presentation when individuals entered a hazardous area, was evaluated by Wogalter, Kalsher and Racicot (1993). Conzola and Wogalter (1999) compared a "talking box," which vocalized safety instructions, to the same instructions printed in the box. Participants exposed to the voice warning carried out the precautionary behaviors more often than those who were exposed to the same warning in print.

Whether people read and comply with a warning can sometimes be ascribed to the factor of perceived relevance. If people believe a warning is irrelevant to themselves or their situation, they may not read or comply with it because they believe it may be directed to others, not themselves (Wogalter, et al., 1993). Adding the user's name to a warning is one way to increase personal relevance (Moray, 1969). Unlike conventional printed warnings, which are not easily changed dynamically, personalization is possible with technology-based warnings.

Only one study has examined the utility of personalized warnings (Wogalter, Racicot, Kalsher & Simpson, 1994). Wogalter et al. (1994) compared the influence of a personalized warning (i.e., displaying the participant's name) with an impersonal warning (i.e., using the word "caution") on compliance (i.e., wearing protective equipment). Results revealed that compliance in the personalized condition was significantly greater than in the impersonal one.

Technological advances may not only benefit the design of warnings but also advance warnings research. Due to recent changes in technology, Virtual Reality (VR) has become mostly widely used by researchers in many areas of study, including warnings and risk communication. Some previous studies have already used VR in warnings research, which has mainly assessed the effectiveness of warnings and exit signs during emergency egress (e.g., Gamberini, Cottone, Spagnolli, Varotto, & Mantovani, 2003; Glover & Wogalter, 1997; Tang, Wu, & Lin, 2009). VR has advantages for investigating factors that influence the effectiveness of warnings (Duarte, Rebelo & Wogalter, 2010). VR is capable of diverse contexts, even hazardous ones. Naturally, increasingly better technology will enable more realism and greater ecological validity. VR provides the means to repeat manipulations, in a systematic manner, benefiting internal validity. Furthermore, VR offers the possibility of overcoming some methodological constraints that have limited research on actual warning compliance research (e.g., ethical and safety issues).

The current study used an immersive virtual environment (IVE) and scenario adapted from Duarte, Rebelo, Teles and Wogalter (2010) to examine two types of technologically-based warnings: personal and impersonal. We hypothesized that presenting a personalized auditory warning (i.e., containing the participant's first name) would significantly increase the compliance rate when compared to the impersonal auditory warning (i.e., containing a tone). Also examined was participant's gender as a factor. There are mixed findings related to gender (see Smith-Jackson, 2006, for a review).

## METHOD

### Design

A between-subjects design with two independent factors was used: the experimental condition (personal and impersonal warning) and the participant's gender. The dependent measure of interest was whether participants complied, or not, with the warning (i.e., if they pressed the button-switch that turned the music off).

### Participants

Sixty university students, ranging in age from 18 to 31 years old (mean = 20.85; SD = 2.29) volunteered for participation. All participants reported normal hearing and normal or corrected-to-normal vision. They all reported that they had no previous experience with IVEs, nor did they have physical or mental conditions that they believed would prevent them from participating in a VR simulation. Participants were assigned to blocks, based on gender, and then, within each block, were randomly assigned to one of two experimental conditions. Males and females were equally distributed in number by the two experimental conditions.

### Apparatus

Participants performed the task immersed in a virtual environment (VE) using the following equipment: two magnetic motion trackers from Ascension-Tech®, model Flock of Birds, with 6DOF, used for the motion detection of the participant's head and left hand; (b) Head-Mounted Display from Sony®, model PLM-S700E; (c) Wireless headphones from Sony®, model MDR-RF800RK; (d) Thrustmaster® USB Joystick; (e) Graphics Workstation with an Intel® i7 processor, 8 Gigabytes of RAM and a nVIDIA® QuadroFX4600. The base structure of the VE was initially designed using AutoCAD® 2009, and then modified by 3ds Max® 2009 (both from Autodesk, Inc.). The VE was then exported using OgreMax v1.6.23 into the ErgoVR system (Teixeira, Rebelo, & Filgueiras, 2010).

### Virtual environment

The VE was created according to a work-related context. As such, the VE was designed as a company headquarters with 4 rooms. The layout can be seen in Figure 1. In terms of visual and auditory complexity or contextual pollution, the VE can be roughly classified as being relatively uncluttered.

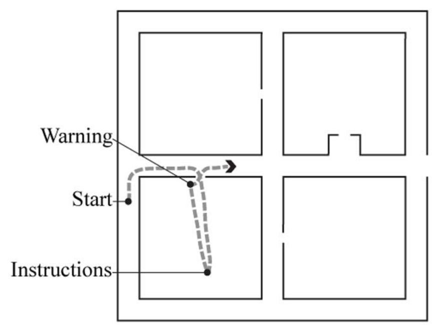


Figure 1. Floor plan of the Virtual Environment, depicting the participants' likely path and the positioning of the target warning.

### Stimuli

The target warning (which indicated that it was mandatory to disconnect the music generator before leaving the room) was designed in accordance with ISO 3864-1 (2002) standard, and was posted on the wall, on top of the button-switch, between the fire-extinguisher and the door, as can be seen in Figure 2.

The warning was a technologically-based, multimodal (i.e., visual and auditory) display, presented in color, in a backlit panel, which was augmented with 5 orange colored flashing lights, 3 on the top and 2 on the bottom, with 4 cm diameter. The flash was twice as bright as the background and was displayed with a flash rate of 4 flashes per second, with equal intervals of on and off time. The warning had two states (i.e., on and off) and was activated by proximity sensors. When activated, the flashing lights were on, the panel was lit and a sound could be heard (i.e., name or tone) according to the experimental condition it was in (i.e., personal and impersonal). In the personal condition, the participant's first name was followed by "Attention to the warning." The female voice for the speech-signal was generated using a Text-to-Speech synthesizer. Further details about the synthesized voice used are reported in Machado et al. (2012). In the impersonal warning, the tone (a beep sound) was given instead of the name. The reason for using the tone/beep was that is the most usual and conventional method of giving a general auditory warning.

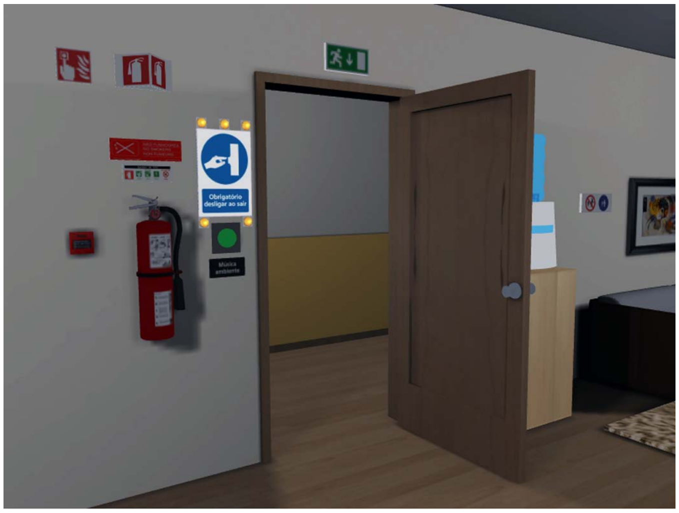

Figure 2. Screen shot of the VE showing the target warning, and the button-switch.

## Procedure

The experimental session was divided into four phases: (a) Introduction; (b) Pre-experimental training session; (c) Experimental session; and (d) Follow-up interview. The phases are described in paragraphs below.

*(a) Introduction.* After signing an informed consent form, the participants filled out a demographic questionnaire. The participants were then introduced to the study's purpose and equipment. According to an incidental exposure approach, the participants were told that the main objective of the study was to validate the new VR software, which was being developed at the ErgoVR, the VR Unit of the Ergonomics Laboratory of the Technical University of Lisbon, Portugal.

*(b) Pre-experimental training session.* The pre-experimental training session consisted of placing the participants in a VE, specifically designed for training purposes, so that they could familiarize themselves with the equipment and the way of interacting within the VE. Participants were asked to explore the VE freely until they felt that they were able to control the input interface.

*(c) Experimental session.* The experimental session began after the participants reported that they were comfortable with the VR system and they took part in one of the experimental conditions. The given scenario was described as a series of end-of-day routine security checks that simulated the closing up of a company's facility at the end of a workday. Participants were asked to search for safety-related devices inside the VE, which involved entering each one of the main four rooms, and once found they were instructed to activate them. Participants were told to start the procedure by directing themselves to the Meeting Room, to look for the initial instructions and then proceed with the task (see the likely path depicted in Figure 1). Just prior to abandoning this room, they were incidentally exposed to a posted warning (which stated that it was mandatory to disconnect the music generator before leaving the room).

*(d) Follow-up interview.* Following the completion of the simulation, the participants were debriefed, interviewed and thanked for participating in the study.

## RESULTS

An alpha level of .05 was used for statistical significance in all tests. Compliance was measured according to whether participants disconnected the music generator. If they did they were given a score of "1" and if they did not they were given a score of "0."

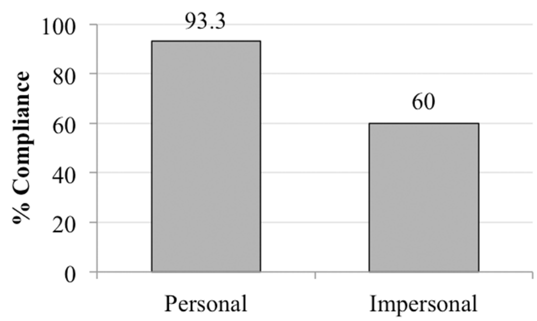


Figure 3. Compliance rate for the personal and impersonal conditions. N=30 in each condition.

Figure 3 presents the compliance rate for the personal and impersonal conditions. Chi-square test indicated a significant difference between conditions, $X^2$ (1, N = 60) = 9.32, $p$ = .005, phi = .39 (medium effect size). The personal condition produced significantly greater compliance than the impersonal condition. The personal condition's compliance rate was 93.3% (28 of 30 instances) compared to a rate of 60% (18 of 30 instances) for the impersonal condition.

Chi-square tests showed no compliance difference between genders ($p$'s > .05) for either warning condition.

## DISCUSSION

The effect of personalized technology-based warnings on compliance was examined using an immersive virtual environment. The warning personalization was operationalized through measurement of compliance with two types of warning: personal and impersonal. The former was a multimodal display containing a speech warning with the participant's first name followed by "Attention to the warning," while the latter contained a beep sound instead of the speech warning. Compliance was assessed by observing the extent to which participants complied with a warning to turn off the music generator.

The results suggest that presenting a personalized warning significantly increased compliance rates when compared to an impersonal warning. These findings are consistent with a study by Wogalter et al. (1994) showing that personalized warnings (with the participant's name) increased compliance. However, it should be noted that, in the present study, the participant's name was conveyed auditorily, while in Wogalter et al. (1994) it was presented visually. Also, the present study uses an IVE whereas the other study involved actual compliance in a chemistry laboratory study.

The gender factor failed to show any significant effect on compliance. This finding fails to support some research showing gender differences on warning-related measures (e.g., Glover & Wogalter, 1997; Vredenburgh & Cohen, 1993, Young, Martin & Wogalter, 1989). However, most research has not found gender differences in most warning studies (see e.g., Smith-Jackson, 2006).

Future research examining the effect of warning's personalization on compliance should examine issues related to the warning design, the environment in which is placed, and specificities of the situation. A number of issues can be raised. First, in this study only one person was present in the room with the warning. Future research could examine the effects of having multiple individuals being simultaneously exposed to the same warning. In those circumstances a different method of personalization – a name for the overall group – may be needed.

Second, the modality used to personalize the warning may influence the compliance outcomes. In the current study, the participant's name was communicated auditorily; previous research has examined the use of visual modality but no study has examined combinations of modalities.

Third, there were particular situational aspects to this study: the warning was a dynamic multimodal display in an environment that was relatively uncluttered and there was no time pressure or multiple concurrent tasks involved. Given that these conditions may be different in real-world contexts, research should examine other contexts, e.g., in environmental clutter, under stress and/or mental workload, to see its effects on compliance with personalized warnings.

The results of the current research, together with findings of Wogalter et al. (1994), lends support for the potential effectiveness of personalized technology-based warnings. Although promising, there are some implications regarding the implementation of these enhanced warnings in real contexts. As described by Wogalter and Mayhorn (2006), their success relies on an effective integration of technology.

There would be a need of electronic devices to present the dynamic and multimodal warning information as appropriate. With the advent of relatively inexpensive flat-panel displays and electronic paper, it is now possible to have electronic displays almost everywhere in our buildings, capable of showing video and playing sound.

Detectors and sensing devices would be also needed to present the warning when and where are necessary. Many solutions are available in the market at low prices (e.g., smartcards, electronic keys or tags, motion sensors) and some are present on smartphones or other mobile devices (e.g., GPS, RF, Bluetooth). These devices, if connected to databases, allow identifying the individual and, thus, giving access to a growing body of personal data (e.g., personal likes, previous knowledge, skill level, special needs), which are critical to the warning's personalization and tailoring (e.g., adjust print size, color contrast, sound properties).

Finally, a number of potential barriers exit and must be considered before implementation: intrusiveness and annoyance, security and privacy, as well as maintenance issues.

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