

Can audio help navigating in virtual environments? An experimental evaluation

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Abstract: The concept of Interaction Locus (IL) has been introduced to help the users to orient, navigate, and identify relevant interaction areas in 3D Virtual Environments (VE). The IL is a multimodal concept: it adds to the 3D visual scene parallel information channels that are perceived by other senses. In particular, the IL emphasizes the role of music as a navigation aid in a VE. The paper reports two experimental evaluations of the audio component of the IL, as implemented in the web site of a famous Italian Museum. The experiments investigated the different roles (functional or aesthetic) that a music component may play in VE navigation and content fruition. Results suggest that music plays an aesthetic role that the users appreciate very much. It can also play a functional role, helping users to recognise scenes in a VE, provided that the users are informed in advance of the semantic linkage between music and virtual space.

Keywords: Virtual Environment, Usability, Audio Help, Web Museum, Experimental Evaluations.

1 Introduction

In recent years, the number of cultural institutions that offer virtual tours inside 3D Web environments is greatly increased. Examples are the *Louvre Museum* in Paris and the *Van Gogh Museum* in Amsterdam. Virtual worlds, however, are still far from usable and lack of orientation is a major problem (Costalli, 2001). Specific help has to be developed to support the user in acquiring the knowledge of the spatial relations that characterise the VE. The absence of such a help causes a significant degradation of the whole VE usability (Stanney, 2002).

The concept of IL has been introduced in (Pittarello et al, 1998; Pittarello, 2003) to help the users to recognise relevant areas in a VE, allowing them to progressively build a mental map of the environment for navigation purposes. The idea at the basis of the IL is to identify in the VE areas characterised by a specific interaction activity (*Loci*) and to denote them by a co-ordinated set of visual, audio and textual components, which are activated

each time the user enters a specific Locus. The IL is a multimodal concept; it adds to the 3D scene parallel information perceived by other senses. The audio component is related to the morphology of a scene and communicates to the users information related to a position. The textual component provides additional information. For example, the entrance in an IL may be notified with a looped sound and a text appearing in a specific area of the screen.

Several studies have demonstrated that the audio channel can be effectively used to improve visual interaction in computer supported tasks (Brewster, 1994). In particular Blattner and colleagues (1989) defined the earcons as counterparts of the icons, or non-verbal auditory streams used for communicating relevant information during user activity. Earcons were originally defined for use in bi-dimensional graphical interfaces; the IL extended this idea to a 3D environment. This paper reports two experimental evaluations of the IL concept, and in particular of the music as a navigation aid.

2 IL Evaluation

The experiments reported in this paper were aimed at evaluating the IL concept as a navigation aid. In particular, we wanted to understand the role of the auditory component in supporting orientation and navigation. Along this view, we have performed two experiments asking users to navigate a 3D virtual environment in different conditions.

The *German Expressionism* web site was used as a test bed. This 3D environment is part of the official web site of Palazzo Grassi, a famous museum in Venice (Pal. Grassi, 1997). It was designed in 1997 on the occasion of an exhibition of German Expressionism paintings and displays a virtual VRML counterpart of the Einstein Tower, the sun observatory built in Potsdam by Erich Mendelsohn.

A selection of the expressionism works from the real exhibition is displayed in the research rooms and the laboratories of the tower. Users may choose to visit the exhibition following a guided modality or at their own pace, by clicking on the arrows placed below the virtual scene.

Several Interaction Loci are available in the Einstein Tower world. The auditory component is implemented in the form of a background music piece univocally associated to a Locus and automatically activated each time the visitor enters the Locus. Different fragments of musical compositions related to the expressionist period had been selected as the auditory components characterizing the specific interaction areas. The textual component of the IL is implemented in the form of a hypertextual area visualized on the left of the 3D scene. Every time the user enters a locus, textual information is provided to help scene identification (Figure 1).

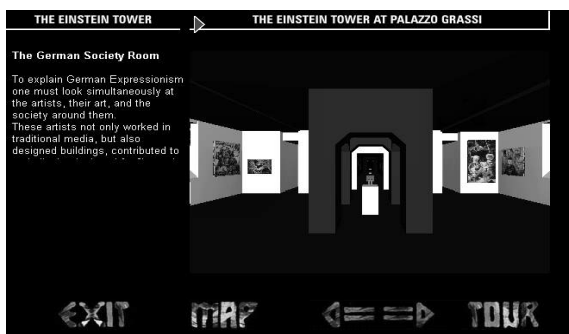


Figure 1: A scene of the Einstein Tower world

3 Experiment 1

The experiment was designed to investigate different roles that a musical accompaniment may play in VE

navigation and content fruition. In theory, the music can have three (if any) positive effects on the user experience and behaviour. Namely, it can play a functional role, an aesthetic role or a combination of them.

In case of a functional effect, the music should help the user to orient, navigate and identify relevant interaction areas in the VE. This hypothesis assumes that a proper use of musical pieces conveys meaningful cues related to the semantic characterisation of the space. It also assumes that this semantic is understood by the users, thus becoming a navigation support. In alternative, the music could provide a mere aesthetic pleasure without conveying semantic meaning related to content and navigation. In this case, it should not improve navigation, rather it should improve the overall user experience of the system. The music could also hamper navigation. Indeed, as navigating in 3D environment is often difficult, an increase in stimulation may augment the mental workload, thus compromising performance.

To investigate these hypotheses, three different system implementations were designed and compared (Table 1). System A is a unimodal version of the German Expressionism web site, no audio is provided. System B is the original multimodal implementation exploiting the IL concept as previously described. System C is a version in which a same musical piece is played as a background accompaniment throughout the navigation, here the music plays only an aesthetic role.

Version	System	Audio	Music role
A	Unimodal	Absent	/
B	Multimodal	Present	Functional
C	Multimedia	Present	Aesthetic

Table 1: Experimental conditions

3.1 Method

Participants

The application topic is a little sophisticated. Therefore, we selected on purpose participants that could get interested and motivated by it. They were 40 master and PhD students of Modern Art and History at the University of Bari, (16 M, 24 F).

Procedure

The experiment was composed of training and two experimental sessions. During the training session, participants used the guided tour option to visit all the rooms and all the exhibits of the virtual museum in a sequence. The guided tour was run in the same condition (without music, with functional music or

with aesthetic music) as the first experimental session.

The experimental sessions consisted of two sets of four tasks each. Participants were required to navigate along a given path for collecting information, such as rooms and paintings names and to record it on an experiment booklet.

At the end of the experiment, participants filled in a user satisfaction questionnaire. It required a general evaluation of the site with particular attention to ease of navigation, perceived sense of direction, and quality of the music. Two evaluators assisted in the experiment. The entire interaction was videotaped and data were automatically logged.

Design

System A was tested as a control condition to assess baseline values of the web site usability. All participants (N=40) used it together with one of the two audio/present conditions (System B or C). To avoid carry-over effect, the test order and task sets were counterbalanced across participants. Music role (Functional vs. Aesthetic) was manipulated between subjects. Participants were randomly assigned to one condition: 20 people interacted with system B (Functional Music) and 20 with system C (Aesthetic Music). This design had the advantage to test several hypotheses simultaneously, minimising the number of participants, increasing the power of statistical comparisons, and controlling individual variability.

3.2 Results

The evaluation addressed navigation performance and user satisfaction. As regards user performance three different variables were considered: (a) *Errors*: average number of wrong answers per task; (b) *Navigation speed*: average time to navigate through the virtual path per task; (c) *Navigation steps*: average number of clicks on the navigation arrows per task.

Wrong answers accounted for some 12% of the total. Eighteen errors occurred without music, and 20 with music. The sample was split into the two experimental conditions (Functional vs. Aesthetic Music) and independent tests performed on each of them using the Wilcoxon Signed-Rank test to compare the number of errors occurred when navigating with music with those occurred when navigating without music. This is a nonparametric procedure used with two related variables to test the hypothesis that the two variables have the same distribution. No differences emerged.

Navigation speed was normalised by a logarithmic transformations and analysed by a repeated measures analysis of variance with Audio (Present-Absent) as the within-subject factor and

Music (Functional-Aesthetic) as the between-subject one. No significant effects emerged. The average values are illustrated in Figure 2. The same analysis of variance was performed on the navigation step scores, yielding no significant effect.

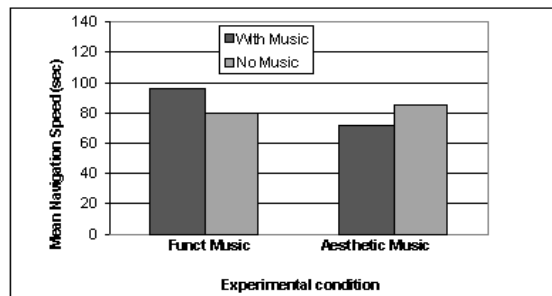


Figure 2: Navigation speed as a function of experimental conditions

Questionnaires and interviews assessed user satisfaction. In total, some 93% of the sample explicitly declared to prefer the musical version. No significant difference emerged between the two musical conditions. A music satisfaction index was computed averaging ratings at 8 semantic differential items covering several evaluation dimensions related to the music played during the evaluation ($\alpha = .82$). On the average, participants declared to be quite satisfied with the music with no difference due to the type of music they listened to. Similarly, no difference emerged with respect to the user satisfaction with the site (as assessed by a 12 items, semantic differential scale) and to the perception of the navigation task.

3.3 Discussion

Our evaluation did not provide support to the hypothesis that the musical component in the IL plays any functional role, i.e. provides a support to user navigation. No differences in performance were found when participants navigated with or without music, nor between the two types of music. However, participants always declared to enjoy the music independent of its intended role, i.e. the aesthetic hypothesis is supported.

A possible explanation of these findings is that the users did not understand the relation of the music with the virtual scene as implemented in the IL. As a matter of fact, the music was quite sophisticated. This may have hampered the recognition of the connection between music and physical space. To the two evaluators who assisted during the experiment, it appeared that the users were actually distracted and annoyed by the music going on or off at some places during the navigation. To test the hypothesis that the results of Experiment 1 were due

to a lack of understanding of the intended value of the music in the IL, a new evaluation was run.

4 Experiment 2

Ten participants were recruited among graduate students at the department of Modern Art and History of the University of Bari. The procedure was exactly the same as that of Experiment 1, but this time participants were explicitly told about the relationship between music and virtual scene. Furthermore, participants used only system A (no Music) and system B (Functional Music).

4.1 Results

All participants used system B first, thus they were compared with participants who followed the same order in Experiment 1. These results are therefore based on 20 participants, 10 from each experiment. For the sake of simplicity, from now on, we will call these two conditions as *Informed IL* and *Uninformed IL* conditions. In the Informed IL participants were explicitly told about the functional role of the music (experiment 2). In the Uninformed IL condition, no explanation at all was given about the link between music and spaces (experiment 1).

Relative performance data were used in the analysis. These include *relative speed*, *relative step*, and *relative errors*. They correspond to performance data obtained in the multimodal system minus performance data obtained in the unimodal one.

Navigation speed was analysed by a t-test analysis. Results demonstrated that, once informed of the functional role of the music, participants actually executed their tasks faster than uninformed participants. The difference is significant $t_{(18)}=1.9$ $p < .05$ (one tail). No significant effects were found comparing the number of steps in the two experimental conditions, but the trend is consistent with that of navigation speed. People in the Informed IL condition tended to navigate less than participants in the Uninformed IL condition did.

4.2 Discussion

The second experiment suggests that the IL has some potentials. Indeed, better performance can be achieved by informing users on the meaning of the music in the IL. Informed participants were faster probably because did not waste time trying to understand what triggered the music on or off during the navigation. Furthermore, they tended to be more precise in their navigation behaviour, as reflected by the lower number of clicks on the navigation arrows.

These results suggest that the functional hypothesis may be valid and the music can actually help people navigate, but the semantics of the music used in the first experiment was inappropriate.

5 Conclusion

Our main question in carrying out the experiments reported in this paper was whether music can help navigating in virtual environments. The outcomes of the experiments show that music plays an aesthetic role that the users appreciate very much. This is certainly an important result since user satisfaction is a significant component of system usability (ISO 9241). Moreover, the second experiment showed that the music can also help users to recognise scenes in a virtual environment, provided that the users are informed in advance of the semantic linkage between music and virtual space.

We are planning further experiments with different 3D worlds to better support these findings, from which useful guidelines for designing multimodal VE can be derived.

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