Effects of Co-location and Crossmodal Interaction between Haptic, Auditory and Visual Cues in Presence

Raquel Viciana-Abad[1] and Arcadio Reyes-Lecuona[2]

[1] Department of Telecommunication Engineering, University of Jaén, Spain
{rviciana}@ujaen.es
[2] Department of Electronic Technology, University of Málaga, Spain
{areyes}@uma.es

Abstract. The elicited sense of presence in a virtual environment (VE) is affected by the sensory cues provided during the interaction. Moreover multimodal integration may also be a contributing effect in this factor. The experiment presented analyzes the extent in which the addition of haptic, auditory and visual cues, as well as the integration that may take place between them, affects presence. We also analyze the effects of co-location between visual and haptic sensory modalities. Thus the experiment has a between subject design, where 16 subjects interact in a co-located condition (C)using the Reachin display and the other 16 in a non co-located condition (NC). The system used is a virtual version of the "Simon" game and subjects are requested to complete a memory task which consists in reproducing sequences, via selecting buttons. Results of this experiment have shown how firstly haptic cues are the principal modality for eliciting sense of presence and secondly the existence of differences in the benefits of multimodality between the two conditions.

Keywords: multimodal integration, haptic, co-location, presence.

1 Introduction

The analysis of the influence of sensory information in the elicited sense of presence is still open to discussion. Many researches have established that the sense of presence is proportional to the actions the environment allows the user to accomplish ([1], [2]). Although definitions of immersion and presence are not yet clearly delimited, many authors affirm that interaction fosters and sustains immersion, thereby enhancing the sense of presence. A main goal of this research is the analysis of how sensory sources should be provided as an output for the system attending to human capabilities that participants in a VE might use. A lot of research exists on separately examining the influence of haptic, auditory or visual ([3], [4]) senses in the elicited sense of presence. However, the literature is surprisingly limited on the analysis, in the same experiment, of these three sensory cues in order identify the modality that has the main influence eliciting presence.

M. Ferre (Ed.): EuroHaptics 2008, LNCS 5024, pp. 832–837, 2008.

Nowadays several VEs provide multiple sensory stimulation, which has been named as multimodality, but less attention has been paid to the evaluation of how the addition of different sensory cues may affect the elicited sense of presence that could be reached only with one of the sensory sources. In addition, there are only a few studies ([5],[6],[7]) where the main issue is the analysis of cross-modal or mixed mode effects, attending to the three stimuli being provided in bimodal or trimodal conditions. Furthermore, the analysis of these sensory cues' influence has been made in terms of task performance or mental work-load but not concerned directly with presence measurements. Thus, we have tried to identify firstly, which sensory cues (visual, auditory, or haptic) more positively affect the elicited sense of presence, and secondly we have also analyzed whether the inclusion of two modalities together or even three may benefit the results already reached by one of the modalities in an isolated way.

Many researchers have evaluated the addition of auditory and visual cues in the feedback provided to the participants in order to improve their interaction within a VE. The inclusion of haptic modality, which is referred as to "the sensory modality involved in touching objects within a natural or synthetic environment", has also been analysed in the last ten years, due to the development of new devices that were able to provide haptic perception of virtual objects. Nevertheless, haptic devices have initially been used in a NC condition. We refer to a NC condition when the visual and the haptic stimulation are not coherently provided, that it to say, the location where users feel that they are touching an object does not match with the location where they perceive visually this object. Nowadays certain haptic devices allow interaction in a C condition, therefore, researchers ([8],[9]) have used them to provide haptic feedback in the interaction within a VE. Furthermore, these researchers have also evaluated the benefits in task performance of providing visual and haptic cues in C condition. In this sense, we stress the necessity in the current study, about the evaluation of the benefits of co-location in presence. Indeed we think that the requirements attending to the sensory information provided may be different in both conditions.

2 The Testbed System

The system used as a testbed reproduces a virtual version of the popular game "Simon" (Figure 1(a)). This game is a simple device that consists of four differently coloured buttons. The interaction with the system is made through a Phantom device (from Sensable technologies), which provides haptic feedback. Participants interact using a stylus, which is part of the Phantom device and is represented in the VE as a wooden pencil. The system produces a sequence (by lightning the buttons and emitting a different sound for each button) and users must then try to reproduce the sequence correctly by pushing the buttons, hence they basically perform a selection task. The length of the sequences is always 5. When the sequence is not reproduced correctly an error sound is emitted and a new sequence is generated.

Multimodal interaction is provided in the system, therefore participants may perceive within the VE, haptic, visual and auditory cues. The interaction with the Simon is made in two different conditions. In one of the conditions the implementation is based on the Reachin workstation (AB Technologies). It consists of a monitor providing stereo display in combination with a standard pair of LCD shutter glasses (Crystal Eyes). The Reachin display provides a co-located visual-haptic setup, where the user looks at the virtual 3D scene via a mirror. On the other condition, the interaction is also made through a Phantom device, but the stereo image is shown on a vertical display. The system provides sound information through headphones, which also isolate users from the external sounds.

3 Method

The purpose of this experiment is the evaluation of the elicited sense of presence during the interaction within a VE with different sensory conditions of feedback indicating a button selection, in order to accomplish a selection task. These feedback conditions consisted in a beep sound depending of the selected button, the button lightning and the sensation of touching it. Aside from independent influence of auditory, haptic and visual sensory sources, the crossmodal influences of these sources were also evaluated. Furthermore, visual and haptic representations of the VE were presented in C and NC conditions in order to analyse differences on the sensory influence.

Participants. Thirty-two participants were recruited from among students and researchers from the Telecommunication Engineering School at the University of Málaga. All participants were quite experienced in computer usage but they were novice users of VR applications and force feedback devices.

Experimental design. The independent variables were the existence or absence of the three different sources of sensory feedback during the button selection and the co-location condition. The experiment has a between subject design for the co-location condition and a within subject design for the sensory conditions. Therefore, this study is a 2x2x2x2 factorial design, with three within subject variables: the auditory (with or without), the visual (with or without) and the haptic (with or without) feedback conditions; and one between subject variable: the co-location condition (C or NC). Participants were divided into two groups named C and NC groups, attending to the co-location condition. In group C, participants were seating in front of the Reachin display, in such a way that they were able to see the virtual game in the horizontal mirror that this display provides. On the contrary, in group NC, participants interacted having the visual game representation displayed in a vertical monitor, thus there was no physical correspondence between haptic and visual workspaces. In both groups, the experience was made up of eight trials (2x2x2 with or without haptic, visual and auditory cues) consisting of five sequences each. Hence, participants performed: one trial without feedback (-); three trials in *unimodal* condition, visual (V), auditory (A), or haptic (H); three trials in *bimodal* condition: simultaneous combination of auditory and visual (AV), haptic and visual (HV) or auditory and haptic (AH); and one in *trimodal* condition (AHV). These trials were shown to the participants in random order.

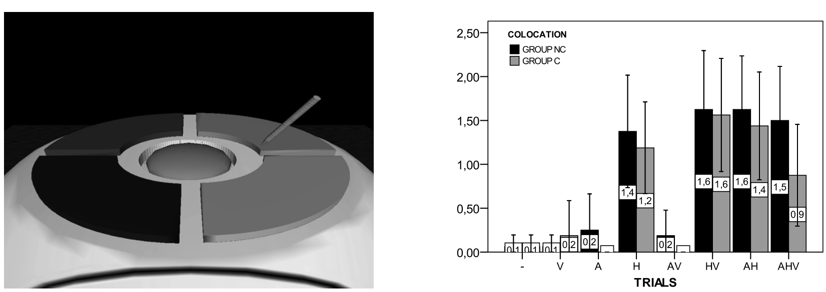
Procedure. The experiment took place in a research laboratory. Upon arrival, participants completed consent forms and received all the task instructions. During the game after every one of the trials, they were asked to answer, using the keyboard, three items about their experience. Once the items had been answered a new trial started once they pressed the space bar. In order to clarify the game mechanism, participants were guided through a training phase where they were able to reproduce one sequence under the eight feedback conditions.

Measurement mechanism. The sense of presence was measured subjectively by a free form questionnaire of three items based on Slater questionnaire [10] and with answers rated in a Likert scale. Task performance measurements as time elapsed between button pressings and scores were also recorded although results are not presented in this paper.

4 Results

Average results of presence for the different trial conditions were evaluated separately for C and NC groups. Thus, figure 1(b) shows average results of the presence questionnaire in the eight trials, calculated computing the number of answers rated over 5 (as Slater proposes), and that we have named the SL factor. The SL factor results showed how the best unimodal condition was haptic, and the difference between unimodal trials and the trial without any feedback was only significant for haptic condition in both groups ($p<0.001$). Differences in visual and auditory conditions were found depending on the co-location condition (see fig. 1(b)). Thus, visual modality was more relevant in group C while the auditory modality influenced more answers in group NC.

As can be also seen in this figure, results in the SL factor in the haptic condition improved slightly when visual and auditory cues were also provided. Thus, results in HV and AH trials were better than those reached in the trial H, in both groups, but without significant differences. Nevertheless, the AV bimodal



(a) Virtual appearance of the Simon game device

(b) SL factor: average values and error interval (95% IC)

Fig. 1. Experiment testbed and SL factor results

modality did not improve results already reached in the A unimodal trial in group NC, and in the V unimodal trial in group C. Furthermore, these results showed how the trimodal trial did not benefit results already reached in trial H in group C and slightly benefit results in group NC. Indeed, results in the trimodal trial (AHV) were worse than the results in the HV and AH trials, in both co-location conditions, although with a greater reduction in group C. We also analysed the influence of the different sensory sources and the interaction between them with a two way ANOVA of repeated measures. This analysis showed how only haptic feedback condition ($p<0.001$) significantly influenced results in both groups. Furthermore, a significant interaction was found between auditory and visual feedback ($F_{1,15}= 4.30$; $p< 0.05$) in the SL factor. This interaction was due to the negative effect of providing both sensory modalities together that make results worse than the results in the trials without any of these two feedback modalities. This negative interaction was translated into a nearly zero value of the SL factor in AV modality and into a reduction in the AHV modality.

Regarding differences between groups, the SL factor did not show a significant difference between co-location conditions, although this factor was higher in group NC (0.83, SD 1.13) than in group C (0.66, SD 1.02). We also analysed possible differences between co-location groups in the average results of the three items separately. This analysis showed with nearly significant difference in the two first items (($F_{1,30}$=4.50; p=0.04; $F_{1,30}$ = 3.17; p=0.08) better results in group C than in group NC.

5 Discussion

Results of the experiment developed in this study have shown how haptic feedback is essential in order to elicit a high level of presence. The addition of auditory and visual cues benefits slightly the sense of presence already reached in unimodal haptic condition. Nevertheless, there is a negative interaction between auditory and visual cues, which arise mainly in co-located condition and leads to a reduction in presence in the trimodal condition. Surprisingly, the addition of more sensory modalities is not always translated into an improvement in presence as we may initially think. Similar findings, about the trimodal condition not being the best, were also found in other works ([6], [5], [7]) but attending to performance measurements and subjective workload or mental demand.

Furthermore in two items, we found a significant difference between co-location conditions, which have shown how the sense of presence elicited has been higher in a NC condition, in nearly all the trials, and more evidently in trials without haptic feedback. This result was not expected because although we did not find a study in which a similar analysis about co-location was made attending to the elicited sense of presence, Swapp's [8] experiment indicated that co-location was a significant factor in improving interaction performance. In the same way, although not presented in this paper, our task performance results are also better in the C condition, but in trials, with more than one sensory modality (bimodal and trimodal). It would seem that the more the virtual experience fits the reality the higher the expectations of the participants are. Hence, in our interaction with computers, we usually interact, using a mouse, in a NC condition, and then our expectations in the interaction in this condition are less than in a situation which is closer to the reality, in which our mental model is constructed attending to a perfect integration between sensory modalities.

Attending only to results in the A and V unimodal trials, we also found, although without significance, how the elicited sense of presence is higher in the visual trial in a C condition while in a NC condition auditory cues benefit to a higher extent. It seems that visual cues lose importance if they are not colocated and their influence is replaced by auditory cues.

Acknowledgements

This work has been partially supported by DIANA research group (PAI: TIC-171) and the project ENVIRA TIN-2006-15202-C03-02.

References

1. Büscher, M., O'Brien, J., Rodden, T., Trevor, J.: He's behind you: The experience of presence in shared virtual environments. In: Churchill, E.F., Snowdon, D.N., Munro, A.J. (eds.) Collaborative Virtual Environments: Digital Places and Spaces for Interaction, pp. 77–98. Springer, Heidelberg (2001)
2. Zahorik, P., Jenison, R.L.: Presence as being in the world. Presence: Teleoperators and Virtual Environments 7(1), 78–89 (1998)
3. Sallnäs, E.L., Rassmus-Gröhn, K., Sjöström, C.: Supporting presence in collaborative environments by haptic force feedback. ACM Transactions on Computer-Human Interaction 7, 461–476 (2000)
4. Whitelock, D., Romano, D., Jelfs, A., Brna, P.: Perfect prsence: what does this mean for the design of virtual environments? In: Zeitschrift Educational and Information Technologies, vol. 5, pp. 277–289. Springer, Netherlands (2000)
5. Cockburn, A., Brewster, S.: Multimodal feedback for the adquisition of small targets. Ergonomics 48(9), 1129–1150 (2005)
6. Jacko, J.A., Barnard, L., Kongnakorn, T., Moloney, K.P., Edwards, P.J., Emery, V.K., Sainfort, F.: Isolating the effects of visual impairment: exploring the effect of AMD on the utility of multimodal feedback. ACM Transactions on Computer-Human Interaction 7, 311–318 (2004)
7. Vitense, H.S., Jacko, J.A., Emery, V.K.: Foundation for improved interaction by individuals with visual impairments through multimodal feedback. Universal Access in the Information Society 2, 76–87 (2002)
8. Swapp, D., Pawar, V., Loscos, C.: Interaction with co-located haptic feedback in virtual reality. Virtual Reality 10, 24–30 (2006)
9. Congedo, M., Lécuyer, A., Gentaz, E.: The Influence of spatial de-location on perceptual integration of vision and touch. Presence 15 (2006)
10. Slater, M., Usoh, M., Steed, A.: Taking Steps: The Influence of a Walking Technique on Presence in Virtual Reality. ACM Transactions on Computer-Human Interaction 2, 201–219 (1995)