Title

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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 33(33)

ISSN

1069-7977

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Publication Date

2011

Peer reviewed

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Abstract

Computer-simulated training environments are frequently used for having people perform behaviors that pose a risk of injury in the real world. The success of such training applications is likely to be impacted by the degree to which they evoke presence. In the current work, we examined whether adding auditory components to a computer-simulated environment might increase presence, thereby leading risk-taking behaviors to be more consistent with performance in an equivalent real environment. In Experiment 1, participants first observed a human or an avatar perform several cuts on a vegetable and then pause. Participants then used a mouse cursor to indicate where they wanted to see the next cut performed. Compared to participants coordinating actions on behalf of the human, those coordinating actions on behalf of the avatar chose cut locations that had a greater likelihood of producing injury. In Experiment 2, we added an auditory component associated with the expression of pain to the computer-simulated environment and found that participants chose cut locations that were comparable to those in the real environment. This curb in risk-taking was not found in Experiment 3, which used a generic sound associated with the cutting task but not associated with pain. This indicates that the effect found in Experiment 2 was not simply due to directing attention to risky portions of the event. These results suggests that adding auditory components to computer-simulated environments involving risk-taking behaviors may be useful. However, more research is needed in order to effectively select and use auditory components most appropriately.

Keywords: Human-computer interaction; presence; pain; virtual human

Introduction

It is well known that computer-simulated environments can provide a safe setting for humans to perform tasks that carry a risk of injury in real environments. They have been used in a number of significant ways, such as improving medical students' ability to perform surgery (Calatayud, Arora, Aggarwal, Kruglikova, Schulz, Funch-Jensen, & Grantcharov, 2010) and even teaching children to avoid danger while crossing the street (Clancy, Rucklidge, & Owen, 2006). These examples illustrate the importance of exploring methods that may enhance the effectiveness of computer-simulated training environments. One factor that is particularly important for the success of such environments is their ability to evoke presence, where people act and respond realistically, even though they are engaging and perceiving the task through computer mediated platforms (Sanchez-Vives & Slater, 2005; Slater, Lotto, Arnold, Sanchez-Vives, 2009). In accordance, finding ways to increase presence is one approach to facilitate the effectiveness of training in computer-simulated environments.

Studies suggest that computer-simulated environments involving physical risk can evoke presence; however, they are oftentimes limited by the fact that no comparisons were made to an equivalent real environment condition. For example, research has shown that observing a virtual fire beneath one's virtual body leads people to raise their real arms as if avoiding harm (Gamberini, Cottone, Spagnolli, et al. 2003); observing one's virtual body stabbed with a knife leads to increased physiological arousal (Hägni, Eng, Hepp-Reymond, Holper, Keisker, Ewa, et al,, 2008); and being asked to inflict pain upon a virtual character can lead some people to withdraw early from a study (Slater, Antley, Davison, Swapp, Guger, Barker, et al., 2006) In such scenarios, it is easy to see that it is not feasible to carry out parallel real-world conditions for obvious ethical reasons. This not only makes it difficult to determine just how realistic their behavior was, but it also presents difficulties when trying to explore methods that could increase presence in scenarios involving risk of injury.

In a recent study, we developed a method that allowed us examine how people coordinate cutting actions in real and computer-simulated environments (Pierce, Lu, & Harter, 2009). Participants first observed a either a human or avatar perform two cuts on a vegetable and then pause, as if deciding where to make the next cut. A mouse cursor then appeared at the knife’s location and participants moved it to where they wanted to see the next cut made. Results showed that there was no difference in the amount of time spent completing the task or the velocity that people moved the cursor to indicate their desired cut location. This indicates that the computer simulated environment successfully evoked some level of presence. However, results also revealed that when coordinating actions on behalf of the virtual human, people had a greater tendency to choose cut locations that would more likely result in injury.

In the current experiments, we extend our previous research by examining whether providing auditory component to a computer-simulated environment might increase presence and thus mitigating the risk taking tendencies mentioned above. We adopted the general methodology as in our previous work just mentioned. Experiment 1 was a replication study and was used to assess baseline performances in the real environment. We replicated the previous finding, in that those coordinating actions on behalf of the avatar chose cut locations that had a greater likelihood of producing injury. Two subsequent experiments were then conducted in which we simply added two different auditory components to the simulated environment. In Experiment 2, we choose to use a sound that was associated with the expression of pain that could result from cutting one's self. Experiment 3, in contrast, used a more generic sound associated with the cutting task but not directly associated pain.

Experiment 1

Experiment 1 was designed to fulfill two purposes. First, it served as a replication of our previous work, which demonstrated that people are more likely carry out actions in a manner that could result in injury to an avatar in a computer simulated environment than a human in a real environment. Second, it served to assess baseline performance in the real environment, so that comparisons can be made with participants in subsequent experiments where we added auditory cues to the simulated environment associated with pain (Experiment 2) and not directly associated with pain (Experiment 3). Participants observed either an avatar in a medium fidelity environment or a human in a real environment. The avatar/actor, holding a piece of food with one hand, performed several cuts on it and then paused as if deciding where to make the next cut. Participants then used a mouse cursor to indicate where they wanted to see the next cut performed. Given that different input devices can significantly influence how motor-based tasks are performed (MacKenzie & Jusoh, 2001; MacKenzie, Kauppinen, & Silfverberg, 2001; MacKenzie, Sellen, & Buxton, 1991), participants in both environments enacted actions using a standard computer mouse.

Method

Participants. Fifty-two undergraduates were recruited from the Texas A&M University – Commerce.

Materials and Design. The experimental stimuli consisted of a movie involving a human and a parallel simulation involving an avatar to accompany our two between-subjects conditions: *human enacting actions* and *avatar enacting actions* (see Figure 1).

Figure 1: Snapshot taken from simulated environment at the point where the avatar paused.

For the stimulus movie, a male actor used a knife to slice a cucumber into pieces. He also performed non-risky entrance events that preceded the risky culinary activity (moving lettuce to a plate). The movie was recorded with a Sony digital camcorder and filmed from a fixed position that was over and behind the actor’s shoulder. Furthermore, to reduce the possibility of drawing attention to certain features of the movies, it was made in one take, without the use of zooms, cuts, or pans.

The movie served as a model for which a medium fidelity simulation was created, using the Alice 2.0 programming environment (Conway et al., 2000). Each event being simulated was approximately the same length as in real environments. Cutting speeds were determined to be comparable between the movie and its simulated version. A sample simulation and movie was also created for a practice trial, where non-risky actions were enacted (moving cookies to a tray).

Procedure. Participants were randomly assigned to one of the two conditions and then escorted to a desk equipped with a computer mouse and 17 in. monitor. The mouse was aligned horizontally on the desk corresponding to where the second cut was presented on the monitor. An outline was also drawn around the mouse at this location, which served as the designated starting position for each trial. Participants were instructed to leave their right hand on the mouse throughout the experiment and to keep it at the starting position until the experiment prompted for a response.

Before the experimental trial, they were informed of the following: (1) they would observe several cuts made on a cucumber; (2) the computer would pause; (3) a cursor would appear where the knife is located; (4) they should move the cursor as quickly as possible to where they would like to see the next cut made; and (5) then they should click the mouse. On experimental trials, the cursor appeared along the x-axis where the knife was located and along the y-axis at the base of the food being cut. Participants were given one practice trial (indicating with a mouse cursor where they wanted a cookie to be placed) followed by one experimental trial.

The x, y screen coordinates of mouse movement were recorded every 10ms, starting at the time that the cursor appeared and stopping at the time at which participants clicked the mouse. E-prime 2.0 (Schneider, Eschman, & Zuccolotto 2007) was used to control the presentation of the stimuli and for the collection of data. The simulation and movie was presented at a resolution of 1024 x 768 and at an average frame rate of 32 frames per second for the simulation and 30 frames per second for the movie. This experiment took approximately 5 minutes to complete.

Injury Index. This measure was created to indicate how much injury the human or avatar would likely incur if the cut location chosen by the participant were actually performed. To calculate the index, the x pixel location that was just to the right of the left index finger was subtracted from the x pixel coordinate corresponding to the location of the desired cut. It was reasoned that since the knife remained perpendicular to the object for each cut, participants might infer that subsequent cuts would be made the same way. Operating under this assumption, the left index finger would become increasingly injured as the participant moved the desired cut location further to the left of the x pixel coordinate located just to the right of the left index finger (see Figure 1). Smaller values on this index are indicative of greater potential for injury. For example, a score of zero on the injury index would indicate that users suggested the cut location right at the finger tip, whereas a score of negative 5 would indicate that the suggested cut locations passed the finger tip and thus brought injury to the avatar.

Results & Discussion

As illustrated in Fig 2, an independent samples t-test revealed a significant effect of task environment on the injury index, t (50) = 2.28, $p < .05$, indicating that participants chose cut locations much closer to the avatar's non-cutting hand (*M* = .35; *SE* 3.17) than the human's non-cutting hand (*M* = 10.85; *SE* = 3.34). This data replicates our previous finding with a new group of participants. Furthermore, it provides baseline performance for those in the human enacting actions condition, which can be compared to those in the simulated environment receiving a sound associated with the experience of pain (Experiment 2) or a sound that is not directly related with the experience of pain (Experiment 3).

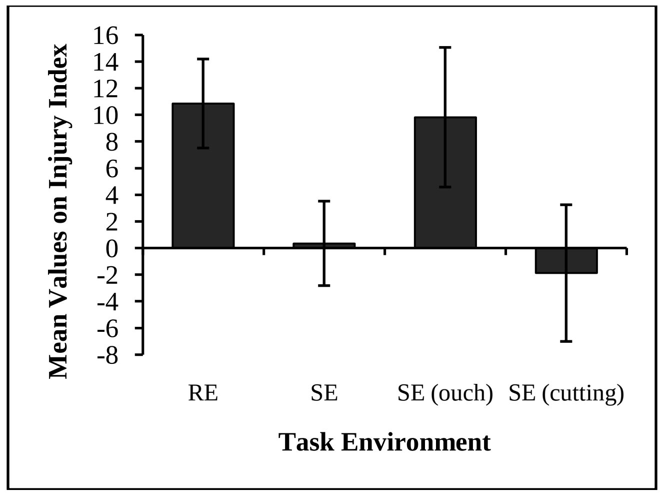

Figure 2: Performance in each condition (RE = real environment & SE = simulated environment). Error bars represent standard errors of the means.

Experiment 2

Experiment 1 showed that people decided to perform cutting actions at location that had a greater potential for injury when coordinating actions in a computer simulated environment than in a real environment. In Experiment 2, we used the same methodology as in Experiment 1, with the exception that we added a voice to the simulated environment saying "ouch" each time the avatar made a cut. The aim of this experiment is to see whether a providing a sound component directly related to the human expression of pain could increase presence and reduce the risk taking that was found in Experiment 1.

Method

Participants & Design. Whereas the human enacting actions condition was comprised of those from Experiment 1, data from a new group of 22 participants was used for the avatar enacting actions condition. The new participants recruited for this between-subjects study were drawn from the same participant pool as described in Experiment 1.

Materials. The materials were identical to those used in Experiment 1, with the exception that a voice saying "ouch" was heard each time the avatar performed a cut. This was achieved by performing a series of audio/videos editing. First, the cucumber simulation and the audio file were imported into video and audio tracks using Cubase, which is a professional music production software program. Third, the audio track was edited so that the voice saying "ouch" was synchronized to the cutting actions in the simulation, followed by the creation of a modified audio file. Fourth, the cucumber simulation and modified audio file were imported into VirtualDub and then combined into a single audio/video file.

Procedure. The procedure was identical to that in Experiment 1.

Data Analysis. The data analysis was identical to that in Experiment 1.

Results & Discussion

As illustrated in Fig 2, an independent samples t-test revealed no effect of task environment on the injury index, t (46) = .17, *p* = .87, indicating that participants chose cut locations that were a comparable distance from the avatar's non-cutting hand (*M* = 9.82; *SE* =5.24) and the human's non-cutting hand (*M* = 10.85; *SE* = 3.34). These results indicate that using a pain-related word as an auditory cue could curb risk taking and make performance comparable to those in the a parallel real environment.

Experiment 3

Experiment 2 provided some evidence that adding an auditory cue signaling pain can lead people to choose cut locations that were comparable to those in the real environment. In Experiment 3, we used the same methodology as in the previous experiments, with the exception that we added the actual cutting sound while preparing cucumber to the simulated environment each time the virtual character made a cut.

Method

Participants & Design. Whereas the human enacting actions condition was comprised of those from Experiment 1, data from a new group of 26 participants was used for the avatar enacting actions condition. The new participants recruited for this between-subjects study were drawn from the same participant pool as described in Experiment 1.

Materials. The materials were identical to those used in Experiment 1, with the exception that participants heard a cutting sound each time the avatar made a cut. The audio/visual editing method was the same as described in Experiment 2.

Procedure. The procedure was identical to that described in Experiment 1.

Data Analysis. The data analysis was identical to that described in Experiment 1.

Results & Discussion

As illustrated in Fig 2, an independent samples t-test revealed a significant effect of task environment on the injury index, t(50) = 2.08, *p* < .05, indicating that participants chose cut locations much closer to the avatar's non-cutting hand (*M* = -1.88; *SE* = 5.13) than the human's non-cutting hand (*M* = 10.85; *SE* = 3.34). This result indicate that at least in our experimental set-up, the cutting sound did not curb risk-taking.

General Discussion

The current findings suggest that adding the dimension of sound to computer-simulated environments, can lead risk-taking behaviors to be more comparable to how they occur in a parallel real environment. This is consistent with the body of research regarding presence and provides support that sound can be a cost-efficient way to increase a computer-simulated environment's ability to evoke presence. However, it appears that not all sounds are equal and effective, as we only found that the sound expressing pain curbed risk-taking.

It is tempting to speculate why the sound component expressing human pain was effective for reducing risk-taking. Recent research has demonstrated that simply hearing a word associated with pain can trigger activity in ACC and insula (Richter, Eck, Straube, Miltner, & Weiss, 2010). A number of studies have implicated these cortical areas as being involved not only with the experiencing pain first-hand, but also when perceiving other humans in pain (see Decety & Grezes, 2006). However, these areas appear to be less involved in situations where mediated representations of humans are in painful situations (Gu and Han, 2007). It is thus possible that people may embody pain less extensively in computer-simulated environments and that this contributed to participants being riskier in our initial computer-simulated condition where no sound was provided. The pain-related word may have in turn reduced risk taking because it facilitated the environment's capacity to evoke an embodied experience, which some believe is an important aspect of presence (e.g., Biocca, Harms, & Burgoon, 2003; Schubert, Friedman, Regenbrecht, 1999).

The current work is by no means free of limitations. First, we only used two different sounds ("ouch" & "knife cutting") within one particular setting (i.e., cutting vegetable). There are a range of possibilities regarding the use of sounds and how they might be implemented in different scenarios, as well as, a variety of different computer simulated environments. This raises an important concern regarding how future research is needed to help better understand how to approach selecting and using auditory cues appropriately for different training scenarios involving risk. Second, participants only received one critical trial. It is an open question as to whether receiving multiple trials with an auditory cue might at some point lose its effectiveness.

Acknowledgments

This research was supported by grants from the National Science Foundation (IIS 0742109 and IIS 0916749) and Texas A & M University-Commerce Faculty Research Enhancement Program. Any opinions, findings, and conclusions or recommendations expressed in this material do not necessarily reflect the views of the National Science Foundation. We would like to thank Lakshmi Pydikondal afor building the simulated environments, as well as, Rachel Bailey and Heather Grimes for helping with data collection.

References

Biocca, F., Harms, C., Burgoon, J. K. (2003). Toward a more robust theory and measure of social presence: review and suggested criteria. *Presence 12*(5), 456–480.

Clancy, T. A., Rucklidge, J. J., & Owen, D. (2006). Road crossing safety in virtual reality: a comparison of adolescents with and without ADHD. *Journal of Clinical Child and Adolescent Psychology, 35,* 203-215.

Conway, M., Audia, S., Burnette, T., Cosgrove, D., Christiansen, K., Deline, R., et al. (2000). Alice: lessons learned from building a 3D system for novices. *Proc. CHI*, pp. 486–493.

Gamberini, L., Cottone, P., Spagnolli, A., Varotto, D., Mantovani, G. (2003). Responding to a fire emergency in a virtual environment: different patterns of action for different situations. *Ergonomics, 46* (8), 842–858.

Gu, X., & Han, S. (2007). Attention and reality constraints on the neural processes of empathy for pain. *NeuroImage*, *36*, 256–267.

Hägni, K., Eng, K., Hepp-Reymond, M. C., Holper, L., Keisker, B., Siekierka, E., et al (2008). Observing virtual arms that you imagine are yours increases the galvanic skin response to an unexpected threat. *PLoS ONE, 3*(8), e3082.

MacKenzie, I. S., & Jusoh, S. (2001). An evaluation of two input devices for remote pointing. *Proceedings of the 8th IFIP International Conference on Engineering for Human-Computer Interaction* (pp. 235-249). Heidelberg, Germany: Springer-Verlag.

MacKenzie, I. S., Kauppinen, T., & Silfverberg, M. (2001). Accuracy measures for evaluating computer pointing devices. *Proceedings of the ACM Conference on Human Factors in Computing Systems* (pp. 9-16). New York, NY: ACM Press.

MacKenzie, I. S., Sellen, A., & Buxton, W. (1991). A comparison of input devices in elemental pointing and dragging tasks. *Proceedings of the ACM Conference on Human Factors in Computing Systems* (pp. 161-166). New York, NY: ACM Press.

Pierce, D., Lu, S., & Harter, D., 2009. Enacting actions in simulated environments. *Proceedings of the Inaugural World Conference on Innovative Virtual Reality*. New York, NY: ASME Publishing.

Richter, M., Eck, J., Straube, T., Miltner, W. R., Weiss, T. (2010). Do words hurt? Brain activation during the processing of pain-related words. *Pain, 148,* 198–205.

Sanchez-Vives, M., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews Neuroscience, 6,* 332-339.

Schneider, W., Eschman, A., & Zuccolotto, A. (2007). E-Prime 2 reference guide. Pittsburgh, PA: Psychology Software Tools Inc.

Schubert, T.W., Friedman, F., & Regenbrecht, H.T. (1999). Embodied presence in virtual environments. In: Paton R, Neilson I (Eds.). *Visual representations and interpretations*. Springer-Verlag, London, pp. 268–278.

Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., Barker, C., et al. (2006). A virtual reprise of the Stanley Milgram obedience experiments. *PLoS ONE, 1*(1), e39.

Slater, M., Lotto, B., Arnold, M. M., & Sanchez-Vives, M. V. (2009). How we experience immersive virtual environments: the concept of presence and its measurement. *Anuario de Psicologia*, *40,* 193-210.