Grigori Evreinov (ed.)

Alternative Access:

Feelings & Games 2005. Proceedings.

TIETOJENKÄSITTELYTIETEIDEN LAITOS
TAMPEREEN YLIOPISTO

B-2005-2

TAMPERE 2005

Alternative Access: Feelings & Games 2005 Spring 2005

Index

Alternative Access: Feelings & Games 2005

Grigori Evreinov
University of Tampere
Department of Computer Sciences
TAUCHI Unit for Computer-Human Interaction
Kanselirinrinne 1, Pinni B
FIN-33014 Tampere, Finland
http://www.cs.uta.fi/~grse/AAFG.htm

PREFACE

The seminar "Alternative Access: Feelings & Games" [1] was organized first time in the spring of 2005 at the Department of Computer Sciences at the University of Tampere. The seminar is one of the advanced courses on human-computer interaction supported by TAUCHI Unit for Computer-Human Interaction.

Game is a natural environment to study and improve interface design and interaction techniques, to test usability and accessibility. Nevertheless, primarily games are intended for people without sensory problems. There are many blind and visually impaired people; there are people with limited dexterity or a cognitive deficit; there are deaf or dumb people. There is a small group of the deaf-blind users who also need special educational and training tools. Perceptual testing & training are exceptionally important for all [2].

The projects and ideas, which were shared during the seminars, present the novel view and understanding human feelings which should be tested as early as possible; moreover, actual or residual feelings might be involved and developed through technologies and augmented communication.

Obviously, the most of students have different background. Some of students have own experience in their use of novel devices; some students, probably, could propose own ideas to improve existing interaction techniques. Others could wish to carry out a usability exploration of game or to do a comparative theoretical study in feature educational games and special application for children with special needs. Any self-expression should be admitted and help should be done to support development of the potential innovations and innovators.

The seminar was designed so that in the beginning of the spring term through a series of lectures (6 hrs) on the key problems in game technology and computer-human interaction the students could be oriented in a huge information flow of the concepts, solutions, approaches and vital-important tasks. In particular, these lectures included the next topics:

– Some common errors in interpreting results of physiology of analyzers and psychophysics of perception. Wishes & challenges.

– Artifacts, intentional motions, behavioral strategy and interaction style. Parameters, signals and patterns, mapping, modality. Introduction to the

– Game and game technology.

– Games & assistive technology.

– Games with sounds and the sounds for special games.

– Logic games with sounds and touch (puzzles).

– Games based on tactile signs & navigation (grids).

– Interaction with graphs. Vibrations.

– Motions & tracking.

Whereas only theoretical considerations is a passive activation for intellectual activity and requires both engineering basics and a high self-concentration on difficult materials we used as much as possible presentations of working prototypes of devices, software or/and video demonstrations.

The practical phase of the course included individual empirical studies in designing or/and usability exploration of the new games and techniques for games (hardware or software), that is, carrying out the pilot project (within about 8 weeks, ~100 hrs). That part was more difficult both for the students and instructor due to very short time, different directions of the research and individual skills of the students. In any case, doing the project the students should receive some experience how to design the experiment, how to organize usability evaluation of some techniques or device, how to collect and process data, and, finally, how to present results of research project via a scientific report. After difficult choice, 8 projects were selected for investigation. Before writing the report of the project development, all students did a special presentation. The goal of this stage was to clarify the tasks for researchers and to involve other students in active discussion around the proposed topics (similar to brainstorm activity). Presentations took 8 hrs.

To pass the course the students should write a research paper formatted according ACM template [3] Conference format. The goal was to draw attention of the students to the general requirements and errors during scientific writing and presentation of own results.

In total, 12 students participated in the lectures. Of them, 7 finished the course. Several papers were submitted to relevant conferences after revision.

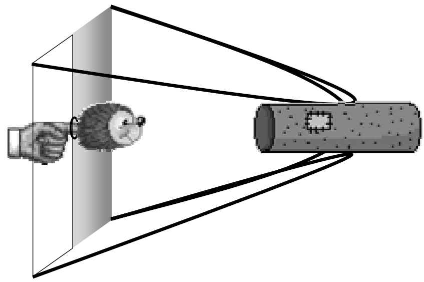
ACKNOWLEDGMENTS

We would like to thank all the students and staff of the TAUCHI Unit who voluntarily help to present new techniques needed to carry out the students' projects within the course. Special thanks to the staff of the Usability Laboratory for offering excellently equipped and organized place that greatly assist and facilitate students' studies. We acknowledge all students who were not daunted by the practical difficulties and successfully finished the projects and course.

REFERENCES

1. Alternative Access: Feelings & Games course web site available at: http://www.cs.uta.fi/~grse/AAFG.htm
2. IGDA, White paper on Game Accessibility. Available at (2004): http://www.igda.org/accessibility/IGDA_Accessibility_WhitePaper.pdf
3. ACM Conference format: http://www.acm.org/

Feelings & Games



Grigori Evreinov

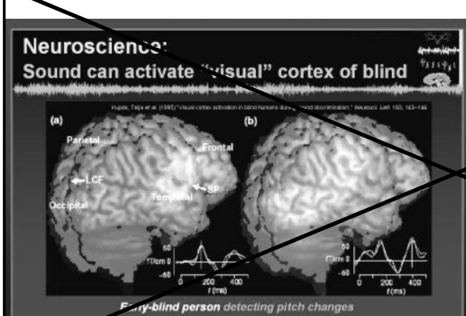
Department of Computer Sciences

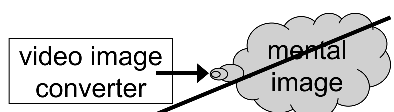
University of Tampere   Finland

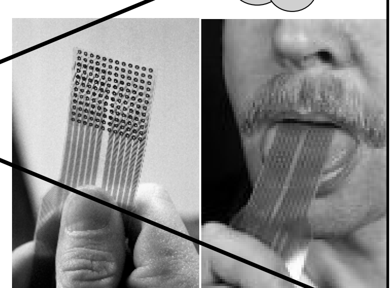
www.cs.uta.fi/~grse/AAFG.htm

some common errors in interpreting results of physiology of analyzers and psychophysics of perception

wishes & challenges



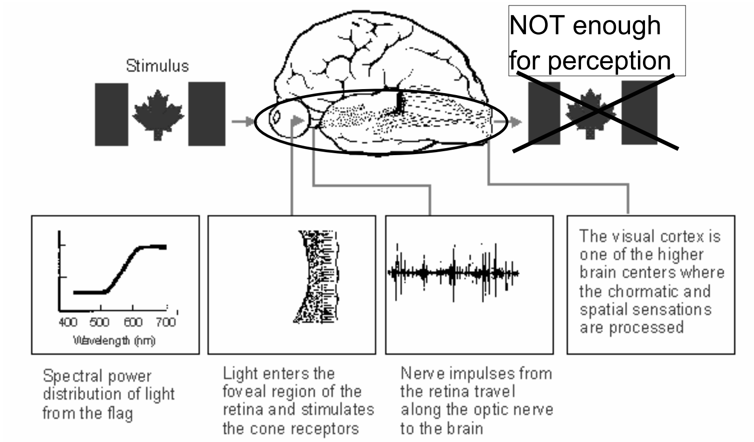




http://www.seeingwithsound.com/ or

http://www.visualprosthesis.com/

[1] Bach-y-Rita, P., Kaczmarek, K.A. Tongue Display System

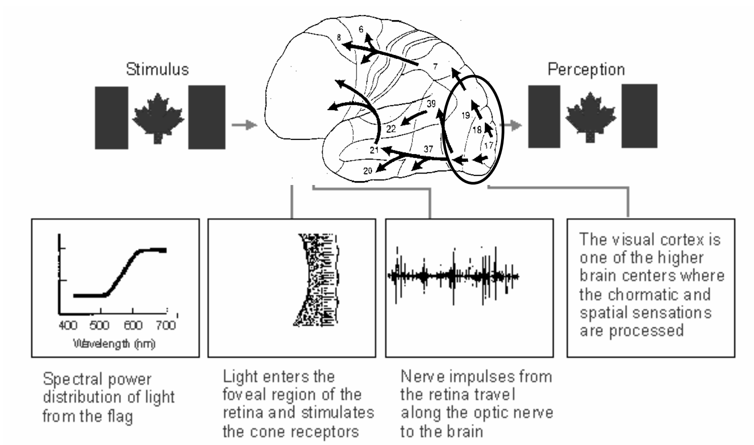


The visual stages from the stimulus to the perception of the external world

(Adapted from Wright, 1964)

http://www.yorku.ca/eye/thejoy.htm

http://www.benbest.com/science/anatmind/anatmd6.html

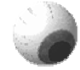


The visual stages from the stimulus to the perception of the external world

(Adapted from Wright, 1964)

http://www.yorku.ca/eye/thejoy.htm

http://www.benbest.com/science/anatmind/anatmd6.html almost 1/2 of our cerebral cortex is involved into the processing of visual information [http://www.geocities.com/medinotes/visual_system.htm]



but this is not only optical tract!!!

pupil is managed with the sphincter and dilator muscles + six extraocular muscles surround the eye and provide synergic control its movements and rotations (inward and outward) [Eye Muscle Control http://www.innerbody.com/text/nerv07.html]

reticulo-spinal neurons participating in the control of synergic eye and head movements [Grantyn A, Berthoz A. Exp Brain Res. 1987;66(2):339-54.]

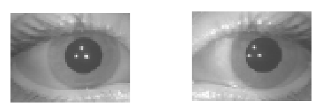
[Neural control of sensory-guided actions at http://publish.uwo.ca/~bcorneil/v1pages/interests.html]

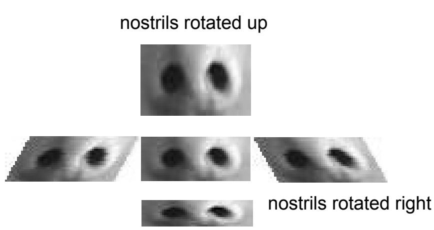
eyes always moving, stabilized image disappears [Pritchard, 1961]

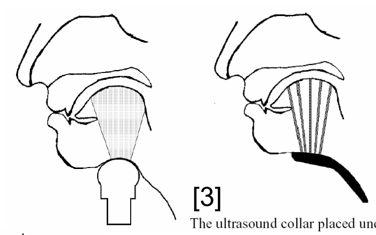
[http://www.med.uwo.ca/physpharm/courses/sensesweb/index.htm

http://www.med.uwo.ca/physpharm/courses/sensesweb/L11EyeMovements/L11EyeMovements.swf]

some extra movements which could be employed for interaction





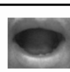
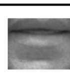
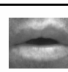
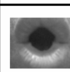


[3] The ultrasound collar placed under chin.

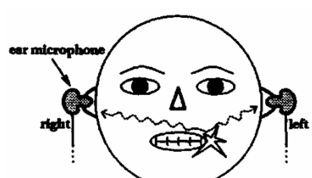
Demo 1

Demo 2

Demo 3

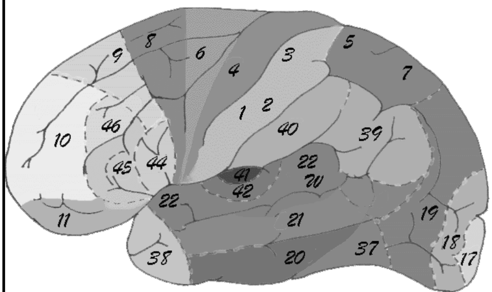
Vowel	a	i	u	e	o
Mouth Image					
Area	largest	small	small	mid-	mid-
Aspect Ratio	mid- or large	small	mid-	small or mid-	large

[2] http://www.mis.atr.jp/~mlyons/vbim/



[4] **Fig.7 Overview of the detection of teeth-chattering.**

the areas corresponding to touch and motor activity are located side by side in the motor cortex http://neuro.psyc.memphis.edu/ugp/ugp-i-cortex3.htm



4 primary motor cortex
6, 8, 9, 44, 45, 46 motor association cortex
10, 11 general motor association cortex

1, 2, 3 somatosensory projection cortex
40 somatosensory association cortex
5, 7, 21, 20, 37, 38 general sensory association cortex

Next cited on Lorimer, P. (1996) [5]

both psychologists Katz (1925) and Gibson (1966) emphasized movement being necessary for active touch to take place

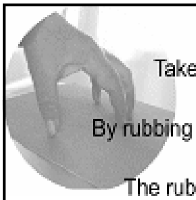
two types of interaction can be defined in touching, they are:

passive touch - the impression made on the skin which involves the excitation of receptors, resulting in a sensation

active touch - which involves movement necessary for seeking for information by mechanoreceptors

the stimulus energy produced originates not with the object perceived, Braille text for example, but with the pressure of the reader's finger pad on the Braille symbol followed by movement to acquire yet more information

Katz wrote "the full richness of the palpable world is opened up to the touch only through movement" (Krueger, 1982, p.52)



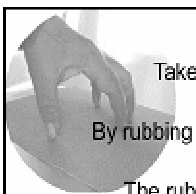
http://www.med.uwo.ca/physpharm/courses/sensesweb/L7Touch/L7Touch.swf

texture or/and shape perception involves complex interactions between the surface and the exploring end effector / fingertips, palm, arm and even vision and hearing that have an impact on the sense of touch

perceived effects depends on fingertip force and speed of relative motion between end effector and surface

increasing applied fingertip force produces increases in the magnitude of perceived qualities (roughness, friction…) [6]

Feelings & Games

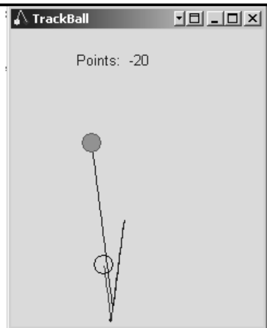


http://www.med.uwo.ca/physpharm/courses/sensesweb/L7Touch/L7Touch.swf

but the speed of relative motion between finger and surface has produced a relatively small effect on perceived roughness (?)

there is an assumption that kinesthetic feedback about hand movements is used to counteract any changes in cutaneous cues produced by changes in speed

[7-10]



Demo 7

Demo 4

Demo 5

Demo 6

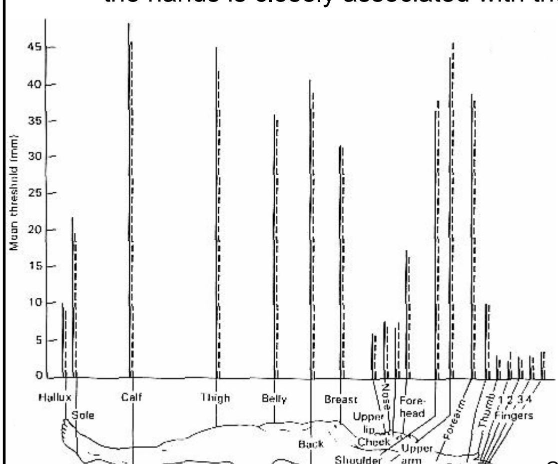
meanwhile, visual processing can influence on a tactile sense and modulate the kinaesthetic component [http://www.irisa.fr/tactiles/index-eng.html http://www.koert.com/work/activecursor/]

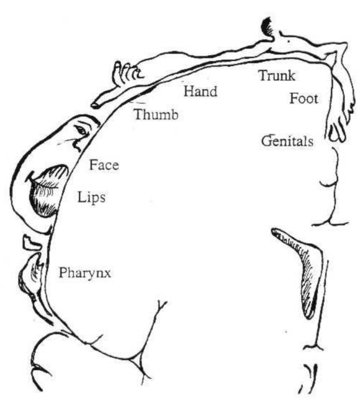
this technique enables to evoke a mental image of the topography of the macroscopic textures

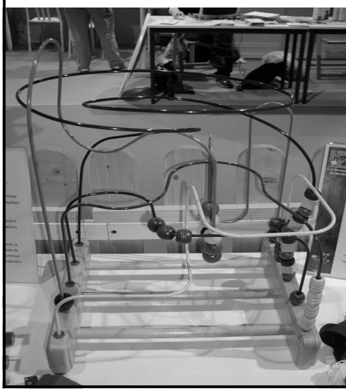
cross-modal tactile illusions can be simulated and used in games

there is a great challenge to design more simulations for haptics and force feedback in mobile computing

haptic (tactual-kinesthetic) perceptual field is consistently smaller than the visual field, and therefore large exploratory movements are needed to perceive external objects, and therefore the perceptual functioning of the hands is closely associated with the motor function [Y. Hatwell]







shape is a static shell of the object

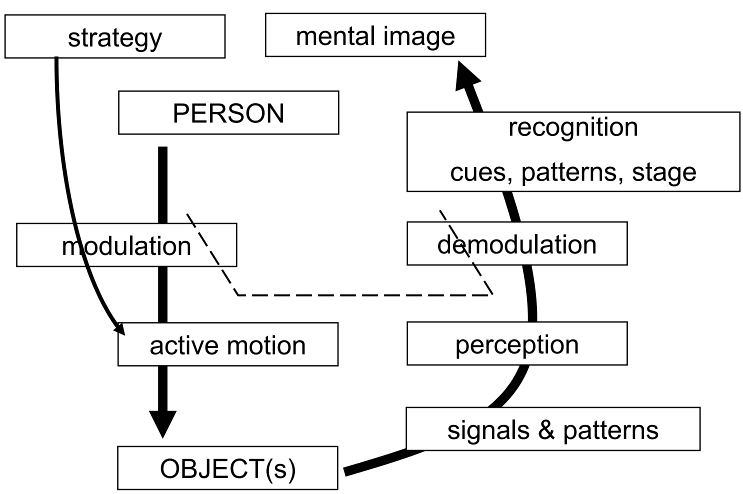
motion creates a dynamic perceptual cues

“the motion plays an overriding role that is central in the process of concept acquisition and in the mechanisms by which concepts are later structured”

“infant’s visual acuity for static displays is low, but motion information is readily detected and attended to”

[11]

behavioral strategy and interaction style



Feelings & Games

parameters | signals & patterns | modality

the state of the interaction environment e.g., number of objects and their general description (name), (dis)appearance/modification of the object(s)	speech cues, alternative icons tactile or sound mapping
navigational cues, coordinates and referent positions	grids & matrixes alternative icons: beacons, landmarks soundmarks, earcons etc.
attentional, predictive, warning cues e.g., signaled varying degrees of action	
natural signals	soundscape, ambient/animal /physical sounds vibration
conditional signals and codes /symbols	any controllable irritation

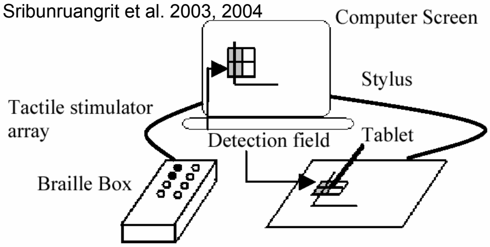
G. Evreinov p 13_65 10.01.2005

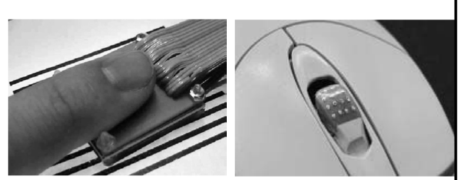
Feelings & Games

signals & mapping

discrete signals: cues	continuous signals: patterns
static imaging with active blind inspection (exploratory movements) e.g., graphic primitives and objects some qualities and physical parameters graphs, diagrams, textures, matrixes	dynamic visualization e.g., graphs, diagrams, tables objects' interaction/interrelationships generalized features

Sribunruangrit et al. 2003, 2004





[12, 13]

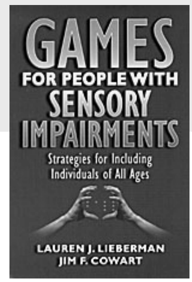
G. Evreinov p 14_65 10.01.2005

Give me the toy - tap on the back of his hand until he lets go of the toy

Go to sleep - cover eyes and move hand down, pat his chest

Finished - put his hands together then down

GAMES!!!!



http://www.tr.wou.edu/tr/dbp/archive.htm

the International Game Developers Association (IGDA) has published the official white paper on Game Accessibility* (June 29, 2004)

"there are a number of assistive technology solutions available today being used for general computer access that could also being used with games

some are designed for disabilities but not for games while others are designed for games but not disabilities"

as game systems become more ubiquitous, different technical platforms have been involved to support more game-like interaction

* http://www.igda.org/accessibility/

a game is a goal-directed and competitive activity conducted within a framework of agreed rules [14]

in being goal-directed, a game provokes activity aimed towards goal attainment or of some intermediate state to facilitate making the final decision or capture

in being competitive, each step and activity have to be evaluated by some kind of payoff value or measure of the progress development

the win/lose criteria may involve absolute or relative measures (time, scores, levels)

game may be realized for a single player, as a competition between player and computer (simulated player) or as a collaborative game involving several real players

for games played without computational support, players need to understand the rules

one of the advantages of computer games is that the machine enforces the rules, relieving the player from the need to know all of the rules in detail [16]

learning to play, making progress within a game and completing or winning a game are a matter of learning how to interact within the game system and its rules in a way that supports progress [14]

a player performs actions having conventional connotations as moves within the formal system of the game

a gameplay behavioral pattern can have many forms for a particular game, capturing different playing styles and strategies to progressing through the game in general, it is a particular way of thinking about the game tasks together with a pattern of repetitive perceptual, cognitive, and motor operations

a particular gameplay behavioral pattern is always unique regarding the system: person – game – conditions

game script is always includes series of smaller scale conflicts and challenges in order to progress within game levels (monsters to be defeated or avoided, puzzles to be solved, or treasures, clues that must be found); usually it is only the lowest level of the game intrigue that is highly interactive

engagement and immersion facilitate the player entering a state of flow which provides a form of playing pleasure based upon the pattern of interaction

the wrong term “disabled person” means that the person does not know her/his real abilities, he cannot use his brain capabilities properly to feel the world and to control the body

How can we open the person for dialogue and communication through technological achievements and our knowledge?

How can we open the person for herself or himself and for the society?

we have a lot of open questions… but the solutions are still in progress

- activation & development of the residual senses and memory
- signals & amodal patterns, gestures, behavioral patterns…
- navigation and orientation in artificial environment
- communication & cognitive information processing…
- techniques, interaction style & behavioral strategies

games with sounds

most sound games are static puzzle games that rely on MIDI, speech synthesis (MS Agent) and/or pre-recorded wave files (*.wav) spoken text (http://www.naturalvoices.att.com/demos/), and sound files can provide any form of mono/stereo/3D… audio feedback for status/progress and special game information

as a rule, the player uses a conventional input technique and interacts with the program objects, the modulation of sound parameters directly still is rarely used in games

there has been a lot of investigation done based on re-writing the traditional scripts taken from the different cultures and the peoples

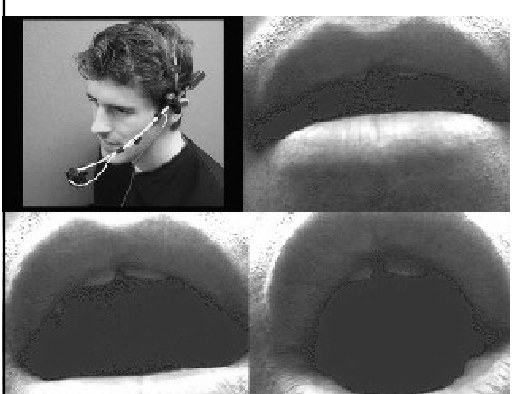
if we'll try to adapt the new technique to the script which was intended for another tools we have a risk to lose the features of both the technique and the game script

games with sounds

for instance,

because facial action is involved in both speech production and emotional expression, there is a rich space of intuitive gesture to sound mappings for face action [17]

New Interfaces for Musical Expression http://www.music.mcgill.ca/musictech/nime/



Demo 8

games with sounds

remember the tones and replay them with your phone

see how long you could remember the melody

in the two Player mode you can get into a competition with another player

http://www.tinysolutions.net/senso/senso.htm

games with sounds

Auditory direct manipulation: Sonification of Towers of Hanoi

Fredrik Winberg and Olof Hellström

http://www.acoustics.hut.fi/icad2001/proceedings/papers/winberg.pdf
http://www.nada.kth.se/~fredrikw/ToH_prototyp/ToH.html

games with sounds

the task is to detect hidden (invisible) squares using the list of earcons/tactons/.../short-speech cues for interaction and navigation

this task (blind interaction) has also didactic goals

it teaches to select the right behavior strategy (interaction style) and to make the sketch or mental imaging of the external objects rationally

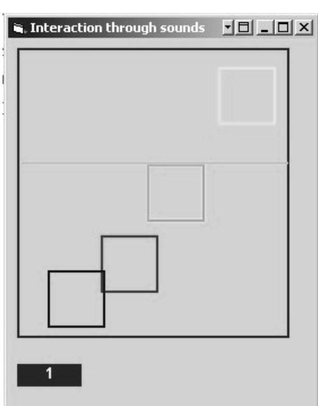
sounds (earcons) have to support the next features:

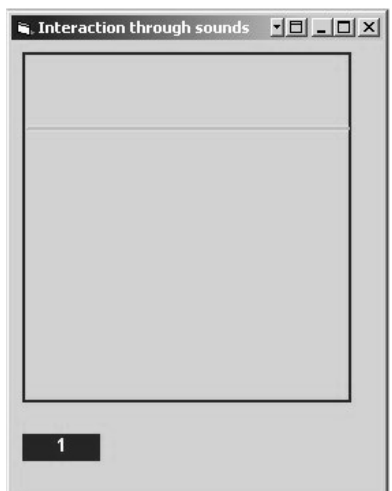
- shape name (sound1…4),
- a collision with the frame of the game field (sound5),
- collisions between cursor/stylus and the shape borders (sound6),
- a capture of the shape in the central field of the shape (sound7),
- collisions between shapes (sound8),
- shapes' overlapping (sound9),

released button (stylus lifting) will delete captured shape (overlapped shape is still present); do it asap, 30 second per level, 5 levels!...

games with sounds

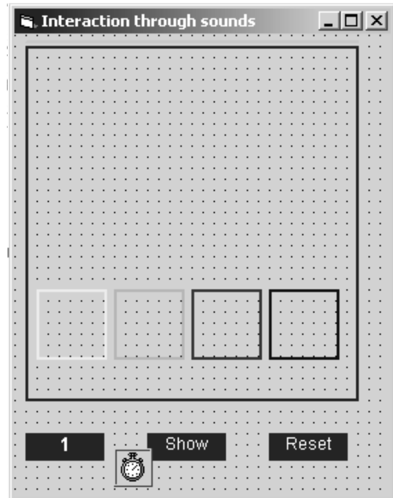
really, the game is based on "manipulating" the arrays which can describe the objects and actions by some way





games with sounds

really, the game is based on "manipulating" the arrays which can describe the objects and actions by some way



SetGame → Timer1

Form_MouseDown

Form_MouseMove

“ultrasonic locator”

Form_MouseUp

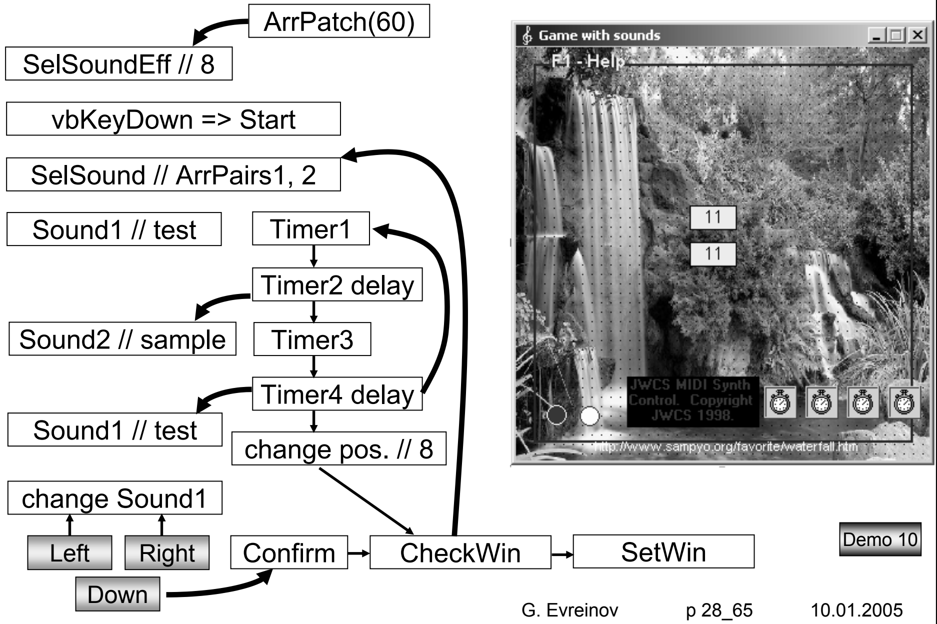
Form_KeyDown

Demo 9

games with sounds

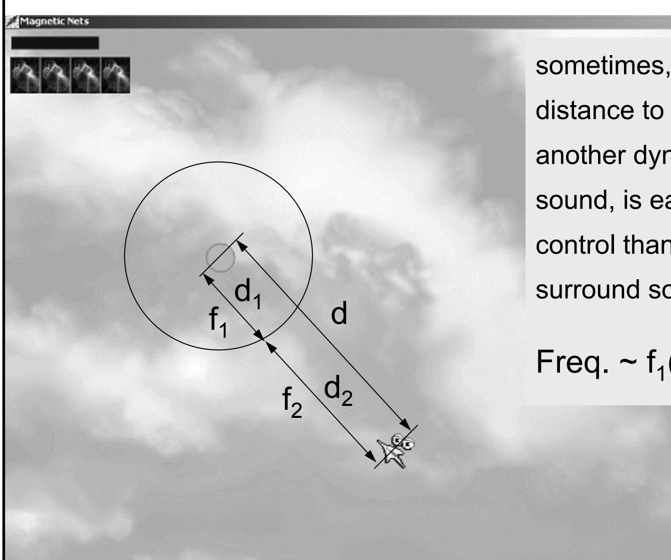
the task is
player has to listen to two different sounds of different musical instruments
one of sounds will change position eight times from the left side to the right side
player has to compare sounds and to change the parameter of moving sound (e.g., timbre/instrument) by pressing down Left or Right arrow keys as many times as needed
if sounds are equal, player has to press the arrow key Down
if sounds are not equal, player will lost one of eight positions which allow to make a choice
if sounds are equal, scan interval will decrease by 25 ms
game will stop when the moving sound has only two positions

games with sounds



Demo 10

games with sounds

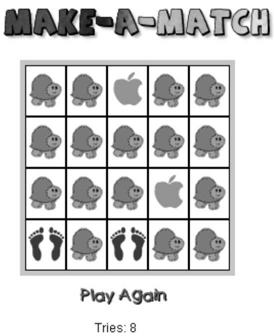


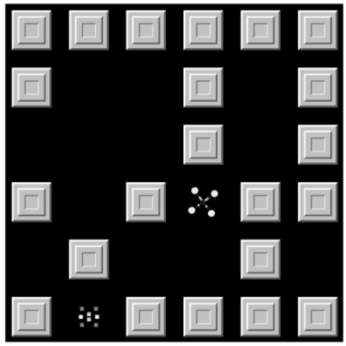
sometimes, 1D-sonification of the distance to target or converting another dynamic parameter into sound, is easier to imagine and control than 2D-sonification or surround sound spatialization

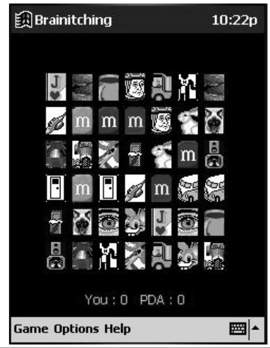
Freq. ~ $f_1(d_1)$, $f_2(d_2)$

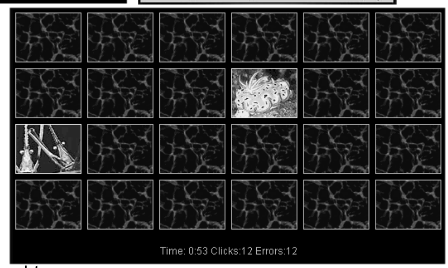
Demo 11

puzzle









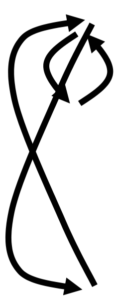
Matching

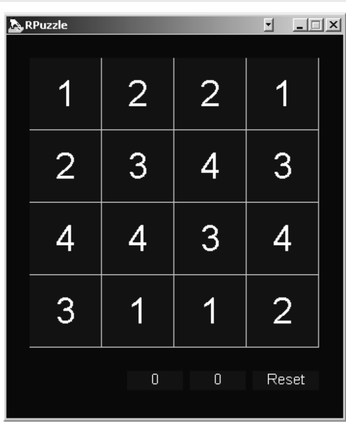
memory & attention concentration

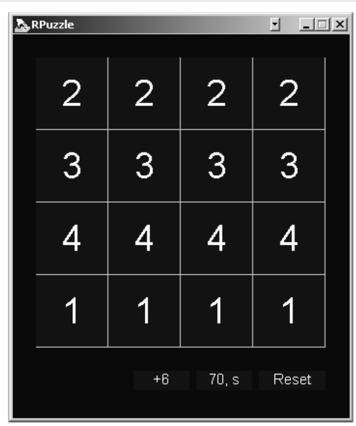
http://www.funbrain.com/match/
http://www.zefrank.com/memory/
http://www.seasky.org/games/sea4e.html
http://www.free-downloads.net/sub_category/Mind_Games
http://www.snapfiles.com/pocketpc/ppc_fwgames.html
http://www.pcworlddownload.com/games/puzzles/Brainitching.htm

puzzle - a toy that tests your ingenuity

the task is to collect similar numbers into the rows, having a minimum number of permutations
the click onto any cell will change the numbers of two adjacent cells in the column





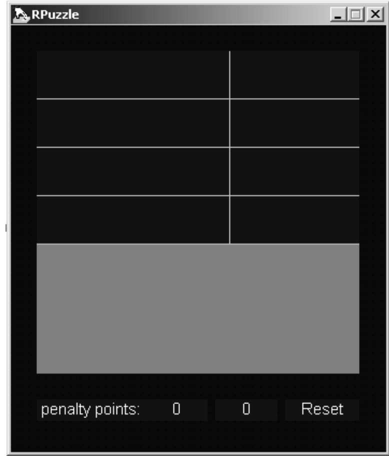


Demo 12

Feelings & Games

puzzle

SetPuzzle
GetTickCount
Grid1_MouseMove
ChangePuzzle
CheckWin
GetTickCount
ChangeLevel
DetectCell
ChangeScale
Public Function CharCount



Ctrl + E / F / M => English / Finnish / Music - numbers or music sounds
Space => to play sound/earcon without permutation
Ctrl + R => to Reset puzzle, Ctrl + 2 / 1 => to reset Zoom

Demo 13

G. Evreinov p 32_65 10.01.2005

Feelings & Games

2
2
2
0
2
2
0
2
0
32547
37835
9965
0
17205
22833
0
40178
0
5
6
2
0
4
6
0
2
0
0
4

puzzle

the goal of the "Burglar" is to investigate and memorize the lock prototype to open it as fast as possible

3 levels of difficulty and 2 phases of the game on each level

all the data, times and number of repetitions per button /sound/, in training phase and during the game are automatically collected and stored in a log file

Demo 14

G. Evreinov p 33_65 10.01.2005

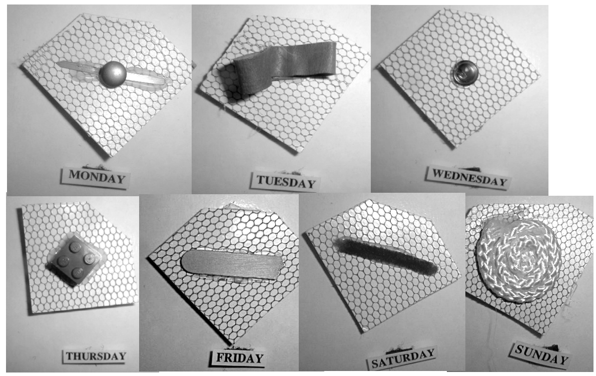
Feelings & Games

games based on tactile signs & navigation

standard tactile symbol list

Texas School for the Blind and Visually Impaired
Functional Academics and Basic Skills Department [19]
http://www.tsbvi.edu/Education/vmi/tactile_symbols.htm

meaning category
time
events
places
people
emotions
objects
food
actions
miscellaneous words
gym symbols



G. Evreinov p 34_65 10.01.2005

Feelings & Games

games based on tactile signs & navigation

standard tactile symbol list

Texas School for the Blind and Visually Impaired
Functional Academics and Basic Skills Department [19]
http://www.tsbvi.edu/Education/vmi/tactile_symbols.htm

meaning category
time
events
places
people
emotions
objects
food
actions
miscellaneous words
gym symbols

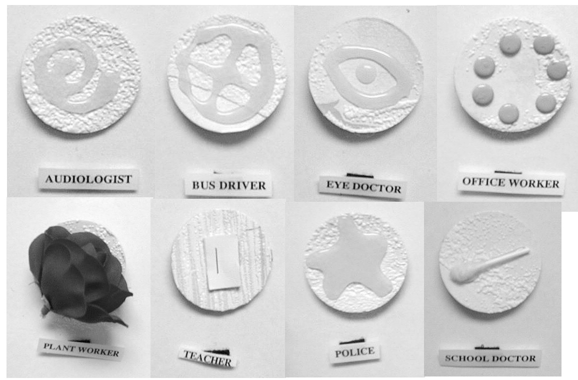
G. Evreinov p 34_65 10.01.2005

games based on tactile signs & navigation

standard tactile symbol list

Texas School for the Blind and Visually Impaired
Functional Academics and Basic Skills Department [19]
http://www.tsbvi.edu/Education/vmi/tactile_symbols.htm

meaning category
- time
- events
- places
- people
- emotions
- objects
- food
- actions
- miscellaneous words
- gym symbols

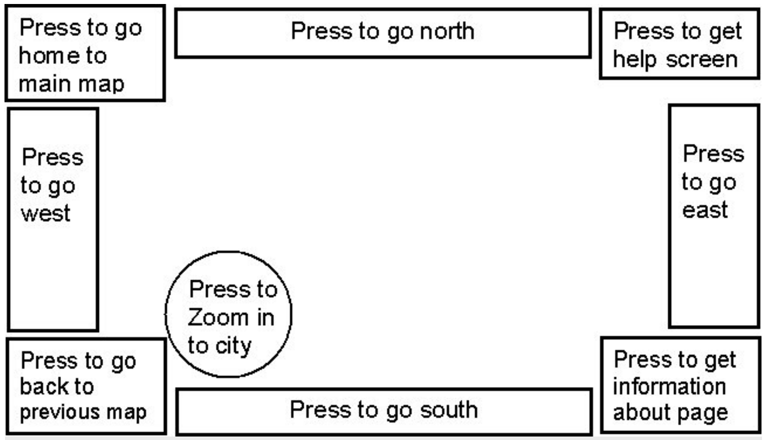


audio-tactile scenario and navigating maps/overlays

File menu	Edit menu	Speech menu	Format menu
Alerts	Dialogues	Document 1	Document 2

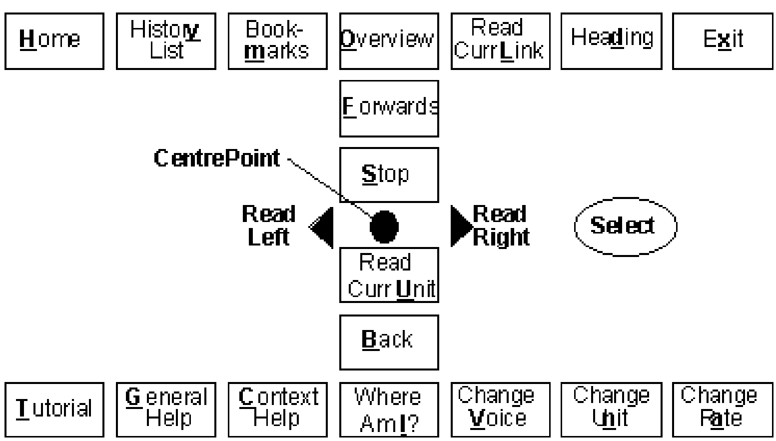
Edwards A.D.N., 1991, [18]

audio-tactile scenario and navigating maps/overlays



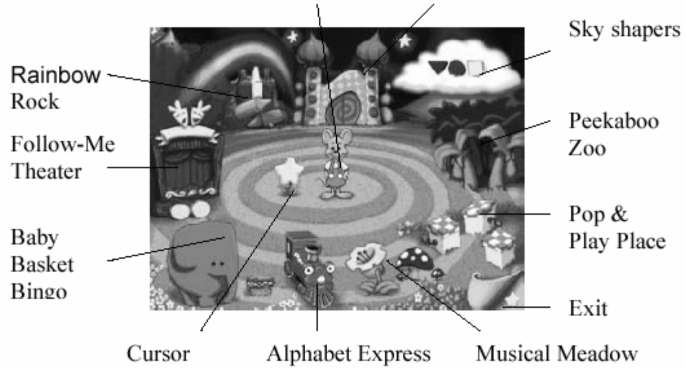
Jacobson, R. D., 1998, [19]

audio-tactile scenario and navigating maps/overlays



commands in DAHNI V2 [20]

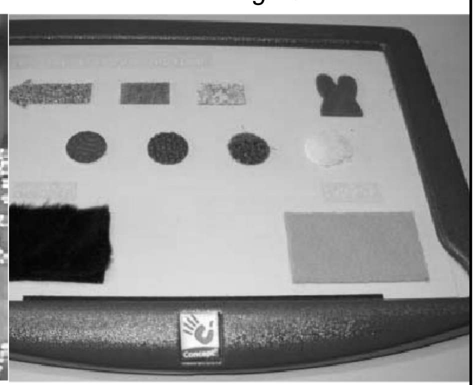
sound + tactile *Feelings & Games*



Reader Rabbit (Mat) game for children (tactile board /input/ + sound)
in a magic environment, an imaginary character guides the child
the child can play with a nine educational games
to enhance tactile discovery and discrimination, to remember board functions and improve motivation all buttons have different textures
http://www2.hku.nl/~audiogam/ag/articles/timd12.pdf

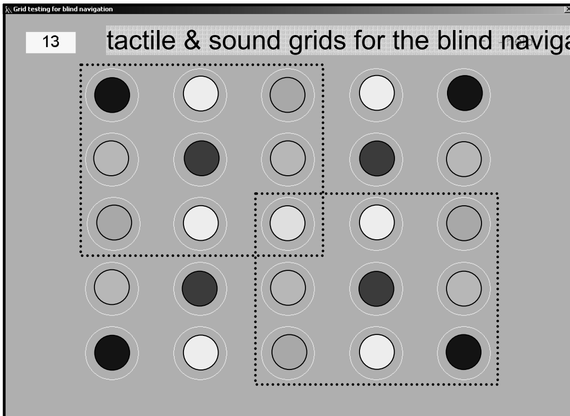
G. Evreinov p 36_65 10.01.2005

sound + tactile *Feelings & Games*



Reader Rabbit (Mat) game for children (tactile board /input/ + sound)
in a magic environment, an imaginary character guides the child
the child can play with a nine educational games
to enhance tactile discovery and discrimination, to remember board functions and improve motivation all buttons have different textures
http://www2.hku.nl/~audiogam/ag/articles/timd12.pdf

G. Evreinov p 36_65 10.01.2005

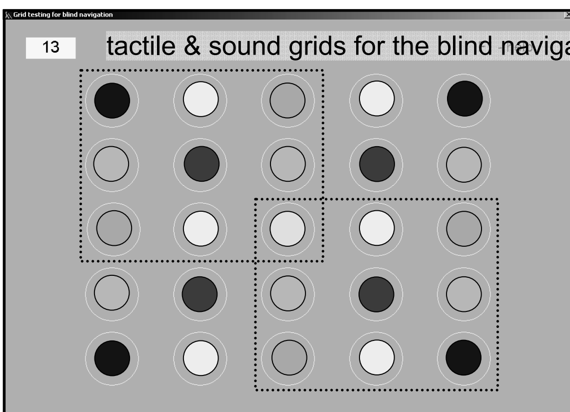


Feelings & Games

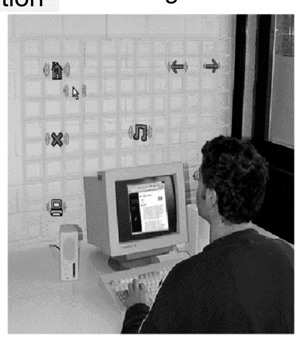
center – 1
angles – 4
middle1 – 4
middle2 – 4
middle3 – 6
middle4 – 6
= 25

the task is to optimize/minimize the number of sounds (3 - 6)
and to estimate usability of the grid designed (sonification)
Grid_S is the tool for research of blind navigation with conventional and alternative input devices (mouse, joystick, touch tablet, touchscreen) when defined positions in a working field are marked with sound or tactile cues (texture, vibration etc)

G. Evreinov p 37_65 10.01.2005



Feelings & Games



[33]

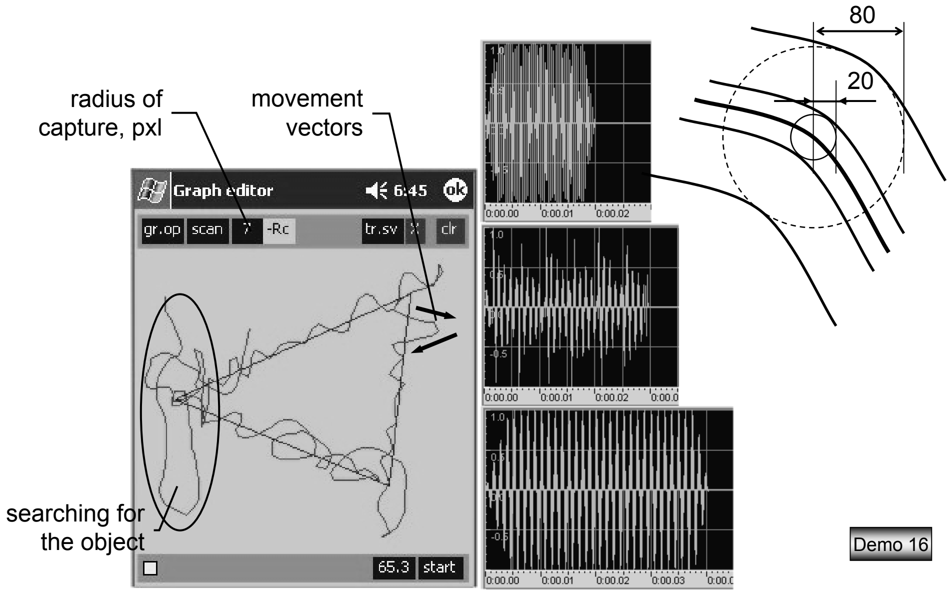
the task is to optimize/minimize the number of sounds (3 - 6)

Demo 15

and to estimate usability of the grid designed (sonification)
Grid_S is the tool for research of blind navigation with conventional and alternative input devices (mouse, joystick, touch tablet, touchscreen) when defined positions in a working field are marked with sound or tactile cues (texture, vibration etc)

G. Evreinov p 37_65 10.01.2005

directional-predictive signals



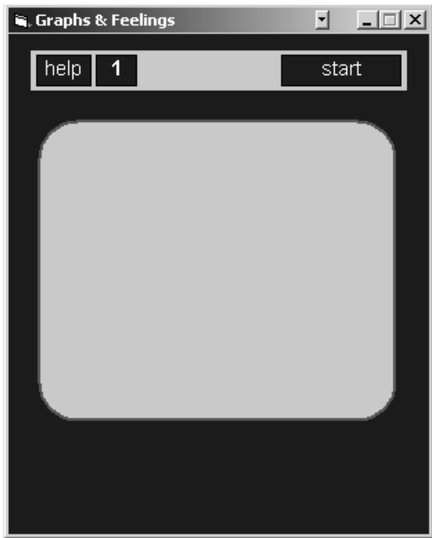
Demo 16

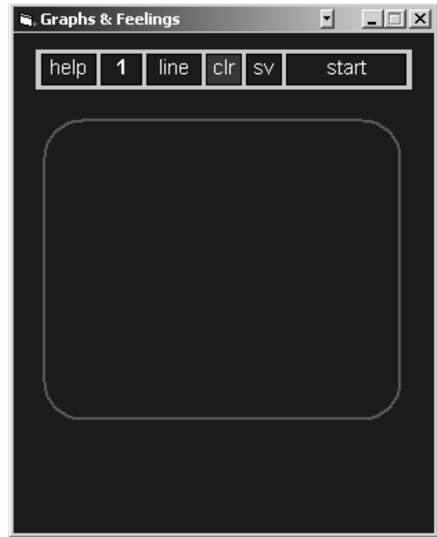
hidden graphs

blind people are deprived the ability to see graphs
sighted people cannot see through opaque substance but...
due to the sound of the metal-detector a sapper can find a mine
hydro-acoustician can see far through ocean, medicine doctor can see the embryo...
3 different sounds will guide player actions to help in detection of hidden graphs
the task is to choose the right strategy and recognize the hidden graph
the task for programmer is
how to install the “dialogue” with player (in a blind mode), estimate the result of the game and the behavior strategy?

Feelings & Games

hidden graphs





Feelings & Games

hidden graphs

GameStart
preliminary inspection
confirmation & statistics

Timer1 //load/unload

Form_MouseDown

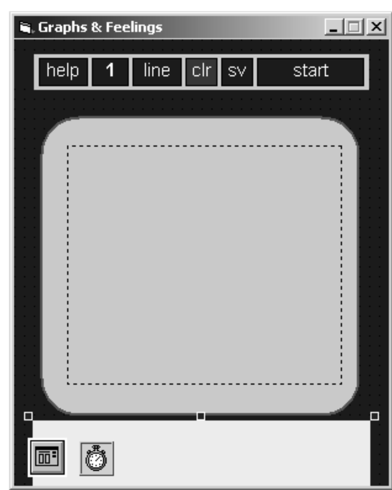
Form_MouseMove → Inspection

Form_MouseUp → PictureRefresh()

SaveData()

Grid()

DrawTrack()
//TestStop



Demo 17

finger dexterity test & training

computer keyboard is widespread but, sometimes, we need to make a signature by handwriting

seems soon, some persons could not make that and they will prefer fingerprint as many years ago…

the reason is very simple: at school, children learn to print only

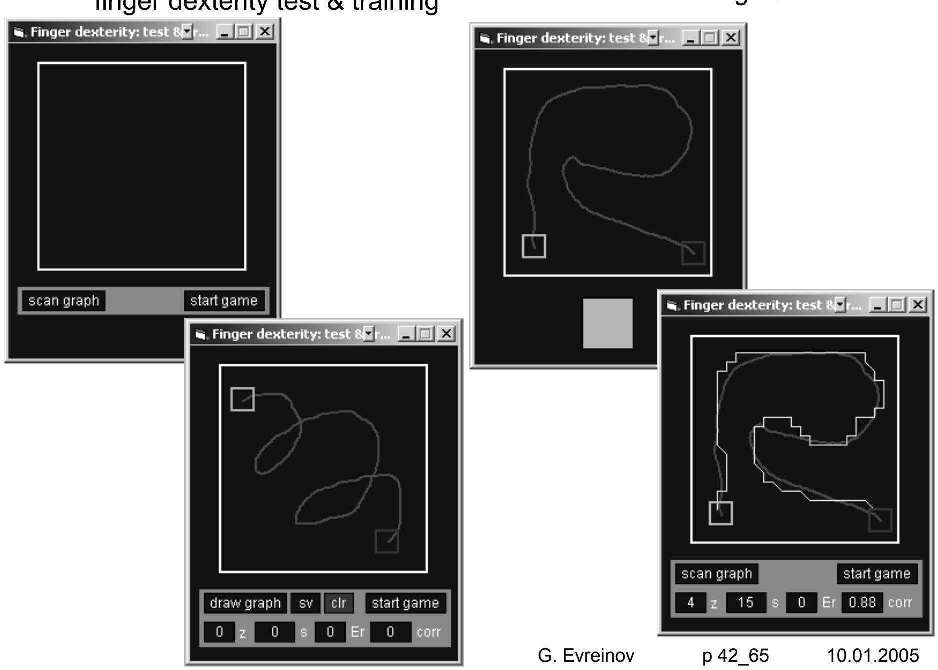
to fill the documents we need also use the capital letters only to avoid mistake when somebody tries to interpret our hieroglyphs

thus, handwriting skills are becoming a rarity in the modern society

the task in this game is the training of fine accurate motions with using of stylus

moreover, this game can be used as the test to measure finger dexterity and hand-eye coordination

finger dexterity test & training



Feelings & Games

finger dexterity test & training

Form_Activate

Form_MouseDown

Form_MouseMove

Form_MouseUp

SetGraph()

DrawTrack()

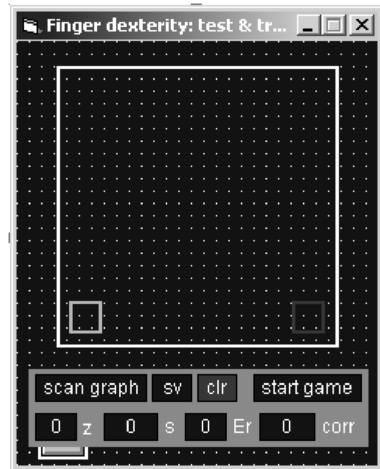
Statistics()

SetFeedback()

ClearGraph()

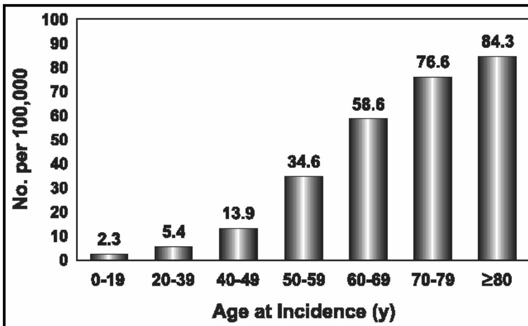
DrawGraph()

lblSave_Click()



Demo 18

G. Evreinov p 42_65 10.01.2005



Feelings & Games

finger dexterity test & training

[21]

NOTE: tremor can be considered as a symptom of some neurological diseases, such as Parkinson's disease, multiple sclerosis, diseases of or damage to the cerebellum, or as a result of some drugs' application

the game allows estimation and measuring an individual's ability to move the fingers and to control micro-movements (finger/tip dexterity)

this is also a fun game for children, who can create their own tasks and play to improve or acquire handwriting skills

G. Evreinov p 43_65 10.01.2005

vibration

Feelings & Games

the human threshold for detection of vibration at about 28 dB for frequencies in the range of 0.4 - 3 Hz

(human eye dynamic range is around 90 dB)

threshold decreases for frequencies in the range of

3 to about 250 Hz

for higher frequencies than 250 Hz the threshold increases [22]

G. Evreinov p 44_65 10.01.2005

vibration

Feelings & Games

Immersion's TouchSense cell phone system controls a phone's vibration motor through its software and custom actuator technology that enable these motors to deliver varying strengths and frequencies, under control of the application developer

it is possible generating distinct vibration patterns for certain callers, events/subjects or actions, a feature that would be useful during meetings or in other public places

http://www.immersion.com/consumer_electronics/applications/cell_phones.php
http://www.manufacturingcenter.com/dfx/archives/0703/0703techspot.asp
http://www.cs.uta.fi/hci/mmig/laboratory.php

G. Evreinov p 44_65 10.01.2005

Feelings & Games

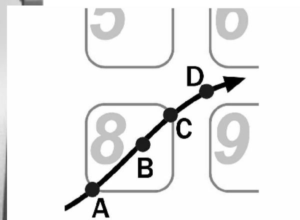


Figure 2: Path of the user's finger as it glides over a virtual button: (a) pop as the finger enters a button region; (b) low amplitude vibration in the button; (c) pulse as the finger leaves; (d) no vibration between buttons.

Nokia 7700 media device

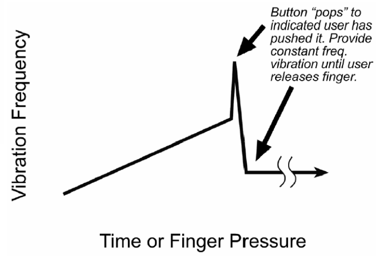


Figure 3: Vibration profile of a button responding to a user push.

Nashel et al. [23]

G. Evreinov p 45_65 10.01.2005

Feelings & Games

Aura Interactor works by "listening" to any game system's audio output triggering an Aura Magnetic actuator within the vest, which in turn creates vibrations (from a feather touch to intense pounding) keyed to the on-screen action

"rabbit" display
consists of a 3-by-3 vibro-tactile array of 40mm diameter flat magnetic speakers (FDK Corp., Japan), 290 Hz, 28 dB SL (sensation level) [24]

G. Evreinov p 46_65 10.01.2005

Feelings & Games

VisPad

a new device for vibro-tactile force feedback designed for visualizing data and constructed from commodity massage chair pads [http://www.goodchairs.com/fuji-massage-chair.htm] with custom controllers and interfaces to a computer [25] (permanent conjunction problem)

G. Evreinov p 47_65 10.01.2005

Feelings & Games

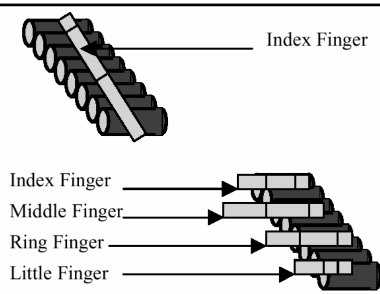


Figure 2. Two ways way of using the 8 vibrating devices interface

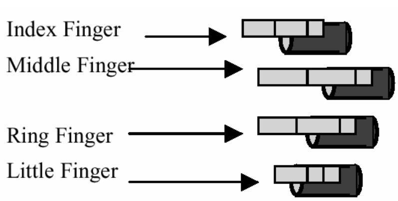


Figure 3. The four vibrating devices interface

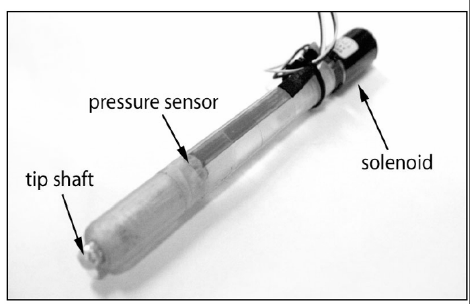
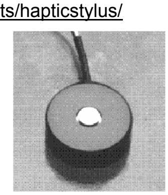


Figure 1. Haptic Pen – a tactile feedback stylus

[26] http://www.merl.com/projects/hapticstylus/

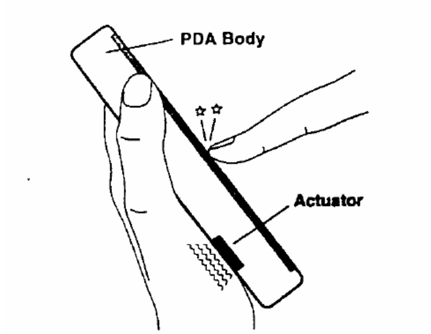


Tactor

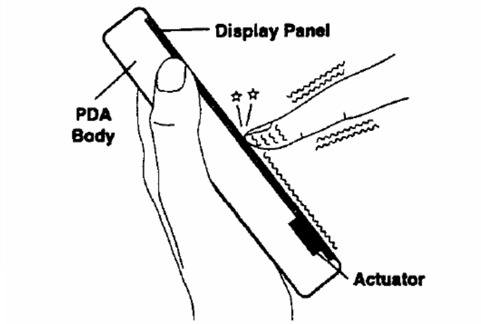
http://www.eaiinfo.com/page5.html

[27] http://www.lac.u-psud.fr/teletact/publications/locomotion_assistance.htm

G. Evreinov p 48_65 10.01.2005

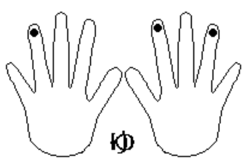


(a) Body mounted actuator for PDA.
Tactile information is conveyed to grasping hand.

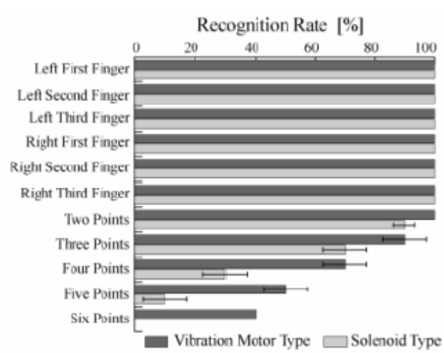


(b) Panel mounted actuator for PDA.
Tactile information directly reaches tapping finger-tip.

Fukumoto et al. [28]

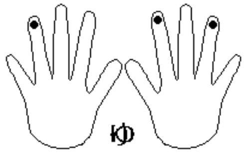


Wearable Finger-Braille Interface for Navigation of Deaf-Blind in Ubiquitous Barrier-Free Space [29]



http://www1.u-netsurf.ne.jp/%7Emacky/yubi.html
http://www1.u-netsurf.ne.jp/%7Emacky/yubi8.html
http://www.cyber.rcast.u-tokyo.ac.jp/~rayn/index3.html

Feelings & Games

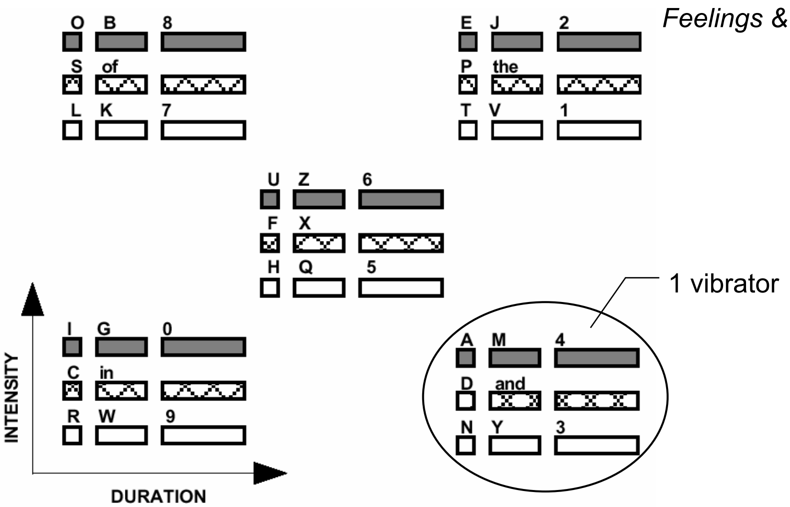


Wearable Finger-Braille Interface for Navigation of Deaf-Blind in Ubiquitous Barrier-Free Space [29]

the palm can be used freely and the device never prevents the user from obtaining original tactile sense information [29]

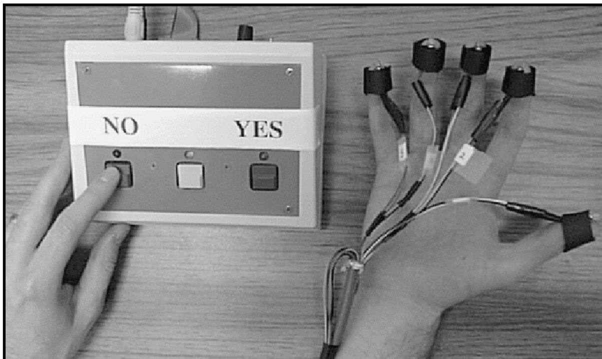
http://www1.u-netsurf.ne.jp/%7Emacky/yubi.html
http://www1.u-netsurf.ne.jp/%7Emacky/yubi8.html
http://www.cyber.rcast.u-tokyo.ac.jp/~rayn/index3.html

Feelings & Games



Vibratese language (Geldard, 1957) [30]
a single vibrator varies in intensity (3 levels) and duration (3 levels)
the 5 vibrators display letters, numerals, and the most frequently used short words; subjects were able to receive a complex message up to 38 wpm

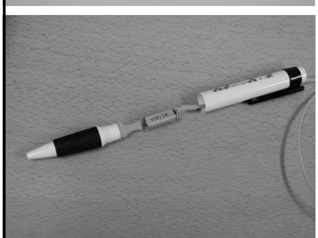
Feelings & Games



Tactile sequential learning: Artificial grammar learning by touch
Conway, 2001 [31]

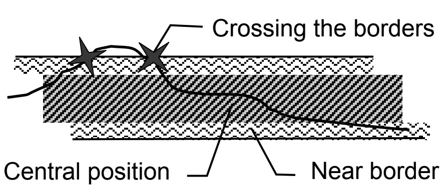
sequential learning means the ability to encode and represent the order of discrete elements occurring in a sequence

Conway showed that touch is capable of performing well on an AGL task in which grammatical and ungrammatical test items differed by the presence or absence of internal pairwise violations



Feelings & Games

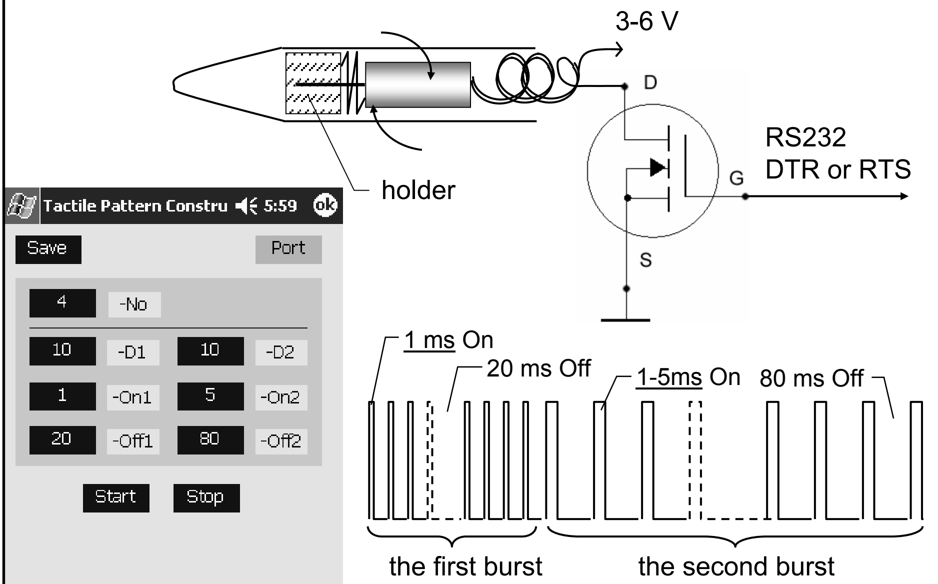
vibro-tactile pen



Evaluating Non-Visual Feedback Cues for Pen Computing [32]

Feelings & Games

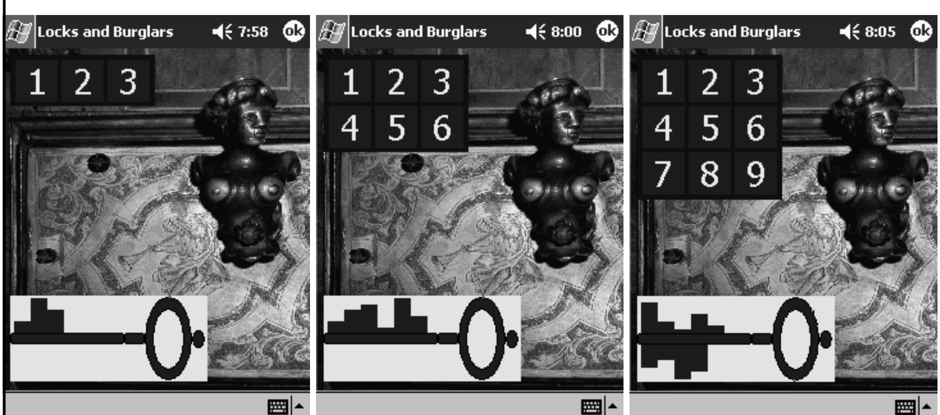
vibro-tactile pen



G. Evreinov p 54_65 10.01.2005

Feelings & Games

method for learning vibro-tactile patterns



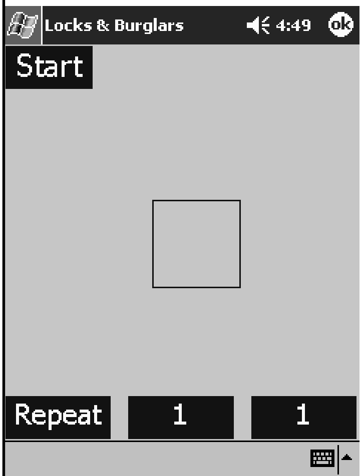
three levels of the game “Locks and Burglars”

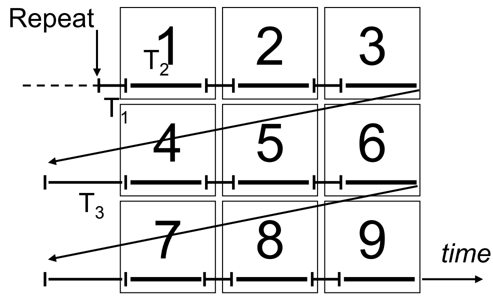
Demo 19

G. Evreinov p 55_65 10.01.2005

Feelings & Games

the versions of the game for blind player



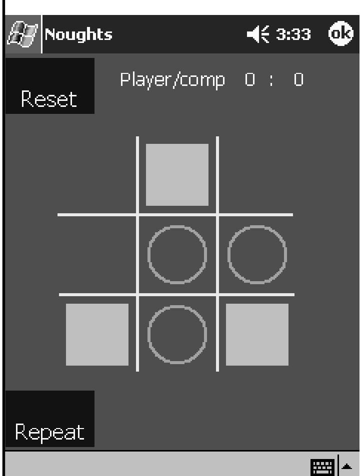


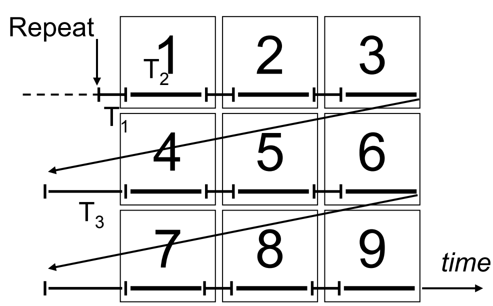
T_1 = 60 ms, T_2 = 1100 ms, T_3 = 300 ms

G. Evreinov p 56_65 10.01.2005

Feelings & Games

the versions of the game for blind player





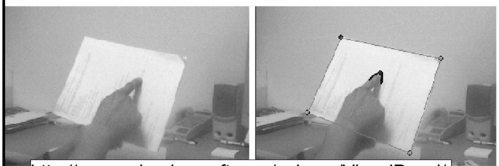
T_1 = 60 ms, T_2 = 1100 ms, T_3 = 300 ms

Demo 20

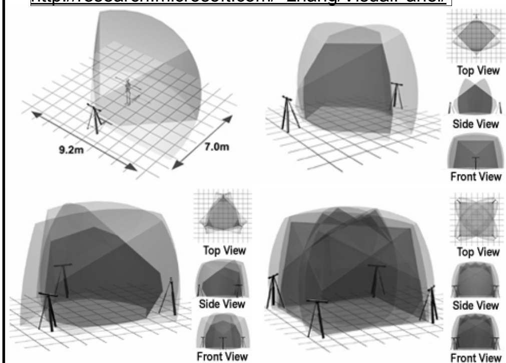
G. Evreinov p 56_65 10.01.2005

Feelings & Games

AnyTracker



http://research.microsoft.com/~zhang/VisualPanel/



Visualeyez™ Multiple Tracker Systems

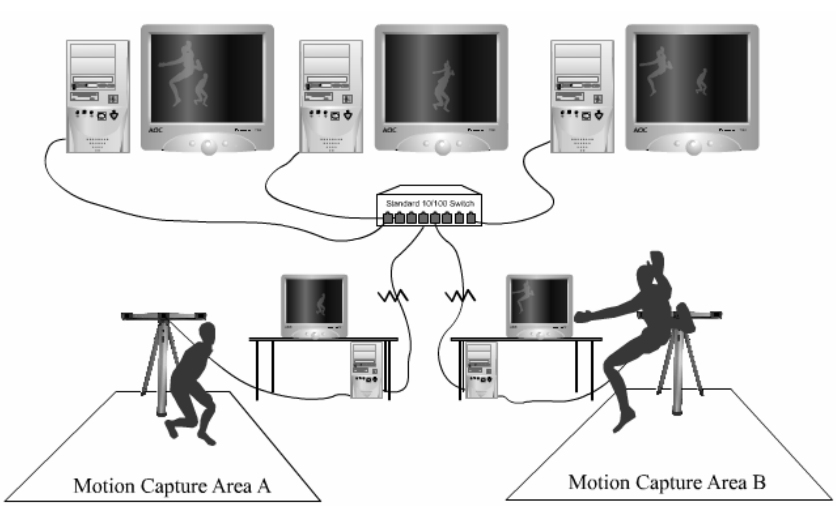
http://www.ptiphoenix.com/products/visualeyez/multitracker.php

http://www.ptiphoenix.com/products/hydranet/

G. Evreinov p 57_65 10.01.2005

Feelings & Games

AnyTracker



Demo 21

Demo 22

Demo 23

Demo 24

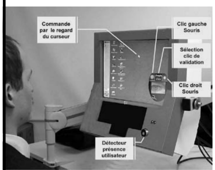
Visualeyez™ Multiple Tracker Systems

http://www.ptiphoenix.com/products/visualeyez/multitracker.php

http://www.ptiphoenix.com/products/hydranet/

G. Evreinov p 57_65 10.01.2005

AnyTracker

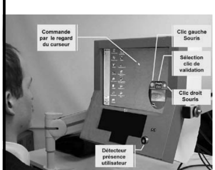


computer users who cannot use hand-operated input devices may use a head-operated mouse simulation and on-screen controls

http://www.delta7.asso.fr/ , http://www.tobii.se/,
http://www.metrovision.fr/mv-vi-notice-us.html
http://www.cs.bc.edu/~gips/CM/ or http://www.cameramouse.com/
http://vret.ces.clemson.edu/ , http://www.naturalpoint.com/

Feelings & Games

AnyTracker



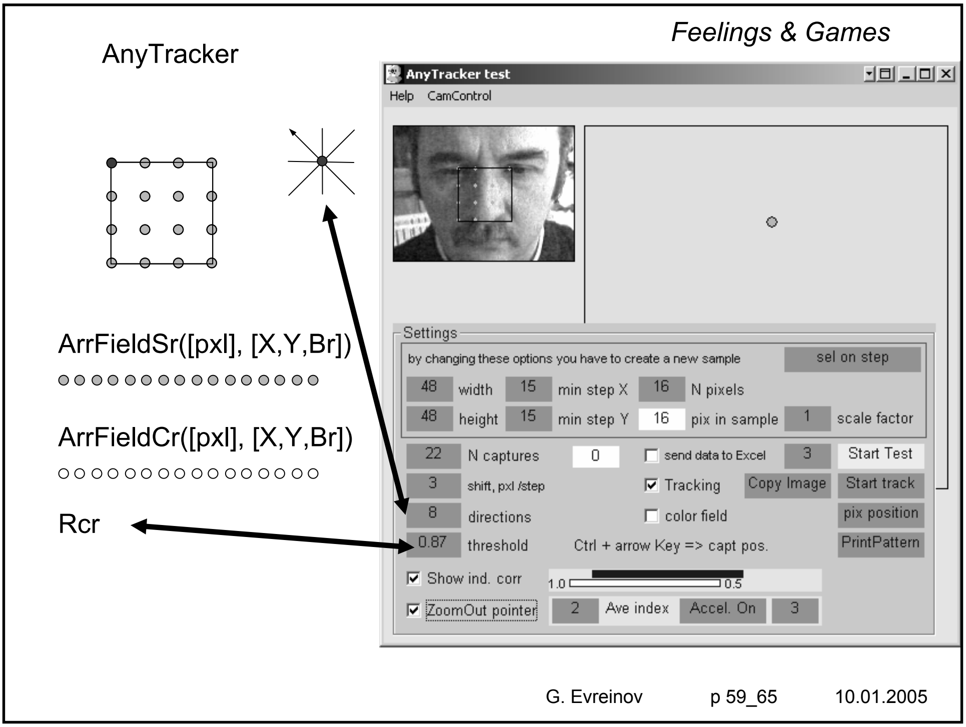
computer users who cannot use hand-operated input devices may use a head-operated mouse simulation and on-screen controls

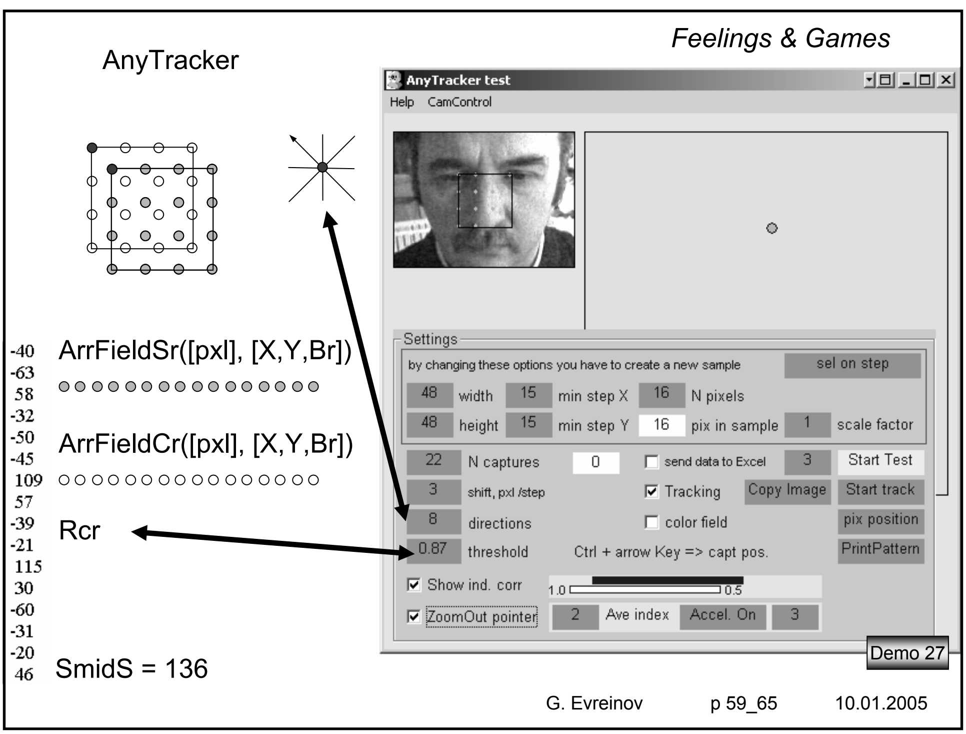
Demo 25

Demo 26

http://www.delta7.asso.fr/ , http://www.tobii.se/,
http://www.metrovision.fr/mv-vi-notice-us.html
http://www.cs.bc.edu/~gips/CM/ or http://www.cameramouse.com/
http://vret.ces.clemson.edu/ , http://www.naturalpoint.com/

G. Evreinov p 58_65 10.01.2005


Feelings & Games
AnyTracker
AnyTracker test
Help CamControl
ArrFieldSr([pxl], [X,Y,Br])
ArrFieldCr([pxl], [X,Y,Br])
Rcr
Settings
by changing these options you have to create a new sample
sel on step
48 width
15 min step X
16 N pixels
48 height
15 min step Y
16 pix in sample
1 scale factor
22 N captures
0
send data to Excel
3
Start Test
3 shift, pxl /step
Tracking
Copy Image
Start track
8 directions
color field
pix position
0.87 threshold
Ctrl + arrow Key => capt pos.
PrintPattern
Show ind. corr
1.0
0.5
ZoomOut pointer
2 Ave index
Accel. On
3
G. Evreinov
p 59_65
10.01.2005


Feelings & Games
AnyTracker
AnyTracker test
Help CamControl
-40
-63
58
-32
-50
-45
109
57
-39
-21
115
30
-60
-31
-20
46
ArrFieldSr([pxl], [X,Y,Br])
ArrFieldCr([pxl], [X,Y,Br])
Rcr
SmidS = 136
Settings
by changing these options you have to create a new sample
sel on step
48 width
15 min step X
16 N pixels
48 height
15 min step Y
16 pix in sample
1 scale factor
22 N captures
0
send data to Excel
3
Start Test
3 shift, pxl /step
Tracking
Copy Image
Start track
8 directions
color field
pix position
0.87 threshold
Ctrl + arrow Key => capt pos.
PrintPattern
Show ind. corr
1.0
0.5
ZoomOut pointer
2 Ave index
Accel. On
3
Demo 27
G. Evreinov
p 59_65
10.01.2005

AnyTracker

a normal cycle looks like this one

Timer1 => CaptureImage =>

=> CheckPosition

=> FieldShift1(1-5)

=> CopyFieldPos

=> Statistics

=> CheckThresh => Timer1

```
If p <= 2 Then
  FieldLeft2 = FieldLeft1 + dshift * (p - 1)
  FieldTop2 = FieldTop1 - dshift
  CopyFieldPos
  Statistics
```


AnyTracker

a normal cycle looks like this one

Timer1 => CaptureImage =>

=> CheckPosition

=> FieldShift1(1-5)

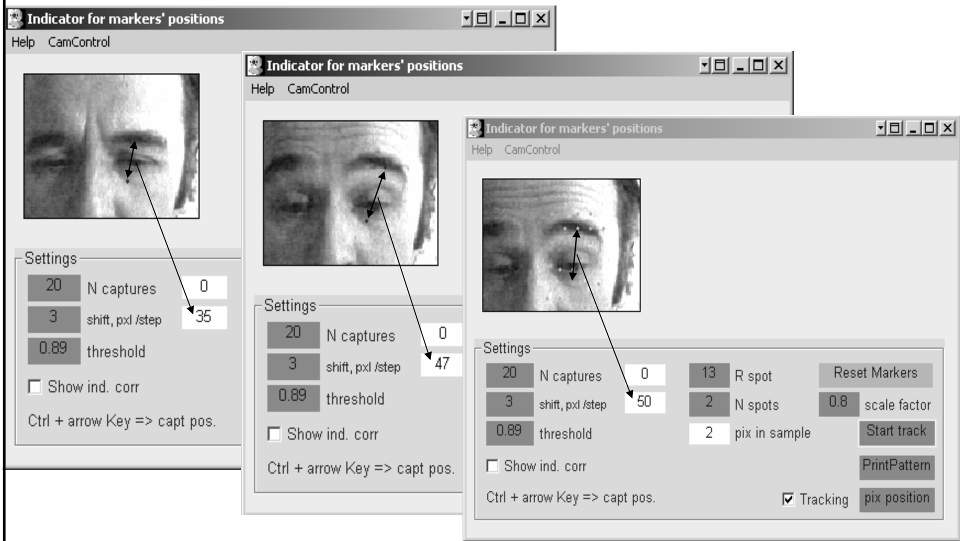
=> CopyFieldPos

=> Statistics

=> CheckThresh => Timer1

```
If iSearch < Rcapt - 1 Then
   dshift = StepN * iSearch     'conditional shift
shpField
   For p = 0 To Ndir            'Ndir = 3, 4, 6, 8
      If lblDirects.Caption = "8" Then FieldShift1
      If lblDirects.Caption = "6" Then FieldShift2
      If lblDirects.Caption = "4+" Then FieldShift3
      If lblDirects.Caption = "4X" Then FieldShift4
      If lblDirects.Caption = "3" Then FieldShift5
      If bTrack = False Then Exit Sub
   Next
   If bTrack = False Then Exit Sub
End If
```

Positions' Indicator



Demo 28 Demo 29

References

[1] Bach-y-Rita, P., Kaczmarek, K.A. Tongue placed tactile output device. http://kaz.med.wisc.edu/TDU.htm
Bach-y-Rita, P., Kaczmarek, K.A. Tongue Display System, ttp://kaz.med.wisc.edu/Patents/US6430450.html

[2] MouthType: Text Entry by Hand and Mouth Michael J. Lyons, Chi-ho Chan, Nobuji Tetsutani Proceedings, CHI 2004 pp. 1383-1386, http://www.mis.atr.jp/~mlyons/pub_pdf/mouthtype.pdf

[3] Konrad Lukaszewicz, The Ultrasound Image of the Tongue Surface as Input for Man/Machine Interface, Human-Computer Interaction – INTERACT'03 M.Rauterberg et al. (Eds), Published by IOS Press, IFIP, 2003, pp. 825-828.
http://www.idemployee.id.tue.nl/g.w.m.rauterberg/conferences/INTERACT2003/INTERACT2003-p825.pdf

[4] Hashimoto, M., Yonezawa, Y. and Itoh, K. New mouse-function using teeth-chattering and potential around eyes for the physically challenged. In: 5th Int. Conf. ICCHP'96 Linz, Austria, July 1996. R. Oldenbourg Verlag GmbH Munich, Germany, Part 1, pp. 93-98.

[5] Lorimer, P., A Critical Evaluation Of The Historical Development Of The Tactile Modes Of Reading And An Analysis And Evaluation Of Researches Carried Out In Endeavours To Make The Braille Code Easier To Read And To Write. http://www.braille.org/papers/lorimer/title.html , or
Psychological Properties Of Touch Perception http://www.braille.org/papers/lorimer/chap7.html

[6] Lederman, S.J., Klatzky, R.L., Hamilton, Ch.L., Ramsay G.I. Perceiving Roughness Via A Rigid Probe: Psychophysical Effects Of Exploration Speed And Mode Of Touch1, at: http://www.haptics-e.org/Vol_01/he-v1n1.pdf

[7] Chavas, M. (1996) Discrimination tactile de textures, in *Int. Conf. "New technologies in the education of the visually handicaped"* (ed. D. Burger), Colloque INSERM, V. 237, Posters, Paris.

References

[8] Taylor, M. M. & Lederman, S. J. (1975). Tactile roughness of grooved surfaces: A model and the effect of friction. *Perception & Psychophysics, 1*7, 23-36.
[9] Hollins, M., Bensmaia, S. & Risner, R. (1998). The duplex theory of tactile texture perception. In *Proceedings of the International Society for Psychophysics, 4th Annual Meetin*g, 115-120.
[10] Lederman, S. J., & Klatzky, R. L. (1999). Sensing and displaying spatially distributed fingertip forces in haptic interfaces for teleoperator and virtual environment systems. *Presence: Teleoperators and Virtual Environments,* 8, 86-103.
[11] Benise S. K. Mak and Alonso H. Vera, The role of motion in children's categorization of objects Cognition Volume 71, Issue 1 , 3 May 1999, Pages B11-B21.
[12] Kajimoto H., et al Electro-Tactile Display with Force Feedback, In Proc. of World Multiconference on Systemics, Cybernetics and Informatics, Vol. XI, Orlando, USA, 2001, pp. 95-99.
[13] Kajimoto, H. *et al* SmartTouch - Augmentation of Skin Sensation with Electrocutaneous Display, HAPTICS 2003. pp. 40-46.
[14] Lindley C. A., "Game Taxonomies: A High Level Framework for Game Analysis and Design", Gamasutra feature article, 3 October 2003, http://www.gamasutra.com/features/20031003/lindley_01.shtml
[15] Lindley, C.A. Ludic Engagement and Immersion as a Generic Paradigm for Human-Computer Interaction Design. In Proc. of ICEC 2004, M. Rauterberg (Ed.), LNCS 3166, pp. 3–13, 2004.
[16] Juul J., "The Game, The Player, The World: Looking for a Heart of Gameness", Proceedings, Level Up Digital Games Research Conference, pp. 30–45, Copier M. and Raessens J., Eds., 4–6 November 2003, Utrecht.
[17] Facial Gesture Musical Interfaces, http://www.mis.atr.co.jp/~mlyons/mouthesizer.html

References

[18] Edwards A.D.N., 1991, http://www.dcs.shef.ac.uk/~stu/HCI/Topic5/
[19] Jacobson, R. D., 1998, http://www.fsu.edu/~geog/jacbsn/dan_jacobsoncvir.pdf
[20] Morley, S., Petrie, H., O'Neill, A.-M., McNally, P. Auditory Navigation in Hyperspace: Design and Evaluation of a Non-Visual Hypermedia System for Blind Users, http://phoenix.herts.ac.uk/SDRU/pubs/ACCESS/MorlPetr.htm
[21] Essential Tremor: A Practical Guide to Evaluation, Diagnosis, and Treatment, Vol. 19 No. 2 ISSN 0264-6404 May 2001. http://www.baylorcme.org/tremor/tremor.pdf
[22] Shimoga, K.B. "A Survey of Perceptual Feedback Issues in Dexterous Telemanipulation: Part II. Finger Touch Feedback." In Proc. IEEE Annual VR Int. Symposium, Seattle, Washington, 1993, pp. 271-279
[23] Nashel, A. and Razzaque, S.: Tactile Virtual Buttons for Mobile Devices. In: Proceedings of CHI 2003, ACM (2003) 854-855
[24] Tan, H., Lim, A. and Traylor, R. A psychophysical study of sensory saltation with an open response paradigm, In Proc. of the ASME Dynamic Systems and Control Division, Vol. 69-2, pp. 1109-1115, 2000, http://www.ecn.purdue.edu/HIRL/publications_pdfs/TAN_IMECE00.pdf
[25] Weissgerber, D., Bridgeman, B., Pang, A. VisPad: A Novel Device for Vibrotactile Force Feedback, http://www.cse.ucsc.edu/~doanna/chair.pdf
[26] Lee, J.C.; Dietz, P.H.; Leigh, D.; Yerazunis, W.S.; Hudson, S.E., "Haptic Pen: A Tactile Feedback Stylus for Touch Screens ", ACM Symposium on User Interface Software and Technology (UIST), ISBN: 1-58113-957-8, pp. 291-294, October 2004
[27] Y. Bellik, R. Farcy, "Experimental Interfaces for a Locomotion Assistance Device", WWDU 2002, Berchtesgaden, Germany, 2002, http://www.cs.uta.fi/~grse/ConferenceWork/WWDU_2002/bellik.pdf

References

[28] Fukumoto, M. and Sugimura, T.: Active Click: Tactile Feedback for Touch Panels. In: Proceedings of CHI 2001, Interactive Posters, ACM (2001) 121-122
[29] Michitaka Hirose and Tomohiro Amemiya, Wearable Finger-Braille Interface for Navigation of Deaf-Blind in Ubiquitous Barrier-Free Space, http://www.cyber.rcast.u-okyo.ac.jp/~rayn/research/pdf/hcii2003.pdf
[30] Geldard, F.: Adventures in tactile literacy. American Psychologist, 12 (1957) 115-124
[31] Conway, Chr. M. Tactile sequential learning: Artificial grammar learning by touch. Unpublished MA Thesis. Southern Illinois University, IL, 2001. http://cnl.psych.cornell.edu/papers/cmc-ma-thesis.pdf
[32] Sharmin, S. Evaluating Non-Visual Feedback Cues. In Grigori Evreinov (ed.), New Interaction Techniques 2003 (Report B-2003-5), Dept. of Computer Sciences, University of Tampere (2003) 3-9. http://www.cs.uta.fi/reports/bsarja/B-2003-5.pdf
[33] Typographic Semantics of Webpages Accessible for Visually Impaired Users - Mapping Layout and Interaction Objects to an Auditory Interaction Space, in Proceedings ICCHP 2000 - International Conference on Computers Helping with Special Needs. Karlsruhe 17-21 July 2000, http://www-cg-hci.informatik.uni-oldenburg.de/resources/ICCHP2000-gorny.pdf
[34] A Head Operated Joystick – Experience with use, G. Evans and P. Blenkhorn, CSUN 99, available at http://www.csun.edu/cod/conf/1999/proceedings/session0019.htm
[35] Sribunruangrit, N., et al., Improving Blind People's Spatial Ability by Bimodal-perception Assistive Device for Accessing Graphic Information. In: Proc. AAATE'03. IOS Press, Netherlands (2003), 476-480.
[36] Sribunruangrit, N. et al. Speed-Accuracy Tradeoff During Performance of a Tracking Task Without Visual Feedback. IEEE Trans. on Neural Systems and Rehabilitation Eng., Vol. 12, No 1, March 2004

References

other useful links
Lieberman, Lauren J. and Jim F. Cowart. Games for people with sensory impairment: strategies for including individuals of all ages. Champaign, Ill. : Human Kinetics, 1996.
see more references here http://www.brockport.edu/pes/faculty/vita/lliebermanpub.html
some papers are here http://www.tr.wou.edu/tr/dbp/archive.htm
Gross Neuro-Anatomy http://www.benbest.com/science/anatmind/anatmd2.html
Gross Neuro-Anatomy http://www.benbest.com/science/anatmind/anatmd2.html
Basic Cerebral Cortex Function Other than Vision http://www.benbest.com/science/anatmind/anatmd6.html
Basic Cerebral Cortex Function with Emphasis on Vision http://www.benbest.com/science/anatmind/anatmd5.html
Neurobiological Correlates of Mental Imagery to Sensory Perception http://serendip.brynmawr.edu/bb/neuro/neuro99/web3/Mintzer.html
Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. Behavioral and Brain Sciences, 17 (2): 187-245. ftp://ftp.princeton.edu/pub/harnad/BBS/.WWW/bbs.jeannerod.html
Standard Tactile Symbol List, http://www.tsbvi.edu/Education/vmi/tactile_symbols.htm
www.adoraentertainment.com
www.audiogames.net
www.soundsupport.net
www.gamesfortheblind.com
www.gmagames.com
www.tpb.se/english/games/ljudspel/index.html
www.certec.lth.se/haptics

Sonification and Basic Behavioral Patterns in Blind Inspection of Hidden Graphs

Leena Vesterinen
Department of Computer Sciences
University of Tampere,
Finland.
Leena.Vesterinen@uta.fi

ABSTRACT

Sonification has become important in encoding information for the blind and visually impaired users. The goal of the Hidden Graphs game project was to optimize the "sonification dialogue" with a player through basic behavioral patterns (BBP) coordinated to capture radius and directional-predictive sound signals (DPS) to facilitate shaping the personal behavioral strategy in discovering the features of the hidden graphs. BBP were applied to build up three different behavioral strategies for the game playing. Concepts of capture radius [Walker and Lindsay, 2004] and DPS were used for guiding the player to attain the goal in the game. Four subjects who started as novices and have become experienced players in blind inspection took part in testing the game. The statistical data analysis showed a significant difference in the performance when three behavioral strategies with different capture radius and directional-predictive sound signals were employed. The performance of the subjects was evaluated in terms of the stylus deviation, the relative frequency of the DPS-sounds used and the task completion time concerning the hidden graphs. The results of the of proposed sonification technique based on directional-predictive sounds paradigm and BBPs are discussed.

Author Keywords

Visually impaired, non-visual interaction, sonification, capture radius, directional-predictive sounds, basic behavioral patterns, graph access.

ACM Classification Keywords

H5.2. User interfaces. Input devices and strategies.

I.3.6 Methodology and Techniques. Interaction techniques.

INTRODUCTION

Over the recent years, there has been an increasing interest into non-visual techniques such as non-speech audio, touch and haptics to signify different forms of information. Need for multimodal data visualization has become more popular due to increasing diverse mobile computer applications serving the user in unfavorable lighting conditions such as smoke, darkness and other distortion factors which hamper observation. As additional space for imaging, sounds and sonification are used to display the huge data arrays in a compact and convenient way due to temporal sound nature [1].

People could have permanent vision loss or a temporary block when vision is occupied by another task. In both cases, there is a challenge to support data imaging and the special techniques should be developed to augment traditional data presentation forms or/and to support an alternative way.

World Wide Web and game industry are progressively increasing fields for sound applications. Moreover, the game is universal medium to test novel metaphors and techniques with a wide contingent of potential users. The blind people are the strong sound experts and, therefore, audio technologies and games (not the sound tricks) oriented on the blind audience would be favorable for all [2][3]. For instance, by grasping virtual graphs, children could develop skills in cross-modal coordination.

The use of special basic behavioral patterns for efficient inspection primarily within the game field, and learning how and when is suitable to apply one or another gesturing in dependence on discovered features of the external objects. Sound feedbacks learning and experience should progress through the game from the concrete level to more abstract level. Gradual improvement on hearing of feedbacks coordinated with motor activity (haptics) should finally form the personal behavioral strategy for outdoor navigation and environment exploration in the absence of visual cues.

Sonification was determined as not the modulation only of acoustic parameters in accordance to some data value, but the function of information content. Sound signals support navigation of blind people both indoors and outdoors. To provide a natural and intuitive analysis of external sounds, Yoshikazu Seki has developed a special training system for obstacle detection based on sound field perception [4].

Unfortunately, white cane training with respect to the particular audio-haptic techniques for blind navigation and the indirect inspection of the external objects is

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

acquired individually. Simulation of the white cane through ultrasonic, laser and IR navigation devices (locators) still leaves the question open: which parameters should be sonified for the blind person to deliver as much as possible useful information and to decrease the noise and distraction. For instance, should it be the continue sonification of the distance to a target or the discrete sounds which warn about changing the distance and in dependence on speed of the person motion?

Due to a narrow haptic (tactual-kinesthetic) perceptual field which is directly involved in interaction through white cane, one or several fingertips could get much more information when a special strategy and the system of feedback cues are employed. Concerning the usage of the locators for blind navigation [5], we think that the feedback cues should be strictly coordinated both with exploratory movements and parameters being sonified.

Sonification is widely discussed as a way to compensate the lack of vision and to provide navigational cues [6], [7] and [8], presenting charts and graphs [9], [10] as well as to allow non-visual drawings [11].

Tran et al. in [12] evaluated the acoustic beacon characteristics for navigation tasks in the real and virtual environments. The study showed that the various auditory parameters have an impact on human accuracy in turning towards the direction of the acoustic beacon. The results revealed that the non-speech beacons were preferred over speech beacons and continuous operation of the sound was favored over a pulsed operation.

The work done by Tran was extended in the research carried out by Walker and Lindsay in [8] and [13]. Walker and Lindsay concentrated on the usage of the waypoint capture radius of an auditory beacon. They define "the *capture radius* of an auditory beacon as the range at which the system considers a user to have research the waypoint where beacon in positioned" [8]. In practice, as a person got closer to waypoint (near the capture radius) sound signal was given as an indication for leading the listener towards the next way point in the map. The authors pointed out that the performance on navigation through the given map differed across the capture radius conditions.

The Hidden Graphs game project discussed in this paper carried out research into suitable behavioral strategies for non-visual interaction and grasping the hidden graphical images. The goal was to optimize the "sonification dialogue" with a player through basic behavioral patterns (BBP) coordinated to capture radius and directional-predictive sound signals (DPS) to facilitate shaping the personal behavioral strategy in discovering the features of the hidden graphs. The experience acquired within simulated conditions might be applied for training of the blind children.

HIDDEN GRAPHS

The Hidden Graphs game was developed as a multimodal game for the blind and visually impaired people. The goal of the game is a blind inspection of the hidden graph to capture as many features as possible of the virtual graphical image. The graph does not exist as the drawing and the interaction occurs with the data array. Thus, the player has to explore the "visually empty" game field.

The game has four levels of difficulty, and each level consists of two phases. The first phase is a preliminary inspection of the game field. The player has to scan a game field by using a stylus-type input device. To support non-visual interaction in each position of the stylus s/he could receive information regarding a single point (pixel) being inspected through sound parameters. If the size of the game field is 250 by 250 pixels and hidden object comprises only of about 250 pixels (i.e., 0.4% of the total number of possible locations), the player has to choose a right strategy which could allow encoding and integration of the feedback signals to re-build the mental image based on the positions which were inspected.

As scanpaths concerning the graph during a non-visual inspection could not be predictable, it is quite difficult to complete the game and evaluate the result based on the data collected in the first phase. Therefore, in the next phase the player has to confirm the detected positions and their sequence suggested. A repetition is also beneficial to fix optimal gestures.

The gameplay is supported by employing only three different sounds. Those feedbacks sonify not parameters of the pixels belonging to the graph, but they have been intended to present the relative distance between a stylus position and the nearest point of the graph. In particular, the changing of the distance regarding the graph manages sound cues. Thus, the sonification is used to guide the player through grasping the graph. Two major concepts are applied in the sonification process: capture radius and directional predictive sound signals.

Another goal, which have been pursued, is the study of the basic behavioral patterns doing the non-visual inspection of the graph efficient and flexible to learn how and when is suitable to apply one or another gesturing in dependence on discovered features and sound feedbacks. Learning and experience should progress through the game from the concrete level to more abstract level and cognitive integration cross hearing and haptics, to finally form the personal behavioral strategy.

The capture radius (Rc) used in the graph inspection is defined as a range of pixels which the game considers the player has reached the target point located on or near the graph curve. The levels of difficulty influence on the player performance and were established in accordance with the different size of the capture radius. The levels of the capture radius are 20, 15, 10 and 5 pixels. 20 pixels is the starting level of the game. Directional predictive sound signals are used in relation to the player gestures with the capture radius. The center of capture radius was associated with the nearest point of the graph regarding the stylus location (Figure 1).

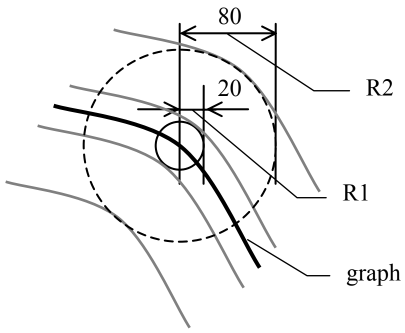


Figure 1. Sonification of the stylus movements within the game Hidden Graphs. R1=Rc, Rc – capture radius in pixels, R2=4×Rc.

Directional Predictive Sounds

Directional predictive sound signals (DPS) used in the game are presenting the navigational cues to support non-visual interaction with the virtual graphical image. DPS sounds are the short sound bursts having duration less than 35 ms. The sounds were composed from several sine wave signals with different pitch, timbre and volume in order to facilitate their perception and discrimination.

DPS sounds will guide player actions to help in navigation and grasping of hidden graphs. Each of those sounds has their own unique denotation as a capturing cue during the game playing. Player hears the crossing sound (CS) when entering or moving inside the capture radius. Capture radius is dependent on the game level as discussed in the previous section 2.1.

In case the player has left the capture radius, s/he will hear the backward sound (BS). Normal procedure at this occasion is that the player moves back towards the location where s/he last heard the crossing sound. During the return towards the graph, the player hears the towards sound (TS). Still, there is no need to activate BS or TS sounds when a stylus location is far from the graph. Therefore, the distance by four times more than Rc was taken as a threshold value after which sound feedback was not supported at all. In other words, if the Rc is equal to 20 pixels the BS and TS are supported within the range of 20-80 pixels (Figure 1).

Basic Behavioral Patterns

The basic behavioral patterns (BBP) were explored in the game as the possible guideline to facilitate shaping the personal behavioral strategy in discovering the features of the hidden graphs. As it was supposed, BBPs should promote attaining the game goal more effectively to demand less cognitive efforts.

The behavioral strategy of the player could be built up as the combination of the basic behavioral patterns. Through the game progress, due to learning and acquiring experience in the coordination of sound and kinaesthetic feedbacks, a personal behavioral strategy would finally be formed. To formalize testing procedure of the possible behavioral strategies based on BBPs three behavioral strategies were proposed for the players.

In the first behavioral strategy to discover the graph the player has to employ spiral and straight-line gestures as the basic behavioural patterns. The player could change a scale, direction or speed of the gestures during an exploration of the game field in relation to the DPS signals.

'S'-shape and straight-line gestures were applied as the basic behavioral patterns for the graph capturing in the second behavioral strategy. The player could change a scale, direction or speed of those gestures in relation to the DPS signals.

The third behavioral strategy was presented as combination of the first and second strategy. Behavioral patterns followed the same rule format.

PILOT EVALUATION OF THE METHODS

The five two-dimensional arrays were plotted and stored for testing. While the subjects were asked to discover the graphs, those never were presented through the game as graphical images. Visualization of the arrays used for testing is presented in Figure 2. To decrease the number of the array elements (pixels), all the graphs were created with the discreteness index 8. That is, if Rc = 20 pixels in the first level of the game, crossing sound would be activated sequentially in two locations of the stylus at inspection the hidden graph in any direction.

To avoid a dependence on the input device resolution the size of the game field was specified in relative units. Thus, the game field had a size of 250×250 relative units (pixels).

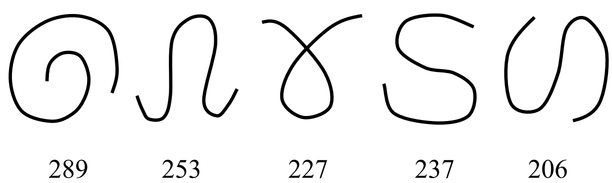


Figure 2. Visualization of the hidden graphs and the number of pixels to be inspected in each array.

Participants

The four students (unpaid volunteers) in the University of Tampere took place in the evaluation of the game Hidden Graphs. They were two females and two males, right-handed persons with normal vision and hearing. The ages of the subjects ranged from 21 to 34 years. All used computers on a daily basis, reporting 6 to 8 hours of usage per day. None of the subjects had prior experience in playing the Hidden Graphs game.

Apparatus

The Hidden Graphs game was written in Microsoft Visual Basic 6.0 under Windows 2000. Hardware used in the game testing included the AceCad AceCat Flair USB graphics tablet with active area of 127 mm by 96 mm and a standard DELL laptop (Intel Celeron Processor 1.4GHz/1Mb) with two external speakers. As only the sound bursts were used, there were no particular requirements for sound equipment.

The next parameters measured were stored in the log file for further analysis: the number of loaded array (graph), the amount of points to be inspected, the capture radius (game level); the time spent, an average distance to the graph and standard deviation, the number of DPS (CS, BS and TS); the amount of points which were captured at inspection phase and confirmation phase accordingly.

Procedure

The evaluation took place in the usability laboratory at the University of Tampere. The subjects were blindfolded (wore mask) throughout the test to avoid visual prediction and approximation of the detected positions concerning touch tablet.

Three separate test sessions for each subject were scheduled in different days, due to high attention level and test duration of about 60 minutes. Test sessions were carried through without a break, in order to maintain the pace and familiarity with the strategies which were being evaluated. Each subject played 40 games in each session. Thus, each of 5 graphs was inspected 8 times in a random order using 3 different strategies. Each game involved playing at the preliminary inspection phase and confirmation phase. The subjects were instructed concerning the features of the game and testing procedure.

RESULTS OF THE PILOT EVALUATION

The data were collected concerning 480 games in total, of 4 players. During the pilot testing we had to restrict the number of games per session. Therefore, all the levels had different relative frequency of appearing. Over 70% (176 and 165) of the games were played in level 2 and 3, capture radius being 15 and 10 pixels. The first and fourth levels were played with almost equal probability of about 15%, (68 and 71) with capture radius of 20 and 5 pixels accordingly.

Starting position of the stylus for the graph capture was free and did not make a difference in the performance. However, stylus lifting would cause confusion for the player regarding the graph location and the direction of those segments which were inspected.

The major question at the study was to consider if the game could be efficiently played by following the DPS signals in relation to the capture radius and by applying different behavioural patterns into the gestures taken.

The results revealed that the average number of TS was repeatedly less than the BS (Figure 3). The player followed the DPS until s/he would lose the track (outside capture radius) and BS would stop the player movement. Therefore, the player would back track stylus in the inverse direction, and soon after TS stylus would cross the graph (CS will follow immediately). Consequently, the CS was noticeably frequent than TS or BS as shown in Figure 3. The similar tendency was found at the confirmation phase for all the subjects when different behavioral strategies were applied (Figure 4).

The Figure 4 shows the ratio between the average number of CS and BS sounds used during an exploration of the hidden graphs at the inspection and confirmation phase (corr. = 0.9956). As it is supposed that at the confirmation phase the player has to track the graph discovered during the inspection, the ratio value (CS to BS or CS to TS) is higher and follows to the capture radius that defines the difficulty level of the game.

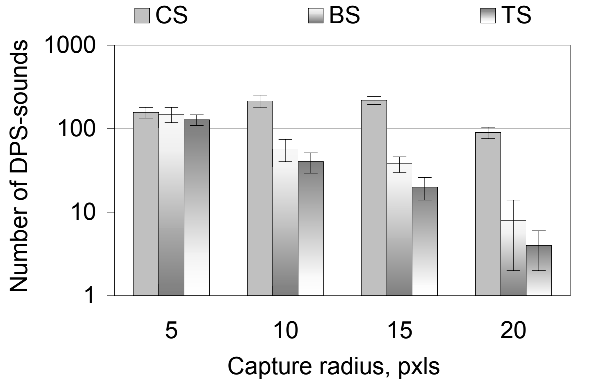


Figure 3. The average number of DPS sounds used during the inspection phase at different game levels.

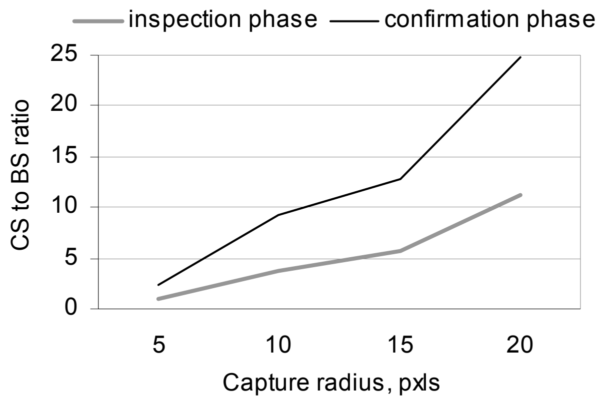


Figure 4. The ratio between the average number of CS and BS sounds during the inspection and confirmation phase at different game levels (capture radius).

When the smaller capture radius (5 or 10 pixels), the difference in the ratio values were decreased and vice versa. Within each behavioural pattern, directional-predictive sounds associated strongly to movement and to each other, resulting in high correlation. Overall, the ratio between the numbers of CS and BS sounds varied at confirmation phase in dependence on some features of the graph and the behavioral strategy used (Figure 5).

Due to a close position of the segments in graph 1 and 3 (Figure 2), the amounts of pixels captured within those graphs were the largest. Possibly, the player had larger probability to discover the points which were positioned closer to each other, even by accidental gestures. However, a fixed value of capture radius constrains accuracy and the cognitive performance in grasping continuity of the invisible track. That means that the capture radius ought to be adaptive regarding to both the player behavior and the graph features being explored.

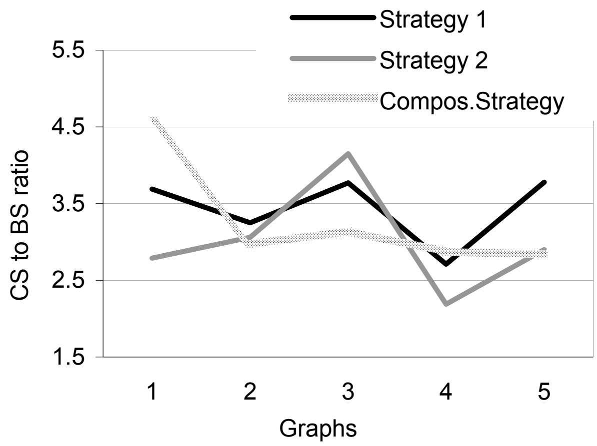


Figure 5. The average ratio of CS to BS in the three behavioral strategies applied to discover five hidden graphs in game testing at the confirmation phase.

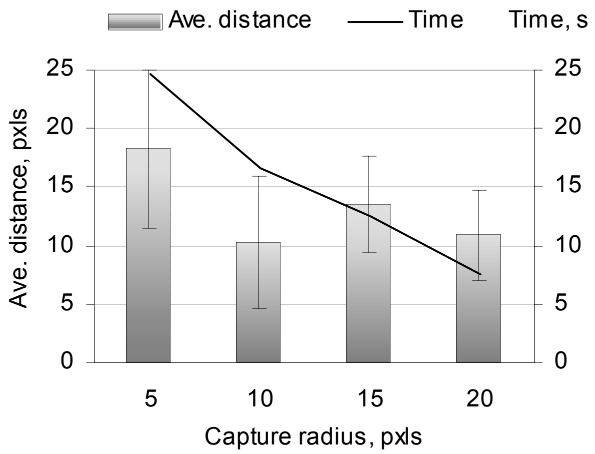


Figure 6: The average distances to the graph with standard deviation and the duration time spent at the confirmation phase averaged over all the cases and strategies regarding the game level (capture radius): 71/5, 165/10, 176/15, 68/20.

Composite strategy seemed the most successful for capturing graph 1 and the strategy 2 appeared to be the most efficient for the graph 3, but not for the other graphs. Especially, the strategy 2 “fell through” in discovering graph 4 comparing to the other graphs. The performance with the strategy 1 appeared to be similar for all the graphs, except for the graph 4 (Figure 5).

All in all, the behavioral strategies suffered from low performance when the graph 4 was explored, the possible reason is the shape, in particular, the segments of the graph in horizontal direction having small curvature.

While the players were blindfolded, they explored the game field by making BBPs most in the diagonal directions, as these movements could be easy coordinated to the hand position which was almost static. The diagonal gestures have maximal variations as reported in [14]. We did not perform special analysis for scanpaths of the player, but the graph 4 has a lower probability to cross diagonal gestures.

The efficiency of the first strategy applied to five graphs explored was very similar. Smaller the capture radius was, longer it would take the player to complete an inspection and confirmation phase. This would lead the player to explore more locations before grasping the virtual object, the whole graph or a separate segment.

Next, we supposed that all hidden graphs were equally accessible with the use of DPS. The Figure 6 shows the average distances to the graph (stylus deviation) and the duration time spent at the confirmation phase, that is, after the preliminary inspection of the hidden graphs. The data were averaged over all the cases recorded and the strategies applied in respect to the game level (capture radius). The number of cases was: 71 (Rc=5), 165 (Rc=10), 176 (Rc=15) and 68 (Rc=20).

The average distances and standard deviation showed that when Rc was more or equal to 10 pixels, that is, Rc was commensurable with the discreteness index 8 pixels which has been used to create the arrays of the hidden graphs, the players could efficiently coordinate sonification through directional-predictive signals and gestural techniques (kinaesthetic feedbacks). And, when Rc was less than 8 pixels, the probability to lost CS was higher and the navigation was supported via balance between BS and TS, within a range of 4×Rc. The stylus movements could extend outside this range as well.

Nevertheless, when the behavioral strategy 2 has been employed the standard deviation (9.67 pxls) on the average distance to graph (16.34 pxls) within any game level was higher than with other gestural techniques. The composite behavioral strategy 3 seemed to gain the best performance when a smaller capture radius (5 or 10 pixels) has been used.

CONCLUSION

The Hidden Graphs game was developed as a multimodal game for the blind and visually impaired people. The goal of the study was to optimize the “sonification dialogue” with a player through basic behavioral patterns (BBP) coordinated to capture radius and directional-predictive sound signals (DPS) to facilitate shaping the personal behavioral strategy in discovering the hidden graphs.

Three behavioral strategies were employed as a combination of BBP in the proposed game script. DPS sounds led player actions in grasping the features of the non-visual objects. Each of those sounds has their own unique denotation as a capturing cue during the game. The sonification technique (the parameters of DPS and the way of their use) was designed so to augment kinaesthetic information and to facilitate cross-modal integration and interaction with virtual graphical images.

The game was structured with four levels of the difficulty and two phases: training (inspection phase) and testing (confirmation phase) to optimize the learning process how and when is suitable to apply one or another movement in dependence on discovered features of the external object and sound feedbacks.

The pilot study has shown that three behavioral strategies applied had differences in performance. The composite strategy gained the fastest and most flexible in the graph grasping. Still, BBPs have to be revised in accordance to the features of stylus gesturing in non-visual conditions. Finally, a fixed value of capture radius constrains accuracy and the cognitive performance in grasping continuity of the invisible track. That means that the capture radius ought to be adaptive regarding to both the player behavior and the graph features being explored.

The experience acquired within simulated gameplay conditions might be applied for training of the blind children in multimodal interaction with mobile applications.

REFERENCES

1. Kramer, G. Auditory Display: Sonification, Audification, and Auditory Interfaces, *Proc. Volume XVIII*, Reading MA: Addison Wesley, 1994.
2. Web site (2005) www.audiogames.net
3. Web site (2004) www.gamesfortheblind.com
4. Seki, Y. Sound Field for Obstacle Perception Training, (2004) http://staff.aist.go.jp/yoshikazu-seki/CD/index.html
5. Bellik, Y., Farcy, R. Comparison of Various Interface Modalities for a Locomotion Assistance Device, *In Proc. of the 8th Int. Conf. on Computers Helping People with Special Needs*. ICCHP 2002 Linz, Austria, 2002, LNCS Vol. 2398, Springer-Verlag Berlin Heidelberg 2002, pp. 421-428.
6. Brewster, S.A. Using Non-Speech Sounds to Provide Navigation Cues, *ACM transactions on computer human interaction*, 5, **3**, 1998.
7. Holland, S., Morse, D.R. and Gedenryd, H. AudioGPS: Spatial Audio Navigation with a Minimal Attention Interface, *ACM Personal and Ubiguitous computing,* 6, **4**, 2002, pp. 253 – 259.
8. Walker, B.N. and Lindsay, J. "Auditory Navigation Performance is Affected by Waypoint Capture Radius," in *Proc. of ICAD 04*, Sydney, Australia, July 6-9, 2004.
9. Brown L.M. et al. Design guidelines for audio presentation of Graphs and Tables, *Proceedings of the 2003 International Conference on Auditory Displays*, 6-9 July, 2003.
10. Franklin, K.F. and Roberts, J.C. Pie Chart Sonification, *Proceedings Information Visualization (IV03)*, pages 4-9. IEEE Computer Society, July 2003.
11. Brown L.M. and Brewster, S.A Drawing by ear: interpreting sonified line graphs, *Proceedings of the 2003 international Conference on auditory displays*, 6-9 July, 2003.
12. Tran. T.V., Letowski, T. and Abouchacra, K.S. Evaluation of acoustic beacon characteristics for navigation tasks. *Ergonomics*, 1 June 2000, 43, **6**, pp. 807-827.
13. Walker, B. N. and Lindsay, J. Effect of Beacon Sounds on Navigation Performance in a Virtual Reality Environment, *Proceedings of the 2003 International Conference on Auditory Display, Boston, MA, USA, 6-9 July 2003.*
14. Keuning, H. and Houtsma, A.J.M. *Cursor trajectory analysis*. In Bouwhuis, IPO Annual Progress Report 35. Eindhoven University Press, Eindhoven, 2001, 128-139.

Games with Sounds: the Blind Navigation and Target Acquisition

Antti Nyman
Alternative Access: Feelings and Games 2005
Department of Computer Sciences
FIN-33014 University of Tampere, Finland
Antti.Nyman@uta.fi

ABSTRACT

Lack of feedback makes mouse use difficult for blind persons. Additional sound feedback can be used to facilitate spatial navigation in a screen space. The game-like navigation task was based on capturing 25 circular targets (spots) with a radius of 65 pxls arranged in a square grid (5 rows by 5 columns). Two different sound mappings were tested and evaluated under blind conditions; one grid was augmented with 6 different sounds and other one with 3 different sounds. It was revealed that the mapping of 6 sounds provided more effective non-visual interaction and made the target acquisition time shorter by about 1.39 times and the number of errors smaller by about 32%. The reasons for navigational problems were also analyzed. It was noticed that the number of spots passed during the target acquisition was smallest when the target was located along the edges of the grid. While the sounds associated with the corners of the grid were more distinctive than other sounds, the eight spots surrounding the central position of the grid were generally the hardest group to detect and capture. The features of sound mappings and behavior of the subjects are discussed in detail.

Author Keywords

Visually impaired, non-visual interaction, blind navigation, sonification, sound mapping, target acquisition.

ACM Classification Keywords

H.5.2 User interfaces: Input devices and strategies.

I.3.6 Methodology and Techniques: Interaction techniques.

INTRODUCTION

Special techniques have been developed for visually impaired people to support and facilitate human-computer interaction and access to information. Braille systems, tactile feedback and speech synthesis all make some aspects of the computer use easier for the blind, but none of these solutions comes without certain difficulties; they might require expensive hardware or/and special software or can be only used with textual information.

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

Nowadays, an ordinary personal computer (PC) system employs mouse as the primary (graphical) input device alongside the keyboard (command mode). Mouse can, however, be very inconvenient input method for blind users because of the lack of feedback. The user has to rely almost solely on visual feedback and the mouse requires the user to use his/her eye-hand-coordination to control the cursor. There is some amount of kinesthetic feedback involved in the moving of the mouse, but it reveals only the movement; it doesn't reveal anything about the relative position of the cursor on the screen. Sighted people can see not only the movements of the cursor immediately as the movement of the mouse happens, but also the location of the cursor on the screen even when the mouse is standing still.

In today's computer environments, Graphical User Interface (GUI) is the most common interface-type. GUIs are problematic for the blind using computers because the textual information on the screen is not easily retrievable [2]. This makes the use of Braille systems or speech synthesis complicated. Tactile and auditory feedbacks have been considered as alternative or complementing signals for output and imaging. Tactile feedback requires special devices, and the methods of using such a display technique are still under investigation. A pair of speakers is included in almost all modern PC packages. That makes the possibility of using auditory feedback more widespread.

Making use of spatial sound is one alternative which has been suggested as a solution to the problem of blind navigation. Bölker and Gorny have tried to solve the problem of blind navigation in GUIs with hearcons [2]. In their software prototype a hearcon, which was characterized by tone, volume, location and size, was associated with every item on the screen. In this approach, the user heard the topographical arrangement of the items on the screen, which made it possible for the user to find a certain item without a long inspection of the whole space. The reliability of recognition in different positions of a grid has also been evaluated. The authors found out a certain disparity between the reliabilities of different positions in the grid [3].

Parente and Bishop in [7] have also presented a system for blind exploring of spatial information. In addition to tactile feedback, their solution employs spatial auditory icons, which give information for the user by identifying the map item, indicating its direction and signaling its distance.

Restrictions in these above mentioned approaches include the limited number of sounds human auditory perception can process simultaneously and the difficulty for humans to sense the direction of a sound; most humans cannot distinguish more than five sounds simultaneously and a sound coming directly from forward direction cannot be distinguished from a sound from backward direction [6]. The spatial sound also requires the computer setup in use to include sophisticated surround sound system to make the playback of spatial sounds possible.

As an alternative to spatial sound, Kamel, Roth and Sinha have designed a virtual sonic grid [8]. In their study of auditory pattern perception by blind people, they showed that with the 9-cell virtual grid (3 rows by 3 columns) the subjects were able to faster locate queried positions than with physical tablet or spatial sound localization techniques. They also found out that easily recognized sound in the center of the grid reduces the navigation time. In the grid used, two different notes were played on every crossing of border of grid cells. The authors concluded that spatial information should be important part of auditory interface design and a technique similar to the “landmark” technique used by cane-travelers could be used to assist blind persons in identifying different areas of the user interface.

Sribunruangrit, Marque, Lenay and Gapenne have studied the use of reference points to provide help for spatial navigation [9]. They used two kinds of approaches: in active mode the reference points were defined by the subjects and in passive mode they were predefined. The authors noticed that the use of active and passive recognition points shortened exploration and recognition times of geometric forms.

As mentioned before, GUIs are generally unsuitable for blind use. This is true, at least, in the normal form filling and widget manipulation tasks. Yet, there might be some tasks that can be modified to make blind pointing and selection techniques possible. Most of the commercially available computer games are impossible to use for the visually impaired players, but with certain modifications, some of them could be altered to make them accessible for blind children.

Research has been done to find out how to better develop games for the visually impaired. Audio games, which are games relying on sound feedback, have been generated for blind audiences. Some of the games are modifications of existing commercial games, but as the popularity of sound games grows, there probably will be new genres specifically designed for auditory interfaces [5]. There is no reason why audio games should be designed solely for the visually impaired; sound makes possible to design game concepts that would not be possible with only graphical illustration. Even though sound liberates the player from the two dimensions of the screen, there might be many uses for blind navigation in game interfaces. Still, sounds and sonification as methods for interaction and conveying spatial information are not as well developed as image processing. When spatial understanding is needed in a sound game, additional speech cues or instructions are required [4].

In this study, a game-like grid navigation task with sound feedback was used to evaluate target acquisition under blind conditions. The subjects were involved in a pilot testing of two sound grids with different sound layouts and the data collected were then analyzed. In the Section 2 the test method is explained in details. In Section 3, the results of the study are presented with further discussion. The conclusions are finally summarized in Section 4.

METHOD

Subjects

Four volunteers participated in the pilot testing. Age of the subjects varied from 22 to 50 years. Two of subjects were males and two were females. All of the subjects used computer and mouse on a daily basis. All had normal seeing and hearing abilities and none used a hearing aid.

Apparatus

A conventional desktop PC (ASUS P4B533) with Intel Pentium 4 processor, 512MB RAM, Trust Sound Expert audio controller, Trust optical mouse and Trust stereo headset was used in the experiment. The application was written in Microsoft Visual Basic 6.0 under Windows 2000.

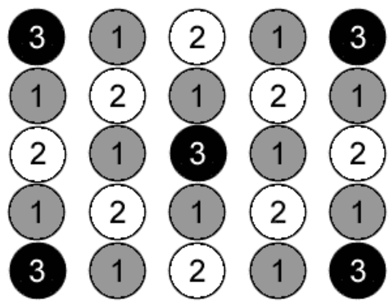


Figure 1. Sound layout of the grid augmented with 3 different sounds.

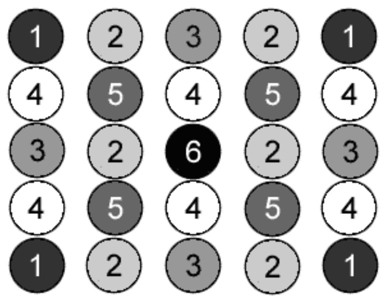


Figure 2. Sound layout of the grid augmented with 6 different sounds.

The original application was modified into two different versions to simplify the pilot testing. The only differences between these two programs were in the sonification techniques applied to support the blind navigation and target acquisition task. The layout of the grid augmented with 3 different sounds is shown in Figure 1. 6 different sounds were distributed as shown in Figure 2.

The software supports functionalities for storing the track of mouse movement, the time spent, the distance traveled and the number of the spots passed for each of the tasks performed. These data could also be stored into files for further analysis. The application also included a Microsoft Agent interface, which was necessary for reading the tasks aloud for the blindfolded subjects. The agent then used Mikropuhe TTS synthesizer through SAPI-interface to make the instructions possible in a native language (Finnish) for the subjects.

The game-like navigation task was based on capturing 25 circular targets (spots) arranged in a square grid (5 rows by 5 columns). In the center of each of the cells was a round

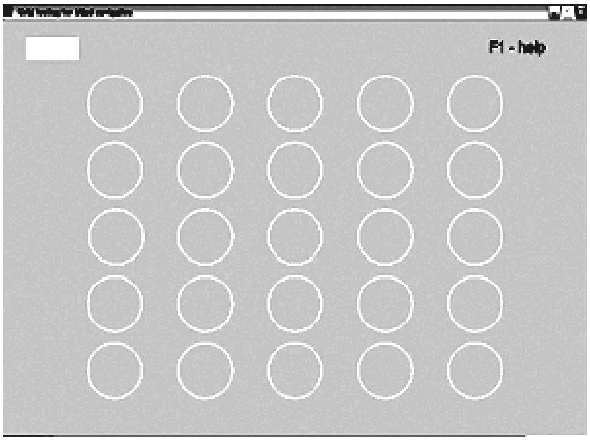


Figure 3. Locations of the target spots within the game field.

spot with a radius of 65 pxls. Distances between center points of the spots were 156 pxls vertically and 156 pxls horizontally. The spots (in opaque mode) and their locations on the screen during the testing are shown in Figure 3. Every time the mouse cursor was moved to any of these spots, a wave file of an animal sound was played, so that the person could know that cursor had arrived into a spot. The durations of the animal sounds used varied from 0.58 seconds to 1.65 seconds. The subjects could also repeat the sound, as long as the cursor remained inside the spot, by pushing the spacebar button. There were no intentional differences in volumes, spatial properties or in any other parameters of the sounds. After the last task had been completed, there was a sound signal indicating the completion of the game.

The sounds used to augment the location of the spots in the grids were animal sounds, which were selected so that they could be easily recognized from one another. In particular, the sounds of dog, cow, cuckoo and cat were used. Of all sounds, animal sounds were selected because of their familiarity for all, children and adults. It was supposed that familiar sounds would make the recognition of the feedback cues easier and shorten the time required for the learning of the sonification technique. Animal sounds also made the game instructions more understandable for the subjects.

The instructions given by the Microsoft Agent character comprised of a target description that is the target spot to be found. The instructions were given in Finnish language, but followed the form of this example in English: “Click the animal in the middle of the center row”. If the subject forgot the instructions or did not understand them on the first time, s/he could repeat the instructions by pushing a button on the keyboard. The instructions for the next task followed instantly after the target of the previous task was captured.

Procedure

The subjects were instructed how to capture the spots described in the tasks spoken by the Microsoft Agent. The subjects were also given five minutes before the test to familiarize themselves with the sounds and the navigation technique. At least some level of experience regarding the detection of the sound locations was necessary for them to clarify the features of the blind positioning of the cursor in the grid and to use navigational cues. When the subjects were ready with the trials, the cursor was placed near the central position of the screen and the test started.

During the test the subjects received the tasks to locate a specific spot within the grid. To accomplish each trial, they had to employ both their knowledge of the positions and associated sounds in the grid and the audio feedback coming from the cursor passing into other spots. The spots to be located were selected randomly, and all of the targets were presented once per session. As the starting spot and target spot varied randomly, the routes to navigate were different for each subject and each trial.

Each session consisted of 25 trials (tasks) to test the sound mapping. Every subject performed one session with each of the two sound mappings. Two subjects started the test with the grid with 6 sounds and two others with the grid with 3 sounds. To decrease stress factor there was a short break between sessions. After the pause subjects had again five minutes to get to know the sounds of the second grid. Two sessions took approximately one hour for each of the subjects.

During the test the data were collected automatically with the application. The actions of the subjects were observed with the objective of finding additional information that could not be calculated from the data gathered. After completing the test the subjects were interviewed.

RESULTS AND DISCUSSION

Two Sound Mappings

As described in the Section 2, the two sound mappings applied to the grid had only differences in the number and layout of the sounds. However, there were fundamental differences in the design ideologies of these two alternatives. The 25-cell grid augmented with 6 sounds consisted of four partly overlapping 9-cell sub-grids and therefore could be described as a hierarchical grid.

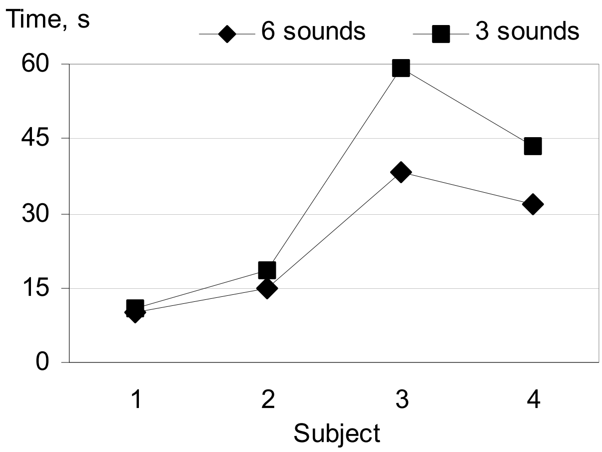


Figure 4. The overall averaged target acquisition time for 6- and 3-sound mappings.

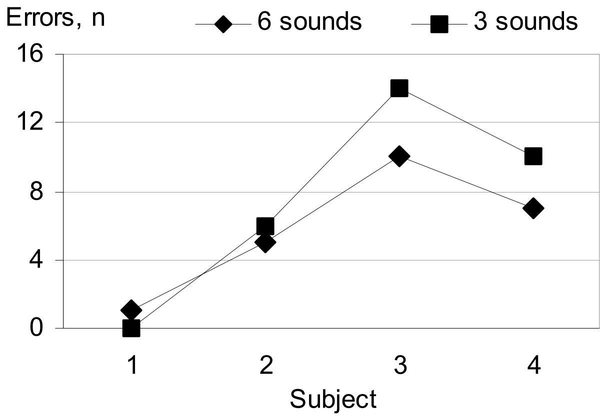


Figure 5. The overall averaged error rates in the target acquisition task with the use of 6- and 3-sound mappings.

The number of sounds was minimized to 6, while there were still enough sounds to make every spot almost unambiguous in each sub-grid. Another sound mapping was implemented to ultimately minimize the number of sounds to 3. The small amount of sounds, the sounds which are certainly easy to remember, comes with the disadvantage of their unambiguousness.

Figure 4 shows the averaged target acquisition times for each subject during the test of different sound mappings and Figure 5 shows the corresponding averaged error rates. Both diagrams indicate that the navigation was faster when the grid was augmented with 6 sounds. Paired-samples t-test also showed the difference $t = 2.022$, $df = 3$, $p < 0.01$.

The target acquisition times were shorter for all subjects when the grid was augmented with 6 sounds, and there was only one subject who had more errors in this session with 6 sounds ($t=1.578$, $df = 3$, $p < 0.01$). These facts might result from the observation that it was easier for the subjects to confuse two spots with each other when multiple locations were marked with only 3 sounds. The differences between grids were also greater for subjects who were slower in finding the targets and who committed more errors. The reason for this might be that some persons require the extra navigational aid which could be provided by the differences in sound parameters (L-R balance) or through other modifications of the grid layout. For instance, non-linear distances between locations of the spots could enlarge kinesthetic feedback.

When asked, most of the subjects reported that after trying only one grid they thought that the blind navigation with 3 sounds would be easier than with 6 sounds. That seemed due to the shorter learning time for three sounds. However, after completing both sessions, the subjects themselves noticed that they had more problems with the grid augmented with 6 sounds.

Task Difficulty

During the study, the factors which have an impact on the task difficulty have been explored as well. The most obvious hypothesis would be that the time of target acquisition depends on the distance between the current position of the cursor (the last captured spot) and the target spot. In Figure 6 we can see that there is no strong dependence between these parameters measured (corr.=0.346) in the data sample of the subject A3. The results for other subjects were alike. The comparison of the same samples of the target acquisition times and shortest paths to target showed the same negative result (corr.=0.233).

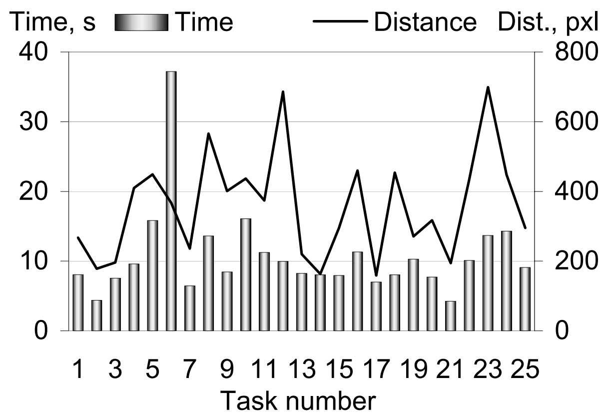


Figure 6. The target acquisition time and the distance to target, the case study of the subject A3.

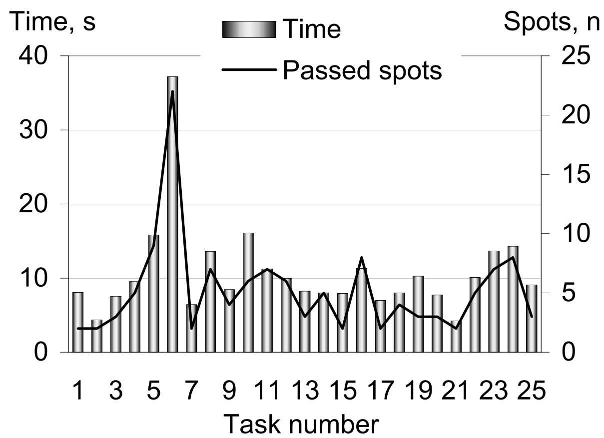


Figure 7. The target acquisition time and the number of spots passed, the case study of the subject A3.

The shortest path was calculated as the minimum number of spots needed to be passed to arrive at the target spot when moving only horizontally and vertically. However, the comparison of the target acquisition times and numbers of passed spots for the same subject A3 (Figure 7) indicated a strong positive correlation (corr.=0.96).

As we look at the correlations between target acquisition time and distance (Figure 8) and then between the time and passed spots (Figure 9) we can clearly conclude that the correlations were higher between time and distance for all subjects and with both sound mappings. All these results together indicate that the reasons for navigation problems lie somewhere else than in length of the scanpaths in different navigational tasks.

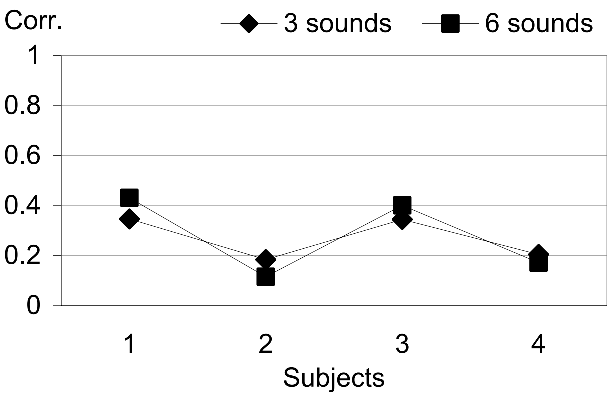


Figure 8. The correlation between the target acquisition time and the distance to target.

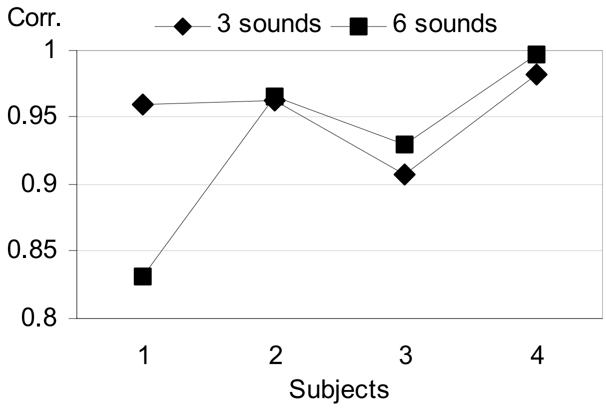


Figure 9. The correlation between the target acquisition time and the number of passed spots.

It was also analyzed how target acquisition times, errors, distances and numbers of passed spots in different tasks relate to the target position. Figure 10 shows matrices which demonstrate the averaged data. Distances between the last captured spot and the target spot were shortest in tasks when the target spot was located near the center of the grid. There is no surprise in this conclusion. However, the number of spots passed during the target acquisition was smallest in the tasks when the target was located in one of the corners or along the edges of the grid. The same holds true with the average time spent for navigation and errors committed during the tasks. The eight spots surrounding the center of the grid were generally the hardest group to detect and capture.

	Both					3 sounds					6 sounds				
Avg. times, s	18	26	11	30	14	27	32	8	51	15	9	19	14	9	12
	26	46	29	29	16	12	45	30	21	18	41	48	27	37	14
	18	37	23	28	32	10	52	26	27	28	26	22	21	28	35
	30	65	36	34	32	41	112	54	48	7	18	18	18	19	57
	15	46	29	20	21	18	46	44	22	30	12	47	15	17	11
Errors, n	1	1	0	4	0	1	1	0	3	0	0	0	0	1	0
	2	5	2	3	0	0	3	1	1	0	2	2	1	2	0
	2	3	2	2	2	0	1	1	1	1	2	2	1	1	1
	3	4	2	4	2	3	3	2	2	1	0	1	0	2	1
	1	3	4	1	0	1	1	3	1	0	0	2	1	0	0
Avg. distances, pxl	340	477	301	283	576	348	526	257	378	558	333	428	345	188	595
	364	396	251	388	446	370	430	253	393	435	358	363	249	383	457
	322	253	303	240	490	348	245	373	198	423	297	261	233	282	557
	431	353	259	291	299	350	389	253	301	166	513	317	266	281	432
	433	300	423	445	468	373	271	490	418	587	493	330	357	473	350
Avg. number of passed spots, n	6,6	7,5	3,4	12,4	7,3	9,8	8,5	2,8	22	9,3	3,5	6,5	4	2,8	5,3
	8	13,8	14,9	7,9	6,4	4,8	12,8	10	8,3	8	11,3	14,8	19,8	7,5	4,8
	9,3	11,9	8,4	8,1	14,1	4,5	15,5	10,5	10	16,5	14	8,3	6,3	6,3	11,8
	11,1	28,1	19,9	15,5	11,6	15,5	50,2	34,5	23	2,3	6,8	6	5,3	8	21
	5,1	15,6	11,5	7	6,9	5,3	13,3	17,3	7,5	10	5	18	5,8	6,5	3,8

Figure 10. Overall data in a target acquisition task with the use of the grid augmented with 6- and 3-sounds.

Navigational Landmarks

As was noted in the first section of this paper, a “landmark” technique could be used to assist blind persons in identifying different areas of the user interface. It was also mentioned that an easily recognized sound in the center of the grid reduces acquisition time [8]. Taking into consideration the observations revealed regarding the difficulty of finding different spots in the grid, it could be supposed that the corners of the grid could also be employed as navigational landmarks to facilitate navigation and reduce the time of wayfinding to target spot. Figure 10 shows that even though the distances to target were generally longer when the target was located in some of the corners of the grid, the average time of target acquisition was shorter and fewer errors were committed than in average.

The behavioral patterns (scanpaths) were also recorded during the tests. Figure 11 shows samples of scanpaths. The reason for extra-movements to some of the corners of the grid might be that the landmarks could be considered as external memory aids [1] for the subjects to formalize a mental image of the navigation route when they first found their way to target. Another reason might be that the sounds associated with the corners of the grid were more distinctive than other sounds.

Unintentional Deviation of the Cursor

When moving the cursor vertically right (mouse is moved right forward), most of the subjects also unintentionally moved the cursor downwards (mouse moving backwards) as shown in Figure 12. This behavioral pattern resulted in a lack in accuracy and other navigational problems. These problems had an impact on cursor traveling between two spots of the grid and near the target spot.

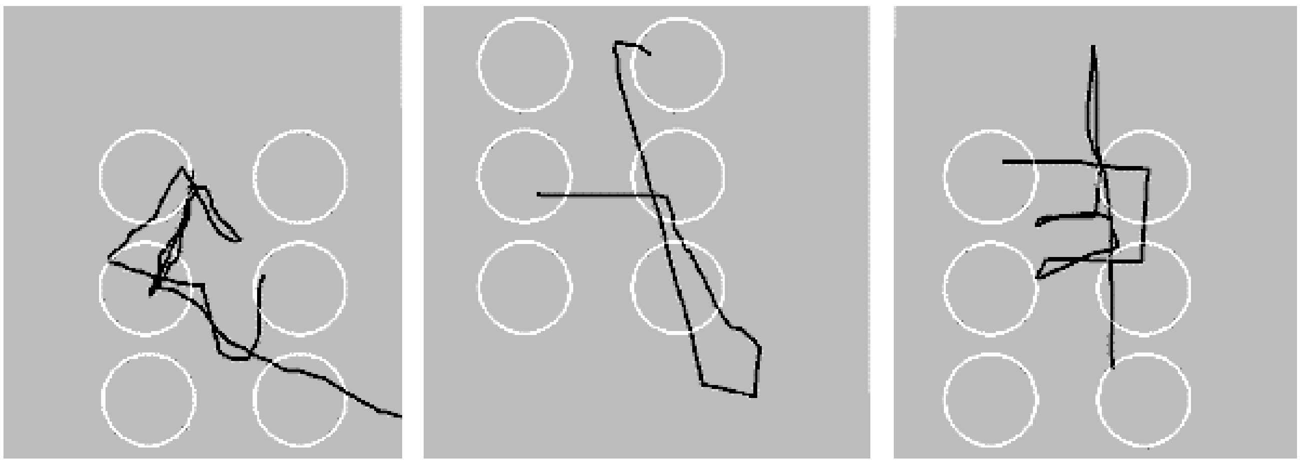


Figure 11. Scanpaths recorded during inspection of the game field indicating the use of the corners as an external memory aid in the target acquisition task.

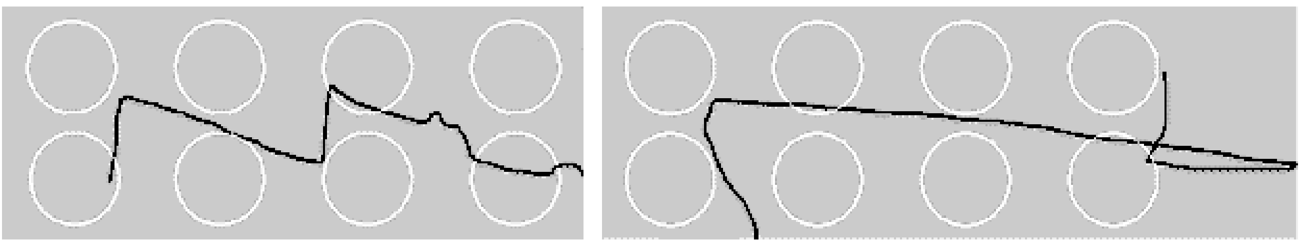


Figure 12. Scanpaths recorded during inspection of the game field indicating the unintentional downward movements of the cursor while trying to move it vertically to the right.

When the subject thought that the cursor is over the right target location, unintentional mouse movement could lead into an error in the task completion. Not all subjects experienced this problem as they applied different techniques to mouse control and blind navigation.

Lifting the mouse also caused orientation problems, because after the lift the subjects were not able to recover the knowledge of the previous location.

Disorientation could be provoked with similar sounds associated with different target spots of the grid as well. This mixing up of sound and location was more probable to happen in conjunction with other problems discussed above. When the subjects mixed up two positions, they tried over and over again to navigate into the target. The subjects were not able to recognize that they had committed an error even if they were in the opposite corner of the grid than they thought.

LIMITATIONS OF THE PILOT STUDY

More subjects and tests should have been performed to get more information on blind target acquisition and possible system of the relevant feedback cues. For the lack of resources and tightness of the schedule this could not be done in this study.

It is impossible to define the level of distinctiveness in navigational sounds. Animal sounds were used and some of them might have been easier to recognize for the subjects than others. Because of this, the selected sounds might have affected the efficiency of the behavioral patterns or strategies which were employed in the pilot test. This problem would have been present even if MIDI sounds were selected as feedbacks. All sounds generated with MIDI synthesis are different in the sense of distinctiveness. The distinctiveness of a particular sound can be different for all persons, so it would have been impossible to totally remove this factor.

FUTURE WORK

Since the different distinctiveness of sounds cannot be totally removed, it would be useful to test both mappings with different sound layouts. If the results with different permutations would be the same, the reliability of the conclusions and generalizations would be higher. The sound parameters of the landmarks (beacons) should be also explored in more detail.

In their study, Eriksson and Gärdenfors stated that all sounds in audio interfaces should be adaptable to personal preferences [4]. It is also a possible to investigate if the results of this study would be applicable when the subjects could choose themselves the sounds and their positions in the grid. That would also make the distinctiveness of the sounds less important, because the users could use their own preferences to place the sounds into the grid.

CONCLUSION

The study has shown that in grid navigation with sound feedback the mapping and number of the sounds influences the difficulty of navigation tasks. Optimization in the number of sounds is needed. Small number of sounds makes the learning time of the sonification technique shorter, but the use of more sounds provides more cues facilitating the target acquisition. Short learning time may result in the sensation of fast task completion even when not true. It was revealed that the mapping of 6 sounds provided more effective non-visual interaction and made the target acquisition time shorter by about 1.39 times and the number of errors smaller by about 32%. The type of the mapping also affects the navigation task by providing the user with different techniques for mental image construction of the external space (game field) and the cues map.

Different locations in the grid have different levels of difficulty when used as targets in navigation tasks. Some locations are preferred as “landmarks” over other locations. The results can be used when designing sound mapping for blind interaction with different applications, for instance, wayfinding systems, mobile games and other software for visually impaired people

REFERENCES

1. Ark, W., Dryer, D.C., Selker, T., and Zhai, S. Representation Matters: the Effect of 3D Objects and a Spatial Metaphor in a Graphical User Interface. *Proc. HCI 98, Conference on Human Computer Interaction 1998*, 209-219.
2. Bölke, L., Gorny, P. Auditory Direct Manipulation of Acoustical Objects by Blind Computer Users. *Proc. International Conference on Auditory Display 1994*, 287-288.
3. Donker, H., Klante, P., Gorny, P. The Design of Auditory User Interfaces for Blind Users. *Proc. NordiCHI 2002*.
4. Eriksson, Y., Gärdenfors, D. Computer games for children with visual impairments. *Proc. Advances in Computer Entertainment Technology 2004*.
5. Friberg, J., Gärdenfors, D. Audio Games: New perspectives on game audio. *Proc. ACE Conference 2004*.
6. Gorny, P. Typographic Semantics of Webpages Accessible for Visually Impaired Users: Mapping Layout and Interaction Objects to an Auditory Interaction Space. *Proc. Int’l Conf. on Computers Helping People with Special Needs 2000*, 251-257.
7. Kamel, H.M., Roth, P., Sinha, R.R. Graphics and User’s Exploration via Simple Sonics (GUESS): Providing Interrelational Representation of Objects in a Non-visual Environment. *Proc. International Conference on Auditory Display 2001*, 261-266.
8. Parente, P., Bishop, G. BATS: The Blind Audio Tactile Mapping System. ACMSE. Savannah, GA. March 2003.
9. Sribunruangrit, N., Marque, C., Lenay, C., Gapenne, O. Improving Blind People’s Spatial Ability by Bimodal-perception Assistive Device for Accessing Graphic Information. *Proc. 7th biannual Conference for the Advancement of Assistive Technology in Europe 2003*, IOS Press (2003), 476-480.

Exploring Micro-Movements for Diagnostics of Neurological Problems

Jalo Kääminen
Alternative Access: Feelings & Games 2005
Department of Computer Sciences
FIN-33014 University of Tampere, Finland
Jalo.Kaaminen@uta.fi

ABSTRACT

Tremor can be as a symptom of such neurological diseases as Parkinson's disease, multiple sclerosis, and damage to the cerebellum. A successful screening method could open the way for earlier treatment that may delay the progression of presently incurable diseases. The goal of this project was an exploration of the pen-based technique for early diagnostics of the deterioration level in a person's ability to control micro-movements. Eight subjects of different age groups took part in the pilot test. The method was based on a comparison of the personal immediate handwriting performance in copying the graphical patterns. The performance of the subjects in game-like testing was evaluated in terms of the stylus deviation and correlation of the scan path to the graph on X-axis and Y-axis separately and the task completion time when output-to-input ratio was non-less than 4. The results of a pilot testing are analyzed. They reveal that coordination problems can be registered even when the problems have not previously been detected by the person himself. We guess that further exploration of the pen-based technique for screening hand-eye coordination problems can increase selective sensitivity of the method regarding verified symptoms of neurological problems.

Author Keywords

Eye-hand coordination, tremor, micro-movements, scale-factor, diagnosis of neurological problems.

ACM Classification Keywords

H5.2. User interfaces. Input devices and strategies.
I.3.6 Methodology and Techniques. Interaction techniques.

INTRODUCTION

Rhythmic, involuntary shaking of the body parts is the most common movement disorder known as tremor. Neurological origin is linked to the occurrence of such causes of tremor as Parkinson's disease and Essential Tremor. At such a physiological state, neurons (cells in the central nervous system) that are being activated once can be activated repeatedly and spontaneously and provoke unintentional spastic muscle activity, which is considered as a tremor phenomenon. Subtle changes caused by the disease are not visually distinguishable at the beginning of the disease. The extent of deterioration in a patient's ability to control micro-movements should be detected as early as possible to open a way for treatment that improves the quality and productivity of the patient's life in spite of the disease.

Movements and gestures analysis has a great potential in development of non-invasive diagnostics and screening methods of neurological disorders. There are several approaches for tremor simulation and recording. Various techniques have been proposed, most of them with complex test procedures and specialized hardware [1-5]. For example, the Precision Image-based Motion Analysis System (PRIMAS) [2] has been tested for recording movement patterns. The PRIMAS system was based on the video/digital conversion method and was able to determine the 3D position of markers in real-time at a 100 frame/s rate. The test procedures have been the following of the predefined movement patters, such as pinching, circling and tapping, where the patient lifts all the fingers except the thump, and then hits the table with their fingertips in the order of little-, ring-, middle- and index finger, imitating the piano-playing movement. It has been shown that Parkinson's disease affects the test performance detectably in this kind of test setting.

We carried out an empirical study of a different technique based on an evaluation of the personal immediate handwriting performance in copying the graphical patterns when stylus movements are displayed with output-to-input ratio non-equal to 1. Eye-hand coordination in such a condition cannot compensate enough motor dysfunction, and behavioral artifacts can be detected and recorded. The "Finger Dexterity Test and Training" (FDTT) game-like application used in the pilot testing records the stylus tracking in two dimensions (X, Y) on a standard pocket PC equipped with touch screen. The advantage of a mobile device employed for screening-test of neurological dysfunctions is a very simple technique and a conventional interaction style compared to the stationary haptic devices, or multi-channel recording of micro-movements through accelerometers attached to each individual finger, or methods based on video-tracking of the tags/markers. The

Alternative Access: Feelings & Games'05, Spring, 2005,
University of Tampere.

goal of the pilot testing was to assess whether we can gain data to detect differences between normal and extra or hyper activity in fingers, which decreases performance of an eye-hand coordination in people who suffer from various medical conditions. We present the results of the pilot testing with the pen-based technique and discuss whether relevant information can be retrieved from the recordings. We guess that a further exploration of the pen-based technique for screening hand-eye coordination problems could increase selective sensitivity of the method regarding verified symptoms of neurological disorders, as visible tremors and muscular rigidity appear only at a later stage in the progress of the disease.

BACKGROUND

The two main symptoms of neurological diseases, we aimed at detecting, are tremor and the muscular rigidity causing problems in hand-eye coordination. According to statistics from Louis et al. [6], one out of every 150 to 200 persons contracts Parkinson's disease during their life. There are from a million to a million and a half cases in the United States alone. In healthy people a set of reflexes accompany the most basic actions: getting up, walking, turning, stopping, and smiling. In Parkinson's patients, many of these reflexes are absent or require intentional efforts. In addition, short, alternating movements, as used when somebody brushes their teeth, are hard for them. Their handwriting usually gets small and cramped after the first few words. They tend to sit and stare, moving the eyes rather than the head to look somewhere else, even though these outward symptoms in no way indicate any degrading of mental capacities in the patient. Muscles and joints get stiffer and may become rigid. Blood circulation suffers, which may lead to other illnesses. A tendency to become withdrawn and eventually totally dependent on others may develop.

Initial symptoms of the disease are ambiguous: deep aching in joints and muscles and difficulty in carrying out tasks such as brushing teeth. The patients do not yet have any idea they have Parkinson's disease. It can take months or even years of visits with various medical techniques to be correctly diagnosed. As symptoms settle in, walking, speaking and carrying out daily activities becomes more difficult. James Parkinson, whose name was given to the disease, described the condition in 1817. His description remains remarkably accurate: *Involuntary tremulous motion, with lessened muscular power, in parts not in action and even when supported; with a propensity to bend the trunk forward, and to pass from a walking to a running pace, the senses and intellects being uninjured.* [7]

Slow, rhythmic tremor, especially of the hands, is the most widely discussed and most obvious symptom associated with Parkinson's disease. Tremors can be classified according to parameters of the symptoms, which are amplitude/magnitude and frequency of body vibration, or other periodic physiological signals that accompany a muscular activity. A clinical rating scale can be used for the assessment of the severity of tremor-induced disability. Another way of measuring tremor is the frequency of unintentional micro- and macro-movements of the body parts.

Table 1 shows a simple classification of the tremor according to the severity of a movement disorder.

Degree	Magnitude of movements deviation
0	No tremor
1	Slight tremor
2	Moderate tremor (less than 2 cm excursion)
3	Marked tremor (2 cm to 4 cm excursion)
4	Severe tremor (more than 4 cm excursion)

Table 1. Classification of the tremor according to the severity of disease. Adopted from [8].

Tremor can be classified according to body involved or according to the movement or position typical to the occurrence of tremor as rest tremor, postural tremor and intention tremor. Rest tremor occurs when without any voluntary movement, and is common in Parkinson's disease. Intention tremor occurs during voluntary movements. Typical causes are multiple sclerosis, Parkinson's disease and Wilson's disease. Postural or physiologic tremor occurs when a position is maintained. Abnormal postural tremor occurs during withdrawal from addiction to drugs and alcohol. Normal postural tremor occurs during fatigue and stress. Table 2 shows a classification of tremors according to the frequency and occurrence of tremor, giving indications of the likely origin of tremor.

For some unknown reason a significant percentage of patients suffering from Parkinson's disease never get visible tremor. In others, tremor is the main symptom and an indicator of the disease's progress.

Our study aimed both at detecting the effects of tremor and the effects of deterioration in hand-eye coordination. In Parkinson's disease, the severity of the tremor is slight in the beginning. A more severe tremor would affect a person's level of test performance more. Our aim was to assess to which extent the pen-based technique could be used to detect different degrees of tremor severity. As the results showed, the effects of tremor could be detectable but additional software options should be used to increase efficiency of the method for detecting micro-movements and vibrations in hands.

Below we will discuss whether the attention should rather be focused on the problems of hand-eye coordination for developing an efficient and inexpensive screening method. The effects of proper treatment and support upon patients who have neurological diseases causing movement disorders can be impressive at the best. The research has been encouraged by patients who have frozen into practical immobility by Parkinson's disease, but have been helped by the proper treatment including the emotional support, resulting into a release of a measure of ability to move again.

Type of tremor	Frequency	Amplitude	Occurrence
Rest tremor	3-6 Hz	High; decreases with target-directed movement	Limb supported against gravity, muscles are not activated
Example: Parkinson's disease. Initial symptoms include resting tremor beginning distally in one arm at a 4- to 6-Hz frequency. It worsens with stress and diminishes with voluntary movement.			
Action tremors			
Postural tremor	4 to 12 Hz	Low; increases with voluntary movement	Limb maintains position against gravity
Examples: physiologic tremor; essential tremor; metabolic disturbance; drug or alcohol withdrawal			
Simple kinetic	3-10 Hz	Does not change with target-directed movement	Simple movements of the limb
Intention	<5 Hz	Increases with target directed movement	Target directed movement
Examples: Cerebellar lesion (stroke, multiple sclerosis, tumor); drug-induced (lithium, alcohol)			
Isometric tremor	~6 Hz	Variable	Muscle contraction against stationary objects
Example: Holding a heavy object in one hand			
Task-specific tremor	4-10 Hz	Variable	Occurs with specific action
Examples: Handwriting tremor; musician's tremor			

Table 2: Classification of the tremor according to the frequency of body movements. Adopted from [9].

METHOD DESIGN

Participants

An empirical study was carried out with 8 right-handed participants (5 male, 3 female). Age of the subjects varied from 10 to 60 years. All test subjects had normal visual acuity or wore prescription glasses. None of them had previously complained on any motor or coordination problems in hands or fingers though 2 of the participants had been suffering from other more severe medical conditions.

Hardware

Hardware platform used in the experiment was an iPAQ pocket PC 3800 series with touch screen and stylus input. The fixed screen resolution of the device was 240 by 320 pixels. The advantage of FDTT software is a standard and affordable platform. There is also a standard desktop pc version available, where the input can be given with a mouse or stylus (digitizer). In our experiment, we tested the subjects with a device that fitted well on the subject's hand and where the input was given with a stylus. We guessed a pen-based method adds to the sensitivity of measuring any possible problems in the subject's game performance, and at the same time, makes the test more mobile and easier to be set up.

Software

The "Finger Dexterity Test & Training" (FDTT) software was originally designed to measure finger dexterity in hand-eye coordination tasks. The software application was developed in Microsoft eMbedded Visual Basic 3.0. The software allows estimation and measuring an individual's ability to move the fingers and to control fine micro-movements when the user draws or copies predefined graphic images using a stylus input [10]. We applied FDTT software to explore a possibility to use micro-movements and behavioral artifacts for earlier diagnostics of neurological problems in children and adults.

Training

Before testing, the subjects were given a brief training on how to give input to the device. The training session was not fixed in length. The subjects were given basic instructions on how to copy the tracks indirectly on the screen. Special attention was drawn to handling stylus. Lifting the stylus could cause orientation problems, because after lifting the person could loose the knowledge of the location for a while. When the participants apparently could handle the task, the application was reset and the recording started. Usually, 2-4 inputs were enough to learn the application well to start the test. The application was surprisingly easy to adopt even with persons over 50 years old with normal vision (or corrected to normal).

Every time the person plays the game, s/he will usually become more and more skilled. As none of the participants had previous experience with the application, this factor did not interfere with comparisons between the subjects.

Setting

Test setting was a normal room, with silent background music to release any tension and concern for how results might be evaluated. During the testing, the subjects could choose a position they felt the most comfortable. The room was kept quiet. Subjects used their preferred hand in giving input. A session of about 10-15 minutes was usually enough to complete the test. Each of the 20 participants entered the total of 20 graph tracking inputs with a stylus. The input was given in successive order with only brief pauses intervening. Any breaks were allowed between blocks if the participant so wished, but all input sessions were completed during the same sitting in successive order. A visual estimation was carried out whether any extraordinary difficulties occurred in using the device during the test.

Graphs used in testing

Five graphs as a game-like scripts were designed to provoke and record micro-movements and behavioral patterns. The graphs were predefined as shown in Figure 1. The Start zone and End zone are shown with different level of gray color. 5 graphs appeared in a random order during the 20 trails done by each of the participants.

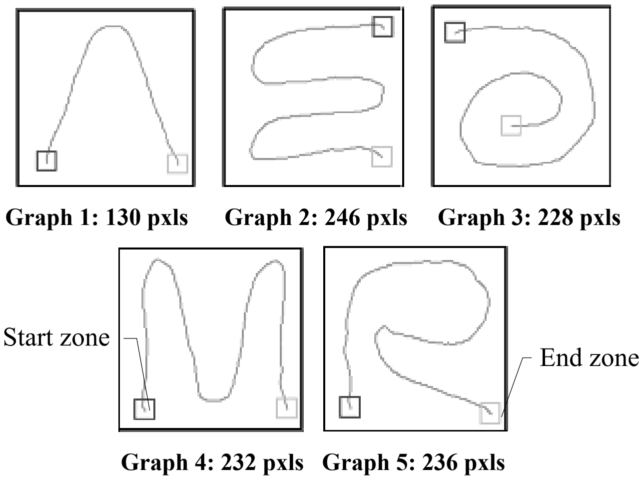


Figure 1. The shapes of the contour graphs used in testing.

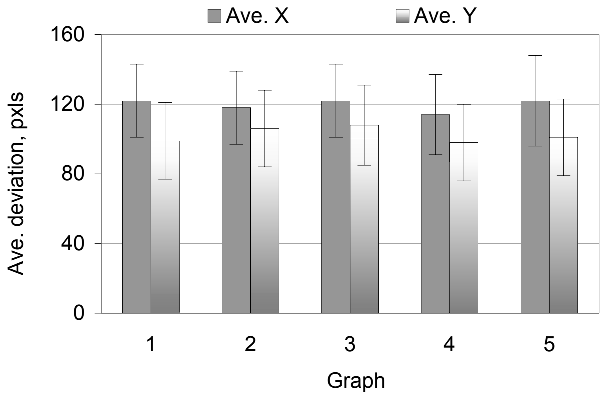


Figure 2. The graphs' sampling was homogeneous enough on both X- and Y-axis.

The test results achieved justify the choice of the graphs' shapes. Figure 2 shows that the graphs' sampling was homogeneous enough in the average deviation both on X-axis (120 pxls, SD=3.6 pxls) and Y-axis (45 pxls, SD=1.1pxls).

As shown in Figure 3, at the startup of application, two fields appear: a big square - game field restricted with the black (white originally) square border (180 by 180 pixels), and the small gray (green originally) field (45 by 45 pixels), where all input is given. The bigger field has a start zone (green rectangle originally), and the end zone (red rectangle). When player moves the stylus within the small gray field and the black (yellow) track is moved to the small green box in the game field. When "primary" scan path has entered the starting zone, the game field is cleared and recording of player movements begins.

To provoke any possible problem in hand-eye coordination, the input is not done in the game field directly over the graph, but through indirect copying via reduced gestures within the input field with amplified gestures. A further provoking of unintentional micro-movements is achieved by using a different scale factor between stylus movement and scan path produced within the game field. The minimal scale factor used is equal to 4. To complete the game the player needs to cross the red rectangle (end zone). During the tracking of the graph, the application measures and records accuracy and performance of the player in terms of average deviation on X and Y-axis regarding the test graph.

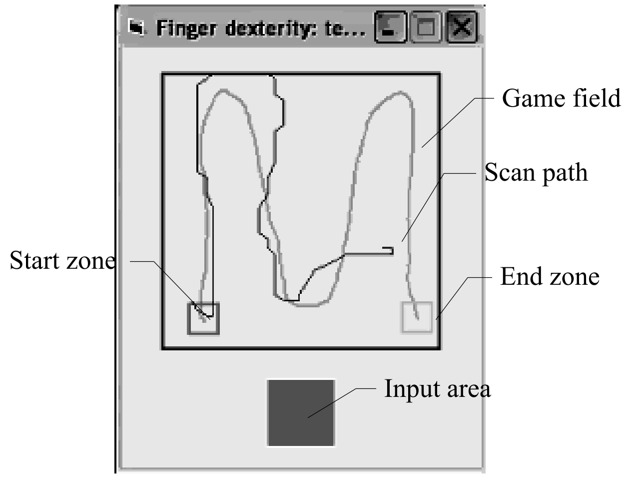


Figure 3. Graph 5 and scanpath produced during the test.

On the test completion the time spent and correlation factors are calculated and the results are stored in a log file.

RESULTS AND DISCUSSION

We had the following three main research questions on mind when analyzing the data. Does tremor have an impact on a personal game performance? How do coordination problems show themselves in the recordings? Can relevant information be gained from the recordings to estimate whether the technique could be used as a screening method?

The performance of individual subjects was usually very close to the mean value. This observation was meaning as it makes it relatively easy to distinguish between 'normal' and 'abnormal' game performance if the test technique was applied to any person.

Figure 4 shows the total averaged scores (correlation on XY-axes) and the individual results for participants 1 and 7. To find out what is the level of tremor needed to affect the results, participant 1 tested the application with simulated tremor. The recordings suggest that subtle deviations caused by invisible tremor affects the results slightly but detectably: the results are slightly poorer (corr. = 0.810) with tremor than without tremor simulation (aver. corr.=0.844). However, participant 1 performed better than the average (corr. = 0.780) both with and without simulated tremor. The differences between individuals' performances are thus greater than the effect of slight tremor.

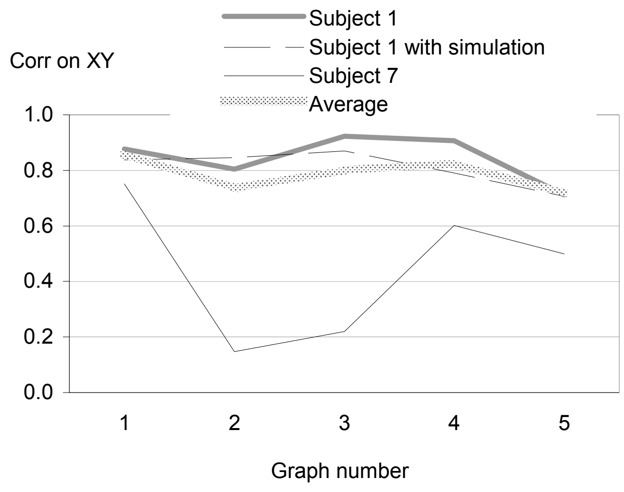


Figure 4. Subject 1 (with and without tremor) and Subject 7 singled out.

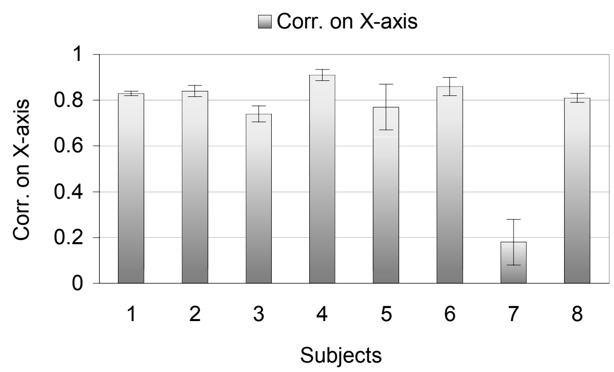


Figure 5. The effects of hand-eye coordination problems in Subject 7.

There is additional software option to change scale factor in a wide range. That could increase a sensitivity of the method especially in detecting the tremor effects.

At the same time, coordination problems show themselves very clearly in the data even though they no problems had been previously detected by the person himself, and they could have the greater diagnostic power. For example, coordination problems in Parkinson's disease include difficulty in carrying out such tasks as brushing teeth, walking, speaking, and writing, and worsening rigidity.

Figures 4 and 5 show the scores of participant 7, who gained exceptionally low results in the test. The participant seven performed remarkably poorer than other subjects. Supported by the evidence from other recent symptoms, the participant 7 has in high risk of displaying the symptoms of a disease of neurological origin. A wise course to follow is to consult one's doctor for further advice.

According to our experience with testing the FDTT application, more graphs requiring small circular movements with reverse directions have the higher diagnostic meaning. Difficulties in using computer-aided equipment usually rise with age. Unlike we had assumed, gathering tracking information from aged people proved be relatively simple. The only requirement for the testing was a normal vision (or corrected to normal with eye glasses.) Age itself did not have much impact on the results. The best results were collected with the Subject 2 (belonging to the age group 50-60). But the population sample under current investigation was restricted to make any final decision. The test might be applicable for people of various ages.

FUTURE WORK

The software used in the testing was still under development. There were a couple of known issues, but according to the visual estimation, they did not change the relative order of results between the participants. When entering the final, the red rectangle, the software could freeze for a couple of seconds, before given a chance to start a new game. Because this could confuse the user, the advisor stood near and asked the participant to wait patiently until the game proceeds to the next level. Sometimes getting into the red rectangle was unsuccessful if the box was not in the right angle. The user needed to do the entering again. These issues were caused by the inadequacy of the device's processor (200 MHz) to perform steadily with this prototype version of the FDTT. Calculation of correlation took additional time once an input had been finished. It also seems that the software did not always display the last pixel before entering the red rectangle, so the user thought not to have yet entered the rectangle. The problems were caused by the display performance and the bugs and restrictions of an embedded display controller.

It is not enough only to measure the tremor amplitude and frequency and the hand-eye coordination performance accurately, but there must be a way of interpreting and evaluating the results effortlessly to detect the cases where the deviation from what is normal is apparent. Devices detecting tremor should aim at converting the amplitude and frequency of tremor into an electrical signal indicative of tremor and then interpreting the results in a way that is easily understandable. In our pilot testing, the results were first processed with statistical analysis and then with an estimation of the visual representations of the results. Evaluation programs and scripts could be developed for the immediate analysis of the results.

Detecting the tremor is a challenging task. There are widely different amounts of tremor, which requires consideration of measurement scales. Normal postural tremor can be of the order of 10 times greater than normal rest tremor. Tremor in Parkinson's disease in turn can be 10 more times greater. What we now tried to do was more similar to handwriting; therefore, the small movements and screen size are currently used. A larger, full screen window might be used for more complicated tasks. The future possibilities to discern the effects of tremor by using additional software options could be tested. There is additional software option to change scale factor in a wide range. That could increase a sensitivity of the method especially in detecting the tremor effects.

CONCLUSIONS

With proper care given started as early as possible in the progress of a neurological disease the vast majority of sufferers were able to manage quite well. A test that is inexpensive, mobile and easy to use is needed. The test we experimented could be done in 10 minutes. The proposed technique could possibly be further developed progressively into a screening method to be applied after an operation, or even as a simple method to be used privately by persons who have a higher risk for neurological diseases typical to a certain age group.

The performance of individual subjects was usually very close to the mean value, but severe problems in hand-eye coordination show themselves clearly in the data. According to our experiment, actual problems in hand-eye coordination are relatively easy to detect. Graphs requiring small circular movements with reverse directions demonstrate the higher diagnostic power. We suggest setting focus on the effects of deterioration of sensomotoric skills, as they are more likely to be detected than the first invisible signs of tremor.

The study was carried out in the field of human-computer-interaction. Further research should be done under medical supervision. Recordings among people suffering from various neurological diseases might be carried out to estimate the values of deviation from the normal.

It has been suggested that various other factors such as a smoking habit could affect the results in exploring the tremor and finger dexterity. The effect of other factors could be evaluated in more thorough testing of larger samples of population.

REFERENCES

1. van Emmerik, R.E.A., Wagenaar, R.C.(1995) Tremor and symmetry properties in bimanual coordination in Parkinson's disease. In: Bardy, B.G., Bootsma, R.J. & Guiard, Y. (eds.) *Studies in Perception and Action*. Lawrence Erlbaum, pp. 61-64.
2. Jobbágy A., Furnée H., Harcos P., Tárczy T., Krekule I., Komjáthi L. Analysis of movement patterns and the early detection of Parkinson's disease. In: *Proceedings of the 19th International Conference*, Oct. 30. Nov. 2., 1997 Chicago, Il. USA. IEEE Engineering in Medicine and Biology Society pp. 1760-1763.
3. Chwaleba A., Kwiatos K., Nitecki G., Portable microprosessor system for tremor signal recording in extrapyramidal disease. *Measurement Science Review*, 2001; 1: 39-42.
4. Barrientos A., Mora A., González R., FerreM., Martínez J.L., Using the PHANToM system for people tremor evaluation.
5. Essential Tremor: A Practical Guide to Evaluation, Diagnosis, and Treatment. *Clinician* 2001; 2:1-20.
6. Louis E.D, Ottman R, Hauser W.A. How common is the most common adult movement disorder? Estimates of the prevalence of essential tremor throughout the world. *Mov Disord* 1998;13:5-10.
7. Parkinson J, An Essay on the Shaking Palsy, 1817. In: *Neuropsychiatry Clin Neurosci* 2002; 14: 223-236
8. Bain P.G., Findley L.J., Atchison P., Behari M., Vidailhet M., Gresty M., Rothwell J.C., Thompson P.D., Marsden C.D.. Assessing tremor severity. *Journal of Neurology, Neurosurgery & Psychiatry.* 1993;56:868-73.
9. Smaga S., Tremor. *American Family Physician,* 2003; 8: 1542-1552.

   http://www.aafp.org/afp/20031015/1545.html
10. Seminar Alternative Access: Feelings & Games, Finger Dexterity software (2005) http://www.cs.uta.fi/~grse/AAFG.htm

eSmileys: Imaging Emotions through Electro-Tactile Patterns

Ruijie Ban
Alternative Access: Feelings and Games 2005
Department of Computer Sciences
FIN-33014 University of Tampere, Finland
Ruijie.Ban@uta.fi
+358 40 8738582

ABSTRACT

Graphical input and visualization has irrefutable benefits as an intermediate between an analog perception of the human being and a computer that operates on and produces discrete data. However, graphical images pose greater problems for blind and visually impaired users. The converting of visual images into another sense (modality) could open new ways in visualization technique and promote alternative communication and user interface technology for all. Tongue is one of the most sensitive parts of human body. There have been several attempts to apply the tongue in human-computer interaction both to control and display information. The current study is based on electro-tactile stimulation of the tongue to transform short conditional messages, presented by symbols or graphics, into electro-tactile patterns. The goal is to estimate the efficiency of sensory substitution of the conditional semantic information regarding emotions with the use of Composite Electro-Tactile Patterns (CETP). The rectangular pulses of stabilized current of 0.3 mA with alternative polarity have been used to shape the CETPs. Three volunteers took part in the pilot testing of the technique. The performance of the subjects was evaluated through match game in the terms of the number of repetitions to memorize each of 9 CETPs, test-time completion and the error rate at recognition of the test patterns. The benefits and lacks of the eSmileys technique are discussed in detail.

Keywords

electro-tactile stimulation, tongue display system, composite electro-tactile pattern, smiley, emotion

ACM Classification Keywords

H5.2. User interfaces. Input devices and strategies

I.3.6 Methodology and Techniques. Interaction techniques

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

INTRODUCTION

In human-computer interaction, there is a challenge to display conditional semantic information in a kind of short messages such as warning signals or secondary feedbacks realized through speech cues and non-speech sounds (earcons). Vibro-tactile signals (tactons [12]) can be also employed for the same purposes. In particular, tacton (tactile pattern) is the physical signal (stimulus) which can be modulated in accordance with some information content which is needed to be delivered in alternative way. Other short messages and conditional signs (Bliss symbols, icons, smileys and emoticons) can be used for alternative communication and to augment human-computer interaction as well. The pulses of electrical current is considered as suitable physical signals, parameters of which can be easier manipulated and recognized/perceived being applied to skin surface as physiological-adequate stimuli [1].

There is a clear trend that various mobile terminals will widely utilized tactile interaction. However, a possible number of actuators to simulate different tactile sensations are very restricted for mobile application due to their size, weight, application, and power consumption. Bach-Y-Rita [1] and other researchers suggested the use of electro-tactile stimulation of the tongue to display graphical information and to diminish converter size and power consumption at a maximum. On the other hand, because of its high sensitivity, the tongue may be an ideal body part for practical application of electro-tactile signals.

In eSmileys project, graphical images of emotions (smileys) were used as conditional semantic messages. The electro-tactile patterns were used to alternatively display these pictographic images and associated information through parameters of the composite electro-tactile patterns (CETP). The performance of the subjects was evaluated through match game in the terms of the number of repetitions to memorize each of 9 CETPs and the error rate at recognition of the test patterns.

BACKGROUND

Based on research in alternative communication techniques, the method to complement graphical and auditory feedbacks with tactile signals is widely used in human-computer interaction and ubiquitous computing devices such as the vibration cues in mobile phones and

Logitech input devices (joystick, mice, game pad, and wheel). Meanwhile, tactile vision substitution system, like Bach-Y-Rita et al. discussed in [1, 2, 3], could be used to deliver image information to the brain via an array of electrodes being in contact with the skin of the body, for example, the abdomen, the back, the thigh or the finger.

At the Department of Biomedical Engineering, University of Wisconsin Dr. Kurt Kaczmarek and Prof. Paul Bach-Y-Rita [1, 2, 3, 5] and other researchers study the use of electro-tactile stimulation of the tongue to display graphical information. Since tongue is in the protected environment of the mouth, the sensory receptors are close to the surface. The presence of an electrolytic solution (saliva) provides good electrical contact. In previous solutions it has been revealed that the tongue has more preferable parameters (for instance, a very low input impedance, of about $1\text{-}10\times10^3$ Ohms$\times$cm^{-2}) to provide a reliable stimulation and perception of the signals results in simpler circuitry than the current pulses needed to stimulate any other parts of skin, such as finger. A high impedance of the skin (of about $10\text{-}100\times10^3$ Ohms$\times$cm^{-2} for dry skin) requires applying high voltage (50-200V) to provide the needed grades in sensation. It could be difficult to control perception when skin impedance is dramatically falling down.

One example of tongue sensation system is the tongue electro-tactile display device (Figure 1). It is a kind of wearable equipment for alternative imaging of some graphical images. The user puts electro-tactile matrix of electrodes, which were produced with flexible film technology, in the mouth. The electrodes array is connecting to stimulator having multiple outputs via a flat cable. The wearable (battery-powered) part of the tongue display unit and a way making use of this device are shown in the pictures. The tongue display unit consisted of an array provided with 144 electrodes having an area of 12 rows × 12 columns. The display unit does benefit over another existing tactile devices due to a low impedance of the interaction surface (tongue).

That is, it would be possible to control voltage parameter of the pulses, whereas on other skin parts such as abdomen and fingertips current controlled stimuli have to be provided [4]. According to Bach-Y-Rita's observations, 50 hours of practice is required to get feel of the unit and learn how to interpret received stimuli. [8]

In case of human-computer interaction, there are many different possibilities of delivering a tactile stimulation in a kind of mechanical (vibration) or of electrical dot-stimuli to a skin surface (palm or finger) with a high efficiency than screen-type matrixes. If a graphical pattern has been presented to the blind person, he can never feel full image and will scan it by fingers sequentially piece by piece.

Some of researchers concluded that it is not necessary to design complicate graphical electro-tactile matrices as only small matrix could be placed under the fingertip (Figure 2). A scan process of the graphics could be implemented with any pointing input device. Thus, a number of devices with built-in electro-tactile transducers have been developed so that people could freely move their hand along virtual plane/space and a state of the limited contact surface could change in dependence on a position or graphic features of the inspected surface. [10, 11, 12]

The concept of electro-tactile pattern perception/recognition is based on cross-modal integration and brain's plasticity. The technique could be used to complement graphical and auditory feedbacks in the user interface. Electro-Tactile messages could support inaudible communication. In this project, the technique similar to Kajimoto et al. [9] was used to provide stimulation of the tongue in respect to graphical images such as 9 smileys. With training, perceptual judgments (percepts), normally applied to visual images can also be associated with electro-tactile patterns describing emotional content.

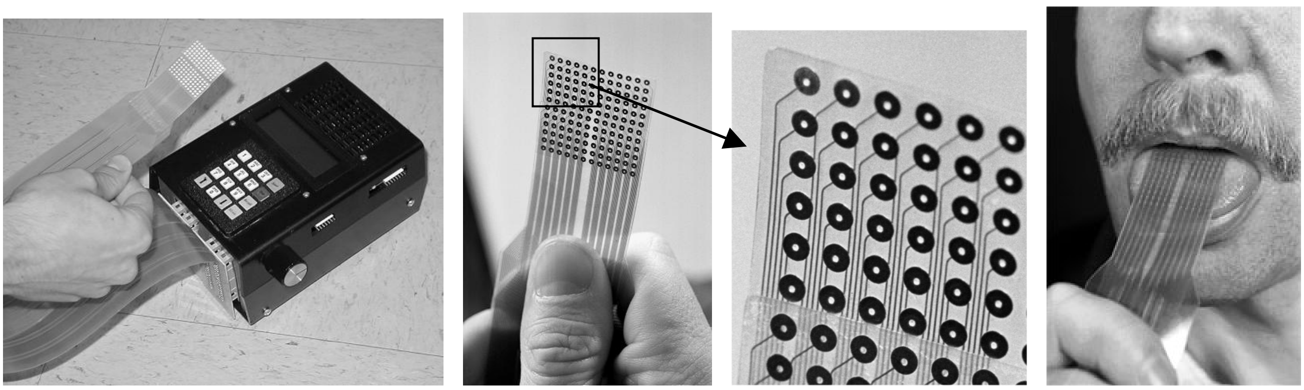


Figure 1. Tongue placed electro-tactile display device: wearable unit, tongue array and a way of using device.

Adopted from [2].

Figure 2. From left to right: Electric Mouse, FantaScan, SmartTouch. Adopted from [8, 6, 9].

E-SMILEYS. DESIGN OF ELECTRO-TACTILE PATTERNS

The goal of the project eSmileys was an empirical study of the possibility to substitute emoticons by electro-tactile patterns. That is, to explore the technique similar to ideographic symbols to code some type of short semantic messages. To validate efficiency of the tongue display technique the program was implemented like a match game. But still, the goal was to study a possibility of the “sensory substitution” through coding (by composite electro-tactile patterns) not of the visual images as graphics or graphical features but of the compressed semantic information which these images display concerning the emotional content they describe. By other words, coding the compressed semantic information with the use of composite electro-tactile patterns is the subject of this pilot research. Personal tongue feelings and reliability of the patterns recognition – that is, the subject performance was measured in terms of dynamics of test-time completion, errors rate and the number of repetitions in training phase.

Apparatus

Electro-tactile stimulation elicits touch feelings by passing a localized, controlled electrical current into the skin through surface electrodes to stimulate directly sensory nerves. Such a technique can be useful for sensory augmentation and sensory substitution, which can extend the capabilities of or partially substitute for vision, hearing and touch [3].

Figure 3 shows the equipment (electro-tactile converter) used with software “ePattern constructor”. The electro-tactile unit is a special converter to produce electro-tactile stimuli with stabilized parameters of the current pulses and to provide their control through parallel LPT1 port of the PC. Two disposable electrodes are set in a special connector on the stick, as shown on the right side in Figure 3, and the user can put the tongue tip between electrodes. When the program starts, the person can feel the electrical pulses that produce different feelings.

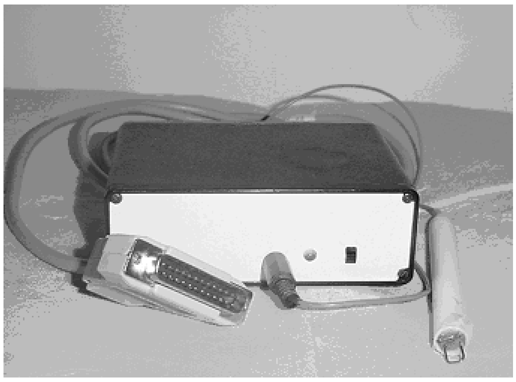


Figure 3. Photograph shows eSmileys equipment.

Participants

Three volunteers took part in the preliminary testing of the technique. The subjects were students of the Department of Computer Sciences at the University of Tampere. The average age of the subjects was 27.3 years old, the ages varied from 23 to 32 years. They were both female, with normal hearing and visual abilities. Both of them are familiar with computer, they are used to work with computers. The average time of computer usage is 8 hours daily. None of the participants had previous experience with electrical display techniques.

Software

The project comprises of two software programs: ePattern Constructor (Figure 4) and eSmileys match game (Figure 5). ePattern Constructor was used to produce and edit basic and composite electro-tactile patterns, while eSmileys match game have been used to display smileys and play associated electro-tactile stimuli to support the testing procedure.

The experimenter constructs electro-tactile patterns by using ePattern Constructor. In “Basic patterns” area, the first active label on the left column is the number of effect. The second active label is the amount of pulses. If the experimenter enters 5 (by mouse click on the label) that means there will be 5 pulses in the effect, in the bottom of constructor there is a monitor which shows the structure of the basic patterns. The third active label shows the intensity of each pulse, the wider the pulse, the stronger the pulse will be sensible. The fourth active label is the opposite polarity of pulses. If the experimenter enters a number in this active label, there will be the same number of pulses shown in the opposite side. The last active label shows the distance (delay) between pulses. The longer delay duration, the longer pause time the tongue could feels. Once the experimenter changed any parameters through these active labels, all the parameters will be stored in ePatterns' log file automatically. When click on "Start" button the sequence of pulses will be produced and the amount of pulses in the basic pattern will be displayed on the monitor according to timeline settings 500-6500 ms.

The experimenter could change the number of the pattern by mouse clicking – left click is to increase the numbers as well as decrease the numbers by right click. The frequency of pulses used in designing eSmileys was 50 and 100 Hz.

The experimenter has to construct 8 basic patterns, those 8 effects are used later to shape 9 composite patterns. In "Composite patterns" area, the first active label is the number of pattern, which will correspond to the smiley icons. The next active label is the scale of timeline in milliseconds to monitor basic patterns in the sequence. The active labels' array allows experimenter enters the number of effect to shape composite patterns from the basic ones. The data will be stored into the log file "cPatterns" automatically by click on "Save" button. The structure of Basic patterns and Composite patterns are shown in Table 1.

When the subjects played with the eSmileys match game, each smiley image initialized composite patterns each time when mouse clicked on the image.

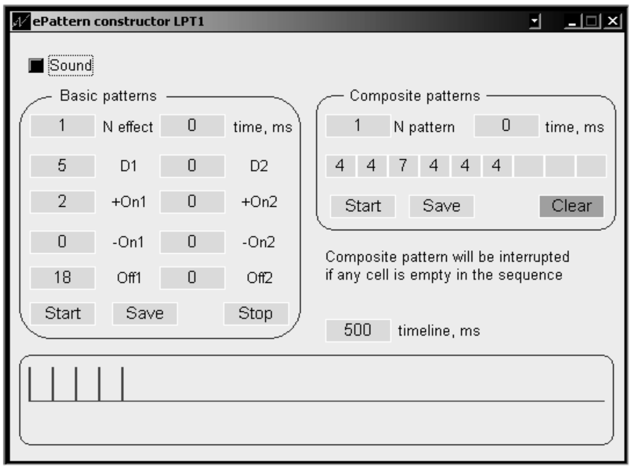


Figure 4. Screenshot of the ePattern constructor for editing basic and composite electro-tactile patterns.

Figure 5. Screenshot of the testing program eSmiley.

<table>
<tr><td colspan="6">Structure of the Basic patterns</td></tr>
<tr><td colspan="2"></td><td colspan="4">The first burst was used only</td></tr>
<tr><td colspan="2"></td><td colspan="3">Pulses duration, ms</td><td></td></tr>
<tr><td colspan="2">Basic pattern number</td><td>+On</td><td>-On</td><td>Off</td><td>D1, n</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>0</td><td>18</td><td>5</td></tr>
<tr><td colspan="2">2</td><td>2</td><td>2</td><td>16</td><td>5</td></tr>
<tr><td colspan="2">3</td><td>5</td><td>0</td><td>15</td><td>5</td></tr>
<tr><td colspan="2">4</td><td>5</td><td>5</td><td>10</td><td>5</td></tr>
<tr><td colspan="2">5</td><td>2</td><td>0</td><td>8</td><td>10</td></tr>
<tr><td colspan="2">6</td><td>2</td><td>2</td><td>6</td><td>10</td></tr>
<tr><td colspan="2">7</td><td>0</td><td>0</td><td>50</td><td>1</td></tr>
<tr><td colspan="2">8</td><td>0</td><td>0</td><td>100</td><td>1</td></tr>
<tr><td>Image</td><td>CP, n</td><td colspan="4">Structure of Composite patterns</td></tr>
<tr><td>☹</td><td>1</td><td colspan="4">447444</td></tr>
<tr><td>:-S</td><td>2</td><td colspan="4">667666</td></tr>
<tr><td>:-!</td><td>3</td><td colspan="4">4747474</td></tr>
<tr><td>:-X</td><td>4</td><td colspan="4">6686686</td></tr>
<tr><td>:-D</td><td>5</td><td colspan="4">11711711</td></tr>
<tr><td>☺</td><td>6</td><td colspan="4">55755755</td></tr>
<tr><td>:-0</td><td>7</td><td colspan="4">22722722</td></tr>
<tr><td>:-Z</td><td>8</td><td colspan="4">222222</td></tr>
<tr><td>:-?</td><td>9</td><td colspan="4">331113</td></tr>
</table>

Table 1. Design features of the Composite electro-tactile patters /eSmileys

Procedure

Before testing, the experimenter has to design electro-tactile patterns, save the created files which contained the parameters of the stimuli and copy them to eSmileys Game.

Short instructions the subjects received directly within the game through message box. However, the procedure and general features of the technique were explained beforehand. To start the game the subject has to press spacebar button. At the *Training Phase*, the subject has to repeat each ePattern as many times as needed to memorize ePattern, which was associated with smiley image. When the subject has memorized all ePatterns, s/he can start *Testing Phase* by press again spacebar button. At the Testing Phase, the subject has to feel the test ePattern (eSmiley) presented and try to recall which Smiley corresponds to the test eSmiley. To repeat test pattern the subject has to press spacebar button again and feel eSmiley with tongue. The subject was asked to find the eSmiley that corresponded to ePatterns and to prove the choice by mouse click. The subject can repeat eSmiley as many times as needed by press spacebar button. If the subject clicked on wrong smiley, which is not corresponds to eSmiley, s/he will listens to a negative sound. A positive sound would be given if smiley and eSmiley matches each other as well. Each eSmily has to be tested 10 times in a random order.

Personal tongue feelings and reliability of the patterns recognition – that is, the subject performance measured in terms of dynamics of test-time completion, errors rate (in testing phase) and number of repetitions in training phase. After few minutes of training and reading the instructions, all the subjects played fast and easily. However, at the beginning they felt nervous of unusual stimuli.

RESULTS AND DISCUSSION

According to the test, all the data were collected automatically in a log file. The data collected included the number of repetitions in each phase of the match game, errors committed by subjects, and test-time completion.

The average times for test completion for the first subject were 10.57 and 4.08 minutes in training and testing phases accordingly; for the second subject 9.87 and 1.93 minutes; and for the third subject 9.65 and 2.47 minutes. Thus, to recognize 90 eSmileys (9 eSmileys x 10 times) they spent in average of about 2.7 s, 1.29 s and 1.65 s per each test pattern.

Figure 7 shows the average number of repetitions in Training Phase of the game needed to memorize nine eSmileys. The graphs present the repetitions of images by three subjects. The highest value (11) is the number of repetitions per images {:-D} and {☹}, as well as the lowest value (3) is the number of repetitions during Training Phase for eSmileys {☺} {:-S} and {:-!} which were coded as shown in Table 1.

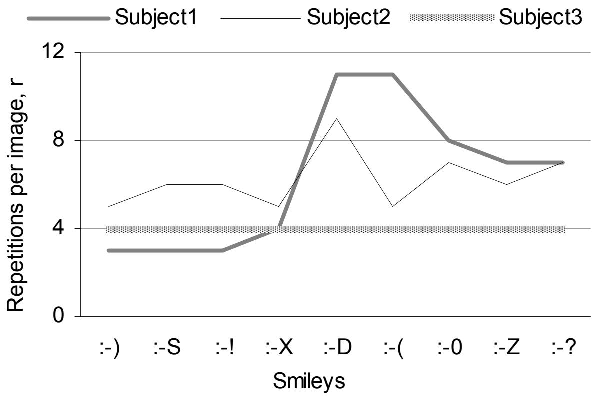


Figure 7. The average number of repetitions in training phase of the game needed to memorize nine eSmileys

From the Figure, it is obvious that the first subject and second subject repeated the {:-D} image relatively more times than other images. While the repetition of {☹} eSmiley the Subject 1 repeated more times than Subject 2.

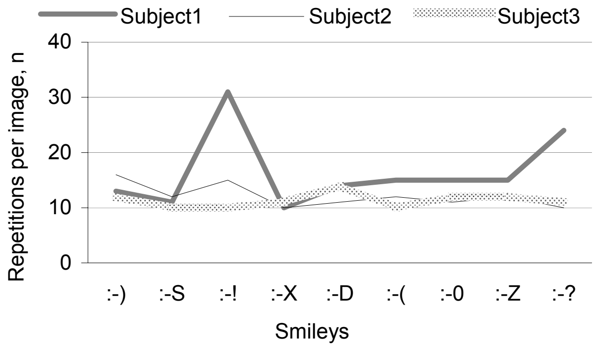


Figure 8. The average number of repetitions in testing phase of the game needed to recognize 9 eSmileys presented 10 times in a random order.

Figure 8 shows the average number of repetitions in Testing Phase of the game needed to recognize 9 eSmileys presented 10 times in a random order. The Figure shows that the result of recognition eSmiley {:-!} has greater difference for the subjects. The Subject 1 repeated the highest number (31) than the other subjects for {:-!} image, while Subject 3 repeated the lowest number (10) for the same image. The graph of the numbers of repetitions for Subject 2 and Subject 3 of each image are relatively smooth than for Subject 1.

Figure 9 shows the error committed by the subjects in recognition of 9 eSmileys presented in a random order 10 times each. From this picture, the results of three subjects have high value of repetitions. Especially {:-X} image is the lowest error rate while {:-D} image is the biggest difference between the three subjects. The first subject committed less errors (17) of {:-0} image, however {:-S} and {:-!} images were difficult for him (33) to recognize.

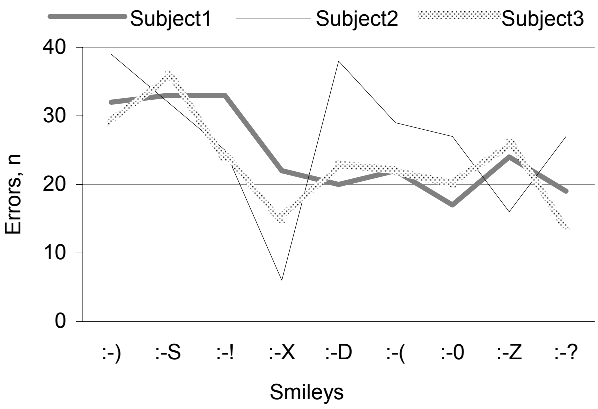


Figure 9. The errors committed by the subjects in recognition of 9 eSmileys presented in a random order 10 times each.

The Subject 2 committed less errors (6) of {:-X} image but {☺} and {:-D} images were unrecognizable many times (39, 38). Subject 3 made less errors (14) of {:-?} image while highest error rate (36) was recorded in a case of image {:-S}. For {☺} image, the three subjects take both failure many times, obviously, for {:-D} image, Subject 2 committed highest error rate (38) while Subject 1 made the lowest number of errors (20).

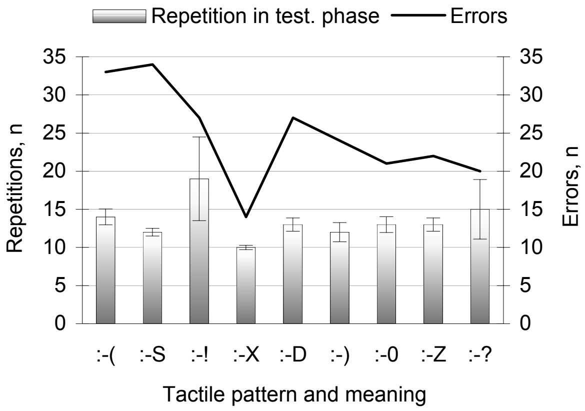


Figure 10. The average number of repetitions in testing phase of the game and errors committed by the subjects in recognition of the eSmileys presented in a random order 10 times each eSmiley.

Figure 10 shows the average number of repetitions in testing phase of the game and errors committed by the subjects in recognition of the eSmileys presented in a random order 10 times each. The bars show the repetition numbers in Testing Phase, the broken line shows the errors that subjects committed in average. From the Figure, the subjects easily memorized (12) the second image {:-S}, but they committed more errors (34) during Testing Phase to recall it through electro-tactile pattern. On the contrary, they easily memorized and recognized image {:-X}: repetition number 10, error rate 14. However, although the repetition number for {:-!} image was the highest (19), the subjects committed relatively more errors (27) of this image.

CONCLUSIONS

The eSmileys was designed for blind and visually impaired people. The goal of the project was to estimate the efficiency of sensory substitution of the conditional semantic information regarding emotions with the use of composite electro-tactile patterns (CETP).

In eSmileys project, graphical images of emotions (smileys) were used as conditional semantic messages. The electro-tactile patterns were used to alternatively display these pictographic images and associated information through parameters of the composite electro-tactile patterns (CETP).

An electro-tactile converter and two software programs were designed for eSmileys project. In the project, a game was constructed with two phases – Training Phase and Testing Phase, to testing the performance of player in understanding the content of electro-tactile patterns perceived by tongue.

Through pilot study, the performance of the subjects was evaluated through match game in the terms of the number of repetitions to memorize each of 9 CETPs and the error rate at recognition of the test patterns.

Because of the human's tongue is the most sensitive part of the body it has strong feeling from very weak electrical stimuli. Therefore, the frequency of stimuli to tongue cannot be too strong as applied to fingers. The strong stimulus might be make tongue numb easily and fast. For such a reason, eSmileys were composed with light stimuli. However, it caused some difficulties in discrimination of the composite stimuli.

The further work could improve the parameters of the basic patterns to make bigger difference in composite electro-tactile patterns. Moreover, to make each stimulus well mapped to the image another work has to be implemented. Therefore, the performance of the players could be improved significantly.

REFERENCES

1. Bach-y-Rita, P., Kaczmarek, K.A. Tongue placed tactile output device. Web Site (2002) http://kaz.med.wisc.edu/Patents/US6430450.pdf
2. Bach-y-Rita, P., Kaczmarek, K.A. Tongue placed tactile output device. Web Site (2004) http://kaz.med.wisc.edu/TDU.htm
3. Tactile Display Research Group. Web site (2003) http://mmb.bme.wisc.edu/Research/TactileSite/Tactile.html
4. Ezequiel Di Paolo, Adaptive systems, Web Site (2005) http://www.cogs.susx.ac.uk/users/ezequiel/…/AdaptiveSystems8.ppt
5. Bach-y-Rita, P., Kaczmarek, K.A., Tyler, M.E., Garcia-Lara, J. Form perception with a 49-point electrotactile stimulus array on the tongue: A technical note. J. of Rehabilitation Research and Development 35(4), 1998, 427-4301.
6. EyePlus, Inc., Web Site (2005) http://www.eyeplus2.com/technology/index.htm
7. Hasser, Ch. J., HAPTAC: A Haptic Tactile Display for the Presentation of Two-Dimensional Virtual or Remote Environments Interim Report. Armstrong Lab., USA. 1995, 38 p.
8. Kajimoto Hiroyuki, *et al* Electro-Tactile Display with Force Feedback, In Proc. of World Multiconference on Systemics, Cybernetics and Informatics, Vol. XI, Orlando, USA, 2001, pp. 95-99.
9. Kajimoto, H *et al* SmartTouch – Augmentation of Skin Sensation with Electrocutaneous Display, HAPTICS 2003. pp. 40-46.
10. Maucher, T., Meier, K., Schemmel, J. An interactive tactile graphics display. In ISSPA 2001, pp. 190-193.
11. Sribunruangrit, N., *et al* Improving Blind People's Spatial Ability by Bimodal-perception Assistive Device for Accessing Graphic Information. In: Proc. AAATE'03. IOS Press, Netherlands (2003), 476-480.
12. Brown, L.M., Brewster, S.A., and Purchase, H.C. *A First Investigation into the Effectiveness of Tactons*. In Proceedings of WorldHaptics 2005 (Pisa, Italy). IEEE Press. pp. 167-176.

Math-Puzzle: Equation Tutor for Sighted and Visually Impaired Children

Jarno Jokinen
Alternative Access: Feelings and Games 2005
Department of Computer Sciences
FIN-33014 University of Tampere, Finland
Jarno.Jokinen@uta.fi

ABSTRACT
Teaching mathematics for blind people is a challenging task, since most of the mathematical methods require logical skills and manipulating by abstract notions that are always easy to understand visually. Math puzzle has been designed for supporting the learning of mathematical operators and equations. The simple graphical interface was augmented with short speech cues and earcons, so it can be played in a blind mode. The game allows to develop spatial imagination, memory and logics in blind or visually impaired children.

Author Keywords
Non-visual interaction, access to arithmetic equations, math-puzzle, visual impaired children, sound feedback.

ACM Classification Keywords
K.4.2 Social Issues. Assistive technologies for persons with disabilities

H5.2 User Interfaces. 1.3.6 Methodology and Techniques. Interaction Techniques

INTRODUCTION

Background

Mathematic formulas, diagrams and graphs are presented as visual models of logically connected figures, values and symbols. Visual inspection of math objects is more understandable because of employing an external memory aid that decreases cognitive loading. There have been made many studies on how to present math notions, objects and methods alternatively for blind and visually impaired people. These solutions can be divided into five categories according to feedback signals and senses used for interaction.

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

- Tactile games, based on pin codes (Braille, VirTouch2.com) and embossed graphics
- Haptic and force feedback tools (PHANTOM Omni)
- Non-speech audio and tonal representation
- Screen reading of the equations
- Multimodal systems (haptic & speech [Patrick Roth, 2000])

The goal of this study was to design a simple game-like non-visual interface for logic skills' training by solution of arithmetic equations. Non-visual interface might be augmented with short speech cues and earcons. In other words, what ways/techniques are possible to compose in designing tutorial for teaching basic mathematics to visually impaired children through game. Besides this, an empirical study should be done in order to estimate the limitations of the game and non-visual interface for interaction with equations.

From the beginning, it was clear that the game was going to be self-made. This decision brought a few other things into consideration. First, we wanted to know how long does it take to solve a puzzle. If the game idea is as simple as we were planning to have, game maker does not want to create a game that takes more than a few minutes to solve. It is quite crucial, for the gameplay experience, how long it takes, because the player may get frustrated if the game is not progressing. Especially when you are struggling against time.

Then we wanted to know how long does it take for the player to get better in this game. In other words, how fast the players progress through the game. Keeping the previous point in mind, this is also important, for the lifespan of the game. A game too easy to master, does not have enough challenge to be played repeatedly. On the other hand, a game too hard to learn is not rewarding enough to keep the player motivated.

Since we were going to do the testing of the game with people able to see, we wanted to find out how dramatic affect does the lack of eyesight have on the game progress. Therefore, we were going to do the tests in both visual and blind mode. In addition, it would have been interesting to see the difference between blind and sighted people.

Together with these questions, we were interested to find out what kind of strategies would the users have when solving these puzzles. And how would they get progress through the game?

MATH PUZZLE

The purpose of this project was to create a game that could be used by visually impaired children. First, the game should be easy to understand and use. Functionality was to be set to minimum so that the child starting to play the game would have no obstacles in getting familiar with the system. As the target audience is children, the game should not have too complex mathematical problems to solve. Therefore, we wanted to keep it simple and use only the most simple equations, with the possibility of addition, subtraction, multiplication and division.

With these operators the game could easily become too hard, so another constraint was to be created. All of the numbers used in the game were set to one integer long. This way the equations were easier to understand and solution would be easier to find. At this point, the appearance of the game board was pretty clear. We were developing a 5 by 5 matrix, which would include 5 simple equations in the form of x + y = z. One true equation in one row would be the way the matrix (or puzzle) would look like when it was solved.

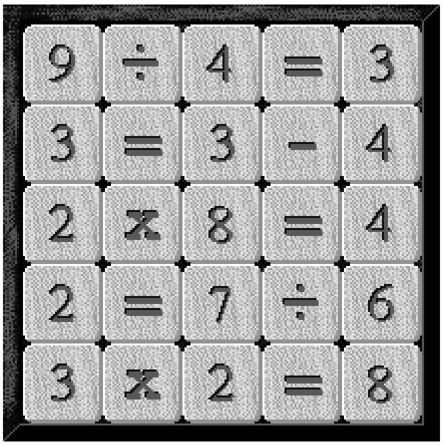


Figure 1. The equation matrix in visual mode.

GAME CONCEPT

As mentioned on the previous section, the equations are shown in a 5 by 5 matrix like in the Figure 1. First, third and fifth column include only numbers, while second and fourth are reserved for operators. At the start, all of the numbers and operators are randomized and the player’s task is to change the locations of the numbers so that all of the equations are true. Randomizing all of the numbers and operators would have made the matrix more complex so simplifications were needed. We decided to restrict the randomization so that each of the columns included only either numbers or operators. Then we had to decide which way should be chosen that the equations could be solved.

Two possible solutions

At this point, we had two possible approaches on how the equations could be solved using a static or dynamic matrix. In a static matrix, the equations would be found by clicking all 5 members of the equation in a row like in Figure 2.

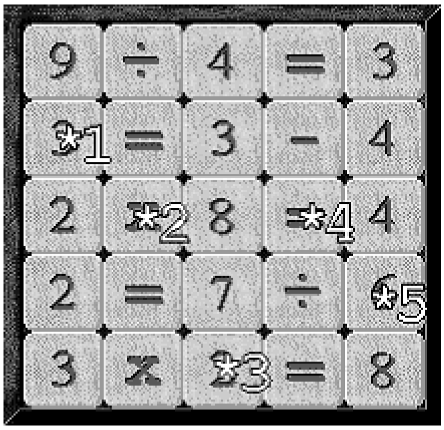


Figure 2. A static matrix approach to solve equations.

In a dynamic matrix each of the equation members are movable and the player can follow the solving progress, when all of the figures are put to their correct locations one by one. The dynamic matrix was found to be a better solution since we could not find any easy way of telling with earcons (short speech cues) to the user what equation members have already been clicked and are therefore reserved. The dynamic matrix would possibly require more memorizing, when the player needs to remember how the matrix has been changed. Even though, we decided to go with the dynamic matrix because it was easier to help the player with the imagination to built a mental model, by reading the equation members every time the user moves over a specific number or operator.

On a dynamic matrix, the squares are swapped so that in the end player would have one true equation on each row.

The idea seemed still pretty hard. The numbers and operators had their own columns already, but we decided to make it so, that the player did not have to even make the changes between different columns. This way the numbers can only be swapped inside the same column, which should make the puzzle a bit simpler to solve. Too many alternatives will increase the number of required moves and the number of moves usually tells the puzzle's difficulty level.

Implementation

The game is made using html and JavaScript. The equations used in the game are not fully randomized, since we wanted to only create a prototype of the actual game. All of the equations are written in the game source code as seen on Figure 3 and randomly selected for each game.

```
var equations = Array();
equations.push ('3x2=6');
equations.push ('4+5=9');
equations.push ('9/3=3');
equations.push ('2x4=8');
equations.push ('7-4=3');
equations.push ('8/4=2');
```

Figure 3. Array of the equations in Math-Puzzle game.

When the matrix has been created, the game can start. For solving the puzzle, the player needs help that is created with sound (short speech cues). All of the sounds are introduced prior to usage so that they are all downloaded to the PC before the game starts (Figure 4). This is crucial point because the game interface allows no delays in sound output.

```
src="0.wav" name="s0" autostart="false" hidden="true"
src="1.wav" name="s1" autostart="false" hidden="true"
src="2.wav" name="s2" autostart="false" hidden="true"
src="3.wav" name="s3" autostart="false" hidden="true"
src="4.wav" name="s4" autostart="false" hidden="true"
src="5.wav" name="s5" autostart="false" hidden="true"
src="6.wav" name="s6" autostart="false" hidden="true"
src="7.wav" name="s7" autostart="false" hidden="true"
src="8.wav" name="s8" autostart="false" hidden="true"
src="9.wav" name="s9" autostart="false" hidden="true"
```

Figure 4. The embedded speech cues.

The sounds are heard whenever the player moves over an equation member. This is done using a JavaScript event handler, called onMouseOver, shown on Figure 5. Also, the onMouseOut - event handler is used to prevent two sounds from playing at the same time.

```
img name="c11" src="s.gif" width="40" height="40"
onMouseOver="on(this);" onMouseOut="off(this);"
onClick="choose(this);"
```

Figure 5. JavaScript MouseOver and MouseOut event handlers.

The event handlers call for functions on and off, which take care of actually playing the sounds. The idea was to use the name of the image for telling what number or operator was behind this location. This was found from the fifth last letter of the image, which was found using the substr function. If this letter is not v, meaning void, the sound is played.

```
function on(obj) {
        sound = obj.src.substr(obj.src.length-5,1);
        if (sound!='v') { document['s'+sound].play(); }
}
function off(obj) {
        sound = obj.src.substr(obj.src.length-5,1);
        if (sound!='v') { document['s'+sound].rewind();
document['s'+sound].stop(); }
}
```

Figure 6. The sound playing functions.

During the game, the player changes the location of the equation members and this way tries to get all of the equations in the matrix true. The game keeps track of how it is progressing by adding one row whenever the number of solved equations changes. This can be seen on the game screen (Figure 7), but a sound is also played telling the player how many moves has s/he used and how many equations are currently solved.

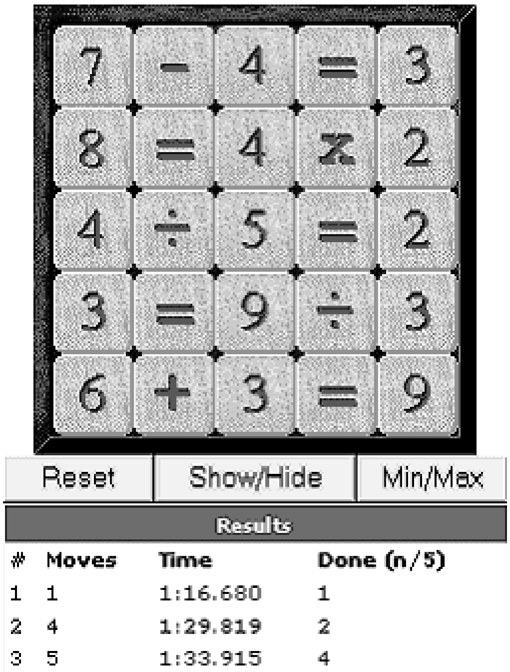


Figure 7. The game results

We have provided some shortcuts in the game for the players' aid. They give access to the most common functions and should make the gameplay a bit more fast. For example, for visually impaired people this removes the need of mouse when starting a new game.

- Alt+R starts a new game (reset)
- Alt+M minimizes/maximizes the browser window
- Alt+S shows/hides the numbers and operators.

Game modes

As mentioned before, the game has two playing modes. In *visual* mode, the player can see all of the numbers and operators. In *blind* mode, the game board is still visual, but the numbers and operators are hidden. Both modes support sound cues for navigation.

TESTING PROCEDURE

When design of the game had reached a state in which it was possible to play, we asked five people to test it. These tests were run independently, and the results were gathered via email. The purpose of these tests was to make sure that the game works, and it is possible to play with only a few simple guidelines.

It turned out, that the rules were not clear and the instructions needed to be more detailed. Also, one of the major problems, concerning missing sound in Mozilla browsers, was found. Beta testers found some minor, mainly visual, errors which we had to fix for the final version.

After the beta testing phase, we had to fix the found errors and start to plan the actual testing sessions.

Participants

We recruited another five people (unpaid volunteers) doing the test - all were males. Their age ranged from 26 to 34 and they were all technologically experienced and knew how to use mouse. All of them had also been familiarized with the game and rules.

Apparatus

The tests were done with an IBM T40 laptop computer, 1600 MHz Intel Pentium M processor with 1024MB RAM. During testing, the participants wore earphones to listen to the sound feedbacks and to get focused in the game. We also used an external mouse, because the tools in the laptop itself are inaccurate and hard to use. Since the game is done in HTML and JavaScript, we had to use some browser for playing the game. Internet Explorer 6.02 was used because of its better compatibility with sound effects comparing to Mozilla.

The log files, created throughout the testing phase were not automatically created. They were copy/pasted from the browser window. This was something we had not thought of so much, and caused unwanted delays in the testing sessions. Though, none of the testers complaint about this.

Procedure

The tests were done in usability laboratory which provided a silent and restricted area for running the tests. Usually, these sessions would have started with an introduction, but the testers were all more or less familiar with the game, so we did not need to explain the details of the game.

Each session consisted of 30 games, 10 for each playing mode - visual, blind and blindfolded. We first started with the visual mode which was in a way rehearsing for the actual game. After this, the participants tried to solve the puzzle in blind mode, with sound as the primary guidance. After that, we asked them to put a mask over their eyes and run the last set of 10 games blindfolded, also with sound as the only help. During these games, the game board was visual, so we had a possibility to observe the player actions and evaluate their strategy.

RESULTS AND DISCUSSIONS

Rather than knowing in what time the puzzle was solved or the number of moves it took, we spent time talking with the participants.

The idea of the game was to develop basic mathematical skills and increase understanding of equations. Based on the findings during testing, the game actually evaluates an imagination of the player, especially ability in spatial imagination. The game forces the player to memorize the location of the equation members and make decisions based on his/her memory. Strong logical prowess and a strategy based on it are advantageous when solving the puzzle.

Though have been included only six equations in the source code, there are a lot of matrix variations. Some are very close to being solved and some are more complex. If game maker want to find out how good the player is in this game, he needs to run more games for reducing the meaning of luck. 10 repetitions for each game mode seemed enough for testing. The subjects were tired after the 30 games they had played.

The game includes short speech cues. However, sound cues are long enough that player really need to concentrate attention strong and listen to them. As a result, the speed was significantly slower when playing the game using only non-speech sounds.

Three players complained about the fact that they could not hear the sound when the cursor is not moving. It is heard only when the mouse is moved over the square. Sometimes they forgot what square they were on and wanted a simple way, like a mouse right click, to replay the sound again.

When following game playing of the subjects, we could find some patterns in their puzzle solving methods. Since the game requires a lot of memorizing, it is obvious that the cognitive loading has to be reduced. Completing the equations in some order (for example from top to bottom) lets player forget what rows are already completed and just concentrate on the next row. One of the participants seemed to first solve the equations that include divisions and multiplications. When asked, the tester replied that these equations include the biggest numbers, either as the result of a multiplication or as the number to be divided.

CONCLUSIONS

At this stage, the game is in many ways still, a prototype has to be tested to be efficiently improved. Nevertheless, the Math Puzzle includes all required functionality. The conclusions are based on the feedbacks received on the parts of the game that were complete.

Faced Problems

During the programming phase of the game, we faced a few problems that seemed impossible to fix. The biggest was certainly that Mozilla based browsers could not be made to produce sound. The standard ways of adding sound to web pages using JavaScript simply did not apply to Mozilla browsers.

Some other platforms and browsers had problems to support exceptionally 22kHz sound and images with 256 colors (iPAQ pocket PC). If this game is further developed, these things should be taken into consideration.

Usually, when player completed the fourth equation, the fifth gets solved too, because all of the pieces are on their correct locations. Sometimes, though, there are two possible correct equations but only the other combination can lead player to a correct puzzle. An example of this is shown on Figure 7, where four of the equations are solved, but incorrectly. Therefore, solving the fifth equation requires breaking one of the equations. In this case, the figures 6 and 3 in the last row should be swapped with 4 and 5 in the middle row accordingly.

The first tries of the blindfolded version took several minutes to complete (if they were not totally aborted due to frustration). Later, the gameplay speed increased significantly, as the players started to use the correct logic models and imagination.

REFERENCES

1. Children's math project. Available at: http://www.udel.edu/educ/cmp2/
2. Edwards, A. D. N., Stevens, R. D. and Pitt, I. J. Représentation non visuelle des mathématiques, (translated by A. Assimacopoulos) in A. B. Safran and A. Assimacopoulos (editors) Le Déficit Visuel, Éditions Masson, pp. 169–178 (1995), http://www.cs.york.ac.uk/ftpdir/pub/alistair/publications/ps/geneva.ps
3. Fitzpatrick D. Speaking Technical Documents: Using Prosody to Convey Textual and Mathematical Material, ICCHP 2002, LNCS 2398, p. 494, http://link.springer.de/link/service/series/0558/papers/2398/23980494.pdf
4. Gaura, P. REMathEx - Reader and Editor of the Mathematical Expressions for Blind Students, 2002, LNCS 2398, p. 486, http://link.springer-ny.com/link/service/series/0558/papers/2398/23980486.pdf
5. http://link.springer.de/link/service/series/0558/papers/2398/23980477.pdf
6. http://www.boowakwala.com/kids/math-game-kids.html
7. http://www.computing.dcu.ie/~dfitzpat/publications.htm
8. http://www.educational-software-directory.net/math/
9. http://www.gamealbum.com/keyword/math/
10. http://www.learn4good.com/games/kids/double_digits.htm
11. Karshmer, A.I., Gupta, G., Geiger, S., and Weaver, C.: Reading and Writing Mathematics: The MAVIS Project, BIT (Behaviour & Information Technology), January 1999.
12. Karshmer, A.I., Gupta, G., Gillan, D. Architecting an Auditory Browser for Navigating Mathematical Expressions, ICCHP 2002, LNCS 2398, p. 477
13. Lambda-project: Linear Access to Mathematic for Braille Device and Audio-synthesis http://www.lambdaproject.org/
14. Math project, http://www.cs.york.ac.uk/maths/index.html
15. Mathematical Access for Technology and Science, http://www.papenmeier.de/reha/research/mathe.htm
16. Prosody in Mathtalk http://www.cs.york.ac.uk/maths/robert/prosody.htm

vSmileys: Imaging Emotions through Vibration Patterns

Deepa Mathew
Alternative Access: Feelings and Games 2005
Department of Computer Sciences
University of Tampere, Finland
Deepa.Mathew@uta.fi
+358-415285461

ABSTRACT
The haptic computer interface is taking a giant leap into the future for millions of people, especially people with sensorial deficiency. A lot of research have been done worldwide on how to create or improve haptic interfaces and are seeking for the challenges and possibilities that the haptic technology can offer. When computer interface is augmented with haptic (or tactile) signals people with sensorial deficiency can play various computer games, learn mathematics by tracing touchable curves, and gain better access to graphical user interfaces [Wall, 2005]. Vibro-tactile patterns can play a vital role for both blind and deaf users by substituting Bliss symbols and earcons. This paper describes the designing and evaluating vibro-tactile patterns (tactons) for the match game "vSmiley" using the tactons for imaging of emotions. Based on the results of the pilot testing of the game it is clear that a carefully encoded tactons are easy to identify and distinguish. This game is also intended for deaf or/and visually impaired children who employ *sense of touch* as a way for communication.

Keywords
People with sensorial deficiency, vibro-tactile feedback, tactons, emotions.

ACM Classification Keywords
H5.2. User interfaces. Input devices and strategies

I.3.6 Methodology and Techniques. Interaction techniques

INTRODUCTION
Tactons are becoming a popular widget in various software applications to build new multi-model or multi-tasking user-interfaces, mainly because of it's ability to directly interact with human skin (cutaneous), which in turn gives an impression of '*sense of touch'*.

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

Even in mobile communications, vibrating rubber cellular phones are taking a leap into the future, allowing people to communicate by squeezing the phone to transmit vibrations along with their spoken words [5]. This kind of "vibralanguages" can be even a fun way of communication and of course people with sensorial deficiency can find it a very useful way of communication using cellular phones.

Various vibro-tactile patterns (tactons) can be designed even to express emotion with sense of touch when it is presented as a Smiley or in any other forms like short conditional messages via icons, graphics and so on. Apart from vibro-tactile patterns there are other display techniques based on tactile images. For example, 2D Tactile Pictures. There is a special software available in the market that allows a user to print graphs, diagrams and drawings on braille printers (embossers). For example: program called Graph-it sold by Blazie Engineering runs on their popular Braille Lite note-taker and prints to most popular braille printers and also a program called AudioCAD allows both sighted and blind computer users to design images and print them on swell paper or on braille printers [9]. However, as stated by Jacobson [8], *Traditional tactile diagrams are static, unintelligent and inflexible - they can only be read by one person at any time, they cannot be 'questioned', they cannot be manipulated to change scale or perspective.*

Shimojo et al. in [12] presented 3D-Tactile Display. It comprises of an array of pins mounted in the form of a matrix to present three-dimensional shapes to the user by raising and lowering the pins. But of course the denser the matrix of mounted pins, problems of difficulty in fabrication will arise. The time of one-frame installation takes tens of seconds.

Braille Keyboard: The overlay measures are approximately 15 by 4 inches and wraps snugly around the sides of the keyboard and can be secured with adhesive tape. Picture Braille software enables the user to create pictures in Braille format using a simple drawing program. The user can draw free hand using the mouse supplied. Enables the user to hear data being displayed on the video monitor [1].

The above mentioned tactile imaging techniques are beneficial to a blind user in its own unique ways but obviously not to a deaf user. Using vibro-tactile patterns can be beneficial to both blind and deaf people and, of course, it also offers them a common ground.

Another alternative would be 2-dimensional haptic devices which can be used to aid computer users who are blind or visually disabled; or who are used special input devices augmented with tactile/kinaesthetic signals to enlarge interaction style by simulating physical properties in virtual objects and software widgets like the edges of windows and software buttons so that the user could "feel" the Graphical User Interface (GUI). This technology can also provide resistance to textures in computer images which enables computer users to "feel" pictures such as maps and “embossed” drawings [6].

Some examples of 2-dimensional haptic devices are: Engineering Acoustics C2 Tactor and TACTAID VBW32 transducer which was used in the research done by Brown et al [11]. iFeel Mouse and the IFeel MouseMan from Logitech [10].

METHOD DESIGN

The goal of the project vSmileys was an empirical study of the possibility to substitute emoticons by vibro-tactile patterns. Tactons could be a useful means of communicating information in user interfaces for the visually challenged and people with hearing disabilities. So, the match game could be a starting point to get them familiarised with the semantic patterns.

Similarly to the envelopes of short sound messages (earcons) that are widely used in graphical user interface (GUI) mechanical vibrations can be composed into vibro-tactile patterns (tactons). And using a tactile output device these vibro-tactile patterns can transmit information to the user by sense of touch. For instance, in the testing of vSmileys we used Logitech iFeel optical mouse with built-in shaking motor. Earcon of the laugh (Figure 1) consists of 6 bursts of different frequency timbre and magnitude in a range of 0-4000 Hz. Duration of each burst is of about 200 ms that easy recognized as rhythm of the message with a small deviation of the duration which increases to the end of earcon. Both the rhythm and spectrum of the bursts simulate an interrupted exhalation which is perceived as the laugh.

Harald Schwende presented the results of the series of tests which showed that an emotional content of the picture and music passage can have high correlation between two senses (vision and hearing). He wrote: *Musical intervals are necessary for the psychological perception of music. The general impression is influenced by the choice of the scale, musical articulation, time and speed. The choice of the musical instruments* (D.M., timbre) *is particularly important* [15]. All of the parameters discussed could be reproduced through vibro-tactile patterns. However, the question remains how to confirm that tactons, which code emotional content, could be really recognized regarding the emotional content but not due to an explicit difference in physical parameters of the patterns.

Many earcons have been produced and widely used to signify a semantically-completed messages and feedback cues in GUI. Vibro-tactile patterns are employed as a way of communication especially for and between people with sensorial deficiency (deaf, blind, deaf-blind). In the next section we will describe the features of the tactons we have designed for conditional imaging of the emotional content.

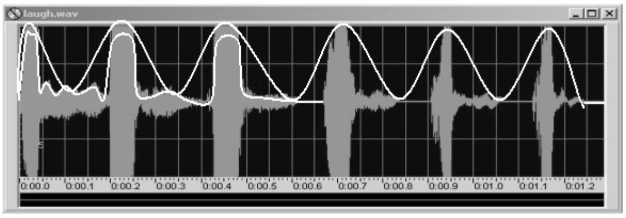


Figure1. Earcon of the laugh (sound wave) and the envelopes of sound bursts (white lines).

TECHNIQUES

First we have selected simple graphical images which display briefly and efficiently an emotional content of smileys (Figure 4). Then, the tactons were designed for 9 smileys. The aim of the pilot testing was estimation of relative identification of the semantics of the constructed tactons (vSmileys) through the match game by comparing them with the emotion of the smileys presented visually.

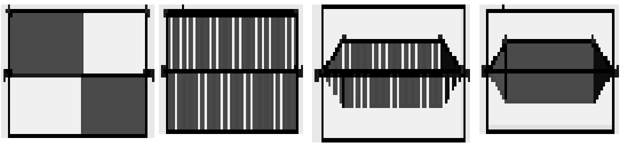


Figure2: Vibrating patters used in designing vSmileys with Immersion Studio 4.0.

Basic vibration patterns (Figure 2) have been used and combined to get the desired sample (vSmiley), which should transform semantics of the graphical prototype (smiley). We used two levels of magnitude (10000 and 5000 of conditional units in IS4.0) of the rectangular pulses (waveform was square) and the basic patterns had rectangular or trapezium shape (with attack and decay of about 100 ms) of the envelope.

Textural conditional messages for the blind

Apart from dynamical vibro-tactile presentation the special tactile symbols were designed as static textures and embossed diagrams composed from different materials. They were used even to express Time, Events, Places, People (vocation), Emotions, diverse objects, Food and Actions. The different ways of expressing emotions through different static Tactile Symbols using a heart as backing shape and plain poster board as background texture are presented in Table 1, adopted from [16].

When the blind person comes in contact with the object so as to feel, they are able to understand the content of embossed symbol/message and the information what it represents. Similar principle have been used when creating dynamical imaging through tactons for the smileys. Instead of direct inspection a composite texture, coding of the conditional expression can be implemented using vibration patterns.

Emotion	Shaping textural message
Anxious	"S' hook on its side
Excited	4 pieces of ribbon curled with scissors
Frustrated	Knot made from nylon string/rope
Gentle	Feather with pom pom glued on top
Happy	Smile made from nylon string
Hurt	Vertical matchstick
Love	Heart made from nylon string
Mad	Vertical row of knots made from nylon string
Patient	Flower bead or silk flower
Sad/Depressed	Frown made from nylon rope/string (upside down smile)
Sick	Vertical piece of nylon rope/string with a glue dot on top
Tired	Arrow made of nylon rope pointing down

Table 1. Emotional conditional textural messages. Adopted from [16].

In the next subsection we discuss designing of the tactons to transform the emotion of the smileys into temporal sequence of pulses of vibration.

Designing the Tactons

Before vSmileys have been created, the appropriate parameters for vibro-tactile patterns in which information could be encoded must be identified [11]. The most obvious parameters used in vSmiley construction are the basic parameters of basic vibratory patterns such as frequency, amplitude, waveform (envelope: attack, sustain, decay) and duration of each segment/burst. However, in designing the vSmileys, only the frequency and duration parameters were changed primarily to encode 9 smileys.

Semantic information could be encoded by manipulating the duration of pulses. While duration alone could be used as a parameter, combining pulses of different durations to form rhythms would offer more flexibility [11].

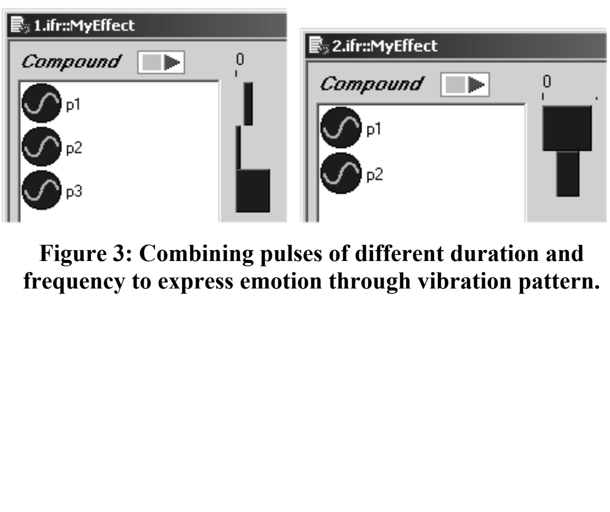


Figure 3: Combining pulses of different duration and frequency to express emotion through vibration pattern.

As shown in Figure 3, different pulses are combined with different durations and the overlapping, by using delays, to create the desired composite pattern that could elicit a sense similar to emotional content of visual smiley.

Figure 4 shows the smileys used as prototypes of conditional emotional expression. Parameters of the basic and composite patterns created are composed in Table 1.

Structure of the basic pattern				
Pattern Number	Attack/ decay	Duration, ms	Delay, ms	Freq., Hz
1	0	150	150	111
2	0	80	0	12
3	100	650	0	333
4	0	900	0	12
5	0	400	250	111
6	0	100	0	111
7	0	850	0	12
8	0	400	0	111
9	0	350	450	12
10	0	600	0	111
11	0	600	0	12
12	0	200	600	111
13	0	900	0	12
14	0	200	0	111
15	0	600	270	12
16	0	750	0	12
17	0	400	825	111
Image	CP, n	Structure of Composite Patterns		
(:|	1	1,2,3		
:((	2	4,5		
:-O	3	6,7		
:D	4	8,9		
:)	5	10		
:-P	6	11,12		
:|	7	13		
X-(	8	14,15		
/:)	9	16,17		

Table 2. Design features of the Basic and Composite vibro-tactile patters /vSmileys

As shown in the Figure 3, the vibro-tactile patterns used for transmitting the emotion of the first smiley which expresses an irritated feeling with a sound "Yack!!!". To express that feeling or sound of "Yack!!!" three different frequencies, patterns and duration have been combined to get a vibro-tactile sense that mimics the sound "Yack!!!" The only difference is that the user can feel it and cannot hear it. The second smiley expressed a crying smiley. Two different vibration patterns with different duration have been combined to mimic the feeling of crying. The third smiley expresses a smiley which makes an "Oh!" expression. This was one of the easiest to design. A very short duration and close frequency level to mimic just the "Oh!" expression have been used. The forth smiley expressed the laughing. It combined two different vibration patterns with different durations and used a very close frequency level for one and less frequency level for the other to express laughter. The fifth smiley was a smiling. Steady vibration patterns with close frequency levels to express the feeling of happiness were combined.

The sixth smiley expressed a tired smiley. This was a tough one to design and, of course, not the best way of expressing the feeling with tactons. The seventh smiley was a sleeping smiley and was an easy one to design. A steady vibration pattern was used to mimic the feeling of sleeping. The eighth smiley was an angry smiley and an irritating or the "growl" expression was simulated with vibration to create tacton to mimic the feeling of anger. The ninth smiley was a puzzled smiley and this was another tough one to design. The above mentioned tactons are not the best way of expressing emotions and still more research has to be done in order to optimize parameters of the tactons to simulate emotional content by different way or graphics and so on.

APPARATUS AND PROCEDURE

A Logitech iFeel optical mouse [10] connected via USB port was used to display the vibro-tactile patterns. A conventional desktop PC (ASUS P4B533) with Intel Pentium 4 processor, 512MB RAM, was used in the experiment.

Immersion Studio 4.0 was used at designing vSlileys to transform smileys into composite vibro-tactile patterns.

The match game "vSmiley testing" for evaluation of the tactons created was written in Microsoft Visual Basic 6.0 SP6 under Windows 2000.

Subjects

Five participants, (two females and three males) with normal vision and hearing took part in the pilot testing of the vSmileys game. None of the participants had any previous experience in this kind of testing and especially had no idea about tactons. Their age varied from 23 to 28 (2 students and 3 employees).

Five minutes training time was given to each of them to memorise vSmileys. If needed, extra time was given as well. After the training time was over the participants were asked to identify different vSmileys by feeling the vibratory patterns presented with Logitech iFeel optical mouse with built-in shaking motor. The test consisted of 90 trials (9 vSmileys by 10 times) and the tactons were selected randomly. Data was recorded on the recognition of the correct smiley and stored in a log file after completion the game.

The procedure was implemented as follows:

The player has to click on each smiley as many times as needed to memorise the vSmileys (vibro-tactile patterns).

After the player has memorised all the patterns, s/he can activate the testing phase by tapping the spacebar.

Tapping the spacebar produces the test-pattern. Player can repeat test-vSmiley as many times as needed.

The player has to identify the test-pattern and point by click the correct smiley having the same meaning.

Figure 4. Screenshot of the match game vSmiley.

RESULTS AND DISCUSSIONS

The players had some trouble choosing the right smiley in the beginning but the results gradually improved. They were able to distinguish the vibrating patterns and identify the correct smiley after few trials. Of course, they had some trouble in differentiating the somewhat-similar vSmileys. They got easily confused and made more errors.

As mentioned earlier, each of the subjects where given five minutes time for training to understand and learn the game. As you can see in the Figure 5, the players had little difficulty in memorising the 6th and 9th vSmileys. Because of the same sequence of frequencies which were used . It can also be associated with duration of the first basic pattern in both the tactons was greater than the duration of the second basic pattern.

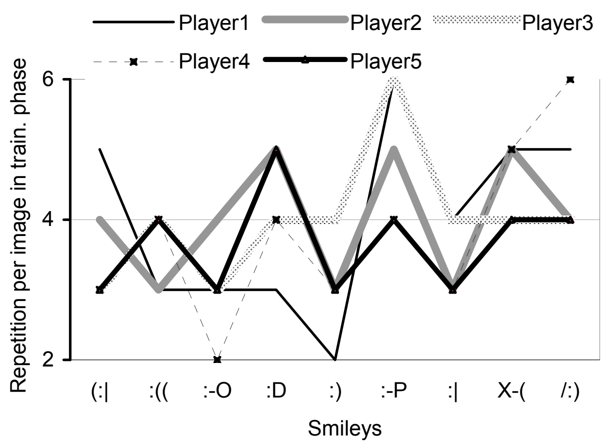


Figure 5. The average number of repetitions per vSmiley in training phase for each player.

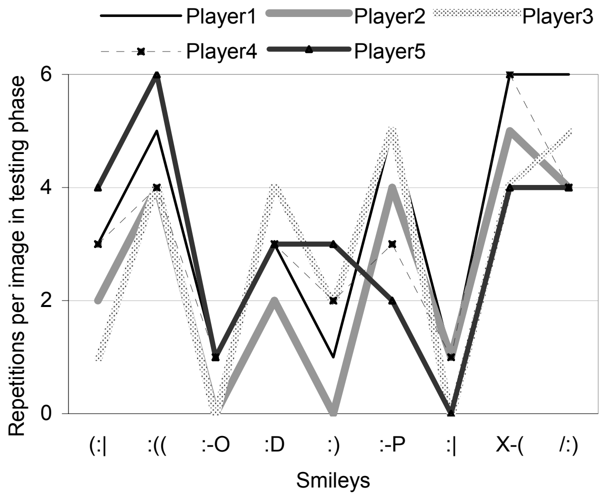


Figure 6. The average number of repetitions per vSmiley in testing phase for each player.

It was observed that the players repeated the tactons that they found not so easy to understand. After a few trials it was noticed that they where able to correlate the smileys to the vibrating patterns without much trouble.

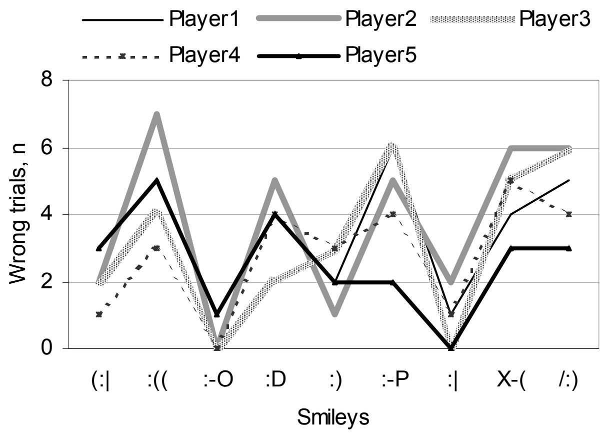


Figure 7. The average number of wrong trials per vSmiley.

In the testing phase the Players made fewer errors with the easy to remember tactons and the one's that mimicked the smiley's emotion, as shown in the image (Figure 4). For example: the players found 3rd , 5th, and 7th smiley easy to identify (Figure 6).

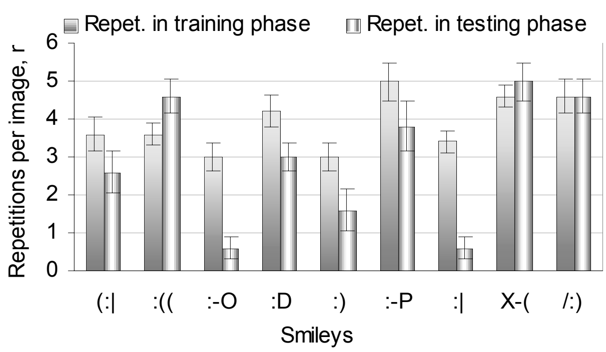


Figure 8. The average number of repetitions per image throughout the test for all the players

As shown in the Figure 8, it is obvious that the repetition of the tactons to identify it is high during the training phase and comes down as the player moves into testing mode. It is evident from the graphs that the tacton's whos smiley is similar to the vibration has a lesser repetition that the other ones, for eg. {:-O}, {:)}, {:|}.

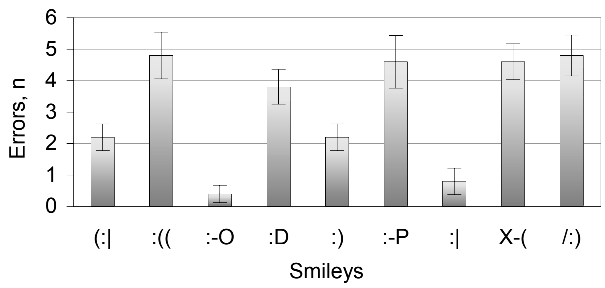


Figure 9. The average error rate during the test.

Figure 9 shows the easily distinguishable tactons and the tougher ones.

The tactons, which had a complex vibration pattern was not so easy to identify. This is visible from the graph given above (Figure 9). The tester was easily able to correlate the simple vibration pattern to the figures and hence the errors are less for those tactons.

CONCLUSION

Vibro-tactile patterns and semantic sequences can play a vital role in building new multi-model or multi-tasking user-interfaces especially for users having a sensorial deficiency and also introduce a possible alternative way of communication.

Tactons have already been used in areas such as tele-operation or displays for blind people to provide sensory substitution [4], certainly not to its fullest abilities.

More research should be done to know the true usefulness of tactile patterns. Based on the pilot experiment it is obvious that the patterns parameters of which have greater differences are easy to identify. However, the goal of the project was to simulate the semantic content of the vibro-tactile pattern which might elicit similar feeling of emotional experience as visual prototype, but not only designing the number of different tactons. With proper structuredness and an experience of addressee, tactons could be efficiently used in communication for people who cannot use conventional techniques due to sensorial deficiency.

REFERENCES

1. Braille Devices Information. Web site (2005): http://www.as.wvu.edu/~scidis/terms/brlframe.html
2. Calle Sjöström, *The IT Potential of Haptics*. Available: http://www.certec.lth.se/doc/touchaccess/
3. David Brook. *Haptic Interfaces in Virtual Reality*. Multimedia Systems Coursework. University of Southampton. 6th December 1997. Available: http://www.hpcc.ecs.soton.ac.uk/~dtcb98r/vrhap/vrhap.htm#Feedback

4. Dr Steven Wall, *An investigation of multimodal interaction with tactile displays*. Department of Computing Science, University of Glasgow. Available: http://www.tactons.org/

5. Eugenie Samuel. *Squishy cellphones add a buzz to calls*. Exclusive from New Scientist Print Edition, Boston. 24 April 2002. Available: http://www.newscientist.com/article.ns?id=dn2206

6. *Haptic Devices*. Adaptive Tecnology Resource Centre. University of Toronto. Available: http://www.utoronto.ca/atrc/reference/tech/haptic.html

7. Immersion Corporation 2005. Homepage: http://www.immersion.com/

8. Jacobson, R.D. "Representing Spatial Information Through Multimodal Interfaces: Overview and preliminary results in non-visual interfaces," in *Proc. 6th Int. Conf. on Information Visualization (IV02)*, IEEE, London, July 2002, pp. 730-734.

9. John A. Gardner. *Tactile Graphics, An Overview and Resource Guide*. Department of Physics, Oregon State University. Available: http://dots.physics.orst.edu/tactile/tactile.html

10. Logitech iFeel MouseMan . Homepage: http://www.logitech.com/index.cfm/support/products/details/NL/EN,CRID=1793,CONTENTID=5275

11. Lorna M. Brown, Stephen A. Brewster and Helen C. Purchase. *A First Investigation into the Effectiveness of Tactons*. Glasgow Interactive Systems Group, Department of Computing Science, University of Glasgow, UK. Available: http://www.dcs.gla.ac.uk/~stephen/papers/WorldHaptics_Brown.pdf

12. M. Shimojo, M. Shinohara, Y. Fukul. *Human Shape Recognition Performance for 3D Tactile Display*, IEEE Transaction on Systems, Man and Cybernetics, Part A, Vol.29, No.6, pp.637-644, November 1999. Available: http://www.rm.mce.uec.ac.jp/study-shmj/TactileDisplayHP/3Dtactile.html

13. Murat Cenk, David Feygin, Frank Tendick. *A Critical Study of the Mechanical and Electrical Properties of the PHANToM Haptic Interface and Improvements for High-Performance Control*. The MIT Press Journals. Available:http://mitpress.mit.edu/journals/pdf/pres_11_6_555_0.pdf

14. Robert L. Williams II. *Control of Kinesthetic Haptic Interfaces in VR Applications*. Ohio University,Athens. http://www.ent.ohiou.edu/~bobw/PDF/IjvrFrhc.pdf

15. Schwende, H. Auditory Emotional Access to Visual Information. In *Proceedings of Computers Helping People with Special Needs, 8th International Conference, ICCHP* (July 15-20, Linz), 2002, Austria, pp. 445-447.

16. TSBVI, *Tactile Symbols,Directory to Standard Tactile Symbol List*.Texas School for the Blind and Visually Impaired. Functional Academics and Basic Skills Department. Available: http://www.tsbvi.edu/Education/vmi/tactile_symbols.htm#EMOTIONS

EyeChess: the tutoring game with visual attentive interface

Oleg Špakov
Alternative Access: Feelings and Games 2005
Department of Computer Sciences
FIN-33014 University of Tampere, Finland
Oleg.Spakov@cs.uta.fi

ABSTRACT
Advances in eye tracking have enabled the physically challenged people to type, draw, and control the environment with their eyes. However, entertainment applications for this user group are still few. The EyeChess project described in this paper is a PC-based tutorial to assist novices in playing chess endgames. The player always starts first and has to checkmate the Black King in three moves. First, to make a move the player selects a piece and then its destination square. To indicate that some squares could be activated, while other ones were forbidden for selection, color highlighting was applied. A square with a green highlight indicated a valid action, and the red color denoted invalid action. There were three options to make a selection: blinking, eye gesture (i.e., gazing at off-screen targets), and dwell time. If the player does not know how to solve the task, or s/he plays by making mistakes, the tutorial provides a hint. This shows up a blinking green highlight when the gaze points at the right square. Preliminary evaluation of the system revealed that dwell time was the preferred selection technique. The participants reported that the game was fun and easy to play using this method. Meanwhile, both the blinking and eye gesture methods were characterized as quite fatiguing. The tutorial was rated helpful in guiding the decision-making process and training the novice users in gaze interaction.

Author Keywords
Eye tracking, gaze-driven chess game, gaze-based interaction.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
With the great improvement of eye-tracking devices in accuracy and ease, the number of gaze-driven interfaces grows very fast [1, 2]. The gaze-based interaction requires from users to be able to control their gaze in a particular manner. Several methods exist to support user attempts to make an action or execute a command in such interfaces. The most common action is the object selection, which in mouse-based interfaces corresponds to the left mouse button click. The most known selection methods are 1) dwelling the gaze [3, 4], 2) intentional blink [5, 6] and 3) eye-gesture [7]. However, for novice users the intentional dwell, blink or gesture could be problematic because of the involuntary nature of eye movements: the eye is the tool to gather information, not to control anything.

Before participants took part in the eye-movement study, Gips et al. [8] trained them using games. The participants were ready for testing after they reached the desired level of success in the game-like target acquisition task. Other researchers supported this idea of using games as the gaze trainer [9, 10].

The games, however, could serve not only as the gaze training tool, but also for the testing interaction methods itself [11] and an evaluation of feedback of the controlling interface [12].

Another set of games have been developed to play employing the gaze as the control media without an intention to use them for training, but for leisure. The famous examples are "EyePainting" and "EyeVenture", developed by Gips et al. [8]. However, these games are not the first known games developed for playing through the manipulating by gaze over conventional graphical user interface (GUI). Nelson in 1992 [13] reported about successful and effective gaze appliance for ball controlling game. During next several years, a number of manufacturers have produced eye-tracking systems and distributed software packages with built-in gaze-driven games [14]. Due to a high cost, low accuracy and inconvenient way of the use of eye tracker systems those games did not become widespread. Nevertheless, the idea of using the gaze as one of the input tools (or/and in cooperation with hands, legs, head and voice) was heavily discussed among researchers and potentials users. An example is the question raised in one of the games forum [15].

Alternative Access: Feelings & Games'05, Spring, 2005,

University of Tampere.

Since early 1970's, games have captured the attention of the researchers who pointed out that it might be useful in studying the processes of high mental activity in attaining the goal. Chase and Simod studied cognitive processes in chess [16]. This game perfectly suits for this kind of studies since it requires a lot of thinking and analysis. Not surprise, those studies were continued with development of more robust eye movements recording techniques and devices. Charness et al. in [17] have built the model of perception during chess game and evaluated a validity of the interface proposed through analysis of recorded eye movements. Not only chess but also other games were used in experimental studies of human behavior in diverse simulated conditions and with different tasks. Aschwanden and Stelovsky used the same methods for evaluation of the cognitive load while playing intellectual and cognitive games, when the subjects were asked to detect an object among others according to some specific parameters [18]. Hodgson et al. explored participant strategies while playing "Tower of London" game [19].

With all mentioned above, games appear to be a powerful tool to use them in visual-attentive interfaces. They can serve for gaze training, to observe user behavior and doing an evaluation of the interaction methods efficiency at the same time. The chess seems to be one of the most suitable games for these purposes. In addition, the game can be developed as the tutor for novices. Sennersten [20] and Kucharczyk [21] investigated the usage of eye tracking in studying efficiency of tutoring games. The authors reported about the promising results in their research.

The goal of this project was to develop a PC-based tutorial to assist novices in playing chess endgames and to carry out a pilot evaluation of the efficiency of the proposed technique. It has been supposed that after the pilot testing the EyeChess software will be explored within framework of GOGAIN project [22]. The size of chessboard squares is similar to software buttons, which have been employed for text entry with the use of eye tracking systems having different resolution. Therefore such a game layout could be especially suitable to check whether the proposed grid cells are large enough to accommodate calibration drifts when different eye tracking systems are being used.

The paper comprises three parts. The first part contains the description of the EyeChess interface design. In the next part we describe a pilot study where the methods of the dynamics of a target selection and the user behavior during an eye-typing task have been investigated. In particular, we were primarily interested in estimating how long the gaze stayed on a key upon selection. The study could also help us to adjust the coefficients of the transfer function as well as the range of dwell time values best suited for the subjects. In the third part, the gameplay algorithm is discussed. Next, the results of pilot evaluation of the EyeChess tutoring will be presented and discussed. In conclusion, we summarize the problems revealed and the benefits of the game as eye-tutorial.

EYECHESS INTERFACE DESIGN

The EyeChess software was designed as a plug-in to iComponent application [24]. Screenshot of the game EyeChess is shown in Figure 1. The main form occupies the full screen size.

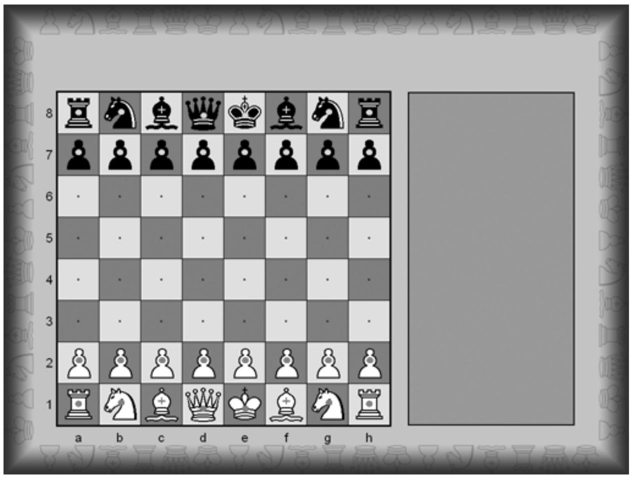


Figure 1. Screenshot of the game EyeChess. The pieces are in original starting positions.

The chessboard field has size of 512 by 512 pixels. It contains 64 squares, that is, each of squares has 64 by 64 pixels in size. Thirty-two standard chess pieces are displayed in original starting positions within the game field. Each piece and square has a dot, which serves as the anchor for the eye gaze. The right-side frame is "a bin" which contains the taken pieces. The field above the chessboard is used for providing instructions and other information.

After an eye-tracker starts gaze direction detection, the player is able to control the pieces. With the gaze movement upon the boards the squares are highlighted. The feedback appears as the pop-up border (Figure 2).

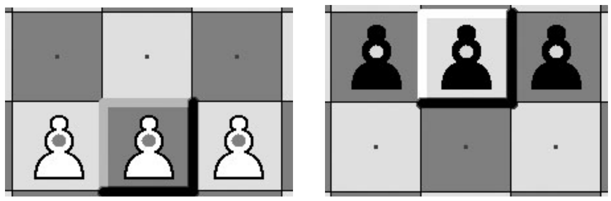


Figure 2. Highlighting and 3D effect to show an active position.

This visual feedback gives the clear hint of what a player is looking at. As shown in Figure 2, the highlighting color corresponds to the square color, that is, the lighter color and the darker one have been used.

The player first has to select a piece. However, empty squares cannot be selected if there is no piece selected yet. If an attempt has been made to choose an empty square, the application plays the sound with slightly negative connotation. Chosen piece will be highlighted with the dark-yellow color, which is easily distinguishable on chessboard.

When the player gazes around within the board, other squares are highlighted according to the ability to move the piece on it (Figure 3). The allowed squares will be highlighted with the green color while forbidden positions will be highlighted with the red color.

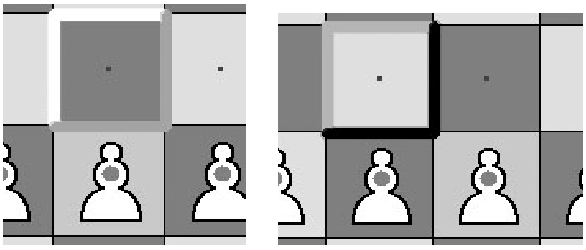


Figure 3. The allowable move (the left picture) and forbidden move (the right picture)

If the destination square was chosen (it appears with light-yellow background), the application performs the animated piece movement from the current position to the target one (Figure 4).

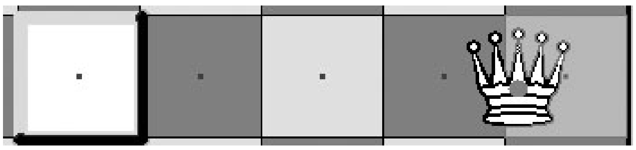


Figure 4. Animated movement of the piece.

If the player tries to move to the forbidden square highlighted with the red color, the application plays the same alert sound to inform that the move is not allowed. Such an attempt is not considered as the wrong move. The wrong move is the attempt to move any piece to the position with the green highlight, when the piece or the move destination does not correspond to the predefine pattern by the task scenario. In case of the attempt to make such a move the application plays the alert sound with very negative connotation. Thus, the tutorial prevents players from the wrong moves.

After two or more wrong attempts were made, the player may check whether the piece, s/he is moving, is the correct one. For this, s/he must look at other pieces one by one. The correct piece will have a blinking green highlighting. If s/he did not find a blinking piece, it means that the piece already selected is the correct one. If the player still has no idea what the correct move is for this piece, s/he can search for the square (empty or occupied by an opponent's piece) with a blinking green highlighting. If the selected piece was wrong and the player found the correct (i.e., blinking) position, the target square looked at will not blink, unless another wrong move is made with the newly selected piece. The algorithm is presented in Figure 5.

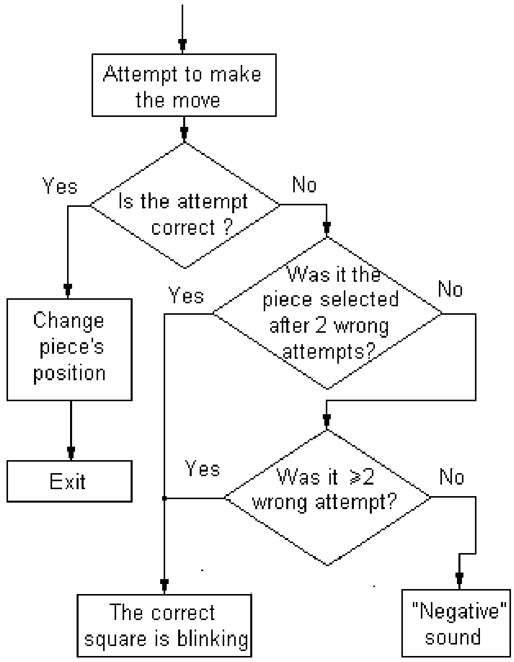


Figure 5. The gameplay algorithm to support the correct square recognition.

PILOT STUDY

Gaze-based selection methods

The EyeChess game requires a method to choose pieces. To find the best way of interaction, a pilot study was conducted. Three methods were implemented in the EyeChess software: selection by dwell, by blink and by gesture.

Employing the first method, players must to spot at a piece (square) for a certain time to select it. This is the most popular target selection method in gaze-controlling interfaces [3]. The dwell time is the crucial criterion. Since the nature of chess tasks supposes a lot of thinking to make a decision, the dwell time can be long enough to let players to consider the arrangement of chess pieces without unintentional selection, and not very long, since it is hard to keep the gaze stable for a long time. Based on an empirical estimation, the suitable dwell time is of about 1.8 seconds.

Using the second method, it is supposed that the players have to blink while gazing at the square to select it. Nevertheless, this method is not much popular, some researchers believe it may be usable in interaction with computer [30, 31], some of them even reported about successful appliance of blink for this purposes [34]. To avoid selection because of unintentional blinks, the selection algorithm accepts blink with the duration 350-1000 ms only. Shorter blinks can be accidental, and the longer are hard to keep [26, 27, 28].

The selection by gesture requires off-screen target that the player must quickly look at to select the square they just left. This method has been applied in some studies as well [5, 30, 32, 33]. The off-targets are placed in four corners of PC monitor. The selection gesture can be produced by the next way: the player finds the square to select, moves his/her gaze upon one of the off-screen targets and quickly (at most 1 second) backs to the same square or near to it. The fixation occurs at the 3 degrees distance at most from the previous fixation on the screen. These gestures were selected according to advices of Ravyse et al. in [25].

Both eye-gestures and blinks have no “Midas-touch” problem as the dwell time has. However, these methods require unnatural eye behavior and may be inconvenient for some reasons. To check the possibility to use different techniques for target selection in game script, the pilot study was conducted.

Participants
Three un-paid volunteers (2 males, 1 female) participated in the preliminary testing. All of them were students at the University of Tampere. One of them wore glasses and two subjects had prior experience with eye tracking technique.

Equipment
The test was conducted on a Pentium III 733 MHz PC with a 17-inch LCD monitor with a resolution of 1024 x 768. A remote eye tracking system iViewX from SensoMotoric Instruments served as the input device.

Procedure
The subjects were asked to move any 10 pieces which they would like to the positions allowed as quickly as possible regardless to errors by using each gaze-based selection method. The completion time was measured and after the test all the subjects were asked to comment their preferences regarding each gaze-based selection method.

Results and Discussion
The first selection method (by dwell) took 3.3 s in average to make a selection; the second method (by blink) took 2.5 s and the last one (by gesture) took 2.8 s. The fastest way appears to be the selection by blink, and the slowest selections were made through dwell. But the subjective opinions reported were sorted in the opposite way: the selection by dwell was recognized as the most convenient technique for target selection, and other 2 methods were recognized as “equally unsuitable/bad”. These results coincide with conclusion made by other researchers [28, 29].

The target selection through dwell time was chosen for the interaction in the EyeChess game. The 1.8 seconds dwell time was recognized as the close to the most suitable for such a case.

THE EFFICIENCY OF THE EYECHESS TUTORIAL

Participants
Four un-paid volunteers (1 male and 3 females) who did not take part in the pilot testing participated in the evaluation of the efficiency of the EyeChess tutorial. All of them were students at the University of Tampere. All of them had a normal vision. Two of them had prior experience with eye tracking technique and two subjects have never used eye-based input technique. All the participants had only a very little or no experience in chess game. However, all of the subjects knew how the pieces move.

Equipment
The experiment was conducted on a Pentium IV 3.06 GHz PC with a 19-inch LCD monitor with a resolution of 1024 x 768. A remote eye tracking system Tobii 1750 from Tobii Technologies served as the input device.

Procedure
The subjects were provided with basic guidelines in a written form about piece selection, piece movement, feedbacks and hint supported by EyeChess software. Then supervisor instructed them to solve endgames in 3 moves in all tasks. The supervisor explained that they have to play “whites” and computer plays with blacks pieces; thus, the player should perform the first move. After eye tracker calibration was completed, the subjects were asked to train in the use game interface while solving two tasks.

In total, the players solved 20 tasks without any break between. At completion the task players were congratulated by sound of applause.

RESULTS AND DISCUSSION
The average solving time was of about 71.4 second (σ=19.3) in total. However, of about 78% of this time (56 s) the players spent to find the first correct move. The second and third moves took of about 9.6 s and 5.8 s respectively (Figure 6).

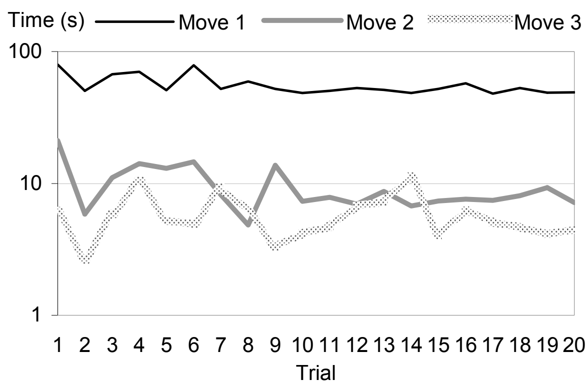


Figure 6. The task completion time in the game progress.

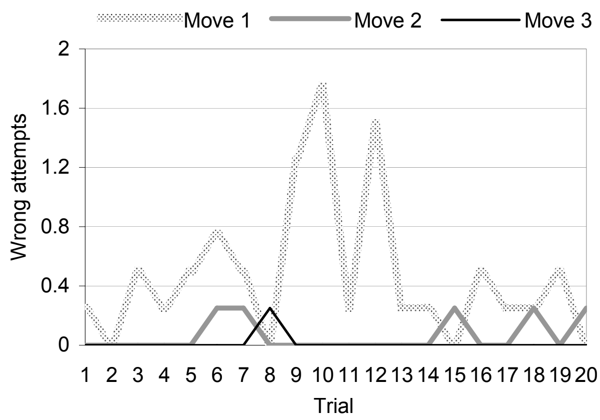


Figure 7. The wrong attempts committed in the game progress.

Of about 18% of all attempts to move were wrong (σ =6%). As it was expected, the greatest part of them (34%) was collected while players were trying to make the first move. While making the second and third moves, only 6% and 1% of the attempts have been recognized as wrong (Figure 7).

In almost every tenth task (9%) the players attempted to make a wrong move, at least 2 times. In such a case all of them found the hint (blinking square). Nobody made 2 or more wrong attempts after the first correct move was found.

While making an attempt to move, the piece was not the correct one in 8% of all attempts (σ=4%), and the attempts to move a piece at the first time in 21% were incorrect because of this reason. The next moves led to the wrong choice of the piece as less as 1% of attempts. However, the players often selected a wrong piece (23% in overall), and then changed their mind and did not move it. It has been observed in 58% cases before they made the first correct move. Then, such a gameplay behavior has been occurred rarely – in 5% and 6% before the second and third moves accordingly. It seems that after the first move was performed, the player did mistakes or selected wrong pieces only because of the calibration drift.

It seems that the players were stressed during the first 7 tasks. They tried to analyze the given task carefully and this resulted to a long thinking. Then they relaxed and this led to more errors (trials 9-13 in Figure 7). At the end all players solved tasks faster than at the beginning. The wrong attempts after the first successful move have been occurred rarely.

CONCLUSION

The EyeChess software was developed and tested in a pilot research. The gaze-based tutorial is intended to assist novices in playing chess endgames. When the player does not know how to solve the task, or s/he plays by making mistakes, the tutorial provides a hint. This shows up a blinking green highlight when the gaze points at the right square.

The pilot study revealed that dwell time was the preferred selection technique than blinking and eye gestures (i.e., gazing at off-screen targets). The study in the efficiency of the EyeChess revealed that the software tutorial was helpful in guiding the decision-making process. However, the tasks were too easy and the EyeChess tutoring support was rarely used.

The average completion time per trial at the end was noticeably shorter then at the beginning. However, both groups of the players showed the same progress. Thus, no significant improvements in the gaze interaction were found.

Overall, the game is eye tracker-friendly and easy to play, as the pieces and squares on the chessboard are large enough to accommodate calibration drifts with different systems used.

FUTURE WORK

The project will be continued to support both novices and experts. The author plans also to extend the game to a full-range game with an opponent: a computer or another player over the net.

REFERENCES

1. Takehiko Ohno Home Page, at http://www.brl.ntt.co.jp/people/takehiko, 2002
2. Gaze-Based Interaction Group: links, at http://www.cs.uta.fi/research/hci/gaze/links.php, 2005
3. Majaranta, P. and Räihä, K.-J., Twenty Years of Eye Typing: Systems and Design Issues. *Proceedings of ETRA 2002*, New Orleans, LA, pp. 15-22, 2002
4. Hansen, J.P., Hansen, D.W. and Johansen, A.S., Bringing gaze-based interaction back to basics, *in Proc. Universal Access in HCI*, Lawrence Erlbaum Associates, (2001), 325-328.
5. Selker, T., Visual attentive interfaces, BT Technology Journal Volume 22, No 4, October 2004.
6. Langford, C., Effective Eye-Gaze Input Into Windows, Proc. Eye Tracking Research & Applications Symposium, pp. 23-27, 2000
7. Ward, D. J., and MacKay, D. J. C., Fast hands-free writing by gaze direction. Nature 418 (6900), p. 838, 2002.
8. Gips, J., Dimattia, P., Curran, F.X. and Olivieri, P., Using EagleEyes – an electrodes based device for controlling the computer with your eyes – to help people with special needs*, in Proc. ICCHP 1996*, Springer Verlag, Oldenburg, pp. 77-84, 1996.
9. Ramloll, R., Trepagnier, C., Sebrechts, M., and Finkelmeyer, A., A gaze contingent environment for fostering social attention in autistic children, *in Proc. of the Eye tracking research & applications (ETRA*), (2004), 19-26.

10. Law, B., Eye movements in a virtual laparoscopic training environment, Master's thesis, Simon Fraser University, School of Computing Science, 1999.
11. Magee, J. J., Scott, M. R., Waber, B. N., and Betke, M., EyeKeys: A Real-time Vision Interface Based on Gaze Detection from a Low-grade Video Camera, *IEEE Workshop on Real-Time Vision for Human-Computer Interaction (RTV4HCI),* Washington DC, June 2004.
12. Seifert, K. Evaluation Multimodaler Computer-Systeme in Frühen Entwicklungsphasen. (in German) PhD thesis, Department of Human-Machine Systems, Technical University Berlin, 2002.
13. Nielsen, J., Noncommand User Interfaces. Communications of ACM 36, pp. 83-99, 1992
14. Youngblut, C., Johnson, R. E., Nash, S. H., Wienclaw, R. A., and Will, C. A., Review of Virtual Environment Interface Technology, Institute For Defense Analyses, USA, (1996), 14-25.
15. Advanced Games Forum, at http://frag.wastegate.org/?q=node/view/30, 2004
16. Chase, W. G. and Simon, H. A., Perception in chess. Cognitive Psychology 4. pp. 55–81, 1973.
17. Charness, N., Reingold, E. M., Pomplun, M., and Stampe, D. M., The perceptual aspect of skilled performance in chess: Evidence from eye movements. Memory and Cognition, 29, pp. 1146-1152, 2001.
18. Aschwanden, C., and Stelovsky, J., Measuring Cognitive Load with EventStream Software Framework. HICSS, pp. 131, 2003
19. Hodgson, T. L., Bajwa, A., Owen, A. M., and Kennard, C., The strategic control of gaze direction in the Tower of London task. Journal of Cognitive Neuroscience 12(5), pp. 894-907, 2000
20. Sennersten, C., Eye movements in an Action Game Tutorial, Technical report, Department of Cognitive Science Lund University, Sweden, 2004. Available at http://www.sol.lu.se/humlab/eyetracking/Studentpapers/CharlotteSennersten.pdf
21. Kucharczyk, D., Using Eye Tracking to Advance Learning Processes, Bachelor of Science Theses, Chester F. Carlson Center for Imaging Science, 2000, Available at: http://www.cis.rit.edu/research/thesis/bs/2000/kucharczyk/title.html
22. COGAIN project, at http://www.cogain.org/
23. Vertegaal, R.. Designing attentive interfaces*, in Proc. of the Symposium on ETRA 2002*, New Orleans, Louisiana, (2002), 59-60.
24. iComponent application, at http://www.cs.uta.fi/~oleg/light/icomp.htm, 2005.
25. Ravyse, I., Reinders, M.J.T., Cornelis, J., and Sahli, H., Eye gesture estimation. In 21st Symposium on Information Theory in the Benelux, Wassenaar, The Netherlands, May 2000.
26. Shaviv, B. D., The design and improvement of an eye controlled interface, Research report, 2002, from http://www.cs.sunysb.edu/~vislab/projects/eye/Reports/report/report.pdf
27. Orden K, Jung T-P, and Makeig S, "Combined eye activity measures accurately estimate changes in sustained visual task performance," Biological Psychology, 52(3), pp. 221-40, 2000.
28. Jacob, R.J.K., Eye Tracking in Advanced Interface Design, In Advanced Interface Design and Virtual Environments, Oxford University Press, Oxford, pp. 258-288, 1995
29. Jacob, R. J. K. What you look at is what you get: Using eye movements as computer input. Proc. Virtual Reality Systems'93, pp. 164-166, 1993.
30. Isokoski, P., Text input methods for eye trackers using off-screen targets, *in Proc. of ETRA 2000*, Palm Beach Gardens, FL, ACM Press, (2000),15-22.
31. Zhai, S., Morimoto, C., and Ihde, S., Manual And Gaze Input Cascaded (MAGIC) Pointing, *In Proc. ACM SIGCHI - Human Factors in Computing Systems Conference*, pp. 246-253, Pittsburgh, PA, May 1999.
32. Jabrain, B., Wu, J., Vertegaal, R., and Grigorov, L., Establishing remote conversations through eye contact with physical awareness proxies. In Extended Abstracts of ACM CHI, 2003.
33. Kaufman, A., Bandopadhay, A., and Shaviv B., An Eye Tracking Computer User Interface. *In Research Frontiers in Virtual Reality Workshop Proc*., IEEE Computer Society Press, pp. 120-121, 1993.
34. Ohno, T., Mukawa, N., and Kawato, Sh., Just blink your eyes: a head-free gaze tracking system. in CHI Extended Abstracts, (2003), 950-957.