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MICOLE

Multimodal collaboration environment for inclusion of visually impaired children

Specific targeted research project

Information society technologies

Deliverable D5: Report on the design and evaluation of haptic focus and context displays

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PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

CONTENTS

1 INTRODUCTION

In MICOLE WP2 we have carried out basic research through empirical experiments and prototype construction to find out how to use different senses in user interfaces for visually impaired children. One main objective was to explore the idea of cross-modal equivalence and multi-sensory perception through a series of empirical studies that contrast different representations of information across different modalities. This objective, **Subtask 2.1.2 Focus and context in cross-modal equivalence,** is reported in this deliverable D5 focusing on the second half of the project (after month 18). The second objective was to design, develop and evaluate a range of navigation and control techniques to allow users to explore, navigate and share data, visualizations (such as graphs, tables and charts) and mathematical formulae. This objective is reported in deliverable D7.

Based on the research conducted within Subtask 2.1.1 in months 1-18, we had initial ideas for more in depth investigations into cross-modal equivalence. A substantial amount of work in this year was more fundamental, underlying research that was applicable to several of the themes and across both sub-tasks. This came out of the prototypes in the first year, where fundamental questions arose that needed to be answered. The following sections outline the work undertaken by partners in each of our themes.

Tools and Techniques

During the course of the period, work was carried out examining techniques for presenting information non-visually that would apply across our themes and apply in both sub-tasks of the WP2. These low-level non-visual perception studies are necessary to provide the basic interaction techniques for use in the accessible interfaces designed during the project. Evaluation of these techniques before integration into the MICOLE environment is important such that we design interfaces that are usable by blind and visually impaired users.

Rhythm perception

A key aspect of audio and tactile displays is the use of rhythm to display information. This is commonly used in Earcons and Tactons, for example. Studies were undertaken to investigate unimodal and cross-modal rhythm recognition and short-term memory for rhythms using auditory, visual, and tactile stimulus modalities. This would give us much of the information we would need to incorporate effective rhythmic cues into our interfaces.

Perception and recognition of rhythms has been studied extensively using auditory and visual stimuli. The results of different studies show that auditory rhythms are recognized and reproduced more accurately than visual rhythms. It has also been shown that performance in short-term memory tasks using auditory rhythmic stimuli is frequently superior to that in tasks using visual rhythmic stimuli. However, there are not many studies that have included the tactile modality in presenting rhythmic stimuli. UTA studied auditory, visual and tactile rhythm recognition. The idea was based on studies carried out at UGLAS during the first project year.

Results showed that modality was important with audio being the best, then tactile. There was no effect for the length of the rhythm. In terms of subjective responses participants found that auditory rhythms had the lowest mental demand and frustration, however the tactile rhythms were most preferred. Visual rhythms performed worst in all cases.

Games

Many of the environments built during this project are based around accessible games. Games play a large part of children's lives in social situations but also for learning. There are therefore important social implications for providing games that allow blind and visually impaired children to easily access information, and work and play together with their sighted peers. These games afford us an opportunity to test our techniques for presenting information in a challenging environment that will encourage children to use the environment and therefore test the techniques.

Maze Applications

One important game type has evolved from our work: the maze. This has many interesting properties that make them challenging to play (and design). They test designers' abilities to create good spatial representations, good feedback about location in the maze, interactions techniques, input devices, etc. UGLAS and ULUND have been working together to investigate the best designs for mazes.

Further to this, ULUND continued work on prototypes for the labyrinth application, developing it into a pac-man game. Informal testing of prototypes with blind users (5 children age 10-16) has been done during two user board meetings held during the autumn and one during the spring.

Investigating Alternative Media Space Topologies

Work has been conducted (by FORTH) on a pong game to test different media space topologies. In addition to the planar auditory display, cylindrical and angular one are investigated. Moreover, some alternative audio interpolation algorithms have been investigated, in order to select the most appropriate one. The key issue is that the movement of the game objects among adjacent cells on the speaker grid must be presented effectively and smoothly to blind persons. We have currently evaluated a cylindrical auditory grid. The evaluation has been conducted using blindfolded sighted persons (age 20-25) using a 3x3 auditory grid.

Maps, Charts, and Diagrams

Accessing non-textual information in a non-visual manner is a difficult problem. At school, blind and visually impaired children can particularly struggle with subjects such as maths, geography and physics where important information such as maps, charts and diagrams must be learned. A large amount of work from MICOLE has looked at developing environments that will allow this type of information to be presented through touch and sound. Work on maps and diagrams has been carried out by UPPSALA, METZ and SIAULIAI.

Maps

The aim of this work within MICOLE has been to investigate the usefulness of some existing devices for visually impaired users in the context of reading virtual maps. In the case of shortages detected, the aim has been to try variations in the hardware or software.

Two devices have been studied, the VTPlayer, a haptic mouse from Virtouch, and a touch tablet device developed by ViewPlus. The investigation of the VTPlayer started during the first year with an experiment about the potential added value of the standard tactile information of the mouse for a task consisting of finding states on a USA map. A similar experiment was then made where some parameters of the tactile presentation had been modified with the intention to improve performance. In the experiments the participants had to solve a geographic task, namely to indicate the locations of a series of states in the USA. Further, a draft version of a paper of the first experiment with the ViewPlus equipment has been written and preparations have been made for new experiments about the usefulness of the tactile information provided by the embossed maps.

Summary

Overall, the topics studied gave us insight and empirical results to help in building the MICOLE inclusive environment in WP4. Many of the cross-modal techniques studied in individual prototypes have now been added in the WP4 software architecture. The remaining techniques are planned to be added in the architecture by the end of the project.

As input and output are inherently related when studying haptics, it was not always clear whether a study belongs in task 2.1.2 or 2.2.2. The work in WP2 has been divided between Deliverables D5 and D7 depending on the main research questions in each study. This resulted in such a situation that deliverable D7 is more extensive than D5, but both parts of WP2 have contributed in the work of the project in the same way.

2 CROSSMODAL RHYTHM PERCEPTION (UTA)

Research on rhythm perception has mostly been focused on the auditory and visual modalities. Previous studies have shown that the auditory modality dominates rhythm perception. Rhythms can also be perceived through the tactile senses, for example, as vibrations, but only few studies exist. We investigated unimodal and crossmodal rhythm perception with auditory, tactile, and visual modalities. Pairs of rhythm patterns were presented to the subject who made a same-different judgment. We used all possible combinations of the three modalities. The results showed that the unimodal auditory condition had the highest rate (79.2%) of correct responses. The unimodal tactile condition was close with 75.0%, and the auditory-tactile condition with 74.2%. The rate remained under 70%, when the visual modality was involved. The results show that in addition to the auditory modality, the tactile modality is suitable for presenting rhythmic information.

2.1 Introduction

Rhythms are most commonly perceived through audio. Rhythms and temporal patterns can, however, also be provided through other sensory modalities, like vision and touch. Perception and recognition of rhythms has been studied extensively using auditory and visual stimuli. The results of different studies (Glenberg & Jona, 1991; Glenberg et al., 1989; Kosonen & Raisamo, 2006) show that auditory rhythms are recognized and reproduced more accurately than visual rhythms.

It has been shown that performance in rhythm comparison tasks using auditory rhythmic stimuli is frequently superior to that in tasks using visual rhythmic stimuli (Collier & Logan, 2000). Glenberg et al. (1989) showed through a series of experiments that the auditory superiority is not due to the alerting nature of auditory stimuli, people's greater experience with auditory rhythms, or specific response requirements in rhythm reproduction tasks. Glenberg & Jona (1991) were able to diminish the auditory advantage when chunking of the beats was disturbed or long beat durations were used. Collier and Logan (2000) showed that when comparing the rhythms at fast presentation rates, mixed modality rhythm pairs were as difficult as or more difficult than the visual pairs. At slower presentation rates, the recognition rate of the mixed modality rhythms was between the unimodal visual and auditory conditions.

Rhythm perception through the tactile modality has largely been left uninvestigated. Touch is a cutaneous sense: tactile information is perceived via skin. Perceiving rhythms through the sense of touch is natural. Sounds are based on similar waves as vibrotactile effects. People can, for example, feel loud music also as vibrations. In user interfaces, vibrotactile rhythmic patterns can be used to present information to the user. For example, tactile icons can be used to communicate messages non-visually (Brewster & Brown, 2004).

Tactile stimuli can provide an extension to the interaction channels between computers and visually or hearing impaired users. Vibrotactile stimuli could be used, for example, to give hearing impaired users information about events and states of a messaging device. With blind users, the auditive information channel can easily become overloaded if it is the only sensory modality used for giving feedback to the user. Thus, the use of vibrotactile stimuli could lower the pressure on the auditive information channel.

The use of tactile rhythms can also support people with no sensory impairments, e.g., in mobile devices, wearable computing, and learning tools (Brewster & Brown, 2004, Miura & Sugimoto, 2005).

There are only few studies that have investigated tactile rhythm perception. Kosonen & Raisamo (2006) studied auditory, visual and tactile rhythm recognition in rhythm reproduction tasks. The results showed that the auditory modality dominated the tactile and visual modalities. Performance with the tactile modality was better than with the visual modality.

In the present research, the goal was to acquire basic knowledge about unimodal and crossmodal comparisons of visual, auditory, and tactile rhythms. We used same-different tasks where pairs of rhythm patterns were presented to the user. In rhythm presentation, we used all possible combinations of auditory, visual, and tactile modalities, which resulted in three same-modality conditions and six crossmodality conditions. We also varied the rhythm length within each condition.

The main research question was the following: how accurately same-different judgments of rhythms are made when the rhythms are presented with different combinations of the visual, auditive, and tactile modalities? We also wanted to find out if the length of the rhythm, subjects' experience with haptic devices or experience in music had an effect on the accuracy of the comparisons. In addition, we collected users' opinions about the rhythms presented through different modalities.

2.2 The experiment

An experimental paradigm introduced by Collier & Logan (2000) was used in this experiment. The procedure consists of trials where two rhythms are presented to the subject sequentially, separated by a short interstimulus interval (ISI). On half of the trials, the rhythms are identical, and on half they are not. On each trial, the subject has to decide whether the rhythms were the same or different. The modality conditions were: auditory-auditory (AA), tactile-tactile (TT), visual-visual (VV), auditory-tactile (AT), tactile-auditory (TA), auditory-visual (AV), visual-auditory (VA), tactile-visual (TV), and visual-tactile (VT).

Our hypotheses were that in the unimodal conditions, performance is the best with the auditory modality (AA), the second best with the tactile modality (TT) and the worst with the visual modality (VV). This prediction was based on the results of Kosonen & Raisamo (2006). In the crossmodality conditions, we predicted that performance would be the best when the first rhythm is auditory (AT, AV), the second best when it is tactile (TA, TV), and the worst when it is visual (VA, VT). This prediction was based on the fact that only the first stimulus needs to be stored in memory to make a same-different judgment. In this aspect, the modality of the first stimulus is more critical for the rhythm recognition process. We also expected performance to be better with the short rhythms than with the long rhythms because of their weaker load on the short-term memory. Our hypotheses on the subjective opinions about the modalities were based on the results of Kosonen and Raisamo (2006). We expected the users to prefer the auditory rhythms over the other modalities and to prefer the tactile modality over the visual modality.

2.2.1 Subjects

Twelve adults participated in the experiment. Four of them were women and eight were men. Their age ranged from 25 to 43 years (mean 30.4 yrs, median 29.5 yrs). Seven subjects had experience on rhythms based on a musical hobby. Almost all subjects (11) had at least some experience on haptic devices.

2.2.2 Stimuli

Each rhythm consisted of five or six beats delimited by a 300-millisecond interval. We decided to use three beat lengths that were formed with a ratio 1-2-3: 125, 250, and 375 milliseconds. For the same trials, the rhythmic pattern was presented two times in concession. For the different trials, the second pattern was altered by changing one or two elements. The rhythmic patterns used with all modality conditions are displayed in Table 1. There were 10 same trials and 10 different trials within each modality condition. Overall, there were 180 experimental trials. The patterns that had five beats ranged in duration from 2200 to 2575 ms, and the patterns that had six beats ranged from 2625 to 3125 ms. Mean trial duration was 5669 ms.

The auditory stimuli were presented using pulses of white noise delimited by a 300-millisecond ISI. The tactile stimuli were created with a Logitech iFeel vibrotactile mouse. The frequency of the vibration was 58.82 Hz and the magnitude 10000 (in scale 0..10000). The selection of the parameters was based on user comments in a study that investigated detection thresholds in frequency and magnitude of mouse and trackball vibration (Raisamo et al., 2005). The visual stimuli were displayed on a computer screen with a square object that appeared and disappeared in the pace of the rhythm.

2.2.3 Design

There were two within-subjects factors in the experiment: modality (AA, TT, VV, AT, TA, AV, VA, TV, and VT) and rhythm length (five and six beats). The presentation order of the modality blocks and the trials within each block were randomized separately for each subject.

First pattern (also second pattern in same trials)		**Second pattern in different trials**	
5 beats	**6 beats**	**5 beats**	**6 beats**
SMSLM	MSSMLS	SLMLM	MMSMLL
LMSSL	LSLSSM	LMSSM	MSMSSM
SSMSL	SSSLML	SMMSM	SSMLMS
MMSLS	LMMLSS	SMSLS	LLSLSS
MLSMS	MMSLSS	MSSMM	MSSLMS
SMLLS	LSMSMM	SMLMS	LMMSSM

Table 1. The rhythmic patterns used in the experiment.

2.2.4 Equipment

The tests were run in a usability laboratory using a standard PC computer. The auditory stimuli were played through in-ear headphones and the visual stimuli were displayed on the computer screen. The tactile stimuli were presented via a Logitech iFeel Mouse. The subject wore hearing protectors to mask the sound of the the vibrotactile mouse motor.

2.2.5 Procedure

First each subject was asked for background information. Before the experiment session, the subject got instructions and completed five practice trials. Then the subject was free to begin the 180 experimental trials. The researcher was present in the test room during the test session.

On each trial, the subject was presented with two rhythmic patterns separated by a 300-millisecond break. After both stimuli had been presented, two buttons labelled as *the same* and *different* were displayed on the screen. The subject was instructed to click one of the buttons. After each response, the next trial was immediately initiated.

The experimental trials took about 30 minutes to complete. The subject was allowed to take two short breaks during the test session. After completing the tasks, the subject filled in a questionnaire where he/she was asked to evaluate his/her effort, performance level, mental demand, frustration level, and preference for the modalities. After that, the subject was interviewed about the experiment in more detail.

2.3 Results

2.3.1 The effect of modality conditions

Repeated-measures ANOVA showed a significant main effect of modality ($F(8,88) = 6.699$, $p < .001$). The proportion of correct responses was the highest, 79.2%, in the AA condition (see Figure 1). The second best condition was the TT with 75.0% of correct responses, and close to that was the AT condition with 74.2%. In the rest of the modality conditions, the proportion of correct responses remained under 70%. Pairwise comparisons with paired-samples t-test showed that 18 significant differences were found between modality conditions (11 with $p < .01$ and 7 with $p < .05$) (Table 2).

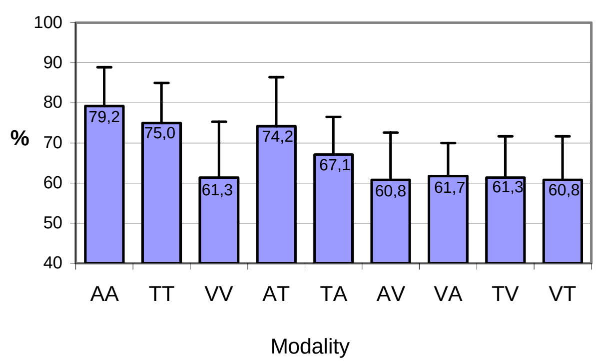

Figure 1. The average proportion of correct responses and their standard deviations in different modality conditions.

	AA	TT	VV	AT	TA	AV	VA	TV	VT
AA		.054	.002	.275	.005	.002	.001	.001	.003
TT	.054		.011	.850	.020	.003	.005	.007	.018
VV	.002	.011		.036	.111	.938	.914	1.000	.925
AT	.275	.850	.036		.058	.022	.012	.005	.040
TA	.005	.020	.111	.058		.128	.127	.009	.210
AV	.002	.003	.938	.022	.128		.830	.920	1.000
VA	.001	.005	.914	.012	.127	.830		.881	.748
TV	.001	.007	1.000	.005	.009	.920	.881		.915
VT	.003	.018	.925	.040	.210	1.000	.748	.915	

Table 2. Statistical significances of the pairwise comparisons of the modality conditions.

2.3.2 The effect of rhythm length

The effect of rhythm length ($F(1,11) = .035$, $p = .855$) and the interaction effect between modality and rhythm length ($F(8,88) = 1.059$, $p = .399$) were not statistically significant.

2.3.3 Subjective opinions

The subjects evaluated the effort they spent on the tasks and their performance level on a scale of -10..10. For effort, the mean was 1.82 points and for performance level, -0.58 points. The subjects also evaluated their mental demand, frustration level, and preference for different modalities. Differences were quite big between the three modalities (see Figure 2). Repeated-measures ANOVA showed that the effect of modality was significant for mental demand ($F(2,22) = 24.12$, $p < .001$), frustration ($F(2,22) = 17.11$, $p < .001$), and preference ($F(2,22) = 20.74$, $p < .001$).

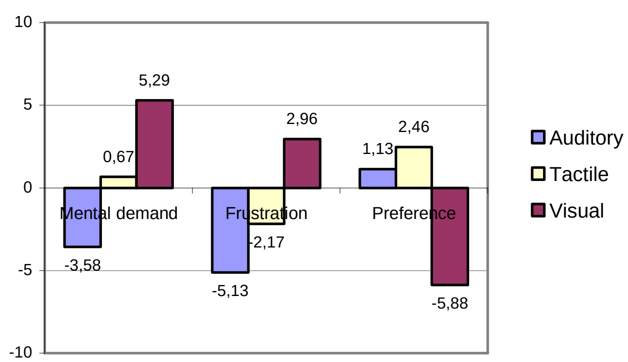

Figure 2. Subjective evaluations of the modalities.

For mental demand, all modalities differed significantly from each other (auditory and tactile $t(11) = -3.559$, $p < .01$, auditory and visual $t(11) = 7.173$, $p < .001$, tactile and visual $t(11) = 3.317$, $p < .01$). The subjective evaluations for frustration level also had significant differences between every modality (auditory and tactile $t(11) = -2.711$, $p < .05$, auditory and visual $t(11) = 5.2$, $p < .001$, tactile and visual $t(11) = 3.411$, $p < .01$). For preference of the modalities, the visual modality differed significantly from auditory ($t(11) = -4.69$, $p < .01$) and tactile ($t(11) = -5.635$, $p < .001$).

Almost all subjects had negative comments on the visual rhythms. They commented that the visual modality was the most difficult one, the visual rhythms evoked negative emotions, or that it is not a natural way to perceive rhythms. All subjects said that the VV condition was the hardest or one of the hardest conditions in the experiment. Most subjects thought that the AA condition was the easiest. One subject felt that the TT condition was the easiest, and another thought that the AT was the easiest. Some subjects told that their strategy was to convert the tactile rhythms, and sometimes also the visual rhythms, into sound. None of the subjects said that they had actually heard the tactile mouse vibrating through the hearing protectors.

2.4 Discussion

The results showed that in unimodal tasks, the perception of rhythms was more accurate with the auditory modality than with the tactile and visual modality. Performance in the tactile modality, however, was better than that in the visual modality. These results were in line with our hypotheses and previous research. The auditory dominance over visual modality in rhythm perception has been demonstrated in several studies (Brewster & King, 2005; Brown et al., 2005; Collier & Logan, 2000). The position of the tactile modality between auditory and visual modalities has also been found in previous research (Kosonen & Raisamo, 2006). Our results confirm that the tactile modality is useful in presenting rhythmic information.

In crossmodal tasks, the auditory-tactile was the only condition where performance did not differ significantly from the best two unimodal conditions, auditory-auditory and tactile-tactile. This new result shows that crossmodal comparisons of rhythms are possible maintaining a good performance level when tactile rhythms are compared to previously presented auditory ones. Performance was poor in the crossmodal conditions whenever visual rhythms were involved. This indicates that the visual channel is not suitable for presenting and accurately perceiving rhythmic information. Our results also coincide with those of Collier & Logan (2000) who showed that at fast presentation rates, auditory-visual and visual-auditory rhythm pairs were as difficult as or more difficult than unimodal visual pairs. In our experiment, the auditory-visual and visual-auditory rhythm pairs were about as hard to recognize as the unimodal visual pairs.

Tactile rhythms have not been widely utilized in user interfaces, but there are some prototype applications. Tactons, or tactile icons, can be used to communicate complex concepts in desktop computers, in mobile and in wearable devices, and applications for visually impaired users (Brewster & Brown, 2004). Vibrotactile rhythms have been shown to be an effective parameter in Tactons. Brown et al. (2005) evaluated a set of Tactons using three values of roughness and three different rhythms. They found an overall recognition rate of 71%, and recognition rate of 93% for rhythm. Vibrotactile effects have been successfully used to present progress information in desktop human-computer interfaces (Brewster & King, 2005). Vibrotactile rhythms have also been utilized in learning tools. The T-

RHYTHM system, a rhythm instruction tool for school children, provides a child with rhythm patterns through the tactile senses. The results showed that the participants performed better when the rhythm example was given with the T-RHYTHM system than after hearing the melody played through a speaker. The system supports individual learners in playing instruments or singing, in solo or ensemble situations (Miura & Sugimoto, 2005).

The results of subjective opinions showed that the users clearly experienced differences in the mental demand, frustration, and preference of different modalities. The results were mostly in line with our hypotheses. For mental demand and frustration, the auditory modality was experienced as the least demanding modality. The visual modality was ranked as the most consuming modality, and the tactile modality was between them. In a previous study (Kosonen & Raisamo, 2006), the subjects preferred the auditory modality over the tactile and visual modalities, but the tactile modality was very close to the auditory. In our study, the subjects preferred the tactile modality over the auditory, but the difference wasn't statistically significant. These results are very promising for the use of the tactile senses in rhythmic interaction. They indicate that it is possible to make tactile rhythmic interaction user-friendly. The results also clearly state that the users didn't like the visual rhythms.

2.5 Conclusion

In unimodal tasks, the perception of rhythms was more accurate in the auditory modality than in the tactile and visual modality. Performance in the tactile modality, however, was better than that in the visual modality. In crossmodal tasks, performance was poor whenever visual rhythms were involved. The auditory-tactile comparisons were the only crossmodal comparisons where performance was nearly as good as in the best two unimodal conditions, auditory-auditory and tactile-tactile. In the future, research is needed on the information processing limits in unimodal and crossmodal rhythm perception. Comparisons need to be made using different tempos and rhythm lengths with all the three modalities and varying other parameters in rhythm presentation (e.g. the type of sound or frequency of vibration). It would be interesting to see how these results apply to special user groups like children or the disabled.

3 PRELIMINARY TESTS OF A PAC MAN GAME (ULUND)

3.1 Introduction

Using one-point haptic VR is not the same as touching and manipulating objects with your own two hands. As e.g. pointed out in (Jansson et al., 1998) the single contact point leads to problems when it comes to getting an overview or finding relevant parts of an object. Also, the contact point and the resolution of the device will put a limit on how the user e.g. perceives textures (Jansson et al., 1999; Penn et al., 2000). This puts particular demands on the design of the haptic virtual environment (Sjöström, 1999; Challis & Edwards, 2000) as well as on guidance (Sjöström, 1999; Fänger et al., 2000) and training (Jansson & Ivås, 2000), and the need of fusing haptics with other modalities, particularly in more complex environments (Magnusson et al., 2002).

Haptic interfaces and haptic-audio interfaces have been investigated to some extent, but a significant amount of work remains to be done. Mappings to the different modalities (here: sound and haptics) and the interplay between modalities need to be investigated in more detail, i.e. how do you optimize the mapping and what information should be present in the different modalities (or both). Also, the level of complexity present in the virtual environment needs to be increased to investigate the potential limits of systems and the useworhtiness of complex virtual environments.

3.2 Interface and equipment

An audio-haptic Pacman game has been developed to investigate combinations of sound and haptics in navigational tasks. The game has been written in OpenHaptics API for the haptic control and with DirectSound for sound control. Various forms of labyrinth games have been investigated by e.g. (Crossan & Brewster, 2006), but to our knowledge, no audio-haptic Pacman game has previously been developed. Pacman was an arcade game of the early 1980's, and it is perhaps the best remembered game from that period. Players guide Pacman around a maze eating dots, while avoiding four ghosts. We have developed a haptic version of Pacman, where the player relies on haptics and sound rather than visual input. Pacman can be guided around the maze using a Phantom device. The Pacman figure is actually placed at the tip of the PHANToM pen. With the help of 3D-sound, the player can monitor the whereabouts of the ghosts. The 3D audio implemented uses the “ears in hand” metaphor which was previously tested in memory game type environments (Magnusson & Rassmus-Gröhn, 2005). The user is supposed to collect “food” along the corridors while keeping out of the way to the “monsters” – attached with a 3D sound source. In each of the outer corners of the labyrinth, special strengthening “food” that enables the user to catch the monster is placed. Three levels of the game exist.

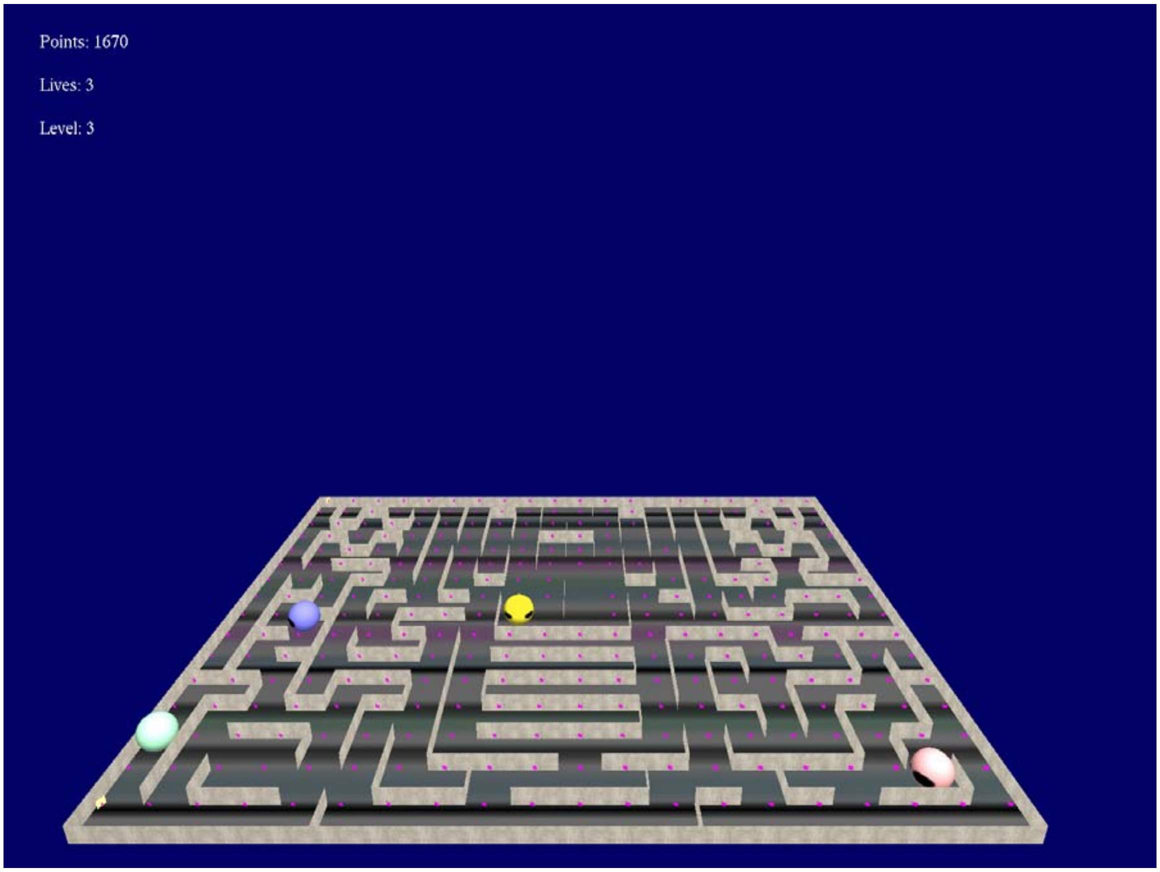

Figure 3. Screen shot from the 3rd level in the pac man game.
Note that the visual interface is not needed to play the game.

3.3 User evaluations

This Pacman game has been evaluated preliminarily by two blind youths (15 and 17 yrs). They were given the opportunity to play the game at a reference group meeting in October 2006. The test was very informal. The game was explained verbally to the users, and then they were allowed to try it without further tasks than to play the game. The game was played with an audience, i.e. the other user, test leaders and accompanying persons were allowed to watch and comment. The group communication was recorded on a DAT tape recorder.

3.4 Results

The test showed that the youths were able to use the available feedback (haptic and 3D audio) to play the game, adding further evidence about the usefulness of the ears in hand type audio feedback. During the test the program crashed several times, which (again) highlights the fact that non-visual interaction is different from visual interaction. A user will simply move the PHANToM differently in the two cases, and in this case the non-visual way of moving the PHANToM pen revealed unknown bugs in the program. Apart from this the program was considered interesting and enjoyable.

3.5 Discussion and conclusions

For the application the following improvements need to be made:

- Make the program stable also for non-visual interaction
- Make it impossible to touch monsters through the walls (this is currently possible since the “user avatar” can be pushed slightly into the walls.
- Develop more labyrinths – the current ones are quite complicated, and simpler ones are needed (or that you stick to the same so that one can learn the labyrinth after a while).

Some other possibilities that were discussed

- Possibly one should change the game a little so that the goal of the game is to eat the monsters, not to eat as many cookies as possible – i.e. once you have eaten the monster you want to get to the next level. This may be due to the fact that the cookie-eating is not so obvious – it just “happens” while you are moving around.
- Make the effect of the “strengthening food” time limited. It is limited in the original pac man game, but in our prototype it is currently not so.
- Possibly it would be interesting to add a “show me around” function that drags the user around the labyrinth initially to provide some kind of initial overview.

It seems clear that an audio-haptic Pacman game can be an enjoyable task to learn navigation. However, it is not evident that the trial-and-error method that is favored in the game will actually make users learn how to navigate. It needs to be investigated further, and perhaps if navigational skill is going to be trained with such a game, tasks could be modified to support learning better, e.g. by placing the “strengthening food” in different places.

4 PROTOTYPE DEVELOPMENT OF A DUAL COLLABORATIVE PONG GAME (FORTH)

4.1 Introduction

Up to now, efforts were concentrated on the development of an accessible Pong game space exploiting merely spatial audio and vibration feedback effects. Although, several and sometimes severe design changes, concerning mainly the auditory environment, have been made so that visually impaired children to obtain a better mental image of the game, we can not ignore the fact that these players still encounter some difficulties in playing it effortlessly. This is probably because of the innovative setup, which is rather unusual to the vast majority of users and therefore it places some obstacles to them. Furthermore, it must be taken into consideration that we should study some additional methods in order to present the required information to users more efficiently.

The investigation of cross modal equivalence using two haptic devices is a many promising idea which may contribute to the achievement of our objective which is to facilitate the interaction with the game for visually impaired children. However, little attention has been given in this topic and as a consequence the literature on this specific field is rather poor. For these reasons, the investigation ought to involve several steps and require sufficient answers to critical questions, otherwise it is likely to turn out to have more problems than it would have solved. Some of these research questions which will be fully explored in the later sections are: Which problems do we try to solve? Which pair of haptic devices should be chosen in order to cooperate complementary? Is it possible for a novice user to handle efficiently both devices? Do they raise any other problems? If so, how important are they and how can they be overcome? What role does each device play?

These devices should have discrete roles and serve two distinct purposes. It could be said that one device should have the primary role and the other an ancillary. In other words, the first one should provide more focused information about a specific element, such as a game object (paddle or ball) whilst the other one should present general information about the context of the game. An important issue is how a player can simultaneously manipulate and perceive information from two haptic devices. The most efficient approach seems to be the following: users handle the primary device with their dominant hand whereas the other device with their non-dominant hand. This implies that the game have to be evaluated against right-handed and left-handed users to ensure that both groups are able to interact equally with the specific haptic devices. Subtask 2.1.2 of the MICOLE project deals with the development of haptic focus and context displays. In this context, two different interactions techniques are investigated in order to examine the impact of bimanual haptic interface upon blind or visually impaired children's ability to interact with the game.

Besides that, it should be noticed that it is necessary to make some additional modifications to the auditory media space in order to accommodate more effectively the use of two haptic devices. The changes deal mainly with the position of loudspeakers, the shape of the auditory wall and the player's position.

4.2 Previous work

As it has already been said, only the last few years bimanual interaction techniques have extensively attracted the interest of the HCI community. It is indicative that the most interesting studies have been published the last three or four years. Most of the research efforts are focused on designing and implementing high quality scientific tools. CINCH (Akers, 2006) is a system for disentangle and analyze neural pathways estimated from magnetic resonance imaging data. This tool makes use of a pen (stylus) and a trackball allowing neuroscientists to navigate through 3D pathways efficiently. Moreover, DTLens (Forlines et al, 2005) is a tool for exploring large maps and design diagrams on interactive tabletops which aims at mechanical engineers and geospatial experts. DTLens employs a multi-user and two-handed technique which enables group exploration of spatial data. Another example of bimanual interface is the symSpline tool (Latulipe et al, 2006). SymSpline introduces a technique for the manipulation of spline curves where two cursors (controlled by two mice) determine the positions of the ends of the tangent to an edit point. Peephole Displays (Yee, 2003) is another indicative investigation of bimanual interaction. Yee contributes to previous studies about spatially aware display (a position-tracked display which provides a window on a larger virtual space) and proposes a two-handed interaction technique combining pen input with spatially aware displays. This interaction technique is accommodated in handheld computers which have a reduced screen space for display and interaction. Several applications make use of this technique such as drawing program, map viewer and calendar.

Although there are several recent studies concerning bimanual interaction, it has not been thoroughly examined in the light of visually impaired users. In the context of a maze environment (Crossan et al, 2006), it is studied a bimanual interface which facilitates the navigation in the game space, exploiting a PHANTOM device and a VTPlayer tactile mouse.

4.3 Two-handed interaction

This study's aim is to ascertain in what degree two-handed interaction affects the way visually impaired children experience PONG game. We have investigated two different haptic interfaces: The first one includes a PHANTOM® Omni™ haptic device (from SensAble Technologies) and a force feedback controller (Logitech™ RumblePad 2), while the second one includes a Braille display and the above force feedback controller or the PHANTOM device. Evaluation conducted show that the players have a better experience of the game when using these interaction techniques. In particular, the assessment results of the first interface indicate a substantial improvement in the ability of players to locate the game objects successfully.

4.3.1 The First Bimanual Interface

The force feedback controller has been already used to provide hints about the position and the direction of user's paddle. This was proved quite helpful to visually impaired players since they have an additional cue (apart from the auditory environment) about the handling of the paddle. However, it would be pretty interesting to further extend this functionality to all game objects (practically to the ball) and investigate whether this has a major impact on the interaction of visually impaired players with the game. The rationale behind this idea is to guide visually impaired children through the game action and show how the game objects behave after certain events occur. This is a fundamental issue, especially for beginner players who are not familiarized with the game. In other words, it is a good way to introduce novice users to the game, demonstrating the rules of it. Moreover, it could act as a guide to the auditory environment and help players to be familiarized with it. For example, when the ball bounces against borders, a tactile effect and a sound reproduction occur simultaneously and in this way players can associate ball bounces with a specific sound from the auditory environment.

Figure 4: The Logitech controller (left) and the PHANTOM device (right) which are used for the first bimanual interface

This bimanual interface employs a PHANTOM device as well as a force feedback controller (see Fig. 4). The latter is manipulated by the users' dominant hand while the former by their non-dominant hand. The PHANTOM device which offers a high quality feedback, aims at indicating to players the orbit of the ball. This task is accomplished by rendering the orbit of the ball in haptic information so that players have an additional cue about the position of the ball at any time. In addition, when the ball hits on the borders or paddles, a force feedback effect is produced to notify the user about this collision. It should be mentioned that different types of effects are produced depending on the game object which collides with the ball so that users to be aware of the ball's position. As far as the Logitech controller is concerned, it is used to provide hints about the ideal position of user's paddle in order to hit the ball, about collisions of the user's paddle with the borders of the game space and finally about successful hits of the ball by the user's paddle. We have already described in details how we exploit this device in the context of Subtask 2.2.1 (deliverable D6). However, it must be noticed that the Logitech controller is designed to be handled with both hands and not with one as we are examining. This implies that we have to investigate whether users face difficulties in handling the controller with only one hand (their dominant).

Another thing that we have to study is if it is the same easy for right-handed and left-handed users to manipulate this bimanual interface. If a user is right-handed (as the majority of users are) then the paddle which handles should intuitively correspond to the right player of PONG game. Otherwise, it would seem odd if a user manipulates the left player's paddle with his right hand. Similarly, a left-handed user should handle the paddle which corresponds to the left player of PONG game. So, it turns out that there must be a menu option from which a user can be able to select which his dominant hand is.

4.3.2 The Second Bimanual Interface

Several speech messages are reproduced from the auditory environment to inform players about the progression of the game. These messages have an important role in the game and we can not circumvent them easily. For instance, the announcement of score is necessary so that players can be able to follow the game flow. However, players are often seemed distracted by the use of those sounds and they often lose touch with the other hints provided by the auditory environment concerning mainly ball's and paddle's position. In the light of the above, we are examining an alternative way to provide players with all these messages, but not through the auditory environment which is already overloaded. The rationale behind this idea is to avoid "noise pollution" and minimizing as possible the players' fatigue. It is a well-known fact that the less sounds are used the easiest is for a player to concentrate on the game action and interact with it without encountering major obstacles (Cohen, 1991).

Figure 5: The Logitech controller (left) and the Braille display (right) which are used for the second bimanual interface

This bimanual interface employs a Braille display and a force feedback controller (see Fig. 5). Users handle the Braille display with their non-dominant hand whereas the force feedback controller with their dominant. All speech messages, including menu options, score announcements, computer opponent moods etc. are conveyed through the Braille display. In this way, the number of sounds which are reproduced by the auditory environment is substantially reduced and it is anticipated that the users will be benefited from this change. The Logitech controller is used in the same way described in the previous section. Nevertheless, the PHANTOM can be used instead to provide cues for the manipulation of user's paddle. This device appears to offer better feedback feeling than Logitech controller and for this reason it is preferred by users. Moreover, the same rule about hand dominance applies also to this interface so the player must be able to choose if he is right or left-handed before the game starts. This does not affect the handling of Braille display, since visually impaired people do not seem to encounter difficulties in handling the Braille display with their non-dominant hand.

4.4 Evaluation

An evaluation was carried out to examine the performance of blind and low-vision users on the game after applying the above changes. This experiment was conducted in a quiet usability laboratory and nine (9) subjects who were all aged between 19 and 27 years old took part. Two of them were blind while the rest encountered severe visual impairments. Also, among the subjects was one left-handed user. Each subject was asked to play the game for five to ten minutes using varying settings (concerning speed of ball, volume of loudspeakers, etc.) that they considered better to suited to their needs. Moreover, the evaluation included two cases: one for each bimanual interface. It must be noticed that these participants had already tried to play PONG game so they were familiarized enough with it. The hypotheses which had been made before evaluation began are:

- Most of the subjects will manage to win the computerized opponent while the rest of them will be close to that achievement.
- Subjects will be able to determine the position and direction of all game objects at any time when they use the first bimanual interface. This will be tested by pausing the game action and asking the subjects.
- Subjects will experience a better performance of the auditory environment when they use the second bimanual interface. This will be determined by interviewing them at the end of the evaluation.
- Subjects will feel easy to interact with the bimanual interfaces.

Seven of the subjects succeeded in winning the opponent readily (in the first level of difficulty where the speed of the ball is low). Although, the other two did not achieve this goal they did not win for only two points. As a consequence we are allowed to say that the first hypothesis is supported. When the subjects were using the first bimanual interface, the evaluators frequently paused the game to ask them where they believe the game objects lie (at the bottom or at the top of game space, on the right or on the left of game space). The subjects answered correctly to almost all questions, exploiting mainly the cues received from the PHANTOM. One element that might have helped them is that all participants had tried the PHANTOM before and therefore they were familiarized with it. So it turns out that the second hypothesis is also supported. After evaluating the second bimanual interface, subjects were asked if they had noticed any improvement in the performance of the auditory environment. Three participants noticed substantial improvement; five participants commented that although this interface is helpful, they could manage to play the game without it; and one participant did not find this interface useful at all. Given that the majority of the subjects found this interface useful we can claim that the third hypothesis is also supported. Nevertheless, seven of the subjects complained about the handling of Logitech controller. As they explained they found quite difficult to handle the controller with only one hand. As a consequence the fourth hypothesis is rejected.

4.5 Conclusion

This study has reported on the design of two bimanual interaction techniques which seem to have a quite positive impact on the players of PONG game. In this context, we have investigated two two-handed interfaces which employ a PHANTOM device and a Logitech force feedback controller; and a Braille display and a Logitech controller respectively. Evaluation showed that users perceived a better mental image of the game and the interaction with it was facilitated. Particularly, the first bimanual interface helped users to better locate the game objects with the use of PHANTOM. However, the evaluation also revealed that users faced some difficulties in handling Logitech controller with only one hand so we have to rework a better solution which is to use a PHANTOM device instead. As a result, a further evaluation is needed in order to examine how effective this new concept is.

4.6 Guidelines

From this investigation, several guidelines can be drawn:

- Force feedback is suitable for providing supplementary cues through the non-dominant hand of users, when information is mainly conveyed by an auditory environment.
- The auditory environment should not be overloaded, since users appear to be distracted and confused. Information can be conveyed by other channels such as a Braille display.
- Visually impaired users do not seem to encounter difficulties in handling a Braille display with their non-dominant hand.

5 THE USEFULNESS FOR NON-VISUAL READING OF VIRTUAL MAPS OF THE TACTILE COMPONENT OF THE VIEWPLUS AUDIO-TACTILE AID (UPPSALA)

5.1 Background

Audio-tactile aids have for about two decades been used by visually impaired people for reading maps. Typically, an embossed map is put onto a touch tablet, where tactile information is obtained by manual exploration of the map, and auditory information when selected areas on the map are pressed. Examples of such aids are the NOMAD (Parkes, 1988), the TACTISON (Burger, Mazurier, Cerano & Sagot, 1993) and the dialogue system AUDIO-TOUCH (Lötzsch, 1995). Experiments have demonstrated that reading of tactile maps is improved when auditory and tactile information are combined as in such cases (e.g., Holmes, Jansson & Jansson, 1996; Holmes, Michel & Raab, 1995).

Virtual maps present new options of getting geographic information without physical maps, which makes it possible for sighted people to explore maps presented on computer screens. It should be possible to make virtual maps available also for visually impaired persons, provided that useful non-visual alternatives are found. Different efforts to reach that aim have been made. One is the VTPlayer (http://www. VirTouch2.com), a device consisting of a computer mouse equipped with two 4x4 matrices of pins that provide tactile information successively when the mouse is moved over the virtual map and auditory information when the mouse is located in specific areas of the map. In addition, kinaesthetic information is obtained from the user's movements during the exploration, but no physical embossed map is involved.

Jansson and Pedersen (2005) investigated the usefulness of the tactile component of this device for a map reading task, namely finding states on a USA map. They compared the efficiency in this task with and without the information obtained from the tactile matrices when the standard software was used, and they found, to their astonishment, that the tactile information did not improve the performance. The kinaesthetic information combined with the auditory information alone was as efficient as with the tactile information added. Other experiments with changed software suggested that some improvement could be obtained with changes of the software, but problems remained, especially because of the lack of visual feedback of the movements and positions of the mouse (Jansson, Juhasz, and Cammilton, 2006; Juhasz, 2006). There are differences between the movements of the mouse and corresponding motions of the cursor on the virtual map, which is no problem when they can be compensated for visually but which cause problems for those who cannot see.

5.2 Problem

The main aim of the present study was to investigate the usefulness of the tactile component of another method for reading of virtual maps, namely a method developed by ViewPlus Technologies Inc (http://www.viewplus.com), which also combines tactile, kinaesthetic and auditory information. What is the usefulness of the tactile component in this case? Is the efficiency improved when the kinaesthetic and auditory information is combined with tactile information? Even if all the three kinds of information partly differ in the VTPlayer and the ViewPlus cases, an improvement of performance for ViewPlus would suggest that pick-up of tactile information via the finger skin directly is superior to picking it up via a matrix with a limited number of pins.

A second aim was to study the effects of amount of tactile information in the meaning of different numbers of fingers used in the ViewPlus option. Earlier experimental evidence concerning this issue differs for 3D objects and 2D maps. There was a significant effect of increasing the number of exploring fingers from one to two in the case of 3D objects (Jansson & Monaci, 2004), but not concerning 2D maps (Jansson & Monaci, 2003). The effects of using one finger vs. more fingers for exploration will be studied here.

5.3 The ViewPlus equipment

The ViewPlus equipment embossed versions of virtual maps are produced that are explored on a touchpad. It includes the IVEO® Creator software suite for making virtual maps, the ViewPlus Cub™ Braille printer for producing embossed maps on paper, and the IVEO Touch Pad designed to combine tactile printouts with synthetic speech produced with IBM ViaVoice software (Figure 6).

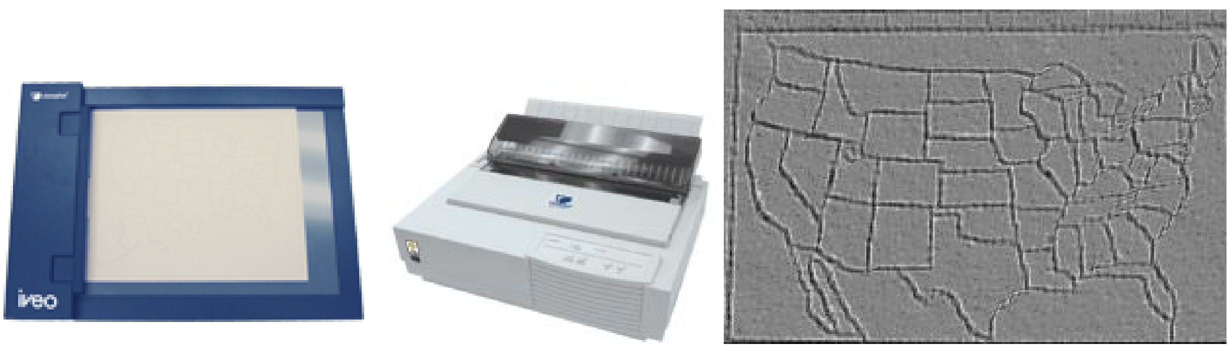

Figure 6: To the left the IVEO TouchPad, in the middle the Cub Braille printer, and to the right a tactile printout of the USA map to be placed on the TouchPad.

5.4 The VTPlayer and the the ViewPlus options compared

A main difference concerning the use of the VTPlayer and the ViewPlus equipment for reading virtual maps is that the virtual maps in the ViewPlus option are presented as embossed maps. Physical map are thus provided for exploration, and in principle this set-up is similar to the older devices described above, but the embossed map is a physical representation of a virtual map. A potential advantage of this is that the tactile information is not restricted to matrices of pins, but information can be picked up in a more natural way via direct contact between the hands and the map. Kinaesthetic information is in both options provided by the movements of the hand, but there are differences between moving the mouse with a hand and moving the hand directly on the map. The auditory information is also similar in the two cases, but differs in how it is initiated. It is produced automatically when the VTPlayer mouse passes the relevant area, but it is obtained in the ViewPlus case when the relevant area is pressed manually. The problems with differences between hand position and position on the virtual map that arise when using the VTPlayer are not present, as only position on the physical map on the touch tablet is involved in the ViewPlus case.

5.4.1 Method

The independent variable was the kind and amount of tactile information presented. The experiment had a between-group design, where 30 participants were randomly distributed to three groups with 10 participants in each. All three groups got kinaesthetic information from their exploratory movements and auditory information via the TouchPad and the synthetic speech, but the tactile information differed. For two of the groups the tactile information was available on an embossed USA map, which one group was allowed to explore with one finger on one hand only, index or middle according to their own choice (*the 1 finger group*). Another group could freely choose to use up to all five fingers on one hand (*the five fingers group*). A third group had a sheet of the same kind as the maps had been embossed on but with no embossment (*the no-embossment group).* The participants in this group were free to use up to all five fingers of the exploring hand.

5.4.2 Procedure

The participants were seated at a table with the TouchPad. The experimenter took place opposite of the table with a computer running the experiment. The height of the chair and the location of the TouchPad were adjusted by the participant for personal fit. The participants were instructed to place their forearm not to be used for exploration horizontally to the table along either the TouchPad or the edge of the table. The not used arm was meant to serve as a reference for the exploring hand. If the participants moved their not-used arm during the experiment they were asked to resume its original position.

As an introduction an embossed picture of a human face was placed on the TouchPad with auditory feedback, in order to help the participant to understand the functioning of the TouchPad. The experimental task was, blindfolded, to find a series of states named by the experimenter one by one, as fast and adequately as possible. The participants read the experimental instructions and were told to ask any questions they might have.

The time for finding each state, from the experimenter giving the name of a state until the participant had found it was measured with a stop watch (to the nearest second). The maximum time allowed for finding a single state was 240 sec This time was reached in 3% of all the explorations), and in these cases this value was given as exploration time. When the time had passed the experimenter stopped the participants' exploration and verbally helped them to locate the state by giving the cardinal points of the compass as guidance. The participants were not told in advance that there was a time limit. When the participant found the required state the experimenter named the next USA state on the list.

Two lists[1] of USA states contained states distributed over the whole country and were created in a random order. However, the smaller east coast states were excluded. The lists were used both forwards and backwards resulting in a total of four different lists in the experiment. The order in which the four lists were read was randomized between the participants with the exception that two orders of the same list were not used in sequence.

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[1] List A: North Dakota, Arizona, Minnesota, Ohio, Colorado, Kentucky, Alabama, New Mexico, Wisconsin, Kansas.

List B: Arkansas, Georgia, Idaho, Illinois, Utah, Florida, Pennsylvania, Nevada, Missouri, Oregon

When the participants had found all the USA states on the four lists they were asked to give general comments about the experiment.

5.4.3 Participants

The participants were 30 (blindfolded) sighted university students (19 females and 11 males) between 22 and 43 years of age (M = 25 years). They served either as a course requirement or for payment in form of a cinema ticket.

5.4.4 Results

The means and standard deviations of the times to find a USA state (sec) were calculated in the three experimental groups for each experimental session and for all sessions (Table 3).

Table 3. Means and Standard Deviations of individual means of times (sec) for finding a US state.

		5 fingers	1 finger	No embossment	All conditions
Series 1	M	**55,7**	**48,2**	**66,2**	**56,7**
	SD	22,4	26,5	35,1	28,5
Series 2	M	**49,0**	**30,1**	**57,1**	**45,4**
	SD	16,6	11,4	29,1	22,8
Series 3	M	**43,9**	**33,5**	**52,5**	**43,3**
	SD	25,0	20,2	26,5	24,5
Series 4	M	**44,2**	**32,6**	**47,3**	**41,4**
	SD	25,7	14,2	32,1	25,1
All series	M	**48,2**	**36,1**	**55,8**	**46,7**
	SD	22,4	19,6	30,5	25,7

An ANOVA was used for significance testing of the results. The ANOVA showed that there was no significant differences between the three experimental conditions, $F_{(2,29)} = 2,37$, $p = 0,111$. Further, the ANOVA showed that there were significant effects over time, $F_{(3,81)} = 5,44$, $p < 0,05$. As can be seen in Table 1 there was improvements over the four series of states in all three experimental conditions.

5.5 Discussion

The results were that there were no statistically significant differences between the three experimental conditions. This indicates that that neither the kind of tactile information (embossment vs no embossment), nor the number of fingers used (1 vs 5) had any significant effects on the performance in this kind of a task. The latter result is in agreement with the result in the Jansson & Monaci (2003) study mentioned above.

Even if the mean of the exploration times in the No-embossment group was not significantly lower than the times in the other two groups, it may be noted that the standard deviation was considerably larger than in the embossment groups. It was noted that most people in the No embossment group found it hard to find the borders between the US states which resulted in more finger pressing on the TouchPad. This may be interpreted such that the kinaesthetic information provided an approximate location of the state, but when finding the exact position of the state the embossment information of the state borders may be useful for the detailed exploration. Thus, providing embossment information may be of some help to at least some people in the exploration task.

The maximum time of 240 sec allowed for finding a state was reached in 3% of the (30*40) 1200 states, that is, for 36 states. There were no differences between the three experimental conditions for the number of participants reaching the maximum time.

It should be emphasized that the results was obtained for *one* task, namely finding a series of states. It is possible that the tactile information is more important in other kinds of tasks. An example of such a task using the TouchPad might be to recreate a map by drawing it after having learnt it by exploration.

5.6 Experiments in Progress on the Usefulness of the Standard Tactile Information with the ViewPlus Equipment

That the tactile embossed information did not have a significant effect on the performance of the map reading task is surprising, even if it is in accordance with the results in the VTPlayer experiment. A hypothesis is that the tactile information also in the ViewPlus case is not optimal. This hypothesis is studied in ongoing experiments on effects of some special features of the tactile information in the ViewPlus equipment, such as t the form deformations caused by the low spatial resolution and the discriminability of textures.

5.7 Conclusions

The tactile component of the ViewPlus equipment had no significant effect on performance, which is the same result as that obtained for the VTPlayer. As was the case for the latter option, continued studies on the ViewPlus equipment will focus on the possibilities of improving the tactile information provided in the standard form.

6 PUBLISHED PAPERS

Several papers have been published on the work reported in this paper. The list also contains some papers that are results of earlier work in WP2, but were published after the previous deliverable.

6.1 UTA

Evreinova, T.V., Evreinov, G. & Raisamo, R. (2006). Video as Input: Spiral Search with the Sparse Angular Sampling. In *Proc. of ISCIS 2006* A. Levi et al. (Eds.), Istanbul, Turkey, 1-3 Nov., LNCS 4263, Springer-Verlag Berlin Heidelberg 2006, pp. 542 – 552. http://dx.doi.org/10.1007/11902140_58

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Kosonen, K. & Raisamo, R. (2006). Rhythm perception through different modalities. *Proc. EuroHaptics 2006*, 365-370.

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6.2 ULUND

Magnusson, C., Rassmus-Gröhn, K. & Eftring H. (2006). A virtual haptic-audio line drawing program, *3rd International Conference on Enactive Interfaces*, 20-21 November, 2006, Montpellier, France

Rassmus-Gröhn, K. (2006). Enabling Audio-Haptics, Licentiate Thesis, Certec 2:2006, Department of Design Sciences, Lund University, September 2006, Lund, Sweden

Rassmus-Gröhn, K., Magnusson, C. & Eftring, H. (2006). User evaluations of a virtual haptic-audio line drawing prototype, *Workshop on Haptic and Audio Interaction Design*, University of Glasgow, 31st August - 1st September 2006

Magnusson, C., Danielsson, H. & Rassmus-Gröhn, K. (2006). Non Visual Haptic Audio Tools for Virtual Environments, *Workshop on Haptic* *and Audio Interaction Design*, University of Glasgow, 31st August - 1st September 2006

Magnusson, C., Rassmus-Gröhn, K., Danielsson, H., & Eftring, H. (2006). Test of three different audio-haptic navigational tools, *2nd Enactive Workshop,* May 25-27 2006 - McGill University, Canada

Rassmus-Gröhn, K., Eriksson, J. & Magnusson, C. (2006). Two haptic-auditory applications for persons with visual impairments, *2nd Enactive Workshop*, May 25-27 2006 - McGill University, Canada

6.3 UPPSALA

Jansson, G., Juhasz, I. & Cammilton, A. (2006). Reading virtual maps with a haptic mouse: Effects of some modifications of the tactile and audio-tactile information. *British Journal of Visual Impairment, 24,* 60-66.

Juhasz, I. (2006). A haptic mouse used for reading of virtual maps. In M.A. Hersh (Ed.), *Conference and Workshop on Assistive Technology for People with Vision & Hearing Impairments. Technology for Inclusion, Kufstein, Austria, 19th-21st July, 2006.* Available on conference CD-ROM.

7 SUMMARY

In this deliverable we have presented design and evaluation of haptic focus and context displays. The main research theme was cross-modal presentation of information. We conducted a range of studies into the different modalities and combinations to really understand how to design and use cross-modal presentations.

Crossmodal rhythm perception studies by UTA produced new scientific results on the effectiveness of tactile rhythms. They can be used cross-modally with auditory rhythms depending on context and available technology. Visual rhythms were performing worst and are not an optimal cross-modal transformation. Based on these results we are implementing a tactile rhythm agent in the MICOLE Inclusive environment to be available for the software developed on top of it.

ULUND has been working on auditory and haptic interfaces throughout the project. The Pac Man game presented in this document applies their earlier work in cross-modal presentation of content. Their preliminary tests showed that the design is performing well. ULUND is continuing their studies and integrating their work in the MICOLE Inclusive environment.

FORTH used their collaborative Pong game in research. They made use of two-handed interaction with two sets of haptic devices. These results help in choosing the interaction devices so that each device is used in tasks where it performs best. This can be thought as cross-modal choice of different haptic devices within the haptic modality which has several sub-modalities, such as force feedback and tactile feedback.

Finally, UPPSALA studied non-visual reading of virtual maps. They compared the VTPlayer mouse and the ViewPlus touchpad. There was no statistical difference between the three experimental conditions. Neither the kind of tactile information (embossment vs no embossment), not the number of fingers used (1 vs 5) had significant effects on the performance in the task. Still, providing embossment information was considered as helping the users in exploration tasks.

This deliverable reported some of the studies carried out in MICOLE WP2. Other studies are presented in parallel deliverable D7, and the earlier ones in deliverables D4 and D6. Overall, WP2 has produced a high number of scientific publications and progressed the state of the art in cross-modal interfaces in many areas. Many scientifically proved results have been taken in the MICOLE inclusive environment to support further development of cross-modal applications for the visually impaired. This works will continue until the end of the project to provide as complete cross-modal support as possible.

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