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Behavioral compliance for dynamic versus static signs in an immersive virtual environment

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ABSTRACT

This study used an immersive virtual environment (IVE) to examine how dynamic features in signage affect behavioral compliance during a work-related task and an emergency egress. Ninety participants performed a work-related task followed by an emergency egress. Compliance with uncued and cued safety signs was assessed prior to an explosion/fire involving egress with exit signs. Although dynamic presentation produced the highest compliance, the difference between dynamic and static presentation was only statistically significant for uncued signs. Uncued signs, both static and dynamic, were effective in changing behavior compared to no/minimal signs. Findings are explained based on sign salience and on task differences. If signs must capture attention while individuals are attending to other tasks, salient (e.g., dynamic) signs are useful in benefiting compliance. This study demonstrates the potential for IVEs to serve as a useful tool in behavioral compliance research.

1. Introduction

Effective warnings are an essential tool of hazard control for products and environments. They can help to maintain safety, reduce injury and limit property damage. Warnings effectiveness as a construct can be conceived and assessed in diverse ways. According to most information processing models, warning processing is described as involving the stages of noticing, encoding, comprehending and behaviorally complying (see Rogers et al., 2000; Wogalter, 2006). Although the pre-compliance stages are critical for warning success, behavioral compliance, the last stage in the process, is often seen as the ultimate measure or "gold standard" of warning effectiveness.

However, from the point of view of conducting research, factors that influence compliance are difficult to investigate because of methodological difficulties and ethical constraints. One main limitation in conducting behavioral compliance studies is that research participants cannot be exposed to real hazards, but it is threat of injury or property damage for which warnings are used. Another difficulty is that producing realistic experimental settings that appear risky but have no actual risk is challenging and can be expensive in terms of money, time and effort (e.g., Wogalter et al., 1987). Consequently, even though there has been a substantial body of research on the topic of warnings, a relatively small proportion of studies have measured actual behavioral compliance (see e.g., Braun and Silver, 1995 for reviews of this literature; Kalsher and Williams, 2006).

Virtual reality (VR) could potentially change this situation by helping to overcome some of the main constraints, since it can simulate risky contexts for use in warnings research (Duarte et al., 2010b). High-quality immersive virtual environments (IVEs) can promote ecological validity while allowing good control over experimental conditions. However, such assumptions require further investigation.

To date, few studies have used VR in warnings research and the majority of them have mainly focused on exit signs (e.g., Glover and Wogalter, 1997; Shih et al., 2000; Tang et al., 2009). VR research on exit signs has demonstrated the ability for this kind of research to measure sign manipulations on compliance. Nonetheless, to fully explore the utility of VR in warning research, other types of signs (e.g., environmental safety warnings) should be tested.

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Furthermore, to increase the ecological validity, compliance with warnings should be tested with participants involved in other types of tasks (e.g., undertaking work-related tasks), which could involve the interaction with potentially hazardous products, as well as provide the opportunity to manipulate situational factors (e.g., emergency, mental workload).

In warning research literature, there are several behavioral compliance studies that demonstrate the effects of sign type (e.g., Wogalter et al., 1993; Wogalter and Young, 1991), and the presence (versus absence) of warnings (Wogalter et al., 1987). In a review of the behavioral compliance literature, Silver and Braun (1999) concluded that the presence of a warning had a positive effect on behavioral intentions and compliance. Several other studies lead to the same conclusion (e.g., Laughery et al., 1998; Wogalter et al., 1987, 1994). Another fairly strong finding is that dynamic presentations produce greater compliance than static presentations (e.g., Wogalter et al., 1993). One explanation for this finding, based on attention theory (e.g., Kahneman, 1973; Wickens and McCarley, 2008), is that dynamic presentations are more likely to be noticed than static ones because of its prominence (also known as salience and conspicuousness) calls attention to itself; more prominent stimuli are better able to switch attention and break into consciousness when attention had been focused on other tasks.

Static signs are traditionally made of paper, metal or plastic and, generally, the method of communication is passive. In contrast, dynamic signs usually use more advanced technology, which allow them to be multimodal and customized. Recent articles suggest that technology-based warnings can be more effective than the traditional solutions (e.g., Smith-Jackson and Wogalter, 2004; Wogalter and Conzola, 2002; Wogalter and Mayhorn, 2005) since they have features that can enhance the warnings in a number of ways, such as making them more noticeable and more resistant to habituation.

1.1. Study goals and rationale

This research was focused on determining whether VR, as a methodological tool, could provide capable means to measure behavioral compliance to warnings. VR's adequacy was determined by examining if it would be sufficiently sensitive to detect differences between manipulated warnings and do so in ways that resemble results found in actual field or in laboratory behavioral-compliance situations (Wogalter et al., 1989). Such finding would be important for warning research because it would give researchers the opportunity to avoid some main limitations of the field and laboratory approaches.

The specific objectives of this research can be summarized as follows: (1) to investigate the effect of warning design variables (sign type: static and dynamic) on compliance with posted safety signs during a work-related task, and with exit signs during an emergency egress; (2) to examine the effect of situational variables (uncued and cued safety signs) on compliance with posted safety signs during a work-related task; (3) to examine a gender effect on compliance.

In the present study, behavioral compliance to different signs was measured using an immersive realistic-appearing virtual environment (IVE). Signs were either static or dynamic or they were absent. A work-related task was designed for the simulation that was believable and allowed incidental exposure to signs as they conduct various parts of the task in the IVE. At several points in the task, participants are confronted with safety signs while taking the role of a security officer who moves through the building to shut down certain systems for the night and who is confronted with different signs as they perform the shutdown task while navigating through the IVE. Later, at a predetermined point, an unexpected emergency (simulated explosion followed by a fire) occurred. As participants try to find their way out of the building, there were static or dynamic exit signs or no signs. Thus, situations (e.g., the unexpected fire) were presented to participants that would be difficult to test in a live setting.

Additionally, the effect of uncued and cued signs was examined. The uncued and cued signs were similar in overall design. The main aspect that differed between them was the task. For the uncued signs, the signage and situation was not pre-cued by instructions given to participants. They were unexpected and they appeared in the VE as participants were attempting to carry out the security shutdown task. The cued signs, however, were pre-cued by being part of the tasks that participants were carrying out as per instructions. Lastly, the emergency exit signs, which were critical for the evacuation taking place later in the simulation, in a separate emergency fire phase.

Attention theory (e.g., Kahneman, 1973; Wickens and McCarley, 2008), suggests that dynamic signs should be more effective at being noticed when individuals are occupied on other tasks than static or no/minimal signs. To switch attention away from the main task, the more salient, dynamic signs would be better able to accomplish this. However, the cued signs might not benefit as much from the dynamic quality since participants were expecting and looking for the information. Thus compliance to cued expected signs ought to be high even when minimally salient. Dynamism might benefit exit signs because emergencies and stressful situations, such as exiting a building due to a fire, could reduce available attention to notice the less salient (static or no) signs. Dynamic exit signs could be better than static ones because in an emergency there is stress that might tie up part of attention capacity. Support for this pattern would be informative, if found.

It is worthwhile to mention that the dynamic signs used were multimodal (i.e., visual and auditory), including flashing lights around the backlit signboards and a tone/beep. The auditory modality has certain advantages, such as omnidirectionality, therefore not dependent from a particular viewpoint, and impossible to shut off. The reason for using a multimodal presentation instead of a unimodal one is it would be expected in presenting dynamic warnings, as most video recording and presentation does (see Cohen et al., 2006 for a review of multi-modal warnings).

Gender was included as a factor in the analysis of conditions, because some research suggests that females are slightly more likely to notice, read and comply with warnings than males (e.g., Glover and Wogalter, 1997; Godfrey et al., 1983; LaRue and Cohen, 1987; Laughery and Brelsford, 1991; Young et al., 1989).

2. Method

2.1. Participants

Data from 90 university students were analyzed. One hundred participated but due to data corruption or simulator sickness, 10 were dropped. The resultant sample was aged 18–35 years old (M = 21.3, SD = 3.2). The experiment was a between-subjects design with participants being assigned randomly to one of three experimental conditions (no/minimal sign, static, and dynamic), each with 30 individuals with the constraint that an equal number of females and males appeared in each condition. All participants completed a consent form. None of them reported prior experience with IVEs or having physical or mental conditions that they believed would prevent them from participating in a VR simulation. All reported having normal or corrected visual acuity. Congenital color vision deficiencies (i.e., total color blindness and strong and mild forms of both protan and deutan deficiencies) were screened