TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

Arttu Perttula

A Design Framework for Engaging Collective Interaction Applications for Mobile Devices:

A Dual Process Prototyping Approach

Julkaisu 1181 • Publication 1181

Tampere 2013

Tampereen teknillinen yliopisto. Julkaisu 1181
Tampere University of Technology. Publication 1181

Arttu Perttula

A Design Framework for Engaging Collective Interaction Applications for Mobile Devices:

A Dual Process Prototyping Approach

Thesis for the degree of Doctor of Science in Technology to be presented with due permission for public examination and criticism in Auditorium 240, at Tampere University of Technology, Pori, on the 13th of December 2013, at 12 noon.

Tampereen teknillinen yliopisto - Tampere University of Technology
Tampere 2013

ISBN 978-952-15-3192-7 (printed)
ISBN 978-952-15-3217-7 (PDF)
ISSN 1459-2045

Abstract

The main objective of this research is to define the conceptual and technological key factors of *engaging collective interaction applications for mobile devices*. To answer the problem, a *throwaway prototyping* software development method is utilized to study design issues. Furthermore, a conceptual framework is constructed in accordance with *design science* activities. This fundamentally *exploratory research* is a combination of literature review, design and implementation of mobile device based prototypes, as well as empirical *human-computer interaction* studies, which were conducted during the period 2008 - 2012. All the applications described in this thesis were developed mainly for research purposes in order to ensure that attention could be focused on the problem statement.

The thesis presents the design process of the novel *Engaging Collective Interaction* (ECI) framework that can be used to design *engaging collective interaction applications for mobile devices* e.g. for public events and co-creational spaces such as sport events, schools or exhibitions. The building and evaluating phases of design science combine the existing knowledge and the results of the throwaway prototyping approach. Thus, the framework was constructed from the key factors identified of six developed and piloted prototypes. Finally, the framework was used to design and implement a collective sound sensing application in a classroom setting. The evaluation results indicated that the framework offered knowledge to develop a purposeful application. Furthermore, the evolutionary and iterative framework building process combined together with the throwaway prototyping process can be presented as an unseen *Dual Process Prototyping* (DPP) model. Therefore it is claimed that: 1) ECI can be used to design *engaging collective interaction applications for mobile devices.* 2) DPP is an appropriate method to build a framework or a model.

This research indicates that the key factors of the presented framework are: *collaborative control*, *gamification*, *playfulness*, *active spectatorship*, *continuous sensing,* and *collective experience*. Further, the results supported the assumption that when the focus is more on activity rather than technology, it has a positive impact on the engagement. As a conclusion, this research has shown that a framework for *engaging collective interaction applications for mobile devices* can be designed (ECI) and it can be utilized to build an appropriate application. In addition, the framework design process can be presented as a novel model

(DPP). The framework does not provide a step-by-step guide for designing applications, but it helps to refine the design of successful ones. The overall benefit of the framework is that developers can pay attention to the factors of engaging application at an early stage of design.

Preface

The research for this thesis has been conducted as a researcher at Tampere University of Technology (TUT), an intern at Fuji Xerox Palo Alto Laboratory, Inc. (FXPAL) and a visiting researcher at Stanford University during 2008-2012. I would like to thank my supervisors Professor Jari Multisilta (University of Helsinki and TUT) and Adjunct Professor Kristian Kiili (TUT) for their support, providing me with suitable research projects and also giving me the freedom to focus on the footsteps on my own research path. Professor Marcus Specht (Open University of the Netherlands) and Assistant Professor Daniel Spikol (Malmö University) reviewed the thesis. I highly appreciate their feedback and constructive comments. I am indebted to Professor Tommi Kärkkäinen (University of Jyväskylä) and Professor Marcus Specht for agreeing to be the opponents in the public defense of my thesis.

I am grateful to the co-authors of the research papers for their contribution to the publications and the thesis. I would like to express my gratitude especially to Professor Jari Multisilta, Research Scientist Scott Carter (FXPAL) and Adjunct Professor Kristian Kiili. Jari Multisilta has guided me to the right path during this process and given me several unforgettable opportunities to fulfill my work. He has provided me with ideas and research environment that has helped focus my efforts in a unified direction. Scott Carter introduced me to the Mobile Python programming language. Soon I realized that it was a starting point for this thesis. His way to conduct academic research and write articles has influenced me a lot. Kristian Kiili's genius way of sharing enthusiasm, criticism, knowledge and effort in our collaborative work has been invaluable.

I have also been extremely lucky to learn to know and work with all other co-authors. Pauliina Tuomi, Antti Koivisto, Marko Suominen, Riikka Mäkelä and Laurent Denoue made a valuable contribution to this thesis. I also want to acknowledge again Research Scientist Scott Carter for hosting my internship at FXPAL and Professor Keith Devlin for hosting my visit to Stanford University. These periods have been invaluable steps during my studies. Also, I was thrilled to share an office room with Professor Jari Multisilta and Professor Hannele Niemi (University of Helsinki / Chair of the Board of Directors, CICERO Learning Network) at Stanford. Furthermore, I am grateful to my colleagues at different locations. Highly competitive and ambitious atmospheres have formed a strong base for many studies of this thesis and early motivation.

Working as a researcher in the academic research projects has made it possible to conduct large-scale studies and act in multidisciplinary research teams. They also enabled the commitment to long-term research goals. These projects were mainly funded by Finnish Funding Agency for Technology and Innovation (Tekes). Working with the research groups of Professor Jaakko Suominen (University of Turku), Professor Jarmo Viteli (University of Tampere) and Professor Marjo Mäenpää (Aalto University) has been an essential part of this thesis.

I am also grateful for receiving financial support for the thesis from the Finnish Cultural Foundation - Satakunta Regional fund (2009 and 2012), Nokia Foundation (2010 and 2011), Satakunta University Foundation (2011), High Technology Foundation of Satakunta (2011) and the Ulla Tuominen Foundation (2009).

I would like to acknowledge Kaija Perttula and Jarmo Perttula for the way they have encouraged me during this process. Finally, I express my gratitude to Niina Tuulivaara for the shared experiences and support.

Ulvila, Finland, March 2013

Arttu Perttula

Financial Supporters

2012 **Finnish Cultural Foundation, Satakunta Regional fund**
Grant for D.Sc. (Doctor of Science) studies (six months)

2011 **Nokia Foundation**
Grant for D.Sc. studies

Satakunta University Foundation
Grant for D.Sc. studies

High Technology Foundation of Satakunta
Grant for D.Sc. studies

2010 **Nokia Foundation**
Grant for D.Sc. studies

2009 **Finnish Cultural Foundation, Satakunta Regional fund**
Grant for D.Sc. studies

Ulla Tuominen Foundation
Grant for D.Sc. studies

Dissertation Committee

Supervisor / Custos	**Director and Professor Jari Multisilta** CICERO Learning Network University of Helsinki, Finland AMC - Advanced Multimedia Center Tampere University of Technology, Finland
Supervisor	**Adjunct Professor Kristian Kiili** AMC - Advanced Multimedia Center Tampere University of Technology, Finland
Opponent	**Professor Tommi Kärkkäinen** Department of Mathematical Information Technology University of Jyväskylä, Finland
Opponent / Pre-examiner	**Professor Marcus Specht** CELSTEC - Centre for Learning Sciences and Technologies Open University of the Netherlands
Pre-examiner	**Assistant Professor and Research Fellow Daniel Spikol** School of Technology and Society Malmö University, Sweden CeLeKT - Center for Learning and Knowledge Technologies Linnaeus University, Sweden

List of Publications

Publication 1 **Perttula, A.**, Carter, S., & Denoue, L. (2011). Retrospective vs. prospective: Two approaches to mobile media capture and access. International Journal of Arts and Technology. Vol. 4, Issue 3, 2011, pp. 249-259. DOI: 10.1504/IJART.2011.041480.

Publication 2 Multisilta, J., **Perttula, A.**, Suominen, M., & Koivisto, A. (2010). Mobile Video Sharing: Documentation Tools for Working Communities. Proceedings of the EuroITV 2010, 8th European Conference on Interactive TV and Video. June 9-11, 2010, Tampere, Finland, pp. 31-38. ISBN: 978-1-60558-831-5.

Publication 3 * **Perttula, A.**, Koivisto, A., Mäkelä, R., Suominen, M., & Multisilta, J. (2011). Social Navigation with The Collective Mobile Mood Monitoring System. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. September 28-30, 2011, Tampere, Finland, pp. 117-124. ISBN: 978-1-4503-0816-8.

Publication 4 Kiili, K., **Perttula, A.**, & Tuomi, P. (2010). Development of Multiplayer Exertion Games for Physical Education. IADIS International Journal on WWW/Internet. Vol. 8, No. 1, pp. 52-69. ISSN: 1645-7641.

Publication 5 **Perttula, A.**, Tuomi, P., Kiili, K., Suominen, M., Koivisto, A., & Multisilta, J. (2013). Enriching Shared Experience by Collective Heart Rate. International Journal of Social and Humanistic Computing. Vol. 2, Nos. 1/2, 2013, pp. 31-50. ISSN online: 1752-6132.

Publication 6 **Perttula, A.** (2012). When a Video Game Transforms to Mobile Phone Controlled Team Experience. Proceedings of 16th International Academic MindTrek Conference: Envision Future Media Environments. October 3-5, 2012, Tampere, Finland, pp. 302-309. ISBN: 978-1-4503-1637-8.

Publication 7 **Perttula, A.,** Multisilta, J., & Tuomi, P. (2013). Persuasive Mobile Device Sound Sensing in a Classroom Setting. International Journal of Interactive Mobile Technologies (iJIM). Vol. 7, No 1 (2013), pp. 16-24. ISSN: 1865-7923.

* Awarded prize: Certificate of Honor, Academic Papers - Special Mention.

List of Figures

List of Tables

Terms and Abbreviations

API	Application Programming Interface.
Co-	Co-prefix stands for collective (e.g. co-experience).
Collective Interaction	In Krogh and Petersen's (2008) collective interaction model, an application involves users co-located cooperation. More than one user is required and users must coordinate and negotiate their actions towards a shared goal.
C++	C++ is a widely used programming language.
Design Science	Fuller and McHale (1963) defined design science as the systematic form of designing. According to Gregory (1966), design science refers to the scientific study of design.
DPP	*Dual Process Prototyping* (DPP) is a model presented as an outcome of this thesis. It combines evolutionary and iterative building process with throwaway prototyping.
DS	DS stands for design science.
D.Sc.	D.Sc. is an abbreviation for Doctor of Science.
ECI	*Engaging Collective Experience* (ECI) is a framework designed in this thesis. It is the answer to the research question: What are the conceptual and technological key factors for designing *engaging collective interaction applications for mobile devices*?
Exploratory Research	According to Lambin (2000) and Bell (2010), exploratory research does not try to provide conclusive evidence and final answers of the research question. Instead, it helps to give a better understanding of the research problem.
FXPAL	Fuji Xerox Palo Alto Laboratory, Inc. (FXPAL) is a research center of Fuji Xerox Co., Ltd.

GPS	Global positioning system (GPS) is a space-based satellite navigation system that provides location and time information on or near the Earth.
HCI	Human–computer interaction (HCI) involves the study, planning, and design of the interaction between people (users) and computers. (Jacko, 2012)
NFC	Near field communication (NFC) is a set of standards for smartphones and similar devices to establish radio communication with each other by bringing them into no more than a few centimeters proximity. NFC builds upon RFID systems by allowing two-way communication between endpoints. (Nosowitz, 2011)
PyS60	Python for Series 60 is Nokia's version of the Python programming language for Nokia's S60 software platform.
Python	Python is a high level programming language.
RAD	Rapid application development (RAD) is a software development methodology. The main focus is on rapid prototyping. (Whitten et al., 2007)
RFID	Radio-frequency identification (RFID) is a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object (see NFC). (Nosowitz, 2011)
Symbian	Symbian is Nokia's mobile operating system and computing platform.
S60	The S60 is a software platform for Nokia mobile devices that runs on the Symbian operating system.

Tekes	Tekes (Finnish Funding Agency for Technology and Innovation) is a part of the Finnish Ministry of Employment and the Economy.
Throwaway Prototyping	The intention is to develop a working prototype relatively fast. After users' feedback on the development of the main system, the prototype is discarded or thrown away. Based on the identified requirements, the next prototype is built. Jayaswal and Patton (2007)
TUT	Tampere University of Technology.

Table of Contents

1. Introduction

"Older people sit down and ask, what is it?
But the boy asks, what can I do with it?"
– Steve Jobs

As Steve Jobs has described it, the advanced mobile devices and applications of today are a part of everyday life in unseen situations. Mobile devices are programmable and come with a set of sensors, such as an accelerometer, digital compass, gyroscope, GPS, microphone and camera (Lane et al., 2010). The range of sensors can even be expanded with external sensors that measure, for example human body functions. In particular, mobile device sensors enable the creation of unprecedented software solutions (Lane et al., 2010; Multisilta and Perttula, 2011). For instance, an accelerometer sensor detects movements and GPS pinpoints the device on a map. Software developers have unrestricted possibilities to utilize these features.

To take an example, the crowd at an ice hockey game can be a sensor that produces a collective heart rate. The reading is visualized and compared to the game events. This can be implemented by using heart rate belts as external sensors for mobile devices via Bluetooth connection. In another case, a mobile device based system motivates students to maintain the noise level at a comfortable tolerance level in a classroom. Sound levels are measured via the device's microphone and an application presents persuasive visualizations. In fact, these examples combine mobile device sensing with collective interaction. These kinds of interfaces are designed for more than one person to use at a time and users must coordinate and negotiate their actions towards a shared goal (Petersen et al., 2010). In Krogh and Petersen's (2008) collective interaction model, users share the input channel that may consist of a number of interaction instruments, which are logically coupled in the interaction. All in all, their model focuses on designing for co-experiences among co-located people. This perspective provides novel interactive solutions and furthermore experiences for users. However, the application development and research is still in its infancy within this area.

This doctoral thesis describes the two prototypes mentioned above and five more; a set of projects that explores the implementation of supporting collective interaction, study mobile device sensing, and study users' perceptions of

developed prototypes. In this study, the user interfaces for the space for collective interaction are mobile devices. The topic of research is important for the development of information technology as well as software and communications engineering because it will provide a conceptual design framework for *engaging collective interaction applications for mobile devices*. It will offer researchers knowledge and know-how about a purpose-built research method. Furthermore, it will reveal several follow-up study topics.

1.1 Scope and Context

This thesis studies the design issues of novel mobile device applications with the main focus on *collective interaction*, *mobile device sensing* and *user engagement*. These three themes are discussed in more detail in chapter 2 (Theoretical Perspectives). Before considering a strategy for solving the challenges of designing these applications, there must be some starting points to expand from. In addition, the scope of the study should be established. However, the intention is not to limit prototype applications too strictly. Tarasewich's (2003) context model (Fig. 1) that builds on the strengths of three models (Abowd and Mynatt, 2000; Schilit et al., 1994; Schmidt et al., 1999) can be utilized to define the scope and context of this thesis. According to Tarasewich (2003), the context model can be created using three broad categories of context: C1) *environment*, C2) *participants*, and C3) *activities*.

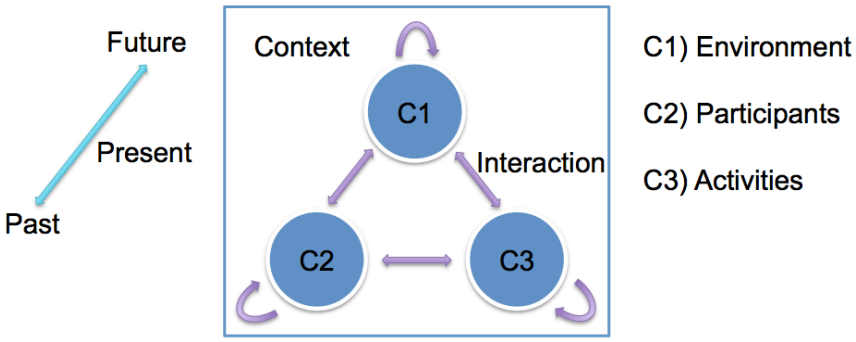


Figure 1. Tarasewich's (2003) context model redrawn from the original source.

(C1) *Environment*. Environment is a co-location of users, such as a large-scale event or a public space. The physical properties for the environment are case-specific, as well as for example brightness and noise levels.

(C2) *Participants.* In this case, participants mean a group of users. The users' personal properties (for example age, gender, education and preferences), mental state, physical health, and expectations may vary depending on the each case. Group size is not limited. Personal one-user mobile device sensing applications are outside the context. In this study, participants are mobile users that utilize mobile devices for collective interaction (see subchapter 2.1 for the definition).

(C3) *Activities.* Activities include such tasks and goals that involve collective interaction (subchapter 2.1). Users' activities are based on the designed mobile application, events in the environment, and other participants' activities.

A time dimension (Fig. 1) focuses on the present or in other words real-time use cases. Interaction happens between categories or inside a category, e.g. participants can interact with other participants. Furthermore, mobile technology is an essential part of this research study although this technology is not present in Figure 1. Multisilta and Perttula (2013) have stated that technologies can mediate and enrich our experiences. To visualize the relations between Tarasewich's (2003) categories and technology, the context model could be modified as presented in Figure 2. Placing the *technology* category (C4) in the center of the model highlights the importance of the designed and developed mobile applications.

(C4) *Technology.* A mobile device or devices and particularly a mobile device application involve users in collective interaction (subchapter 2.1). A mobile device is a hand-held computing device (Hanson, 2011). Mobile device sensor(s) monitor the environment, participants, and their activities. The collected data is processed and provided as a feedback or visualizations for users. The study focuses mainly on the devices' built-in sensors but it also takes into consideration external sensors. Although this study uses the terms mobile device application or mobile application, all the presented prototypes (P1-P7) also include a server-side solution. The term mobile device refers to mobile phone in this study.

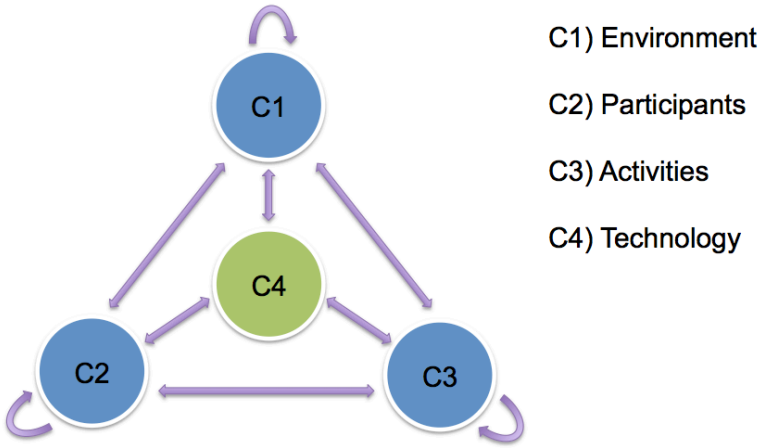


Figure 2. Tarasewich's (2003) context model enhanced with technology category (C4).

All the four counterparts (*environment*, *participants*, *activities,* and *technology*) form the context of this doctoral study. The mobile application prototypes presented (referred to in the text by P1-P7, see subchapter 1.4) are not limited to certain software categories; solutions deal with social media (P1, P2), navigation (P1, P2, P3), entertainment (P4, P5, P6, P7), games (P4, P6, P7), information (P1, P2, P3, P5, P7), and education (P2, P7), for example. All in all, they are steps during the process to solve design issues and determine key factors of engagement within the context described.

1.2 Motivation for the Research

The author became interested in mobile human-computer interaction (HCI) when he was an intern at the Fuji Xerox Palo Alto Laboratory, Inc. (FXPAL) in 2008. During that time the author became familiar with the Mobile Python (PyS60) programming language (Scheible and Tuulos, 2007). It turned out that the language is easy to learn and takes only a few days to master most of its features. The author realized its rapid prototyping possibilities and relatively straightforward access to mobile devices' sensor readings. The scripting language seemed to be more suitable for research purposes, experiments, and exploratory programming if compared with the author's previous experiences of Symbian S60 C++ programming. With his host, Scott Carter, the author created a mobile device map application (P1) called Kartta (Perttula et al., 2009; Perttula et al., 2011 a) that derives points-of-interest and associated landmarks from user-generated content captured onsite. In addition, the invention termed 'Image Matching in Support of Mobile Navigation' (Carter et al., 2010) was patented. The Kartta application (P1) met its purpose as a research prototype but the study also

raised new research problems and questions. These questions formed the aim of this research. The research objectives and approach are discussed in the next subchapter (1.3).

Over the course of time, the author realized that he was fascinated by PyS60 programming and its unlimited possibilities to program Nokia's S60 3rd and later 5th edition devices. The author even ended up teaching a course on Python programming language at the Adult Education Centre of Pori, Finland in 2009. After the FXPAL internship, the author worked continuously as a researcher at Tampere University of Technology and as a visiting researcher at Stanford University in 2010. During 2008-2011, the author was involved in two Tekes funded research projects ('Mobile Social Media: video applications for entertainment and learning' and 'Co-creational spaces in supporting sharing of experiences') conducted by Professor Jari Multisilta. These projects offered excellent possibilities to continue the research that began at FXPAL and create new prototypes to find answers to the questions raised. The publication and prototype P2 are based on the first Tekes project and publications/prototypes P3, P4, and P5 are based on the second project. However, to create enough prototypes (P6 and P7) for the process and work towards the goal presented in this thesis, the author applied for and received additional financial funding (Finnish Cultural Foundation - Satakunta Regional fund, Nokia Foundation, Satakunta University Foundation, High Technology Foundation of Satakunta and Ulla Tuominen Foundation) for research purposes to conduct further essential parts of the project and thus managed to finalize this thesis.

Even though the mobile industry is fast-paced and this doctoral research started in 2008, the prototypes P1-P7 presented are still not outdated as of the beginning of 2013. In fact, they are still novel for both research and commercial purposes. Furthermore, research outcomes and results provide recent knowledge to researchers as well as designers and developers within the context described in the previous subchapter (1.1). All these aspects have motivated the author during the process of writing this thesis.

1.3 Research Objectives and Approach

As mentioned in the previous subchapter, P1 raised research problems and a question. The prototype was created independently and before forming the thesis' research approach (Fig. 3). Thus, the research process of the thesis has begun

from the findings and results of P1. All in all, three questions arose from P1: How to involve people in more concrete collective interaction? Is it possible to automate mobile device sensing? How to create a more engaging experience? Therefore, collective interaction, mobile device sensing and user engagement became the main design issues based on P1. Furthermore, an initial assumption based on P1 is that when the focus is more on activity rather than technology, it has a positive impact on the engagement.

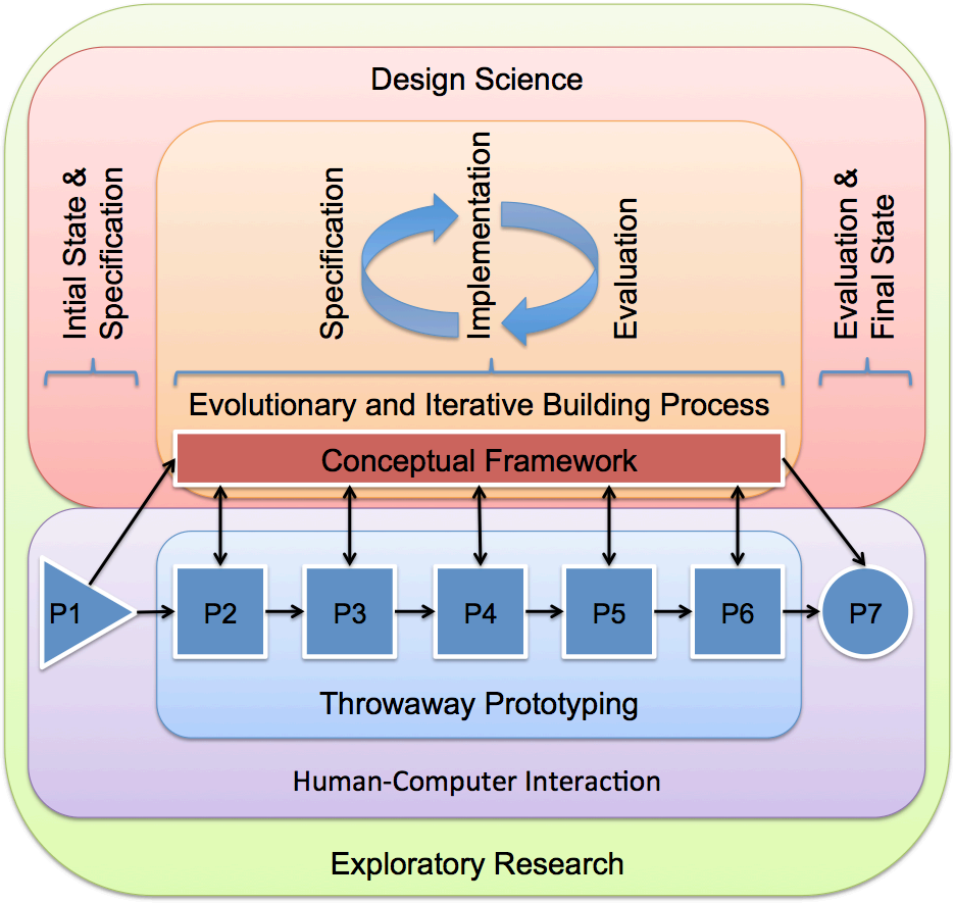


Figure 3. Research approach of the thesis.

The main objective of this research is to study how to create *engaging collective interaction applications for mobile devices*. This endeavor is significant because there are no frameworks that successfully integrate these aspects. Therefore, it can be argued that various approaches (P1-P7 in this study) need to be explored to solve design issues for these kinds of applications. Thus, this thesis will argue for the construct of a conceptual framework (Fig. 3) to help design and implement *engaging collective interaction applications for mobile devices*.

The framework is known as the *Engaging Collective Interaction* (ECI) framework. The author wants to stress that the proposed conceptual framework does not aim to provide a simple recipe for designing *engaging collective interaction applications for mobile devices*, but it will facilitate the design of successful ones. In addition to the conceptual framework, this research also concentrates on producing design exemplars. Furthermore, during this research new knowledge about collective interaction mobile applications and user engagement has been attained.

The focus of investigation for this thesis and the research question (referred to in the text by RQ) is as follows:

(RQ) What are the conceptual and technological key factors for designing *engaging collective interaction applications for mobile devices*?

The intention is to provide guidelines to developers and designers. Therefore in addition to RQ, the other aims (A1-A3) of this thesis can be described as follows:

(A1) What kind of collective interaction does mobile device sensing enable in this context?

(A2) What kinds of applications are appropriate and successful in practical terms in the context described?

(A3) What kinds of design issues are there and how to solve them?

To investigate the RQ, the study is performed according to *exploratory research*, *human-computer interaction* (HCI), *design science* (DS), and software development methods (Fig. 3). These are discussed in more detail in chapter 3 (Research Methodology). In order to evaluate the prototypes (P1-P7), traditional evaluation methodologies in HCI are utilized, such as observations and interviews. A *throwaway prototyping* approach was selected from software development methods to study the RQ. A framework is formed from the key factors with constructive research methods based on DS. The research of framework was carried out in two phases related to the two basic activities of DS: building and evaluating (March & Smith, 1995).

The empirical work presented in this thesis is based on throwaway prototyping, which consists of pilot testing of seven prototypes (P1-P7). The analysis of these prototypes is discussed and the different design approaches used in each one of the efforts are compared to see their advantages and drawbacks. To define the target state of throwaway prototyping, engagement comes into the picture. In other words, each prototype is thrown away until engaging user experience is attained, which allows users to perceive the experience as worthwhile, successful, and one they would seek again in future (O'Brien and Toms, 2010). Finally, the conceptual ECI framework based on the key factors of *engaging collective interaction applications for mobile devices* is evaluated by building a prototype (P7) in accordance with the conceptual framework.

1.4 Overview of the Publications

The thesis is based on seven peer-reviewed original publications (P1-P7) that consist of four journal articles (P1, P4, P5 and P7) and three papers in conference proceedings (P2, P3 and P6). The publications are referred to in the text by P1, P2, and so forth. In this case, P stands for Publication but it also means a Prototype. They are presented in the order in which they are considered in this thesis. Due to the variable time frames of publication processes, the list (see List of Publications) is not ordered and presented based on publication dates. The publications are reproduced by the permission of the publishers.

1.4.1 Mobile Application Prototypes

Publications can be considered as separate research studies with their own research aims, approaches and results. In addition, they form a logical interrelationship as an entity of the throwaway prototyping procedure, which is not self-evident in the articles themselves. Each publication presents a prototype application towards a solution of the research question (RQ). Publication P1 is a starting point to this research. The research question (RQ), aims (A1-A3), and context (C1-C4) are based on this publication. Publications P2-P6 are parts of the throwaway prototyping approach. Publication P7 presents a prototype for evaluating the conceptual framework formed during the research process. Prototypes of the publications are described briefly in this subchapter. All the prototypes/publications (P1-P7) are discussed in accordance with the ECI

framework creation process within chapter 4 (Conceptual Framework Development).

(P1) ***Perttula, A.**, Carter, S., &, Denoue, L. (2011). Retrospective vs. prospective: Two approaches to mobile media capture and access. International Journal of Arts and Technology. Vol. 4, Issue 3, 2011, pp. 249-259. DOI: 10.1504/IJART.2011.041480.*

Even though this publication presents two prototypes (a retrospective prototype called Notelinker and a prospective prototype called Kartta), only Kartta is considered in this thesis. It provides a guide for users in the field based on location-based feedback by other users. Kartta is composed of a server and a mobile application built using Mobile Python. The mobile application can capture content and context data, which are sent to the server automatically. The server uses this information to create a map of the immediate region around a user, highlighting points-of-interest as well as landmarks to help the user to navigate.

(P2) *Multisilta, J., **Perttula, A.**, Suominen, M., & Koivisto, A. (2010). Mobile Video Sharing: Documentation Tools for Working Communities. Proceedings of the EuroITV 2010, 8th European Conference on Interactive TV and Video. June 9-11, 2010, Tampere, Finland, pp. 31-38. ISBN: 978-1-60558-831-5.*

This publication presents MoViE (Mobile Video Experience), a social media service that enables users to create video stories using their mobile devices. The idea of the service is that users can upload video clips they have shot using their mobile devices to the service. In the MoViE, users can watch each other's clips and create remixes of video clips they find from the service. In order to support automatic tagging of videos, a specific mobile client application is designed that uses GPS and cell tower data for creating tags for location, place, and weather. In addition, MoViE's mobile client makes uploading process automatic and possible to utilize smart tagging suggestions.

(P3) ***Perttula, A.**, Koivisto, A., Mäkelä, R., Suominen, M., & Multisilta, J. (2011). Social Navigation with The Collective Mobile Mood Monitoring System. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. September 28-30, 2011, Tampere, Finland, pp. 117-124. ISBN: 978-1-4503-0816-8.*

At events, people could benefit from the experiences of others to find out interesting areas. In this publication, a mobile computing platform for monitoring and collecting information about people's moods at a public event is presented. Moods are represented in real time on a public map as a social navigation recommendation system. Thus, with the concept of collective emotion tracker, the audience at the event gives social navigation advice to other participants by using a custom-made mobile application.

(P4) *Kiili, K., **Perttula, A.**, & Tuomi, P. (2010). Development of Multiplayer Exertion Games for Physical Education. IADIS International Journal on WWW/Internet. Vol. 8, No. 1, pp. 52-69. ISSN: 1645-7641.*

This paper presents three mobile multiplayer exertion games. However, they can be considered as a one game prototype from the point of view of this thesis because they all utilize the same developed platform. Mobile devices with a built-in accelerometer sensor are used as game controllers in this study. Players control game characters by performing different kinds of movements all together.

(P5) ***Perttula, A.**, Tuomi, P., Kiili, K., Suominen, M., Koivisto, A., & Multisilta, J. (2013). Enriching Shared Experience by Collective Heart Rate. International Journal of Social and Humanistic Computing.* Vol. 2, Nos. 1/2, 2013, pp. 31-50. ISSN online: 1752-6132.

This publication presents two pilot studies on using a mobile device enabled collective heart rate. It is visualized in an indoor ice rink and utilized in exertion games to bring intensiveness to audience

experience. The game part is a follow-up for the publication P4. However, the collective heart rate system uses the same platform in both cases. Thus it can be considered as a one prototype. Basically, a group of users is a sensor that produces a collective heart rate via mobile devices.

(P6) ***Perttula, A.*** *(2012). When a Video Game Transforms to Mobile Phone Controlled Team Experience. Proceedings of 16th International Academic MindTrek Conference: Envision Future Media Environments. October 3-5, 2012, Tampere, Finland, pp. 302-309. ISBN: 978-1-4503-1637-8.*

An existing rhythm game was modified to provide a new kind of collective experience. A rhythm game modification is based on an extraordinary custom-made user interface that involves players in cooperation with mobile devices. Players point devices towards a corresponding color in time to game events. The game will utilize the devices' sensors to capture the color. To succeed in the game, players must act as a team. An approach to utilize the ambient light sensor of mobile devices to recognize teams activities failed because of the delay of the sensor. Another approach to utilize the camera function failed because of an inefficient code. Therefore, a corresponding electronic system was built to simulate these sensors.

(P7) ***Perttula, A.,*** *Multisilta, J., & Tuomi, P. (2013). Persuasive Mobile Device Sound Sensing in a Classroom Setting. International Journal of Interactive Mobile Technologies (iJIM). Vol. 7, No 1 (2013), pp. 16-24. ISSN: 1865-7923.*

This publication presents an idea on how to utilize mobile devices to support learning in the classroom. In this study, a mobile device is programmed to function as a collective sound sensor. To achieve an appropriate learning atmosphere, the designed system attempts to maintain the noise level at a comfortable tolerance level in the classroom. The main aim of the mobile application is to change student behavior through persuasive visualizations.

1.4.2 Author's Contributions

To meet the requirements of the thesis, the author's contributions to the publications are described in detail. In addition to research and writing, it is notable that all these publications include the design and implementation of a technological solution. It also has a significant role in each publication. Therefore, all aspects of contributions are taken into consideration.

(P1) Scott Carter had the main role in writing this article but Arttu Perttula (the author of this thesis) programmed the mobile device application. Arttu Perttula was involved in the planning and conducting of the field study and analyzing the results of the study. The author of this thesis also studied and wrote the related work as well as scenarios of use. Scott Carter implemented the server side solution. Laurent Denoue was consulted as an expert during this study. A part of the publication is based on Scott Carter's earlier research.

(P2) The concept of presented mobile video sharing was Jari Multisilta's idea. Arttu Perttula programmed the mobile client application. Antti Koivisto worked towards automatic tagging feature. Marko Suominen implemented the server side solution. Arttu Perttula planned and conducted the field study and analyzed the results. Arttu Perttula and Marko Suominen did the background survey.

(P3) Arttu Perttula was the main writer of this publication. The idea of this solution came from Jari Multisilta. Marko Suominen programmed one version of the mobile client application and Arttu Perttula created another version for different mobile devices. Marko Suominen programmed the server side solution and Antti Koivisto implemented visualizations. Riikka Mäkelä studied the background information. Arttu Perttula, Antti Koivisto and Riikka Mäkelä conducted the field pilot study.

(P4) The original idea to utilize mobile devices as game controllers was Arttu Perttula's. He programmed the mobile client application. Marko Suominen did not participate in writing this article but he programmed the server side solution. Kristian Kiili created the theory based on the games. In addition to Kristian Kiili and Arttu

Perttula, Pauliina Tuomi was involved in carrying out the field pilot. Kristian Kiili and Marko Suominen created the graphics.

(P5) Jari Multisilta and Arttu Perttula outlined the original idea. Arttu Perttula programmed the mobile client application. Marko Suominen programmed the server side solution and created visualizations. Pauliina Tuomi, Kristian Kiili and Antti Koivisto participated in the pilot study planning and realization. Antero Lindstedt did not participate in writing but he gave invaluable assistance during the data gathering process at ice hockey games.

(P6) Arttu Perttula is the only author of this publication. However, Niina Tuulivaara offered invaluable assistance during this project. She helped to build light sensor items to prototype the solution. She also took notes during the study.

(P7) Arttu Perttula designed and implemented the presented mobile application. The idea was formed by brainstorming with Kristian Kiili although he is not a co-author of the publication. Arttu Perttula planned and conducted the study by himself. He is the main author of the article. Jari Multisilta and Pauliina Tuomi wrote some background information and provided expertise for this study.

1.5 Thesis Structure

The thesis is divided into six chapters as presented in Figure 4. The figure also illustrates the relationship between the publications included and different parts of the thesis. In essence, chapter 1 is a description of the research. Chapter 2 presents the theory behind the counterparts of the ideal application in this thesis. Chapter 3 is about research methods. The conceptual framework is defined in chapter 4. Chapter 5 is mainly a review of the results and the research. Finally, chapter 6 concludes the study.

1. Introduction. The first chapter (this chapter) provides an introduction to the topic and thesis. Relevant background knowledge, motivation for the research, research problems, the study approach and structure of the thesis are presented in this chapter. Additionally, an overview of publications included is described briefly.

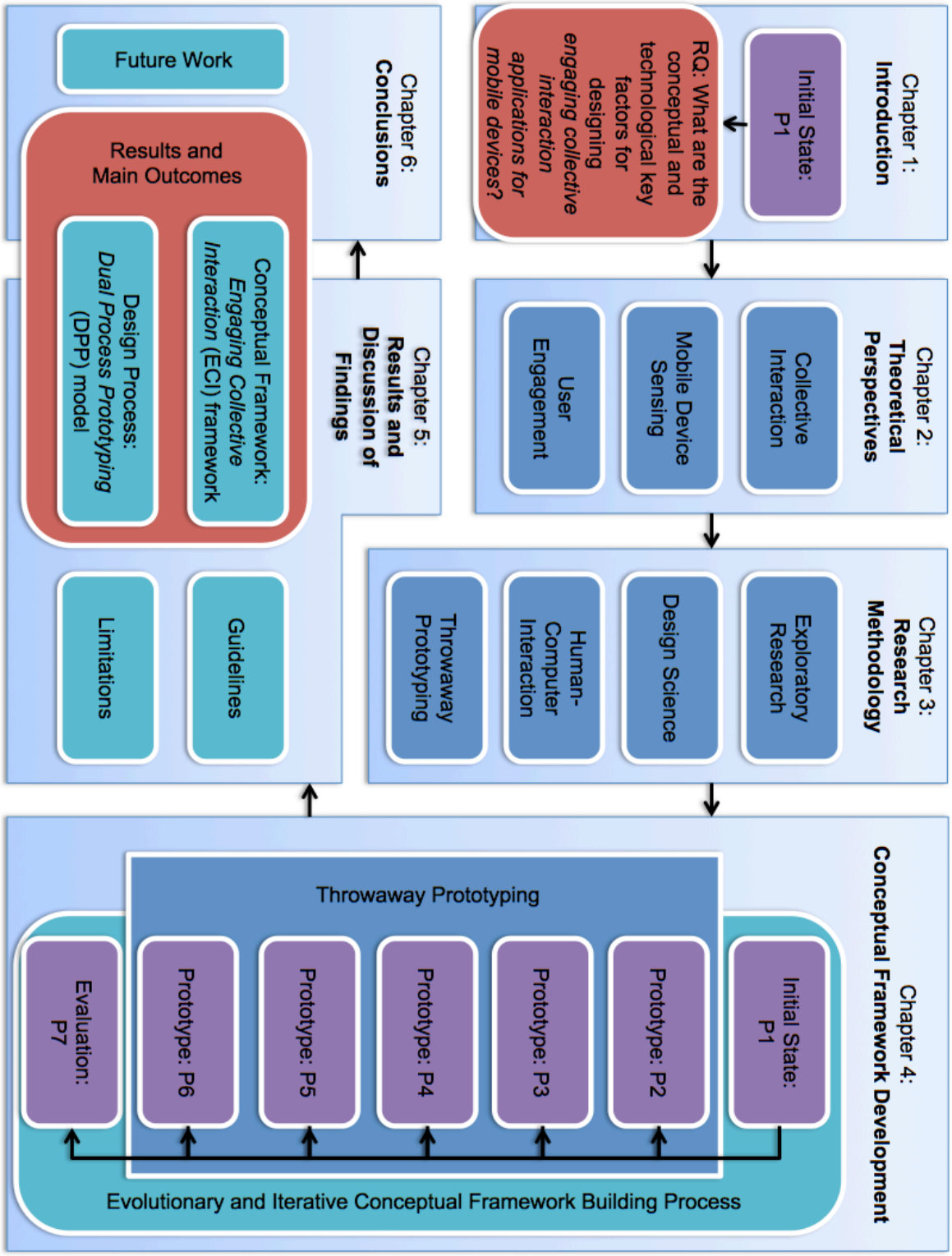


Figure 4. Thesis structure.

2. Theoretical Perspectives. Chapter 2 presents the theoretical perspectives from the standpoint of collective interaction, mobile device sensing and the role of user engagement in research. These three aspects are taken into consideration because they are essential parts of the ideal application in this study (see subchapter 1.3). All the applications presented involve collective interaction among users, enabled by mobile device sensing. All in all, the intention of this thesis is to create an *engaging collective interaction application for mobile devices*.

3. Research Methodology. Chapter 3 discusses the methodological approaches employed. This study is fundamentally based on exploratory research. Also, the HCI, DS, and software development methods are each described and relevant aspects of their utilization are provided. HCI provides traditional evaluation methods for prototypes. DS provides a way to conduct this research. The throwaway prototyping approach is selected from the software development methods.

4. Conceptual Framework Development. The empirical work based on an entity of seven projects (P1-P7) is summarized in chapter 4. The chapter is divided into three parts according to DS: Initial State (P1), Building and Evaluating Phase (P2-P6) and Evaluation before the Final State (P7). The intention of each publication (P1-P7) is described. A conceptual framework based on the key factors (RQ) is created and presented in this chapter.

5. Results and Discussion of Findings. The findings are discussed in chapter 5 along with the limitations of the proposed conceptual framework and the study. The appropriateness of research methods is taken into consideration. In addition, guidelines are provided for software developers.

6. Conclusions. Chapter 6 concludes the thesis by presenting the main outcomes. In addition, this chapter reveals future work needs and plans. Finally, a summary of the thesis is provided. The results and main outcomes are the proposed conceptual framework and the design process itself. The conceptual framework is also the answer to the research question (RQ). This chapter reveals the success level achieved of the research; are enough solutions provided to satisfy expectations?

2. Theoretical Perspectives

This chapter presents the theoretical approach that brings together *collective interaction*, *mobile device sensing*, and *user engagement*. As described in subchapter 1.3, these three aspects are essential parts of the ideal application in this study. Each of them is discussed on a general level and from the point of view of this thesis. In addition, the intention is also to provide background information and a review of the literature. This chapter focuses on elements of this study's mobile applications and the next chapter reveals how to study these implemented prototypes. Thus, research methods are presented in chapter 3, entitled Research Methodology.

Overall, collective interaction, mobile device sensing, and user engagement are synthesized to form the design factors that guide the framework (chapter 4, Conceptual Framework Development). These theoretical perspectives define objectives of the developed prototypes. They can be considered also as requirements and borderlines in this thesis. Due to the nature of the exploratory study (see subchapter 3.1), they guide the process but the intention is not to define eligible application features precisely. To clarify the approach see the research question and aims (subchapter 1.3).

2.1 Collective Interaction

Interaction is a kind of action with a two-way effect. It occurs when two or more objects have an effect upon one another. (Wagner, 1994) Even though collective interaction happens in everyday situations, for example when two or more people coordinate their actions to carry a heavy piece of furniture together (Krogh and Petersen, 2008; Petersen et al., 2010), nevertheless few interactive systems are designed to support collective interaction according to Petersen et al. (2010). Hindmarsh (2005) also identifies that there is more potential to design interaction between people in interactive systems. Although this thesis uses Krogh and Petersen's (2008) collective interaction term, there are also other definitions and models to describe social interaction, experiences, and activity. To understand collective interaction principles, a review of existing approaches is included.

Collaborative Control. Marschak (1972) has defined collaboration in a way that all the participants work together as a team, sharing the payoffs and outcomes; if the team wins or loses, everyone wins or loses. In a team, the interests and beliefs

are the same (Marschak, 1972). Collaboration as a team differs from cooperation among individuals in that cooperative players may have different goals and payoffs where collaborative players have only one goal. The challenge is to work together to maximize the team's utility. A collaboratively-controlled system requires that multiple users provide a collective input to an entity. Thus users must work simultaneously and in concert with each other to achieve their intended goals. Collaborative control refers to a mechanism that allows multiple users to control a single entity. (Zagal, 2006)

Social Interaction. Ludvigsen's (2005) framework of interaction in social situations provides a scale of engagement. Its lowest level of engagement is named distributed attention. There the only shared factor is the presence in the space. The next level is shared focus where participants share a single focus that the situation develops. In third level, called dialogue, people invest themselves and their opinions in a dialogue visible to all participants. The highest level is collective action where participants work collaboratively towards a shared goal. In Ludvigsen's framework, it is socially the most engaging interaction. Ludvigsen (2005) also argues that collective experiences are often significant and remembered.

Collective Experience. According to Sanders and Dandavate (1999), experiencing is a constructive activity. Furthermore, the term co-experience refers to user experience, which is created in social interaction (Battarbee, 2003). The experience, while essentially created by the users, would not be the same or even possible without the presence of the product and the possibilities for experience that it provides. The action of co-experience is described as creative and collaborative. (Battarbee, 2003; Battarbee and Koskinen, 2005) Furthermore, Forlizzi and Battarbee (2004) offer a framework for understanding different types of experiences in relation to the design of interactive systems. They also argue that interactive technology can play an important role in supporting co-experience.

Active Spectatorship. Participants are in social interaction with other participants instead of passive spectating (Esbjörnsson et al., 2006; Jacucci et al., 2007 a; Jacucci et al., 2007 b). It refers to seeing spectator activity (spectating) of an event as an engaging and interactive experience with lots of social interaction with other spectators (Esbjörnsson et al., 2006; Jacucci et al., 2007 a; Jacucci et al., 2007 b). Active spectatorship has parallels with the notion of active user (Carroll and Rosson, 1987), which emphasizes that users are not just systems

automatically processing information they are provided with. (Peltonen et al., 2007)

Single Display Groupware (SDG). Stewart et al. (1999) have introduced the SDG interaction model. This is an approach to designing to support collaborative work among co-located people. In the SDG model, each user has a separate input channel (a keyboard and a mouse) to the computer. An output channel (a display) is shared among users. In this model, users may independently provide input to a system.

Collective Interaction. Krogh and Petersen's (2008) collective interaction focuses on designing for co-experiences among co-located people. In their model, an application involves users' co-located cooperation. More than one user is required and users must coordinate and negotiate their actions towards a shared goal. Collective interaction can be compared to the SDG model (Fig. 5).

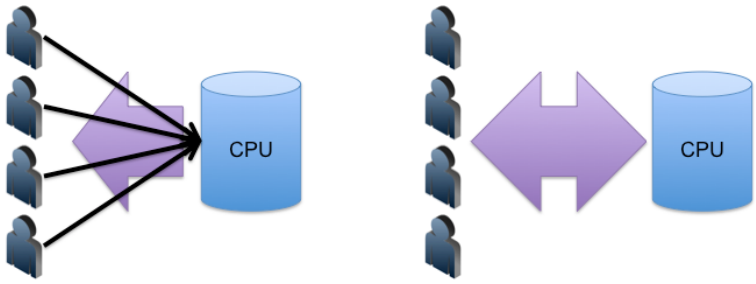


Figure 5. From left to right: the single display groupware interaction model (Stewart et al., 1999) and collective interaction model (Krogh and Petersen, 2008).

The main difference is that in collective interaction, users also share the input channel, although both models can be seen as sharable interfaces (Sharp et al., 2006). These kinds of interfaces are designed for more than one person to use at a time. However, according to Krogh and Petersen (2008), in the collective interaction model, the input channel may consist of a number of interaction instruments, which are logically coupled in the interaction. Krogh and Petersen (2008) have summed up the five key characteristics of collective interaction:

1. *The interaction itself allows for human-human interaction beyond what is in the interface – potentially deviating discussions from what is displayed.*

2. *The spatial organization of people induces expectations of use.*

3. *A shared goal is established on the basis of sharing responsibility and negotiating control of interaction.*

4. *Establishing a shared goal through negotiation is essential both in order to achieve it and in order to challenge and thereby tease other participants.*

5. *The interaction may be asymmetrical, in the sense that people take on different roles, but the efforts of all participants are accounted for and valued in the use of the system.*

The intention is to study which kind of interaction model is the most suitable within the context of this thesis (see subchapters 1.1 and 1.3). Therefore, all of these approaches and definitions are taken into consideration. The throwaway prototyping method offers a possibility to shape the collective interaction definition during the research process (see chapter 4 and prototypes P1-P7). However, the background information presented provides a starting point for designing *collective interaction applications for mobile devices*.

2.2 Mobile Device Sensing

A sensor is typically a device that measures its environment and sends the measurements to a data gathering system. Such a system can be for example a mobile device. (Multisilta and Perttula, 2011; Multisilta and Perttula, 2013) Sensors are essential parts of today's mobile devices. There are a great variety of the mobile device sensors (depending on the model of the device), including a gyroscope, digital compass, accelerometer, proximity sensor, and ambient light sensor, front and back facing cameras, a microphone, GPS, WiFi, NFC, and Bluetooth (Fig. 6). Wireless connections, Bluetooth and WiFi also enable external sensors like heart rate belts. Devices are programmable and sensor readings accessible. In other words, appropriate programming languages provide APIs for sensors. Therefore, it depends on the developers how to utilize mobile device sensing.

Lane et al. (2010) describes how mobile device sensors are utilized in different ways for user interface and location purposes. For example, the accelerometer

sensor enhances the user interface and use of the camera. It determines the orientation of the device. Thus the display is automatically re-oriented between a landscape and portrait view. The proximity sensor detects, for example, how far away the device is from the face during a phone call. If it is close, the touchscreen is disabled to save power and prevent it from accidentally being pressed with the face or ear. Light sensors are used to adjust the brightness of the screen. The GPS allows the device to localize itself. It enables location-based applications such as local search and navigation. The compass and gyroscope measure the device's position in relation to the physical world. Thus the device's direction and orientation can be determined, e.g. for navigation purposes.

Figure 6. Sensors of a mobile device (Lane et al., 2010).

According to Lane et al. (2010), sensors also provide an opportunity to gather data about users and their environments. For example, accelerometer data is capable of characterizing the physical movements of the user (Miluzzo et al., 2008). Different activities e.g. running, walking, and standing can be also determined via the accelerometer sensor. By collecting audio from the device's microphone, for example, it is possible to classify sounds associated with a particular context or activity, such as making coffee and driving (Lu et al., 2009). The front camera can be used e.g. for tracking the user's eye movements and thus activating applications. Two or more sensors can also be utilized at the same time. For example, the combination of accelerometer data and a GPS stream provides a possibility to recognize the mode of transportation of a user, such as a bike, a car, a bus, or a subway (Mun et al., 2009).

There are mobile device sensing applications ranging from personal sensing to global sensing. Therefore, these systems can be presented as sensing scales that are 1) *individual*, 2) *group*, and 3) *community sensing* (Fig. 7). 1) *Individual sensing* applications are designed for an individual user. According to Lane et al.

(2010), these applications are often focused on data collection and analysis. For example, health and fitness applications can belong to a personal sensing category. However, there are also exercise applications with social features. 2) *Group sensing* applications are defined as based on a common goal, concern, or interest among users. 3) *Community sensing* becomes useful once there are lots of people participating, for example in the case of a noise map of a city. (Lane et al., 2010) Collective interaction (see chapter 2.1) involves more than one user. Thus, this study focuses on group sensing although some of the created prototypes can be used as on a personal or community level. However, as well as in the case of collective interaction, the definition of the group will take shape during the research process (chapter 4).

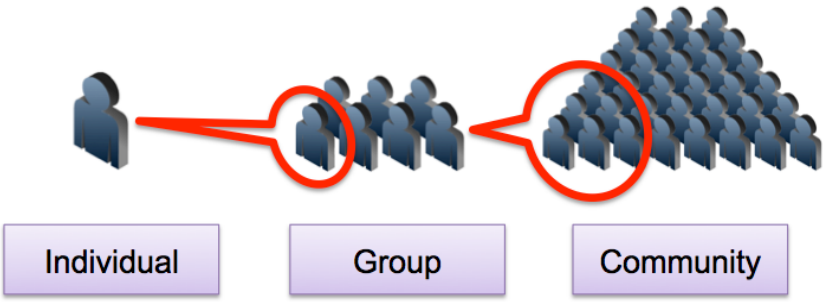


Figure 7. Mobile device sensing scales (Lane et al., 2010).

In addition to the sensing scales, mobile device sensing can be categorized into two kinds of sensing activities, depending on the mobile user involvement to the sensing process (Lane et al., 2010). If the user should actively participate in taking photos for example, it is known as *participatory sensing* (Burke et al., 2006). Otherwise, if the user participates passively e.g. the phone stores the acceleration sensor readings automatically, it is called *opportunistic sensing* (Campbell et al., 2006). Both of them are taken into consideration during the throwaway prototyping process (chapter 4). Furthermore, *continuous sensing* means that a mobile device's sensor is activated to work all the time. Thus, the user's input is not needed. A requirement for continuous sensing is that the device supports multitasking and background processing. Lane et al. (2010) have stated that this kind of continuous sensing will enable new applications across a number of sectors. (Lane et al., 2010) This study also seeks answers to the questions: how automatic can sensing be and what kinds of sensors offer possibilities for opportunistic sensing?

2.3 User Engagement

In addition to usability, HCI studies have indicated the need to understand and design more engaging experiences, because successful technologies are both usable and engaging (Hassenzahl & Tractinsky, 2006; Blythe et al., 2003; Jacques et al., 1995; Laurel, 1993). Engaging user experiences are pleasurable and memorable (O'Brien and Toms, 2008). According to O'Brien and Toms (2010), it is essential to pursue an engaging user experience in the design of interactive systems. To accomplish this, it is necessary to understand the composition of the engagement and how to evaluate it. Despite the need for user engagement, there is no commonly agreed definition of it. (O'Brien and Toms, 2010) This chapter is a literature review of user engagement and its measurement metrics. A selected approach in the case of this thesis is introduced and rationalized.

Brown and Cairns (2004) define engagement as the first step in immersion. The next step is engrossment and the third one is full immersion. Chapman (1997) stated that engagement draws us in, attracts and holds our attention. It is a form of attention, intrinsic interest, curiosity, and motivation (Chapman, 1997). According to Merriam-Webster (2003), engagement describes the state in which an object or event holds the attention of a person. Laurel (1993) argues that engagement includes playfulness and sensory integration. According to Quesenbery (2003), engagement is a dimension of usability. The user's first impression of an application and the enjoyment of use affect engagement. Furthermore, research studies have suggested that engagement consists of users' activities, attitudes, (Kappelman, 1995), goals and motor skills (Said, 2004), system feedback, user control (Brown & Cairns, 2004), and appropriate challenge (Skelly et al., 1994). Based on the user engagement literature and their own studies, O'Brien and Toms (2010) presented a definition of engagement, which is also in line e.g. with the findings of Attfield et al. (2011):

> *Engagement has been defined as a quality of user experience that is comprised of: Focused Attention, Perceived Usability, Endurability, Novelty, Aesthetics, and Felt Involvement.* (O'Brien and Toms, 2010)

If individual engagement is compared with collective engagement, collective interaction (subchapter 2.1) itself can be engaging. O'Brien and Toms' (2008) research suggests that users must be made to feel connected to other people

(social awareness). Furthermore, participants can be motivated for social reasons. (O'Brien and Toms, 2008) According to Champion (2003), social presence is a factor of engagement with video games.

2.3.1 Related Theories

Flow. Chapman and his co-authors (Chapman, 1997; Chapman et al., 1999) have related engagement to flow theory (Csikszentmihalyi, 1990). Csikszentmihalyi's (1990) flow theory depicts a state of mind. In it, a person is so engaged by an activity that actions and awareness merge. It is also known as optimal experience and closely linked with motivation and attention. An optimal level of challenge is necessary to maintain motivation (Berieter & Scardamalia, 1992). Webster and Ahuja (2006) argued that engagement is a subset of flow. O'Brien and Toms (2008) suggest that engagement probably shares attributes with flow, e.g. focused attention, feedback, control, activity orientation (i.e. interactivity), and intrinsic motivation.

Aesthetics. Jennings (2000) has suggested that aesthetic experiences are intrinsically motivating, require focused attention, stimulate curiosity, and are interesting and pleasurable. Interest and aesthetics have also been associated with engagement (Chapman, 1997). Aesthetics is the visual appearance of the interface. It is important to engagement, but only one aspect of engagement. (O'Brien and Toms, 2008)

Play. According to Rieber (1996), play is the physical activity that encourages learning and creativity. It develops and satisfies psychological and social needs. Furthermore, it includes competition and collaboration. Atkinson & Kydd (1997) argue that play is associated with increased frequency and satisfaction of system use. Increased motivation, challenge, and affect also belong to play (Woszczynski et al., 2002). According to O'Brien and Toms (2008), the elements of play are intrinsic to engagement.

Information Interaction. Interaction is communication between a user and an interface. The interface enables user experiences (Schneiderman, 1997). According to Toms (2002), information interaction is a process that people use in interacting with the content. According to O'Brien and Toms (2008), information interaction provides the connectivity for engagement. Even if the system would be aesthetically appealing with elements promoting play and the user is in a state of

flow, all in all, it is the interaction between the user and system that facilitates an engaging experience. (O'Brien and Toms, 2008)

According to O'Brien and Toms (2008) flow, play, aesthetics, and information interaction as well as engagement builds upon the foundation of a usable system that is effective, efficient, and satisfying. They have collected the characteristics presented in the table below (Table 1), which presents the attributes that may be intrinsic to engagement. In addition, an engaging experience is formed from the sensory appeal, the level of feedback, and challenge of the system. Involvement, motivation, and control over the interaction make users engaged.

Table 1. O'Brien and Toms (2008) have collected the attributes of flow, aesthetic, play, and information interaction theories, and proposed their relevancy to engagement.

Attributes from the theories	Flow theory	Aesthetic theory	Play theory	Information interaction	Attribute of engagement ?
Aesthetics		X	X		Yes
Affective appeal		X	X	X	Yes
Attention	X	X			Maybe
Challenge	X	X	X	X	Yes
Feedback	X		X	X	Yes
Goal-directed	X		X		Maybe
Meaningfulness	X	X			Maybe
Motivation	X	X	X		Yes
Perceived control	X			X	Maybe
Sensory appeal		X	X		Yes

It is important to notice that the related theories and engagement presented also have notable differences. For example, an engaging experience has the attention of the user but in flow and aesthetic theories, users become so focused that they lose their awareness of physical reality. In addition, in the case of engagement, users may for example use an application without a specific purpose but not in flow and play. (O'Brien and Toms, 2008)

2.3.2 Measuring User Engagement

Based on user engagement literature, this study seeks to create novel, attractive, aesthetically appealing, motivating, curiosity-provoking, and high usability prototypes and thus provide an engaging experience. However, it is difficult to

measure the level of user engagement. For example, according to Lehmann et al. (2012), currently there is no consensus on which metrics should be used to measure which types of engagement. Physiological measurement methods (Lehmann et al., 2012; O'Brien and Toms, 2010), like galvanic skin response and eye movements, are insufficient in this case because the intention is to pilot all the prototypes as field pilots (see subchapter 3.3). It would not give a proper view of a use of a prototype if study participants were disturbed with these kinds of measurement devices and methods.

Therefore, this study utilizes traditional HCI methods such as observations and interviews (see subchapter 3.3). Motivation is related to engagement and it is an attribute of engagement (O'Brien and Toms, 2008; Chapman, 1997; Jacques et al., 1995; Said, 2004, Webster and Ho, 1997) and it can be observed as described below. Thus it is reasonable to focus especially on users' motivation to use a prototype. In this study, engagement is divided into three aspects (E1, E2 and E3):

E1) Do the study participants want to try a prototype? Are they all participating?

E2) Are they willing to complete the study? Are they active and motivated during the pilot?

E3) Do they want to use it again? Do they ask how and when it is possible to use the prototype in the future?

Similarly to Göth and Schwabe (2008), levels of engagement are categorized as low, medium, and high engagement. As they have stated, the level of engagement describes how much a study participant is interested, works, interacts, or thinks about the object or event, which is in this case a prototype. The engagement metrics of this study illustrated in Figure 8. E1, E2, and E3 are integrated in a pilot study's phases (Start, Ongoing, and End in the figure).

If all of them (E1, E2 and E3) can be answered no, a prototype is not engaging. If E1 seems to be true but E2 and E3 fail, the prototype's engagement level is low. If E1 and E2 are true, but E3 still fails, the prototype's engagement level is medium. If all three E1, E2, and E3 are true, a prototype can be considered as having a high level of engagement. In other words, each prototype is thrown away until attaining a highly engaging level of user experience, which allows users to

perceive the experience as worthwhile, successful, and one they would seek again in future (O'Brien and Toms, 2010).

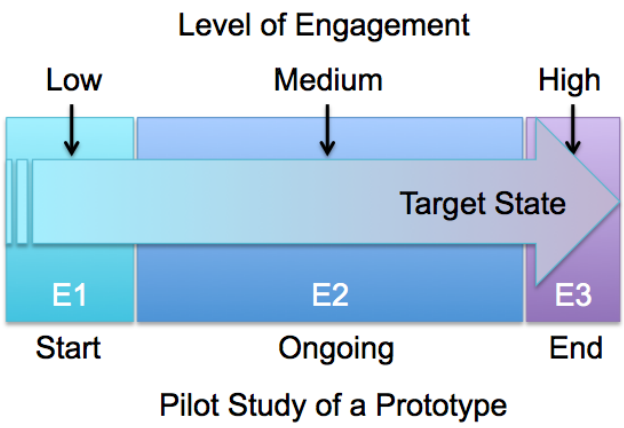


Figure 8. Levels of engagement of prototypes used in this study.

Although the method presented to measure engagement is custom-designed, it is based on existing approaches. For example, O'Brien and Toms (2008) have presented four phases of engagement: a point of engagement, sustained engagement, disengagement, and re-engagement. Michalowski et al. (2006) have used social space to help categorize engagement according to the stages of present, attending/interested, engaged, and interacting. Lehmann et al. (2012) considered three types of engagement metrics in their study reflecting popularity, activity, and loyalty. In addition, according to Dobrian et al. (2011), engagement is a qualitative reflection of user involvement and interaction. These and earlier discussed literature also support the approach of this thesis when compared to the three aspects E1, E2, and E3.

The author acknowledges that there are other aspects of user engagement and ways to measure it beyond the above-mentioned motivational aspects E1, E2, and E3. The choice of these metrics is based on two reasons in addition to the literature review. Firstly, these metrics can be measured directly and objectively via observations and interviews. Secondly, the results of these metrics can be translated into the purpose of the study. They can be presented as a level of engagement (as illustrated in the Fig. 8) that is essential in the throwaway prototyping and the framework designing processes in this study.

2.3.3 Technology's Role in Engagement

Technology has an essential role in this context of this thesis (see subchapter 1.1). Technological solutions can be designed in a way to support the attributes of engagement (see Table 1, p. 24). In addition for instance to technology-enabled *collaborative control* (see subchapter 2.1), *continuous sensing* (subchapter 2.2), *active spectatorship* (subchapter 2.1) and *collective experience* (subchapter 2.1), the literature review reveals that there are other things to take into consideration such as *gamification* and *playfulness*. The effect of technology on engagement and its implementation options has been examined during the conceptual framework development process (chapter 4).

Gamification is the use of game-thinking, game mechanics, game design techniques, and game style in a non-game context in order to engage users, motivate, and solve problems. According to Bouca (2012), the growing acceptance and adoption of games shows that human beings are naturally playful, regardless of age. Gamification relies on extrinsic motivations. In other words, an activity is done in order to attain some separable outcome such as a reward like points or badges. (Zichermann and Cunningham, 2011; Huotari and Hamari, 2012; Deterding et al., 2011; McGonigal, 2011)

Playfulness is also a way to motivate and activate participants (Kangas and Cavén-Pöysä, 2005). Fullerton et al. (2004) propose that a playful approach can be applied to even the most serious or difficult subjects because playfulness is a state of mind rather than an action. The definition of playfulness in user experience can be constructed from the elements that engage people's attention or involve them in activity for the sake of playing, amusement, or creative enjoyment (Draper, 1999). Playful user experience provides users with opportunities to develop skills through exploratory behavior (Väänänen-Vainio-Mattila et al., 2008). Several design methods can be used to evoke playfulness in the user. A playful application can contain elements of experimentation (Väänänen-Vainio-Mattila et al., 2008) and social interaction (Rosenbloom, 2003). Frivolous interaction such as a component of interactive silliness can be implemented. According to Malone (1982), an enjoyable user interface is based on three aspects: challenge, fantasy, and curiosity (Malone, 1982). Playfulness attracts users and provides enjoyable user experience. It should also inspire and enable users to develop their knowledge and skills. (Kuts, 2009)

3. Research Methodology

This chapter presents the research methodology (see Fig. 3, p. 6), which is a combination of *human-computer interaction* (HCI), *design science* (DS), and the software development method called *throwaway prototyping*. In order to study the research question (RQ), throwaway prototyping and constructive research methods based on DS are utilized. Traditional evaluation methodologies in HCI are used for evaluating the prototypes P1-P7 designed to study the RQ. Furthermore, the whole approach of this thesis is based on *exploratory research*.

All in all, methodological approach was selected based on the following reasons. The results of this thesis are intended to be guidelines instead of conclusive answers. Thus, the approach is based on exploratory research. The design science procedure is based on two main activities: building and evaluation (March and Smith, 1995). Therefore, it is an obvious choice to construct a framework. In this study, users are in human-computer interaction with mobile devices. According to Jayaswal and Patton (2007), throwaway prototyping is a way to test the implementation method and end-user acceptability. Research methods are discussed on a general level and from the point of view of this thesis. The intention is also to provide background information and a review of the literature.

3.1 Exploratory Research

Malhotra and Birks (2000) have defined research design as exploratory research and conclusive research. Exploratory research is reviewed here as a starting point of the research methodology of this study. Although it does not actually provide research methods, it offers background information about the components of this kind of research project: research purpose, data needs, data sources, data collection form, sample, data collection, data analysis, and inferences/recommendations (Table 2). Therefore it also affects the other selected research methods.

According to Lambin (2000) and Bell (2010), exploratory research does not try to provide conclusive evidence and the final answers to the research question. Instead, it helps to give a better understanding of the research problem. According to Brown (2006), exploratory research studies new problems on which little or no previous research has been done. Singh (2007) suggest that it forms

the basis of conclusive research. Saunders et al. (2007) argues that as a result of revelation of new data and insights, a research direction may change.

Table 2. Differences between exploratory and conclusive research (Parasuraman et al., 2006).

	Exploratory research	**Conclusive research**
Research purpose	General: to generate insights about a situation	Specific: to verify insights and aid in selecting a course of action
Data needs	Vague	Clear
Data sources	Ill defined	Well defined
Data collection form	Open-ended, rough	Usually structured
Sample	Relatively small; subjectively selected to maximise generalisation of insights	Relatively large; objectively selected to permit generalisation of findings
Data collection	Flexible; no set procedure	Rigid; well-laid-out procedure
Data analysis	Informal; typically non-quantitative	Formal; typically quantitative
Inferences/recommendations	More tentative than final	More final than tentative

According to Sandhusen (2000), the difference between exploratory and conclusive research is that the former provides alternative options for a solution of a research problem, explores the research questions, and leaves room for further research. Conclusive research identifies the final information, findings, and exact answer to the problem. The main differences between these two forms of research design (Table 2) are summarized by Parasuraman et al. (2006).

This thesis describes an exploratory research study. The intention is to provide ideas and guidelines for developers. In addition, the thesis offers a starting point for researchers to conduct more comprehensive studies in this context. The results provided are not intended to be conclusive.

3.2 Design Science

In this thesis, the framework development (see Fig. 3, p. 6) follows the design science (DS) procedure. However, there are different kinds of definitions about DS research activities. To understand the process, this chapter presents a summary. Based on the literature review, the approach of the thesis' framework process is formed.

The DS literature provides several suggestions on how to conduct research. Peffers et al. (2007) have collected processes from the presented concepts (Table 3). Based on their literature review, they propose common design process elements (the first column in Table 3). Furthermore, March and Smith (1995) noted that DS is based on two main processes: building and evaluation. Their activities also include theorizing and justifying. To present a more comprehensive summary of different approaches, the table is extended with elements from March and Smith (1995) and Kiili (2005).

According to Hevner et al. (2004), DS basically solves problems. In DS, the intention is to create innovations that define ideas, practices, technical capabilities, and products. Through these new artifacts the analysis, design, implementation, management, and use of information systems can be accomplished. (Denning, 1997; Tsichritzis, 1998) Such artifacts are based on existing theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem solving capabilities of the researcher (Markus et al., 2002; Walls et al., 1992). Knowledge of a problem and its solution are achieved via building and utilizing the designed artifact. (Hevner et al., 2004)

Similarly to Kiili's (2005) research (the last column in the Table 3), DS is equated with constructive research in this thesis. Järvinen (2004) has described the purpose of the building process. The intention is to achieve movement from the initial state to the final state. The initial state is described as the starting point of a construction process of a new artifact. The final state occurs when the new artifact is achieved. In this thesis, the term artifact is used to describe the conceptual ECI framework and related design knowledge. Figure 9 illustrates the movement from the initial state to the final state.

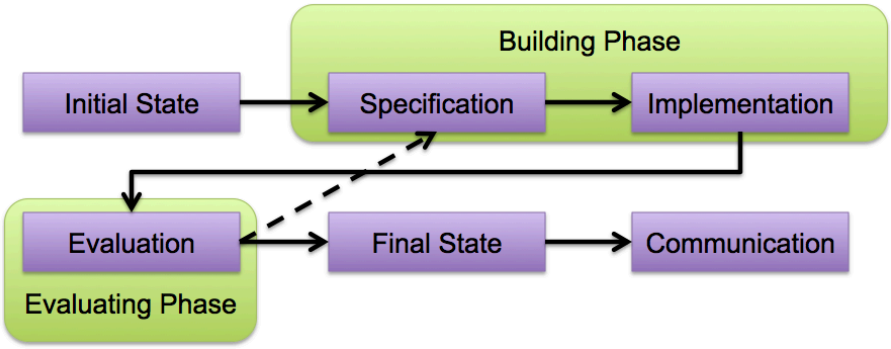


Figure 9. Design science approach based on Kiili's (2005) figure. Theorize has been changed to communication (Peffers et al., 2007). Building and evaluating phases (March and Smith, 1995) are added.

Table 3. DS research activities summarized by Peffers et al. (2007) extended with elements from March and Smith (1995) and Kiili (2005).

Peffers et al. (2007)	**Archer (1984)**	**Takeda et al. (1990)**	**Eekels and Roozenburg (1991)**	**Nunamaker et al. (1990)**
Problem identification and motivation	Programming, data collection	Problem enumeration	Analysis	Construct a conceptual framework
Objectives of a solution			Requirements	
Design and development	Analysis, synthesis, development	Suggestion, development	Synthesis, tentative design proposals	Develop a system architecture, analyze and design, build the system
Demonstration			Simulation, conditional prediction	Experiment, observe and evaluate the system
Evaluation		Confirmatory evaluation	Evaluation, decision, definite design	
Communication	Communication			

Walls et al. (1992)	**Cole et al. (2005) Rossi and Sein (2003)**	**Hevner et al. (2004)**	**March and Smith (1995)**	**Kiili (2005)**
Meta-requirements, kernel theories	Identify a need	Important and relevant problems		**The Initial State**
		Implicit and "relevance"		**Specification**
Design, method, meta design	Build	Iterative search process, artifact	Build	**Implementation**
Testable design process/product hypothesis	Evaluate	Evaluate	Evaluate	**Evaluation**
		Communication	Theorize, Justify	**Final State, Theorize**

In this research, the initial state of the ECI framework is presented after the results of P1 (subchapter 4.1). Specification, implementation, and evaluation activities are conducted after each prototype (P2-P6) during throwaway prototyping (subchapters 3.4 and 4.2). Thus, the ECI framework is designed and developed as an evolutionary and iterative process. The final state is reached

when P7 can be considered as an appropriate *engaging collective interaction application for mobile devices*. Finally, Kiili's (2005) figure is slightly modified based on the purpose of the exploratory research (subchapter 3.1). Theorize activity has been changed to communication (Fig. 9) as Peffers et al. (2007) have suggested. Therefore, this thesis can be considered as a communication effort of the artifact, its utility and novelty, with relevant audiences such as researchers and practicing professionals (Peffers et al., 2007). Also, March and Smith's (1995) two basic activities (building and evaluating) of DS are placed in the figure to clarify the process.

3.3 Human-Computer Interaction

The research of this thesis is in the mobile human-computer interaction (HCI) field. This chapter provides a snapshot of mobile HCI research methods. They are briefly summarized and compared. Furthermore, in the case of this research, suitable methods to study prototypes P1-P7 are described.

According to Kjeldskov and Graham (2003), defining and differentiating research methods can be a challenge. In addition, definitions are sometimes vague and different aspects of different methods overlap. However, Kjeldskov and Graham (2003) have extracted eight research method definitions from Wynekoop and Conger (1990) with supplementary input from general references on research methodology in information systems (Lewis, 1985; Myers, 1997; Rapoport, 1970; Yin, 1994). Kjeldskov and Graham (2003) have also divided eight methods according to Benbasat's (1984) categories of natural, artificial, and environment independent settings. Thus, a summary of mobile HCI research methods is presented in Table 4.

To obtain information about user engagement and receive reliable feedback, fully working prototypes P1-P7 are piloted in real-world situations with real users in each case. In addition, mobile applications in the context of the thesis are very difficult to emulate in a laboratory setting. Therefore, it is relevant to concentrate on Benbasat's natural settings category (Table 4). It includes three research methods: 1) *case studies*, 2) *field studies,* and 3) *action research*.

Table 4. A summary of mobile HCI research methods as extracted by Kjeldskov and Graham (2003) from Wynekoop and Conger (1990).

	Method	Strengths	Weaknesses	Use
Natural setting	Case studies	Natural settings Rich data	Time demanding Limited generalizability	Descriptions, explanations developing hypothesis
	Field studies	Natural settings Replicable	Difficult data data collection Unknown sample bias	Studying current practice Evaluating new practices
	Action research	First hand experience Applying theory to practice	Ethics, bias, time Unknown generalizability	Generate hypothesis/theory Testing theories/ hypothesis
Artificial setting	Laboratory experiments	Control of variables Replicable	Limited realism realism Unknown generalizability	Controlled experiments Theory/ product testing
Environment independent setting	Survey research	Easy, low cost Can reduce sample bias	Context insensitive insensitive No variable manipulation	Collecting descriptive data from large samples
	Applied research	The goal is a product which may be evaluated	May need further design to make product general	Product development, testing hypothesis/ concepts
	Basic research	No restrictions on solutions Solve new problems	Costly, time demanding May produce no solution	Theory building
	Normative writings	Insight into firsthand experience	Opinions may influence outcome	Description of practice, building frameworks

1) *Case studies.* Case studies are often empirical studies of small size entities such as groups and systems. Data is usually a combination of qualitative and quantitative means such as observations, interviews, and questionnaires. (Kjeldskov and Graham, 2003) According to Kjeldskov and Graham (2003), case studies could be used to provide data to explain the use of mobile devices in context.

2) *Field studies.* Field studies offer ideal opportunities to study real world use cases. It is used to explore use context and promote understanding of

users' needs. Field studies reveal needs that could be used to create new designs and improve existing ones. (Kjeldskov and Graham, 2003)

3) *Action Research.* According to Wynekoop and Conger (1990), in action research, the researcher participates in the intervention of the activity and at the same time evaluates the results. According to Kjeldskov and Graham (2003), the outcome of this research can be difficult to generalize. Action Research could be used for extending field or case studies by researchers introducing different solutions or theories during the process as well as evaluating their effects and validity. (Kjeldskov and Graham, 2003)

It is obvious that these three research methods have overlapping definitions and intentions. For example, case studies are often done in the field but it is unclear how this method differs from field studies (Kjeldskov and Graham, 2003). Thus it is convenient to focus on natural settings without a more comprehensive definition of the research method. Furthermore, according to Lazzaro (2004), currently the most common methods of assessing user experience are through subjective self-reporting, including interviews, and through objective reports from video observation and analysis. Subjective evaluation through interviews is generalizable, and is a good approach to understanding the attitudes of users (Marshall & Rossman, 2006). Therefore, based on the literature, to study the user engagement of prototypes P1-P7, observations and interviews are essential research methods.

3.4 Throwaway Prototyping

This chapter clarifies the selection of the software development method in this thesis. Methodology specifies the rules and activities for the development process. Although there are several different kinds of software development methods, most of them represent a variation of one existing and well-known concept. Therefore, according to Bruegge and Dutoit (2004), all methodologies can be divided into the following three groups:

1) *Structural* (waterfall and V model). These models follow a certain path from the beginning to the end. There is no returning back to previous points.

2) *Agile* (extreme programming model). In extreme programming, functionality is developed quickly and tasks have time limitations. When the time runs out, the developer moves on to the next task even if the previous one was unsolved.

3) *Rapid Application Development* (phase model, system and throwaway prototyping, spiral model). In rapid application development (RAD), software development activities have been repeated over and over again until the desired functionality is achieved.

As mentioned before, it is unclear what the elements of a desirable application are in this study. To define them, only the trial and error method is suitable, which is exactly the purpose of prototyping (belonging to RAD). The intention is to build, test, and re-engineer until the acceptable requirements are achieved. Requirements elicitation is done first, followed by quick design, discovering only the major concepts. After the first iteration, the prototype is evaluated. The aim is not necessarily to create the whole system at once. Different functionalities can be created in several iterations. A prototype is never a final product but it can be used as a reference for a real system. (Bruegge and Dutoit, 2004) Naumann and Jenkins (1982) have defined the term prototype as a system that captures the essential features of a later system.

However, there are two major streams of prototyping: system and throwaway prototyping. Both of them go through a prototyping cycle: elicitation, design, build, and test. The difference is in the object design activity. (Bass et al., 2003; Bruegge and Dutoit, 2004) To select the most appropriate of these two, both of them are reviewed in brief. System prototyping mainly concentrates on well-understood concepts. The first version will contain the expected functionality. After prototyping, the system prototype is retained and used as a reference for the final product. The design is done during prototyping. Once the prototype is accepted, it is followed by implementation. There is no need to redesign the system. In contrast, throwaway prototyping (Fig. 10) targets the requirement elicitation, and is discarded, or thrown away, once this activity is completed. Typically, the development concentrates on the least understood concepts. (Bass et al., 2003; Bruegge and Dutoit, 2004)

Thus, throwaway prototyping suits the purposes of this study better. According to Jayaswal and Patton (2007), a throwaway prototype approach is often used if the

goal is to test the implementation method or end-user acceptability. Therefore, it was also selected for this study. All in all, throwaway prototyping can be divided into four parts (Bass et al., 2003; Bruegge and Dutoit, 2004): 1) prototype is developed, 2) requirements are gathered, with complexity understanding, 3) the prototype is thrown away and 4) the process starts again from the requirement documentation followed by design. To clarify the approach, Figure 10 illustrates the throwaway prototyping process with the seven prototypes P1-P7 used in this study.

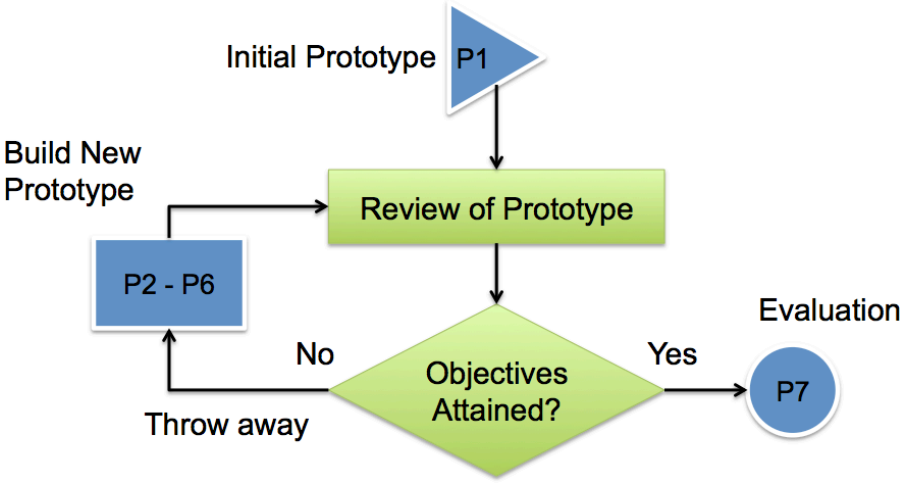


Figure 10. Throwaway prototyping process used in this study.

The evolutionary models take the concept of evolution into the engineering paradigm. Therefore, evolutionary models are iterative. A framework is constructed as an evolutionary process during throwaway prototyping (see Fig. 3, page 6). This means that the same framework is improved from each prototype created. The process continues until the objectives of this study (see subchapters 1.3 and 2.3.2) have been obtained. The framework is not thrown away. Furthermore, the intention is also to test the suitability of the throwaway prototyping approach for a framework development.

4. Conceptual Framework Development

To study the RQ, this chapter describes the seven-step (P1-P7) throwaway prototyping process from the initial position to the evaluation phase. From the point of view of this approach, the essential parts of each publication (P1-P7) are presented briefly. However, to gain an explicit image of the study, it is also recommended to explore the publications. The ECI framework is designed according to the design science building and evaluating phases during the process. Prototypes can be considered as tools to create the framework. To make it easier to follow up the throwaway prototyping process, each step is presented in Figures 11, 13, 15, 17, 19, 21, and 23, whereas the current step is indicated in different color.

4.1 Initial State

This chapter explains the initial state of the throwaway prototyping (Fig. 10, p. 36) and design science (Fig. 9, p. 30) process. As explained in the Introduction, the P1 is the starting point of this thesis as well as the throwaway prototyping approach. The prototype was created independently and before forming the thesis' research approach (Fig. 3, p. 6).

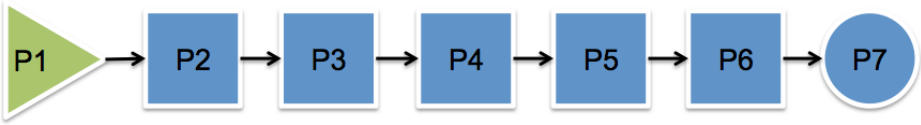


Figure 11. First step of the throwaway prototyping process.

Based on P1 (Perttula et al., 2011 a), the first sketch of the ECI framework is constructed (Fig. 12). It is a combination of a server side solution communicating with mobile devices. A mobile application, sensors, sensor data, and visualizations are defined as the main elements of the mobile device side. Study participants are defined roughly as users of the mobile application. Collective interaction remains unclear. There is no common goal even though users benefit from each other's actions. There are no identified engaging factors. The arrows indicate relations between the elements. The arrowhead also illustrates the direction of the interaction. Basically, the figure can be considered as the system's architecture diagram at this point. However, it forms the basis of the framework development.

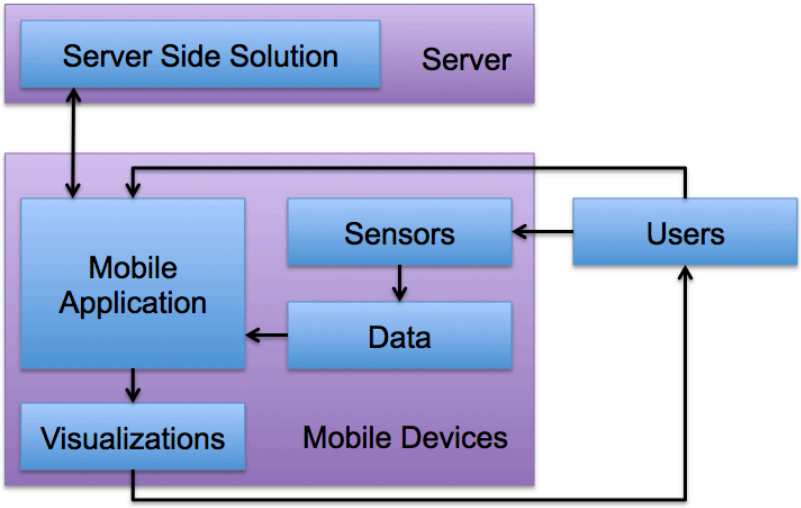


Figure 12. Initial state of the ECI framework (P1).

The prototype is valued as a low engaging prototype in this study (see subchapter 2.3.2). All the study participants took part in the pilot study but they were occasionally unmotivated to complete all the tasks. Collective interaction, mobile device sensing and user engagement became the main design issues based on this prototype (P1). They also formed the RQ and aims A1-A3 (see subchapter 1.3). Furthermore, an initial assumption based on the P1 is that when the focus is more on activity rather than technology, it has a positive impact on engagement. All in all, there are three questions to solve: How to involve more concrete collective interaction? Is it possible to automate sensing? How to create a more engaging experience?

4.2 Building and Evaluating Phase

This chapter explains the building phase of the ECI framework (Fig. 9, p. 30). Each piloted prototype is followed by the specification and implementation of the framework. The designed framework is also evaluated by the next prototype when the specification and implementation are realized once again. This cycle continues until a high engaging prototype is achieved.

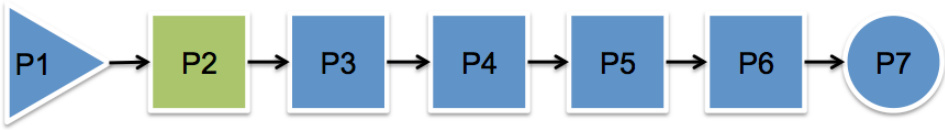


Figure 13. Second step of the throwaway prototyping process.

To seek answers to the questions introduced in the P1 phase, this solution (P2) focuses on minimized user input and required attention. P2 does not include a map view on the mobile device and the mobile client is designed especially for video capturing instead of media capturing. Tagging of videos was designed to be as automatic as possible. (Multisilta et al., 2010) Even though the study participants had a common purpose for the use of the prototype, the collective interaction remains unclear and the approach does not support engagement. The refined ECI framework (Fig. 14) differs from the previous one (Fig. 12) in visualizations. The solution includes mobile device and desktop computer interfaces. No other aspects were discovered.

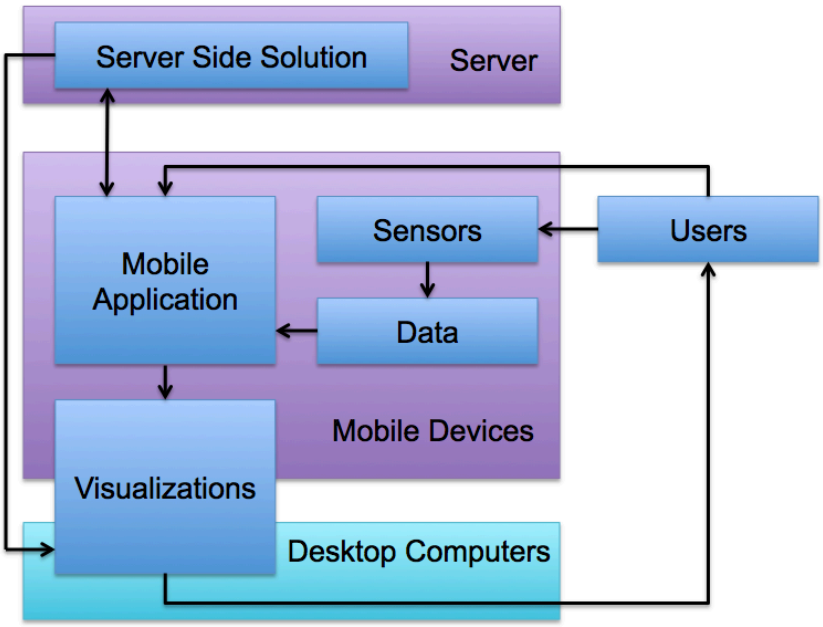


Figure 14. ECI framework after P2.

The prototype is valued as a low engaging prototype like P1. All the study participants took part in the pilot study but quite soon they were unmotivated with their activities. If the required user input is minimized even more, does it engage users more? How to bring people together to establish collective experience? Could the benefit of the application be more obvious to users?

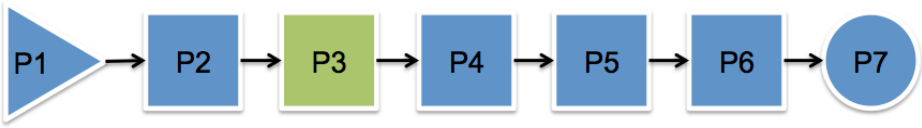


Figure 15. Third step of the throwaway prototyping process.

In addition to location sensors, this prototype (P3) also considers the touch screen as a sensor. Users should only input their moods by touching the screen. In this prototype, visualizations (a collectively produced mood map) are presented on a public screen in addition to mobile devices. (Perttula et al., 2011 b) This seemed to provoke the study participants' interest. This aspect was then changed in the framework (Fig. 16).

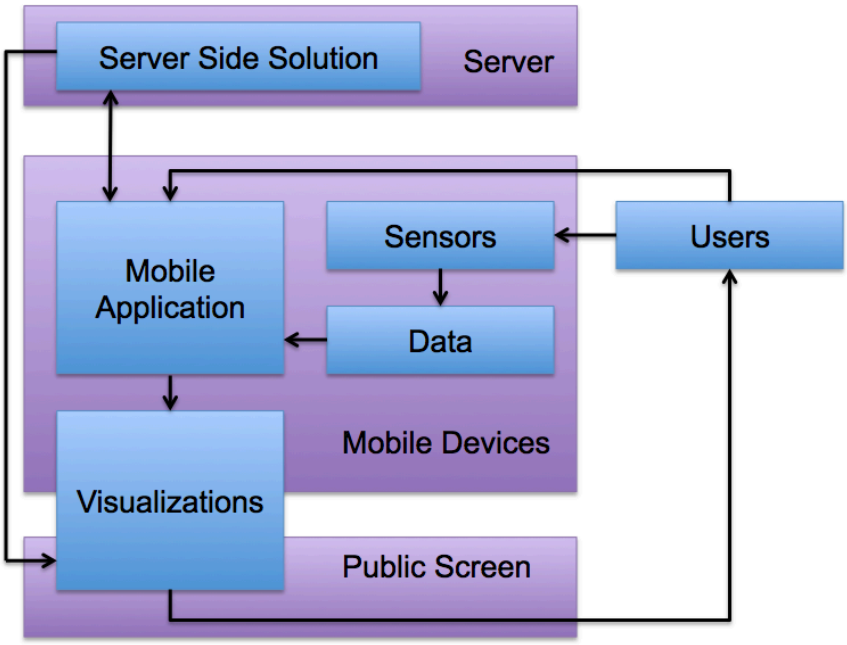


Figure 16. ECI framework after P3.

However, this prototype also offered low-level engagement or even no engagement at all. Only a few people participated in the study. They did not actively use the developed system after all. Therefore, the elements of engagement should be sought from other perspectives. What kinds of possibilities do other sensors offer? Is it an appropriate way to implement collective interaction so that it occurs only in a co-located space? Could the user input mechanism be automated completely?

Figure 17. Fourth step of the throwaway prototyping process.

This prototype (P4) utilizes the mobile devices' accelerometer sensor to control games. Sensing is automated in a sense that users only need to perform movements according to the game. The mobile device is kept in the hand or placed in a pocket. The public screen conception is taken forward with active participating to control the game. The concept is called *active spectatorship* (subchapter 2.1). Study participants are situated more clearly in a co-located place as opposed to the previous prototypes P1, P2, and P3. This approach also affects the experience felt. Furthermore, this approach (P4) included three multi-player games. In one of them, a participant controlled one game character personally while the others controlled their own characters. All of them were visualized on the same public screen. Two other versions were based on teams; a team was involved in working together to control the game. Team-controlled versions were experienced as more engaging. (Kiili et al., 2010) Recognized concepts, *active spectatorship* (subchapter 2.1), *continuous sensing* (subchapter 2.2) and *collective experience* (subchapter 2.1) seemed to have a positive effect on engagement. Thus, they were added to the framework (Fig. 18). Although they are linked to the mobile application with an arrow, they of course influence the whole design (e.g. visualizations, sensors etc.) of the developed solution. The technological side of the framework maintains its composition.

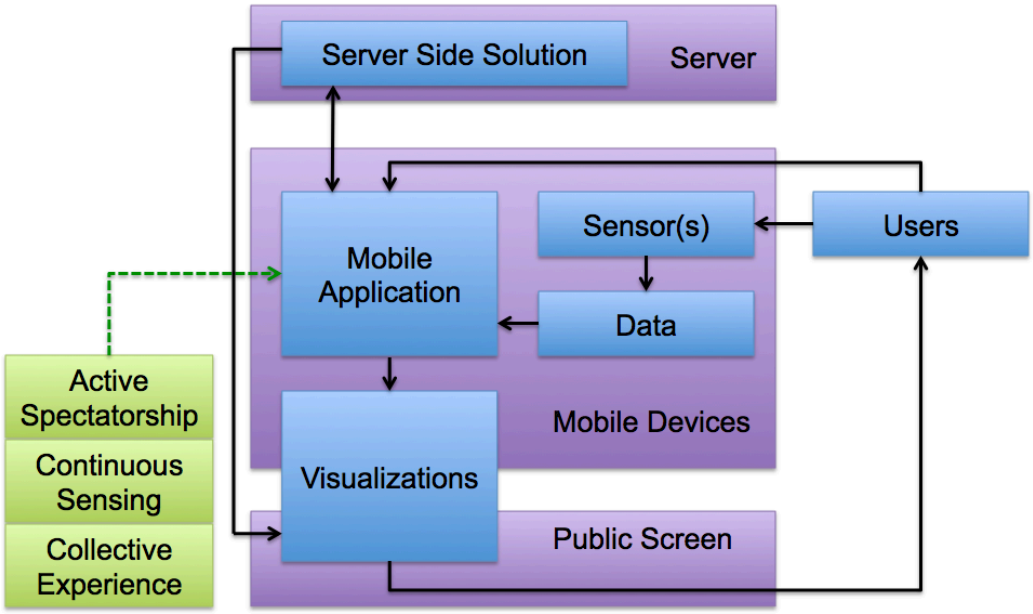


Figure 18. ECI framework after P4.

The prototype P4 can be seen as a breakthrough in this design process. All the study participants wanted to play during the pilot studies. They were also excited,

curious, motivated, and active. However, they believed that P4 offered an amusing experience but there was not enough hold to try over and over again. Therefore, P4 is rated as a medium-level engagement prototype. Is there a way to enhance collaboration and collective interaction aspects more and does it raise the engagement level?

Figure 19. Fifth step of the throwaway prototyping process.

P5 presents the concept of the collective heart rate measurement. To accomplish it, an external sensor (the heart rate measurement belt) is utilized via Bluetooth connection (see Fig. 20). Study participants did not appreciate wearing the external sensor. It felt uncomfortable and had a detrimental effect on usability. (Perttula et al., 2013 b) Therefore, the next prototype would focus on the device's internal sensors.

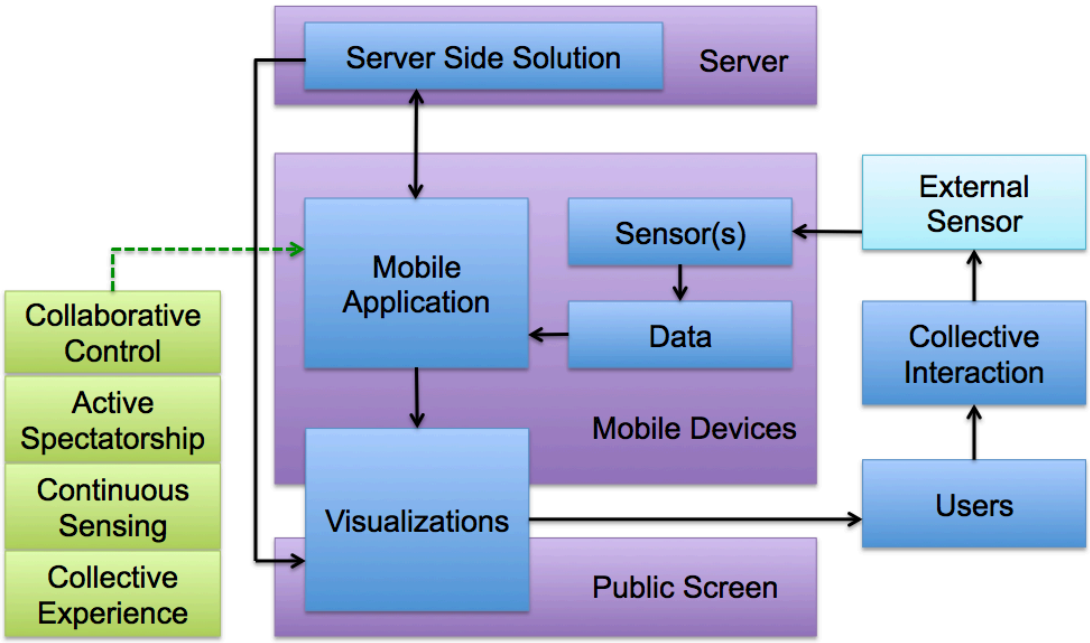


Figure 20. ECI framework after P5.

However, the approach successfully implements *active spectatorship* (subchapter 2.1), *continuous sensing* (subchapter 2.2) and *collective experience* (subchapter 2.1). In addition, this prototype involves the study participants' concrete *collective*

interaction (subchapter 2.1) via *collaborative control* (subchapter 2.1). Thus, the users had to work simultaneously and in concert with each other to achieve their intended goals, as stated by Zagal (2006). The concept of *collaborative control* seemed to motivate the study participants. It was added with *collective interaction* to the framework (Fig. 20). In addition, the 'external sensor' is in the figure at this point.

In spite of adding the elements of *collaborative control* and concrete *collective interaction*, the study participants indicated that the prototype was still on the level of medium engagement like P4. P4 is a game and P5 can be utilized as a game or to control a game. How could a concept of the game be utilized to evoke even more engagement – shifting it from medium level up to a high level of engagement?

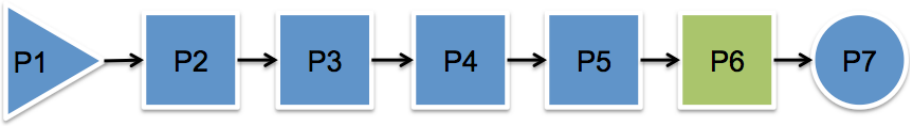


Figure 21. Sixth step of the throwaway prototyping process.

The development of the prototype (P6) was troublesome. The approach of utilizing the mobile devices' ambient light sensor failed due to sensor delay. Also, another approach to utilize the camera function failed because of an inefficient color detection code. However, a corresponding electronic system was built to simulate these sensors. Ultimately, the designed system was applicable and furthermore the pilot study was a success. (Perttula, 2012) Figure 22 presents the refined framework.

A custom-made way to control the game is based on *playfulness* (subchapter 2.3.3). In this case, a novel way to control the game provides elements of *playfulness* such as experimentation, social interaction, silliness, challenge, fantasy, and curiosity. A playful game can contain elements of experimentation (Väänänen-Vainio-Mattila et al., 2008) and social interaction (Rosenbloom, 2003) as the game modification does. Even though this prototype is a game, most of the study participants considered it as an interactive music performance *co-experience* that contains elements of *gamification* (subchapter 2.3.3). Mainly they wanted to have fun and enjoy the experience, instead of competing or collecting points. (Perttula, 2012)

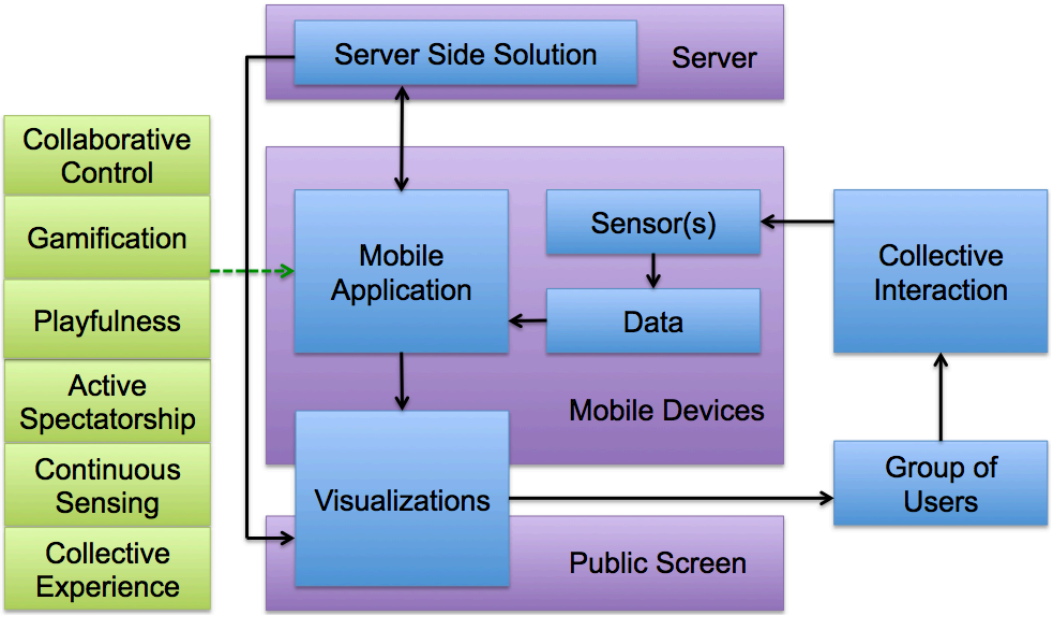


Figure 22. ECI framework after P6.

At this stage the 'users' element was changed to the 'group of users' because the group seemed to fit in the context better than an indefinable amount of users. Based on this prototype (P6), *gamification* and *playfulness* elements were added as design considerations to the framework. All in all, P6 was a high engaging prototype. Study participants did not want to stop playing at all. They were also eager to play it in the future. The objective of the throwaway prototyping was achieved.

4.3 Evaluation before the Final State

The previous subchapter described how the high engaging prototype P6 was achieved. Thus the objective of the framework design process was also attained. This chapter evaluates (see Fig. 9, p. 30 and Fig. 10, p. 36) the designed ECI framework once again. Then in chapter 5 (Results and Discussion of Findings) the final state of the DS process is presented. Furthermore, the whole thesis can be considered as a communication part of the DS approach.

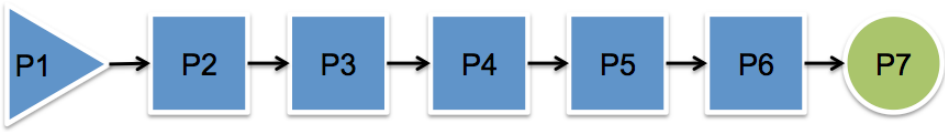


Figure 23. Seventh step of the throwaway prototyping process.

In the last evaluation phase (P7), the framework was used to design and implement a collective sound sensing application in a classroom setting (Perttula et al., 2013 a). In this case, the server side solution was not necessary although it was still possible. All the design considerations, 1) *collaborative control*, 2) *active spectatorship*, 3) *collective experience*, 4) *continuous sensing*, 5) *playfulness*, 6) *gamification*, were utilized to design P7. 1) In this study, a mobile phone is programmed to function as a collective sound sensor. 2) The solution utilizes one mobile phone for sound monitoring and one external display for visualization. 3) To achieve an appropriate learning atmosphere, the designed system attempts to maintain the noise level at a comfortable tolerance level in the classroom. 4) The idea is related to the concept of opportunistic sensing, where the data collection stage is fully automated with no user involvement. 5) Graphics that are based on an egg-shaped character were created to be suitable and entertaining for different age groups from 6 to 18 years. 6) Too noisy environment causes “a game over” visualization and sound level measuring ends up.

The evaluation results indicated that the framework offered knowledge to develop a purposeful prototype that is highly engaging like P6. "Students tried to maintain an appropriate sound level in the classroom because they did not want to break the visualized egg. The application clearly had a persuasive effect on the students. They learned the differences between proper and inappropriate sound levels. In fact, they perceived the experiment as a game. If someone was too noisy the others instructed the disruptive student to be quieter. Team spirit improved significantly during the pilot study. They perceived the application as such a challenge that they discussed among themselves during breaks how they could keep the egg unbroken for as long as possible. During the pilot week, the students asked the teacher if they would have the experiment during the next lesson. And if the answer was no, they were disappointed. Other classes would have liked to try the system, too." (Perttula et al., 2013 a)

Thus no more modifications were implemented in the framework (Fig. 24) at this point. However, to highlight the fact that design considerations affect the whole entity, the dashed arrow has been removed from Figure 24 (compare to Fig. 23) and is replaced with a continuous line around the figure. All in all, during the research process all the design considerations were selected based on the literature review, trial and error approach (throwaway prototyping), intuition, creativity, and evaluation (DS). Collaborative control, active spectatorship and collective experience that is created in social interaction (Battarbee, 2003), are

closely related to collective interaction. Based on the results, they can be considered as a basis of the collective interaction. Furthermore, they seemed to actually positively impact on user experience and engagement. Therefore, they were selected to the ECI framework during the throwaway prototyping approach. Continuous sensing facilitates collaborative control and active spectatorship. Thus, it is also an essential part of the framework. Based on the literature review (chapter 2) and findings of this study, playfulness and gamification influence positively to the user engagement.

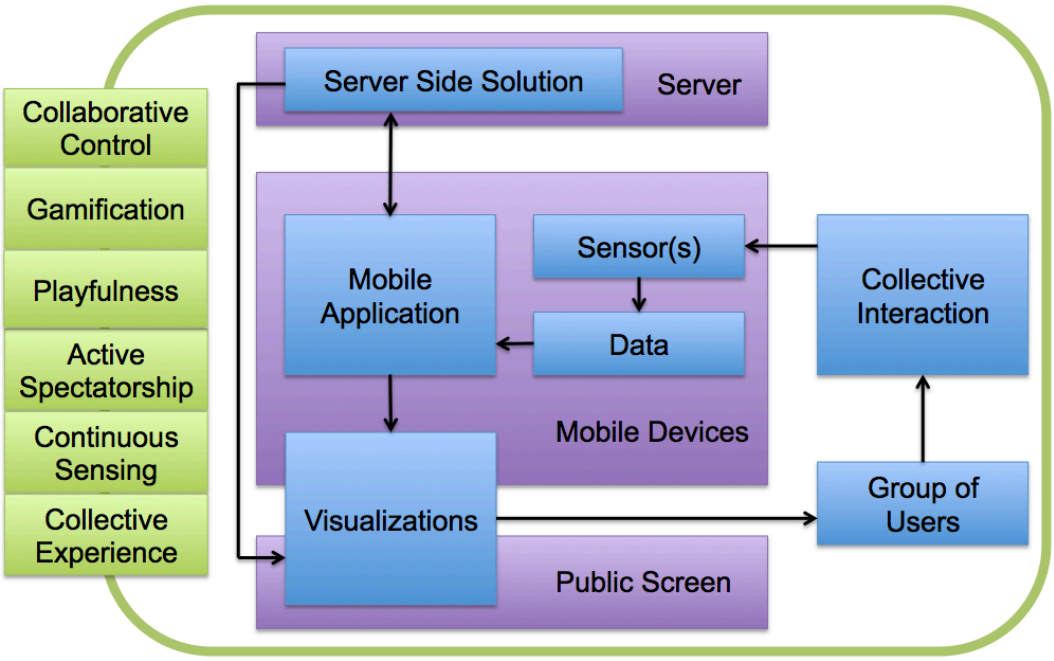


Figure 24. ECI framework after P7.

The next chapter summarizes the presented design process. The final state of the ECI is revealed. Guidelines are also provided for developers to utilize the framework. Furthermore, limitations are discussed.

5. Results and Discussion of Findings

In this chapter, two main outcomes are presented: an *Engaging Collective Interaction* (ECI) framework and *Dual Process Prototyping* (DPP) model. The ECI framework is a result of the throwaway prototyping process combined with the design science approach described in chapter 4. The DPP model is a refined visualization of the design process itself. Furthermore, guidelines for developers and limitations are discussed.

5.1 Conceptual Framework

To sum up the conceptual framework development process (see chapter 4), the key factors of each prototype (P1-P7) are collected in Table 5. Even though two (P6 and P7) of the prototypes fully met the requirements of the study (engagement, collective interaction, and mobile device sensing), all of the prototypes are useful applications for their own purposes. In the case of this study, the intention is not to order them from the worst to the best. Thus, in this case throwaway prototyping produced a set of prototypes, although, according to Jayaswal and Patton (2007), the development process produces a program that performs some essential or perhaps a typical set of functions for the final product.

Table 5. Selected key factors of prototypes P1-P7.

		Prototypes	P1	P2	P3	P4	P5	P6	P7
Technology	Mobile Phone(s)	Mobile Application	X	X	X	X	X	X	X
		Sensors	X	X	X	X	X	X	X
		Data	X	X	X	X	X	X	X
		External Sensor					X		
	Server	Server Side Solution	X	X	X	X	X	X	(X)
Environment	Visualizations	Mobile Phone(s)	X	X	X	X	X	X	X
		Public Screen			X	X	X	X	X
		Computers		X					
	Participants	Users	X	X	X	X	X		
		Group of User						X	X
	Activities	Collective Interaction					X	X	X
Design Considerations		Active Spectatorship				X	X	X	X
		Continuous Sensing				X	X	X	X
		Collective Experience				X	X	X	X
		Collaborative Control					X	X	X
		Gamification						X	X
		Playfulness						X	X
		Level of Engagement		Low		Medium		High	

On the whole, Table 5 indicates that the process made progress with each step. In fact, there are no prototypes with total drawbacks. All of them provided more and more knowledge to build the framework. Furthermore, context categories C1-C4 (see subchapter 1.1, Fig. 2) can be inserted into the framework (Fig. 24, p. 46) to compose the definitive version of the ECI framework (Fig. 25) in this study. Tarasewich's enhanced context categories (Fig. 2, p. 4) were mainly added to clarify the figure. Thus, the final state of the design science process is achieved (see Fig. 9, p. 30).

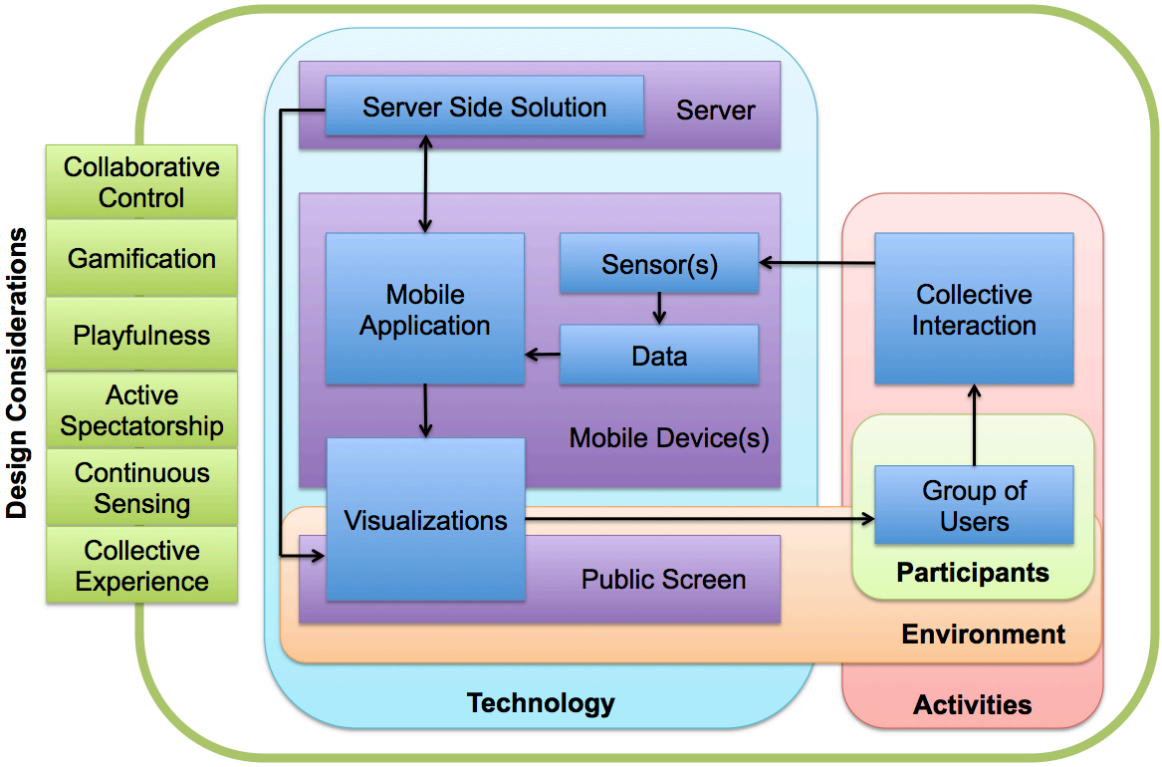


Figure 25. *Engaging Collective Interaction* (ECI) framework.

Some of the elements are overlap each other in the figure (Fig. 25). The simple reason for that is because they can be considered to belong to more than one category. For example, group of users can be seen as a part of activities, environment, and participants. Moreover, design considerations affect the whole system.

5.2 Design Process

The study has shown that it is possible to combine two processes (the throwaway prototyping process & evolutionary and iterative design science process) into a

single entity. The findings of the throwaway prototyping approach were used to design the ECI framework and, conversely, the framework offered knowledge for developing the prototypes. To sum up the design process, Figure 3 (p. 6) is refined below in Figure 26 to illustrate the novel *Dual Process Prototyping* (DPP) model.

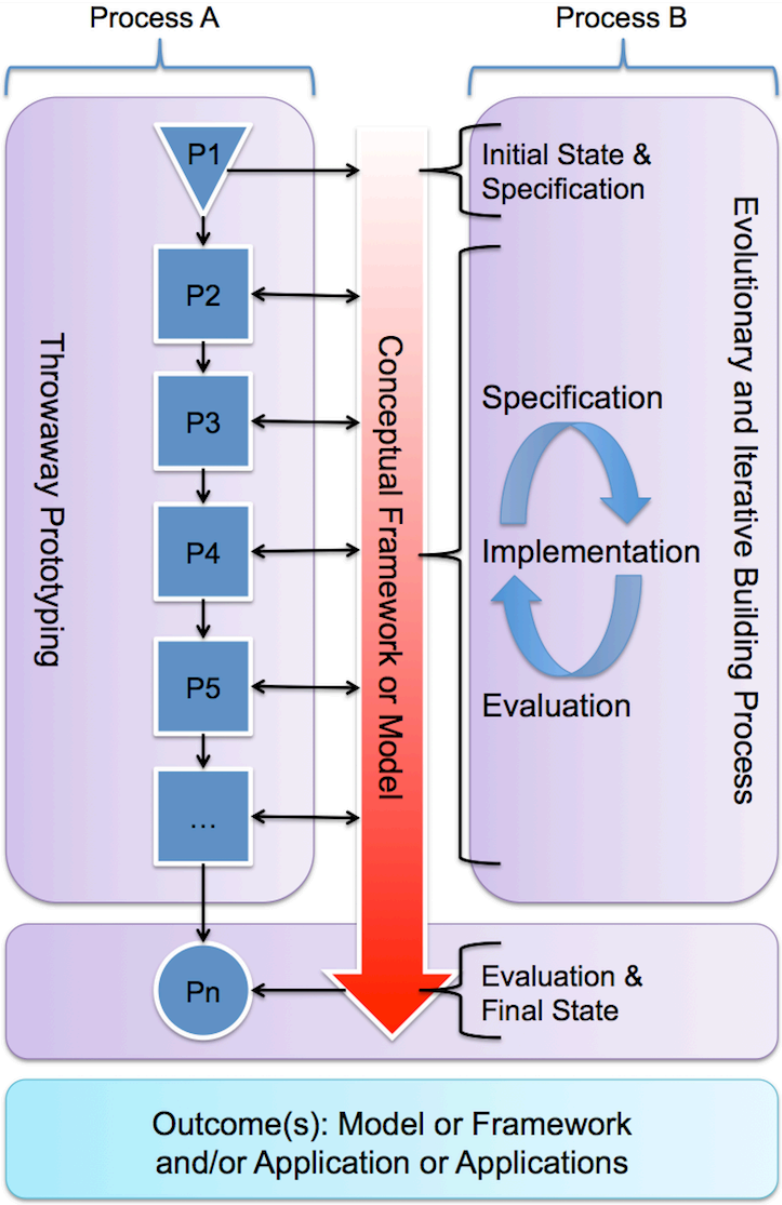


Figure 26. *Dual Process Prototyping* (DPP) model.

There are two processes in DPP as illustrated in Figure 26. Although this study included seven prototypes (P1-P7), the number of prototypes is not restricted. The outcomes pursued may vary depending on the aim of the approach. The aim might be to develop an appropriate application (prototype) or applications or to

design a framework or a model based on prototypes. Hence, there might be one or more outcomes.

5.3 Guidelines

To provide guidelines for developers, each design consideration element (see Fig. 25, p. 48) of the ECI framework is briefly discussed based on the lessons learned during the research process. Although each of them has already been introduced in general in chapter 2, the intention is to provide ideas and viewpoints on how these could be considered. In addition to the design considerations, the framework also includes the aspects of technology, activities, participants, and environment. They form the core of the application but they are also dependent on the design considerations. The design decision affects other elements. For example, a certain kind of collaborative control involves a certain kind of collective interaction. Furthermore, it utilizes certain sensors and it might be the appropriate action for a certain target group of users and so on. All in all, the framework is not a step-by-step guide and each application is its own kind of entity. A successful application does not need to include all or even any of these elements. Therefore, the ECI framework should be considered as a suggestion, guide, or a checklist.

Collaborative Control. As mentioned earlier (subchapter 2.1), collaborative control refers to a mechanism that allows multiple users to control a single entity (Zagal, 2006). Based on the results of this study, collaborative control should be implemented in such a way that it supports collective interaction. In addition to controlling something together, participants are also involved in interaction with each other (see e.g. P6). In the case of P6, collaboratively controlled gameplay requires that multiple players provide collective input for an entity or system (Perttula, 2012). This approach might provide new kinds of experiences and support engagement. Krogh and Petersen (2008) have summed up the five key characteristics of collective interaction (see subchapter 2.1) that also support engagement in the context of this thesis.

Gamification. Even though the application is not a game, there could be a challenge, competition, or task that engages and motivates participants. Another aspect is to provide positive feedback, prizes, or achievements. Game design techniques, game mechanics, and game style could probably be implemented in any kind of collective interaction application. For example, the activity measured could be presented with game-like visualizations (see P7) instead of numbers or

values. During the pilot study of P7, students tried to maintain an appropriate sound level in the classroom because they did not want to break the visualized egg (Perttula et al., 2013 a). The idea is not necessarily to create a game. Instead, the intention is to motivate participants.

Playfulness. There should be a way to motivate and activate participants; playfulness is a tool for it. According to Väänänen-Vainio-Mattila et al. (2008), playfulness can contain elements of experimentation. Furthermore, according to Rosenbloom (2003), it can also contain social interaction. These support the findings of this study that collective interaction could be arranged in a silly and novel way. See e.g. P6 – players utilized mobile devices to control a virtual guitar (Perttula, 2012). When participants are involved in performing out of the context activity to control the application, a new kind of experience might occur. In addition, playfulness may include some humor in visualizations.

Active Spectatorship. As described in subchapter 2.1, active spectatorship involves participants in social interaction with other participants instead of passive spectating (Esbjörnsson et al., 2006; Jacucci et al., 2007 a; Jacucci et al., 2007 b). According to the research of O'Brien and Toms (2008), it is important to maintain the participants' attention and interest. Thus the key idea is to provide awareness of what the system is doing and feeling connected to the technology and to the other participants. Participants should be in control over what is happening. These aspects generate positive emotions in users. (O'Brien and Toms, 2008) Overall, it is important to focus on meaningful visualizations that are informative, entertaining, and interactive. Participants should be able to see their actions affect the visualizations in real-time (see e.g. P5). For example in the case of P5, collective heart rate is visualized in real-time (Perttula et al., 2013 b).

Continuous Sensing. If participants have to perform extra actions to provide input for the sensors utilized, the overall experience will probably get worse. For example, taking and tagging photos may interfere with collective interaction, participation, and co-experience. Thus, it is essential to focus on simplicity and furthermore continuous and opportunistic sensing. In addition, every reading measured is not always important to users (see e.g. P7). There are only three visualized images based on all decibel readings measured in the case of P7 (Perttula et al., 2013 a). Therefore, reduced sensing might offer a more user-friendly end result. It can also scale down for example a mobile device's power consumption and wireless network traffic between the devices and the server.

Another perspective is whether sensors could be used in unseen ways? For example, in video games novelty is usually unexpected auditory or visual stimuli (Aboulafia & Bannon, 2004) but in the content of this thesis the sensors also offer this aspect. In fact, novelty played an important role in this study. Each presented prototype (P1-P7) was unprecedented to the study participants. It might have had a positive effect on the experience and furthermore engagement. For example, in P7 a microphone is utilized to control a crashing egg instead of phone calls or voice recording (Perttula et al., 2013 a). However, Webster and Ho (1997) suggest that participants do not wish for so much novelty that they become lost while trying to complete their task. Therefore, despite the novelty aspect, it is important to design clear and easy ways or actions to control an application.

Collective Experience. To create an engaging and a successful application, the focus of design should be shifted from a technological solution to support collective experience more. It could be the starting point of a design and development process. What kind of collective experience is pursued and how to achieve it or how to enhance existing co-experience? When these have been answered, thereafter the question is raised of how to implement it from a technological point of view? It is good to keep in mind that the action of co-experience is creative and collaborative (Battarbee, 2003; Battarbee and Koskinen, 2005). For example P4 presents games that are based on collective experience (Kiili et al., 2010).

5.4 Limitations

The current findings are based on a limited number of study participants at specific events or situations. As in most exploratory research, it is difficult to make absolute conclusions. In addition, although the ECI framework was evaluated after each build cycle with a new prototype, the last version of the ECI based on the P6 was evaluated only once (P7) during this study. Also, the DPP model needs further investigations even though it is an outcome of this study. However, the findings are in accordance with the literature review, leading one to speculate about the potential for generalization.

In the case of engagement, the literature indicates that there is not enough empirical evidence about how it should be measured (Webster & Ho, 1997; Jacques et al., 1995). According to O'Brien and Toms (2008), attempts so far have been incomplete, non-generalizable, or one-dimensional. As in this study,

measurement of the participants' engagement is limited. However, observations and interviews offered rough evidence about engaging prototypes. Furthermore, the key factors of the ECI framework were also difficult to determine. On the whole, the throwaway prototyping process combined with the literature findings revealed elements that engaged the study participants in the context of this thesis.

The ECI framework does not provide a step-by-step guide for designing applications. In fact, the essential intention was not to create a step-by-step guide. Instead, the framework presents suggestions; it may generate novel ideas and it helps to refine the design of successful applications. The overall benefit of the framework is that developers can pay attention to the factors of an engaging application in the early stage of design.

The intention of throwaway prototyping is to develop prototypes relatively fast. It is also known as rapid prototyping. (Kordon and Luqi, 2002) However, in the kind of purpose as described in this thesis the process was not quick at all. Arranging field pilots, analyzing results and determining the subsequent steps during the process were time-consuming. In other hand, everything is relative; software development projects take their time. It is good to keep in mind that although the development of the prototypes is probably rapid, the whole process tends to be time-consuming.

Specification of the initial state based on the first prototype (P1) could be more exact and constrained. To study engagement, collective interaction, and mobile device sensing altogether is challenging and demands a broad approach. Therefore, this study may also be difficult to repeat. However, the intention was not to limit the research to one certain kind of application and improve it. On the contrary, the intention was to develop different kinds of prototypes and thus find out the kinds of solutions that engage users and that are enabled by sensors. All in all, as mentioned earlier (see subchapter 3.1) the purpose of exploratory research is to help to give a better understanding of the research problem (Lambin, 2000; Bell, 2010) and form a basis for conclusive research (Singh, 2007).

6. Conclusions

The goal of this thesis has been to examine how to create *engaging collective interaction applications for mobile devices*. The goal was attained using the design science approach combined with the throwaway prototyping process. Based on the studies (P1-P7) conducted for this thesis, the research question RQ and aims A1-A3 (see subchapter 1.3) can be answered:

(RQ) The ECI framework (Fig. 25, p. 48) presents the conceptual and technological key factors for designing *engaging collective interaction applications for mobile devices*. In particular, the factors which affect user engagement are *collaborative control*, *gamification*, *playfulness*, *active spectatorship*, *continuous sensing,* and *collective experience*. The framework also highlights the importance of the mobile application, server side solution, visualizations, and the group of users, *collective interaction*, sensors, and data. Each of them has a role within the entity to form an *engaging collective interaction application for mobile devices*. The ECI framework is discussed in more detail in subchapter 5.1.

(A1) Mobile device sensing enables new kinds of opportunities in this context. Nowadays, mobile devices include a set of different kinds of sensors. These can be utilized in novel ways to provide users with engaging collective experiences. This thesis has tried to give some ideas about opportunities for designers and developers. Mobile device sensing is also an essential part of applications in this context. In fact, sensors enable these *engaging collective interaction applications for mobile devices*.

(A2) Based on the findings of the study, users were especially attracted to and engaged by prototypes P6 and P7. Therefore, P6 was an end point of the throwaway prototyping process and P7 was implemented to evaluate the designed framework. In fact, the study participants did not want to discontinue using these solutions, which includes all the elements of the ECI framework. Further, the results indicated that when focus is more on activity rather than on technology, it has a positive impact on engagement. Although it is

not possible to provide a definition of the perfect solution in this context, the ECI presents design considerations in particular.

(A3) There are still some design issues. How to implement *collaborative control*, *gamification*, *playfulness*, *active spectatorship*, *continuous sensing,* and *collective experience*? How to combine these design considerations into a working entity? This needs creative thinking and there is no straightforward answer to this question. In addition to the idea of the application, it might need a couple of prototypes (throwaway prototyping) to create a successful solution.

6.1 Main Outcomes

In addition to the prototypes created, there are two main outcomes of this thesis. The first one is called the *Engaging Collective Interaction* (ECI) framework (see subchapter 5.1), and the second one is *Dual Process Prototyping* (DPP) model (see the model in subchapter 5.2).

(ECI) This research has shown that a framework for *engaging collective interaction applications for mobile devices* can be designed and it can be utilized to build an appropriate mobile application. As mentioned earlier, the ECI framework (see Fig. 25, p. 48) is also the answer to the RQ.

(DPP) In addition, the evolutionary and iterative framework building process in accordance with design science activities, combined with the throwaway prototyping process can be presented as an unseen DPP model (see Fig. 26, p. 49).

Therefore it is claimed in this thesis that:

1) ECI can be used to design *engaging collective interaction applications for mobile devices*.

2) DPP is an appropriate method for building a framework or a model.

As mentioned in subchapter 5.4 (Limitations), more empirical work and evidence is required to evaluate both of the outcomes (ECI and DPP). Nevertheless, this

thesis offers a starting point to develop these further. Thus in the next subchapter, it is meaningful to reveal and focus on other future work topics that came up during the study. Those presented here mainly concentrate on mobile technology (e.g. future sensors, sensor data, energy and resource management). These issues offer challenges for researchers as well as developers.

6.2 Future Work

As mentioned in subchapter 5.4 (Limitations), the intention of the ECI framework is not to provide a step-by-step guide for designing applications. However, one of the future work topics is to upgrade the ECI framework with technological aspects of possible issues on an implementation, upscaling, performance and system stability. In addition to mobile technology issues, the engagement metrics (see subchapter 2.3.2 and Fig. 8) presented and utilized in this study could be evaluated and developed further. At least it seemed to be a suitable approach in the case of this thesis by offering rough evidence of the level of engagement. However, it is important to keep in mind that it was also considered a limitation of the study (see subchapter 5.4). Engagement measurement will remain a research problem in the future, since there are no commonly agreed measuring methods and metrics (Lehmann et al., 2012; O'Brien and Toms, 2010)

As mobile device technology is progressing all the time, there might also be new aspects to take into consideration with the ECI framework. Interesting questions are what kinds of new sensors there will be over the next few years and what will they enable? Choudhury et al. (2008) have already shown value from using barometer, temperature, and humidity sensors for activity recognition. For example, accelerometer sensor readings combined with barometer values can be used to identify walking, climbing stairs, and the direction of these activities. Honicky et al. (2008) have studied air quality with custom-made sensors embedded in mobile devices. Poh et al. (2009) have embedded sensors in mobile device earphones to read blood pressure values. Campbell et al. (2010) have used neural signals from customer-level electroencephalography (EEG) headsets to control mobile devices. All these sensors may be included in mobile devices in the near future. (Lane et al., 2010) Thus, these sensors offer interesting research opportunities currently as external sensors. In addition, not all of the mentioned sensors in Figure 6 (p. 20) were utilized in this study. For example, the creative utilization of the NFC sensor could offer a new kind of co-experience.

Mobile device sensors collect raw sensor data that is worthless without interpretation (e.g. human behavior recognition). For example, accelerometer sensor readings do not reveal the user's activities or movements directly. Instead, the sensor produces measurements of acceleration forces. A variety of data mining and statistical tools can be used to distill information from the data collected. (Lane et al., 2010) Thus, it is possible to extract features from the data. Furthermore, these features can be identified as classified inferences such as walking and standing in the case of the accelerometer sensor. Figure 27 presents three processes to handle sensor data. However, different kinds of sensors produce different kinds of raw data (compare e.g. a camera and an accelerometer sensor). This is challenging. Recognizing specified inferences more exactly from raw sensor data is obviously one task for future work.

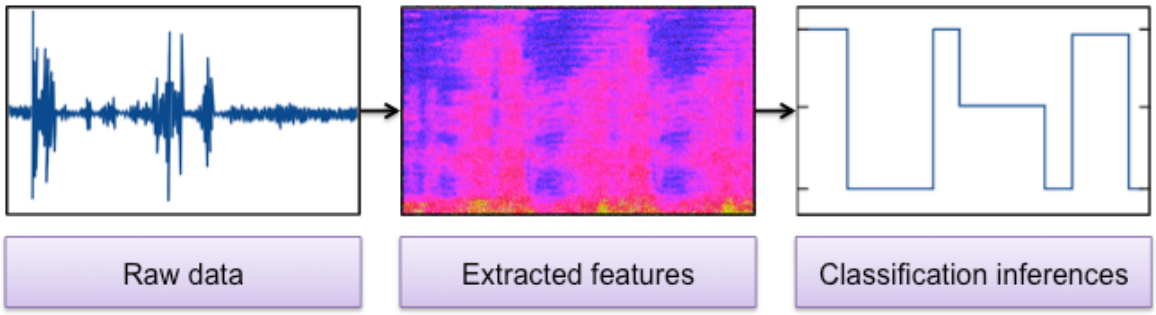


Figure 27. Processing the sensor data (Lane et al., 2010).

During the pilot studies of prototypes (P1-P7), the issue of energy management arose. According to Lane et al. (2010), radio interfaces in particular such as Bluetooth and GPS are power-hungry. Therefore, it is important to design efficient duty-cycles for the application. It is challenging to reduce the use of these wireless connections without impacting the overall experience. The sensing and classification algorithms discussed earlier can also reduce battery life. Signal processing and machine learning require the mobile device's computational resources, which also consume power. Therefore, the application should be designed in a way that the sensors are utilized as little as possible. In contrast, Lane et al. (2010) argue that continuous sensing may enable novel real-time applications in the future. However, the power consumption aspect combined with continuous sensing for example should be studied and developed further. Furthermore, continuous sensing should be enabled without disrupting the making of calls, etc. In general, researchers and developers should currently be seeking breakthroughs in low-energy algorithms. (Lane et al., 2010)

P7 was a step towards mobile learning. It is also one interesting direction for future work. Spikol (2010) has created 'A Design Toolkit for Emerging Learning Landscapes Supported by Ubiquitous Computing' and Specht et al. (2011) have studied mobile augmented reality for learning. Could the ECI be utilized in a mobile learning context or could it be combined with Spikol's (2010) toolkit? In addition, what kind of augmented reality collective interaction applications could be designed?

Furthermore, this study indicated that it is important to take the presumed target group into consideration. For example, in the case of P7, the younger age group of study participants appreciated the solution more than the older ones. All in all, this observation is relevant for all the designed prototypes P1-P7. Tapscott's (2008) Grown Up Digital book gives a view of this phenomenon. However, whether it is possible to design a collective interaction mobile device application in a way to engage all kinds of people (e.g. young, old, female and male) can be seen as a research problem for future work. Could this kind of approach be implemented in the ECI framework?

6.3 Summary

To sum up, this thesis presented the design process of a novel *Engaging Collective Interaction* (ECI) framework that can be used to design *engaging collective interaction applications for mobile devices*. The initial state of the process is based on the prototype P1. In the building and evaluating phase of design science, six different prototypes (P2-P7) were implemented during the throwaway prototyping process. The implementation of an engaging prototype was realized and thus the established goal was achieved. During the study, key factors that seemed to affect engagement were picked up and added to the framework. These design considerations are *collaborative control*, *gamification*, *playfulness*, *active spectatorship*, *continuous sensing,* and *collective experience* (see subchapter 5.1). After throwaway prototyping, the framework was evaluated once again (P7) before the final state; the ECI framework was used to design and implement a mobile application in the context of this thesis. The evaluation results indicated that the framework offered knowledge for developing a purposeful application.

Additionally, the throwaway prototyping method was found to be a valuable tool in designing a novel framework. Furthermore, the design science based evolutionary and iterative framework building process combined with the throwaway prototyping process can be presented as an unseen *Dual Process Prototyping* (DPP) model (see subchapter 5.2). While the experiments were limited, it has been shown that it is possible to create an *engaging collective interaction application for mobile devices*. Study participants seemed to appreciate these kinds of applications. Also, it is possible to define the key factors for designing such a solution. Furthermore, the key factors can be presented as a framework (ECI) for developers. The framework does not provide a step-by-step guide for designing applications, but it helps to refine the design of successful ones. More empirical work and evidence are required to evaluate both of the outcomes (ECI and DPP). Nevertheless, this thesis offers a starting point for developing these further. Finally, for an overview of this thesis, please refer to Figures 3 (p. 6), 4 (p. 14), 9 (p. 30), 10 (p. 36), 25 (p. 48), and 26 (p. 49).

References

Aboulafia, A., & Bannon, L. J. (2004). Understanding affect in design: an outline conceptual framework. Theoretical issues in ergonomics science, 5(1), pp. 4-15.

Abowd, G. D., & Mynatt, E. D. (2000). Charting past, present, and future research in ubiquitous computing. ACM Transactions on Computer-Human Interaction (TOCHI), 7(1), pp. 29-58.

Archer, L. B. (1984). Systematic method for designers. In. N. Cross (ED.), Developments in design methodology, pp. 57-82.

Armstrong, S. (2007). Wireless connectivity for health and sports monitoring: a review. British journal of sports medicine, 41(5), pp. 285-289.

Atkinson, M., & Kydd, C. (1997). Individual characteristics associated with World Wide Web user: An empirical study of playfulness and motivation. The DATA BASE for Advances in Information Systems, 28(2), pp. 53–62.

Attfield, S., Kazai, G., Lalmas, M., & Piwowarski, B. (2011). Towards a science of user engagement. Workshop on User Modeling for Web Applications, Feb 2011, Hong Kong, China.

Bardram, J. (1998). Collaboration, Coordination and Computer Support: An Activity Theoretical Approach to the Design of Computer Supported Cooperative Work. Ph. D. Thesis. DAIMI PB, 27(533).

Bass, L., Clements, P., & Kazman, R. (2003). Software architecture in practice. Addison-Wesley Professional.

Battarbee, K. (2003, June). Defining co-experience. In Proceedings of the 2003 international conference on Designing pleasurable products and interfaces, ACM, pp. 109-113.

Battarbee, K., & Koskinen, I. (2005). Co-experience: user experience as interaction. CoDesign, 1(1), pp. 5-18.

Bell, J. (2010). Doing your research project. Open University Press.

Benbasat, I. (1984). An analysis of research methodologies. The Information Systems Research Challenge, pp. 47-85.

Berieter, C., & Scardamalia, M. (1992). Surpassing ourselves: An inquiry into the nature and implications of expertise. Chicago, IL: Open Court.

Blythe, M., Overbeeke, K., Monk, A.F., & Wright, P.C. (2003). Funology: From usability to enjoyment (Vol. 3). Dordrecht, The Netherlands: Kluwer.

Bouca, M. (2012). Mobile Communication, Gamification and Ludification. Proceedings of 16th International Academic MindTrek Conference: Envision Future Media Environments. October 3-5, 2012, Tampere, Finland, pp. 295-301. ISBN: 978-1-4503-1637-8.

Brown, R. B. (2006). Doing your dissertation in business and management: the reality of researching and writing. Sage Publications Limited.

Brown, E., & Cairns, P. (2004). A grounded investigation of game immersion. In the proceedings of the ACM Conference on Human Factors in Computing. ACM Press, pp. 1297-1300.

Bruegge, B., & Dutoit, A. H. (2004). Object-Oriented Software Engineering Using UML, Patterns and Java-(Required). Prentice Hall.

Burke, J. A., Estrin, D., Hansen, M., Parker, A., Ramanathan, N., Reddy, S., & Srivastava, M. B. (2006). Participatory sensing. WSW ’06 at Sensys ’06, Oct 31, 2006, Boulder, Colorado, USA.

Campbell, A. T., Eisenman, S. B., Lane, N. D., Miluzzo, E., & Peterson, R. A. (2006, August). People-centric urban sensing. In Proceedings of the 2nd annual international workshop on Wireless internet, ACM, p. 18.

Campbell, A. T., Choudhury, T., Hu, S., Lu, H., Mukerjee, M. K., Rabbi, M., & Raizada, R. D. (2010, August). NeuroPhone: brain-mobile phone interface using a wireless EEG headset. In Proceedings of the second ACM SIGCOMM workshop on Networking, systems, and applications on mobile handhelds, ACM, pp. 3-8.

Carroll, J. M., & Rosson, M. B. (1987). Paradox of the active user. In Carroll, J. M. (Ed), Interfacing Thought: Cognitive Aspects of Human-Computer Interaction. Cambridge, MA, US, MIT Press (1987), pp. 80–111.

Carter, S., Denoue, L., & Perttula, A. (2010). Image Matching in Support of Mobile Navigation. U.S. Patent Application 12/359,222. Filed January 23, 2009.

Champion, E. (2003, February). Applying game design theory to virtual heritage environments. In Proceedings of the 1st international conference on Computer graphics and interactive techniques in Australasia and South East Asia, ACM, pp. 273-274.

Chapman, P. (1997). Models of engagement: Intrinsically motivated interaction with multimedia learning software. Unpublished master's thesis, University of Waterloo, Waterloo, Canada. Chapman, P., Selvarajah, S., & Webster, J. (1999). Engagement in multimedia training systems. In Proceedings of the 32nd Hawaii International Conference on System Sciences. Washington, DC: IEEE, p. 1084.

Chapman, P., Selvarajah, S., & Webster, J. (1999). Engagement in multimedia training systems. In Proceedings of the 32nd Hawaii International Conference on System Sciences (HICSS-32), Los Alamitos, CA. IEEE Press, pp. 1-9.

Choudhury, T., Consolvo, S., Harrison, B., Hightower, J., LaMarca, A., LeGrand, L., Rahimi, A., Rea, A., Borriello, G., Hemingway, B., Klasnja, P., Koscher, K., Landay, J. A., Lester, J., Wyatt, D., & Haehnel, D. (2008). The mobile sensing platform: An embedded activity recognition system. Pervasive Computing, IEEE, 7(2), pp. 32-41.

Cole, R., Purao, S., Rossi, M., & Sein, M. K. (2005, December). Being proactive: where action research meets design research. In Proceedings of the Twenty-Sixth International Conference on Information Systems, pp. 325-336.

Csikszentmihalyi, M. (1990). Flow. New York: Harper Collins Publishers, 1990.

Dahlbom, B. (1996). The new informatics. Scandinavian Journal of Information Systems, 8, pp. 29-48.

Denning, P. J. (1997). A new social contract for research. Communications of the ACM, 40(2), pp. 132-134.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining gamification. In Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, ACM, pp. 9-15.

Dobrian, F., Awan, A., Joseph, D., Ganjam, A., Zhan, J., Sekar, V., Stoica, I., & Zhang, H. (2011). Understanding the impact of video quality on user engagement. SIGCOMM-Computer Communication Review, 41(4), 362 pp.

Draper, S. W. (1999). Analysing fun as a candidate software requirement. Personal and Ubiquitous Computing, 3(3), pp. 117-122.

Eekels, J., & Roozenburg, N. F. (1991). A methodological comparison of the structures of scientific research and engineering design: their similarities and differences. Design Studies, 12(4), pp. 197-203.

Esbjörnsson, M., Brown, B., Juhlin, O., Normark, D., Östergren, M., & Laurier, E. (2006, April). Watching the cars go round and round: designing for active spectating. In Proceedings of the SIGCHI conference on Human Factors in computing systems, ACM, pp. 1221-1224.

Forlizzi, J., & Battarbee, K. (2004, August). Understanding experience in interactive systems. In Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques, ACM, pp. 261-268.

Fuller, R. B., & McHale, J. (1963). World Design Science Decade 1965–1975. Five Two-Year Phases of World Retooling Design Proposed to the International Union of Architects for Adaptation by World Architectural Schools. Phase I (1963). Document 1. Inventory of World Resources Human Trends and Needs. World Resources Inventory, Southern Illinois University, Carbondale, Illinois, USA.

Fullerton, T., Swain, C., & Hoffman, S. (2004). Game Design Workshop: Designing, prototyping, and play testing games. Focal Press.

Gregory, S. A. (Ed.). (1966). The design method. Butterworths.

Göth, C., & Schwabe, G. (2008). Designing tasks for engaging mobile learning. In Proceedings MLearn2008 conference Telford, UK.

Hanson, C. W. (2011). Chapter 2: Mobile Devices in 2011. Library Technology Reports, 47(2), pp. 11-23.

Hassenzahl, M., & Tractinsky, N. (2006). User experience: A research agenda. Behaviour and Information Technology, 25(2), pp. 91–97.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. MIS quarterly, 28(1), pp. 75-105.

Hindmarsh, J., Heath, C., Vom Lehn, D., & Cleverly, J. (2005). Creating Assemblies in Public Environments: Social interaction, interactive exhibits and CSCW. Computer Supported Cooperative Work (CSCW), 14(1), pp. 1-41.

Honicky, R., Brewer, E. A., Paulos, E., & White, R. (2008, August). N-smarts: networked suite of mobile atmospheric real-time sensors. In Proceedings of the second ACM SIGCOMM workshop on Networked systems for developing regions, ACM, pp. 25-30.

Huotari, K., & Hamari, J. (2012, October). Defining gamification: a service marketing perspective. In Proceeding of the 16th International Academic MindTrek Conference, ACM, pp. 17-22.

Jacko, J. A. (2012). Human-Computer Interaction Handbook (3rd Edition). CRC Press. ISBN 1-4398-2943-8.

Jacques, R., Preece, J., & Carey, T. (1995). Engagement as a design concept for multimedia. Canadian Journal of Educational Communication, 24(1), pp. 49-59.

Jacucci, G., Oulasvirta, A., Ilmonen, T., Evans, J., & Salovaara, A. (2007, April). Comedia: mobile group media for active spectatorship. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 1273-1282). ACM.

Jayaswal, B. K., & Patton, P. C. (2007). Design for Trustworthy Software: Tools, Techniques, and Methodology of Developing Robust Software. Prentice-Hall PTR.

Jennings, M. (2000). Theory and models for creating engaging and immersive ecommerce Web sites. In Proceedings of the 2000 ACM SIGCPR Conference on Computer Personnel Research, New York: ACM, pp. 77-85.

Järvinen, P. (2004). On research methods. Tampere, Finland: Opinpajan kirja.

Kangas, S., & Cavén-Poysa, O. (2005). Ambient utility games: connecting utility to play. International Conference on Internet and Multimedia Systems and Applications (EuroIMSA '05), February 21-23, 2005, Grindelwald, Switzerland, pp. 18-24.

Kappelman, L. A. (1995). Measuring user involvement: A diffusion of innovation perspective. Database Advances, 26(2/3), pp. 65-86.

Kiili, K. (2005). On Educational Game Design: Building Blocks of Flow Experience. Thesis for the degree of Doctor of Philosophy. Tampere University of Technology. Publication 571. ISBN: 952-15-1489-2.

Kiili, K., Perttula, A., & Tuomi, P. (2010). Development of Multiplayer Exertion Games for Physical Education. IADIS International Journal on WWW/Internet. Vol. 8, No. 1, pp. 52-69. ISSN: 1645-7641.

Kjeldskov, J., & Graham, C. (2003). A review of mobile HCI research methods. Human-computer interaction with mobile devices and services, pp. 317-335.

Kordon, F., & Luqi (2002). An introduction to Rapid System Prototyping. The IEEE Computer Society, Sep 2002, Vol. 28, No. 9, pp. 817-821.

Krogh, P. G., & Petersen, M. G. (2008, May). Collective Interaction--Let's join forces. In proceedings of COOP, Vol. 8, pp. 20-23.

Kuts, E. (2009, September). Playful user interfaces: Literature review and model for analysis. In Breaking New Ground: Innovation in Games, Play, Practice and

Theory: Proceedings of the 2009 Digital Games Research Association Conference, London.

Lambin, J. J. (2000). Market-Driven Management, Strategic and Operational Marketing, Macmillan Business, London.

Lane, N. D., Miluzzo, E., Lu, H., Peebles, D., Choudhury, T., & Campbell, A. T. (2010). A survey of mobile phone sensing. Communications Magazine, IEEE, 48(9), pp. 140-150.

Laurel, B. (1993). Computers as theatre. Reading, MA: Addison-Wesley.

Lazzaro, N. (2004). Why we play games: 4 keys to more emotion. In Proceedings of Game Developers Conference 2004.

Lehmann, J., Lalmas, M., Yom-Tov, E., & Dupret, G. (2012). Models of user engagement. User Modeling, Adaptation, and Personalization, pp. 164-175.

Lewis, I. M. (1985). Social Anthropology in Perspective. Cambridge University Press.

Lin, T., Maejima, A., & Morishima, S. (2008, May). Using subjective and physiological measures to evaluate audience-participating movie experience. In Proceedings of the working conference on Advanced visual interfaces, ACM, pp. 49-56.

Lu, H., Pan, W., Lane, N. D., Choudhury, T., & Campbell, A. T. (2009, June). SoundSense: scalable sound sensing for people-centric applications on mobile phones. In Proceedings of the 7th international conference on Mobile systems, applications, and services, pp. 165-178.

Ludvigsen, M. (2005). Designing for Social Use in Public Places – a Conceptual Framework of Social Interaction. In Proceedings of Designing Pleasurable Products and Interfaces, DPPI 05, pp. 389-408.

Malhotra, N., & Birks, D. (2000). Marketing Research: An Applied Approach. European Edition, Prentice Hall.

Malone, T. W. (1982, March). Heuristics for designing enjoyable user interfaces: Lessons from computer games. In Proceedings of the 1982 conference on Human factors in computing systems, ACM, pp. 63-68.

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. Decision support systems, 15(4), pp. 251-266.

Markus, M. L., Majchrzak, A., & Gasser, L. (2002). A design theory for systems that support emergent knowledge processes. Mis Quarterly, pp. 179-212.

Marschak, J., & Radner, R. (1972). Economic theory of teams. New Haven, CT: Yale University Press.

Marshall, C., & Rossman, G. B. (2006). Designing Qualitative Research. Sage Publications.

McGonigal, J. (2011). Reality is broken: Why games make us better and how they can change the world. Penguin Press HC.

Merriam-Webster, Inc (Ed.). (2003). Merriam-Webster's collegiate dictionary. Merriam-Webster.

Michalowski, M. P., Sabanovic, S., & Simmons, R. (2006). A spatial model of engagement for a social robot. In Advanced Motion Control, 2006. 9th IEEE International Workshop on, IEEE, pp. 762-767.

Miluzzo, E., Lane, N. D., Fodor, K., Peterson, R., Lu, H., Musolesi, M., Eisenman, S. B., Zheng, X., & Campbell, A. T. (2008, November). Sensing meets mobile social networks: the design, implementation and evaluation of the CenceMe application. In Proceedings of the 6th ACM conference on Embedded network sensor systems, ACM, pp. 337-350.

Multisilta, J., & Perttula, A. (2011). Learning Scenarios with Wireless and Networked Sensors. The 2nd International Conference on Education, Training and Informatics: ICETI 2011. March 27-30, 2011, Orlando, Florida, USA, pp. 300-305. ISBN: 978-1-936338-18-4.

Multisilta, J., & Perttula, A. (2013). Supporting Learning with Wireless Sensor Data. Future Internet, 5(1), pp. 95-112. DOI: 10.3390/fi5010095.

Multisilta, J., Perttula, A., Suominen, M., & Koivisto, A. (2010). Mobile Video Sharing: Documentation Tools for Working Communities. Proceedings of the EuroITV 2010, 8th European Conference on Interactive TV and Video. June 9-11, 2010, Tampere, Finland, pp. 31-38. ISBN: 978-1-60558-831-5.

Mun, M., Reddy, S., Shilton, K., Yau, N., Burke, J., Estrin, D., Hansen, M., Howard, E., West, R., & Boda, P. (2009, June). PEIR, the personal environmental impact report, as a platform for participatory sensing systems research. In Proceedings of the 7th international conference on Mobile systems, applications, and services, ACM, pp. 55-68.

Myers, M. D. (1997). Qualitative research in information systems. Management Information Systems Quarterly, 21, pp. 241-242.

Naumann, J. D., & Jenkins, A. M. (1982). Prototyping: the new paradigm for systems development. Mis Quarterly, pp. 29-44.

Nosowitz, D. (2011). Everything You Need to Know About Near Field Communication. Popular Science Magazine. Popular Science. Retrieved 14 June 2011.

Nunamaker, J. F., Chen, M., & Purdin, T. D. M. (1990). Systems development in information systems research. Journal of Management Information Systems, Vol. 7, No. 3 (Winter 1990–91), pp. 89-106.

O'Brien, H. L., & Toms, E. G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. Journal of the American Society for Information Science and Technology, 59(6), pp. 938-955.

O’Brien, H. L., & Toms, E. G. (2010). The development and evaluation of a survey to measure user engagement in e-commerce environments. Journal of the American Society for Information Science & Technology, 61(1), pp. 50-69. DOI: 10.1002/asi.21229.

Parasuraman, A., Grewal, D., & Krishnan, R. (2006). Marketing Research. 2nd edition. Houghton Mifflin Company, U.S.A. 641 pp. ISBN 13: 978-0-618-66064-3.

Peffers, K., Tuunanen, T., Rothenberger, M., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems. Vol. 24, No. 3, Winter 2007-2008, pp. 45-77. DOI: 10.2753/MIS0742-1222240302.

Peltonen, P., Salovaara, A., Jacucci, G., Ilmonen, T., Ardito, C., Saarikko, P., & Batra, V. (2007, December). Extending large-scale event participation with user-created mobile media on a public display. In Proceedings of the 6th international conference on Mobile and ubiquitous multimedia, ACM, pp. 131-138.

Perttula, A. (2012). When a Video Game Transforms to Mobile Phone Controlled Team Experience. Proceedings of 16th International Academic MindTrek Conference: Envision Future Media Environments. October 3-5, 2012, Tampere, Finland, pp. 302-309. ISBN: 978-1-4503-1637-8.

Perttula, A., Carter, S., & Denoue, L. (2009). Kartta: using multimedia and context to navigate unfamiliar environments. In: Lugmayr, A. et al. (eds). Proceedings of 13th International Academic MindTrek Conference: Everyday Life in the Ubiquitous Era, 30.9.-2.10.2009, Tampere, Finland.

Perttula, A., Carter, S., & Denoue, L. (2011 a). Retrospective vs. prospective: Two approaches to mobile media capture and access. International Journal of Arts and Technology. Vol. 4, Issue 3, 2011, pp. 249-259. DOI: 10.1504/IJART.2011.041480.

Perttula, A., Koivisto, A., Mäkelä, R., Suominen, M., & Multisilta, J. (2011 b). Social Navigation with The Collective Mobile Mood Monitoring System. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. September 28-30, 2011, Tampere, Finland, pp. 117-124. ISBN: 978-1-4503-0816-8.

Perttula, A., Multisilta, J., & Tuomi, P. (2013 a). Persuasive Mobile Device Sound Sensing in a Classroom Setting. International Journal of Interactive Mobile Technologies (iJIM). Vol. 7, No 1 (2013), pp. 16-24. ISSN: 1865-7923.

Perttula, A., Tuomi, P., Kiili, K., Suominen, M., Koivisto, A., & Multisilta, J. (2013 b). Enriching Shared Experience by Collective Heart Rate. International Journal of Social and Humanistic Computing. Vol. 2, Nos. 1/2, 2013, pp. 31-50. ISSN online: 1752-6132.

Petersen, M. G., Krogh, P. G., Mortensen, M. B., Møller-Lassen, T., & Mortensen, D. H. (2010, October). Collective interaction by design collective controllers for social navigation on digital photos. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, ACM, pp. 353-362.

Poh, M. Z., Kim, K., Goessling, A. D., Swenson, N. C., & Picard, R. W. (2009, September). Heartphones: Sensor earphones and mobile application for non-obtrusive health monitoring. In Wearable Computers, 2009. ISWC'09. International Symposium on, IEEE, pp. 153-154.

Quesenbery, W. (2003). Dimensions of usability. In M.Albers & B.Mazur (Eds.), Content and complexity: Information design in technical communications, Mahwah, N.J.: Lawrence Erlbaum, pp. 81-102.

Rapoport, R. N. (1970). Three dilemmas in action research with special reference to the Tavistock experience. Human relations, 23(6), pp. 499-513.

Rosenbloom, A. (2003). A Game Experience in Every Application. Communications of the ACM, New York, NY, USA. Vol. 46, Issue 7, pp 28-31.

Rieber, L.P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. Educational Technology Research and Development, 44(2), pp. 45-58.

Rossi, M., & Sein, M. K. (2003). Design research workshop: a proactive research approach. 26th Information Systems Research Seminar in Scandinavia Association, IRIS, August 9-12, Hakko, Finland.

Saariluoma, P. (2005). The challenges and opportunities of human technology. Human Technology, 1(1), pp. 1-4.

Said, N. S. (2004). An engaging multimedia design model. In Proceedings of the 2004 Conference on Interaction Design and Children, New York: ACM, pp. 169-172.

Sanders, E. B. N., & Dandavate U. (1999). Design for Experiencing: New Tools. In proceedings of the First International Conference on Design and Emotion, Delft 1999, pp. 87-92.

Sandhusen, R. L. (2000). Marketing. Barron's Educational Series. Hauppauge: Barron's.

Saunders, M., Lewis, P., & Thornhill, A. (2007). Research Methods for Business Students, 4th edition, Prentice Hall.

Scheible, J., & Tuulos, V. (2007). Mobile Python: Rapid Prototyping of Applications on the Mobile Platform. John Wiley & Sons, Ltd. 327 pp. ISBN: 978-0470-51505-1.

Schilit, B., Adams, N., & Want, R. (1994). Context-aware computing applications. In Proceedings of the Workshop on Mobile Computing Systems and Applications (Santa Cruz, CA, Dec. 1994), IEEE Computing Society, pp. 85-90.

Schmidt, A., Beigl, M., & Gellersen, H.-W. (1999). There is more to context than location. Computers and Graphics 23, 6 (Dec. 1999), pp. 893-901.

Schneiderman, B. (1997). Direct manipulation for comprehensible, predictable and controllable user interfaces. In Designing the user interface, 3rd ed., Reading, MA: Addison-Wesley, pp. 33-39.

Singh, K. (2007). Quantitative social research methods. Sage Publications Pvt. Limited.

Sharp, H., Rogers, Y., & Preece, J. (2006). Interaction Design: beyond human-computer interaction. 2nd edition. John Wiley & sons.

Skelly, T.C., Fries, K., Linnett, B., Nass, C., & Reeves, B. (1994). Seductive interfaces: Satisfying a mass audience. In C.Plaisant (Ed.), Proceedings of the

Conference on Human Factors in Computing Systems, New York: ACM, pp. 359-360.

Specht, M., Ternier, S., & Greller, W. (2011). Mobile augmented reality for learning: a case study. Journal Of The Research Center For Educational Technology, 7(1), pp. 117-127.

Spikol, D. (2010). A design toolkit for emerging learning landscapes supported by ubiquitous computing. Linnaeus University Dissertations No 27/2010. ISBN: 978-91-86491-44-4.

Stewart, J., Bederson, B. B., & Druin, A. (1999). Single Display Groupware: A Model for Co-present Collaboration. In Proceedings of CHI 1999. ACM Press, pp. 286-293.

Takeda, H., Veerkamp, P., Tomiyama, T., & Yoshikawam, H. (1990). Modeling design processes. AI Magazine, 11, 4 (Winter 1990), pp. 37-48.

Tapscott, D. (2008). Grown Up Digital: How the Net Generation is Changing Your World, McGraw-Hill, 2008. ISBN 0-07-150863-5.

Tarasewich, P. (2003). Designing Mobile Commerce Applications. Communications of the ACM, December 2003, Vol. 46, No. 12, pp. 57-60. DOI: 10.1145/953460.953489.

Toms, E.G. (2002). Information interaction: Providing a framework for information architecture. Journal of the American Society for Information Science and Technology, 53(10), pp. 855-862.

Tsichritzis, D. (1998). The Dynamics of Innovation, in Beyond Calculation: The Next Fifty Years of Computing. Denning, P. J. & Metcalfe, R. M. (Eds), Copernicus Books, New York, 1998, pp. 259-265.

Väänänen-Vainio-Mattila, K., Roto, V., & Hassenzahl, M. (2008, April). Now let's do it in practice: user experience evaluation methods in product development. In CHI'08 extended abstracts on Human factors in computing systems, ACM, pp. 3961-3964.

Wagner, E. D. (1994). In support of a functional definition of interaction. American Journal of Distance Education, 8(2), pp. 6-29.

Walls, J., Widmeyer, G., & El Sawy, O. (1992). Building an information system design theory for vigilant EIS. Information Systems Research, 3, 1 (1992), pp. 36-59.

Webster, J., & Ahuja, J. S. (2006). Enhancing the design of web navigation systems: The influence of user disorientation on engagement and performance. MIS Quarterly, 30(3), pp. 661-678.

Webster, J., & Ho, H. (1997). Audience engagement in multimedia presentations. The DATA BASE for Advances in Information Systems, 28(2), pp. 63-77.

Whitten, J. L., Lonnie D. B., & Dittman, K. C. (2003). Systems Analysis and Design Methods. 6th edition. ISBN 0-256-19906-X.

Woszczynski, A.B., Roth, P.L., & Segars, A.H. (2002). Exploring the theoretical foundations of playfulness in computer interactions. Computers in Human Behavior, 18(4), pp. 369-388.

Wynekoop, J. L., & Conger, S. A. (1990). A Review of Computer Aided Software Engineering Research Methods. In Proceedings of the IFIP TC8 WG 8.2 Working Conference on The Information Systems Research Arena of The 90's, Copenhagen, Denmark.

Yin, R. K. (1994). Case Study Research, Design and Methods, 2nd ed. Newbury Park, Sage Publications.

Zagal, J., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. Simulation & Gaming, Vol. 37, No. 1, March 2006, Sage Publications, DOI: 10.1177/1046878105282279.

Zichermann, G., & Cunningham, C. (2011). Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. O'Reilly Media.

Original Publications

Publication 1

Perttula, A., Carter, S., & Denoue, L. (2011). Retrospective vs. prospective: Two approaches to mobile media capture and access. International Journal of Arts and Technology. Vol. 4, Issue 3, 2011, pp. 249-259. DOI: 10.1504/IJART.2011.041480.

Retrospective vs. prospective: two approaches to mobile media capture and access

Arttu Perttula*

Tampere University of Technology,
P.O. Box 300,
Pori FI-28101, Finland
E-mail: arttu.perttula@tut.fi
*Corresponding author

Scott Carter and Laurent Denoue

FX Palo Alto Laboratory, Inc.,
3400 Hillview Avenue, Bldg. 4,
Palo Alto, CA 94304, USA
E-mail: carter@fxpal.com
E-mail: denoue@fxpal.com

Abstract: Mobile media applications need to balance user and group goals, attentional constraints and limited screen real estate. In this paper, we describe the iterative development and testing of an application that explores these trade-offs. We developed early prototypes of a retrospective, time-based system as well as a prospective and space-based system. Our experiences with the prototypes led us to focus on the prospective system. We argue that attentional demands dominate and mobile media applications should be lightweight and hands-free as much as possible.

Keywords: mobile; capture and access; prototyping; maps; social computing; multimedia; sharing; collaborative; attention; location-based services.

Reference to this paper should be made as follows: Perttula, A., Carter, S. and Denoue, L. (2011) 'Retrospective vs. prospective: two approaches to mobile media capture and access', *Int. J. Arts and Technology*, Vol. 4, No. 3, pp.249–259.

Biographical notes: Arttu Perttula is a Graduate Student at the Tampere University of Technology in Pori, Finland. His research focus includes mobile social media and mobile games.

Scott Carter holds a PhD from The University of California, Berkeley. He is a Research Scientist at FX Palo Alto Laboratory. His research focus is mobile multimedia.

Laurent Denoue holds a PhD from The University of Savoie, France. He is a Senior Research Scientist at FX Palo Alto Laboratory. His research focus includes HCI, CSCW with an emphasis on mobile computing.

1 Introduction

People are capturing increasing amounts of multimedia data with an increasing diversity of mobile devices. However, tools to organise and synthesise this data are scarce. In some cases, synthesis is not as important and simple streams suffice (e.g. informal sharing via Flickr). For many other tasks, though, it is vital to be able to structure or abstract media. Especially, when data must be synthesised over not only a group of devices but also groups of users this can be so difficult that much media can go completely unaccessed (Klemmer, 2002).

In this work, we show how we evolved a system to capture and access media on mobile devices (see Table 1). We followed the approach pioneered by Trevor et al. (2002) in which two different early-stage prototypes are developed and deployed in order to understand a design space. One prototype uses a time-based visualisation to facilitate *retrospective* review of media captured by individuals and groups. In this approach, the focus of the mobile application is on recording activities for *post hoc* perusal. The other version uses a space-based visualisation to use media to suggest *prospective* activities. In this approach, the focus of the mobile application is on supporting current or immediate tasks rather than access after-the-fact. Importantly, though, these early-stage prototypes are not necessarily 'suggestive of the finished product', but instead serve as a means of exploration (Greenburg and Buxton, 2008). As Shrage (2000) writes, such early-stage prototypes can help 'externalise thought and spark conversation'. Our goal at this stage in our work is to use applications to help to understand the challenges with mobile media capture and access tools.

In the rest of this paper, we describe our two systems: the retrospective prototype that links captured data to other media previously captured in the same place using a temporal representation; and the prospective prototype that uses media to guide users towards more entertaining or useful areas. We also describe case studies and pilot tests for each application and our field evaluation of the final version.

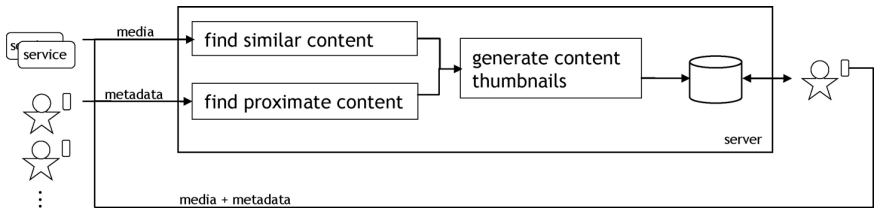
Table 1 Attributes of the retrospective and prospective capture prototypes

Retrospective	*Prospective*
Temporal representation	Spatial representation
Focus on media nearby user	Media where user might want to be
Media captured in the past	Media just captured or potential to be captured

2 Retrospective prototype

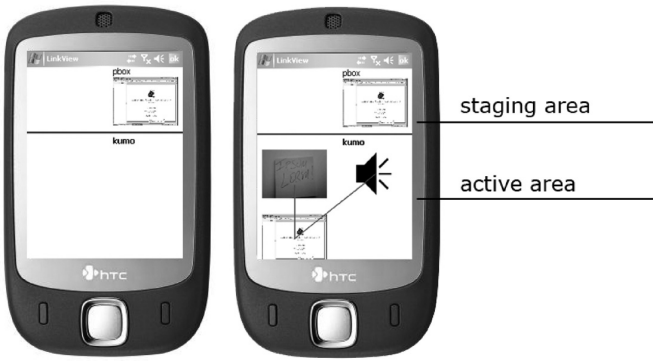
Our retrospective prototype – *Notelinker* – structures recorded media by creating links based on proximity and content. Users can record media with a mobile application that forwards captured content to a server. The server analyses content and metadata to establish links that are forwarded back to the mobile application (Figure 1). The mobile application can capture a wide variety of media (including video, image and audio) as well as metadata (including Bluetooth proximity and device interaction history). The mobile application also includes a pannable interface to organise and annotate media (Figure 2). The server can receive data from the mobile application as well as a variety of different media formats uploaded through a webpage. The server can also receive data from capture services (such as meeting capture systems) running in smart environments. The core novelty of the system is in the links it establishes between different media as well as between annotations of representations of digital documents and the original documents themselves.

Figure 1 Data flow in the Notelinker system



Note: Location-aware services and mobile devices send media and metadata (including location, Bluetooth proximity information and interaction history) to the server. The server creates similarity scores between media using content-based methods and finds nearby media using location and proximity information. The server then generates thumbnail representations of each captured picture or clip and pushes them to relevant users. Users can download the full versions of captured media by dragging a thumbnail from the staging area to the main panel in the mobile application's main UI.

Figure 2 Notelinker in a smart environment



Note: (Left) The system has determined its location ("kumo") automatically from Bluetooth tags in the environment and connected to a slide capture service available in the room ('pbox' in the upper right). (Right) The user has clicked on the slide from the capture service to create a copy in the active area (lower left). The user has also captured an image of notes she made (middle left) and an audio note (middle right) and linked both annotations to the slide.

The server creates links based on proximity and content. To create proximity-based links, the mobile system continuously records audio as well as Bluetooth IDs of nearby devices. When a user makes a recording, this contextual metadata is saved on the server with the original recording. When media from other devices are synchronised with the server, the system automatically connects recordings with nearby Bluetooth IDs. The system also searches for similar audio clips (using a normalised amplitude method) in any video recordings and links to the appropriate segments.

To create content-based links, the system can use image-based features. For pictures, features (such as Grabner et al., 2006) and extracted OCR text are saved as meta-content and linked against other data uploaded to the server. In combination, these features allow

users to connect seamlessly media captured by their device to media captured by non-enabled devices. Furthermore, the system allows users to collect, annotate and organise representations of digital media that will be substituted with their original content when it becomes available.

Importantly, the system also includes mechanisms for organising media captured by other nearby users, as well as proximate services, on-the-fly. The mobile application makes available representations of captures as they are recorded, including keyframes for videos, thumbnails of the most recent photo taken and icons representing audio clips. The mobile application also automatically retrieves these representations from nearby users and makes them available to the user in a staging area on the mobile interface. Also, a location resolution system on the mobile application continuously checks Bluetooth IDs recorded by the client against a capture service location database on the server. When the application finds a nearby service, it grabs a representation of the latest capture and places it in the staging area. Once in the staging area, icons can be dragged into the main scene. When this occurs, the system automatically saves the original file to the user's profile i.e. available via the web interface (e.g. if the user selected a keyframe from a video, the video is saved). At this point, the user can select two icons to manually link content, and can add annotations to captured content (Figure 2). In this way, the system not only automatically links content, but also exposes content that otherwise might go unnoticed.

2.1 Scenarios of use

The simplest scenario involves a single user capturing media and linking to media from capture services. Suppose that Bob, a user, wants to make a note during a presentation. If the presentation room has been tagged with a Bluetooth ID and includes a synchronous slide capture service, the system automatically processes the slide stream and makes a keyframe of the current slide available to Bob. He can drag this icon into the main scene and begin annotating it.

Now suppose Bob is in the field and wants to make a text annotation of a segment of video that his friend Marcia is recording on a standard Bluetooth-enabled digital video device. In this case, Bob will necessarily be near Marcia since he is commenting on something that she is recording. Bob can use the system to enter his comments. Behind-the-scenes, the system will automatically send with the comment a clip of 15-sec of audio recorded before and after the comment as well as a snapshot of all of the nearby Bluetooth devices. Later, when Marcia uploads her recorded video, the system will use the audio and Bluetooth data to link Bob's comment to the correct device as well as the correct sequence of video that Bob was annotating. Note that links would have been created for any type of media (e.g. rather than making a text comment Bob could have taken a picture or recorded his own video).

Bob could also take a photo of the same scene that of Marcia is recording just before or after he makes his comment. This action links Bob's comment to a particular keyframe in Marcia's video. Immediately after making the comment, Bob sees on his device the picture he took of the scene with the comment already linked. Later, when Marcia synchronises her video, Bob's picture will become an active link into the source video. Bob can use this method to create collections of media on-the-fly that are combinations of original recordings he has made as well as pointers to recordings others have made. He can organise these clips on his own device immediately – all of the linking will occur *post hoc*.

2.2 Experience

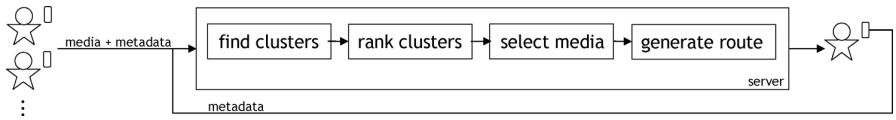
We ran studies to understand how people might use this tool to diary important events (Perttula and Carter, 2008). The studies made use of information exposed from a meeting capture service (Denoue et al., 2005) and an informal public display service (Churchill et al., 2003). These services already include web application programming interfaces (APIs) to expose data, making it easy to connect them to the database. Interviews with participants about their experiences revealed that the system should tie captures more directly not only to other captures, but also their work process. One participant mentioned that she 'want[ed] to be able to make a note on a journal paper I have printed and have the system link in the PDF in the background'. All the participants also agreed that audio was the most useful annotation mechanism.

Importantly, most participants focused on what the tool had linked to that was related to their current task as well as the tool's ability to reveal sources currently available for linking. That is, artefacts were important only if they related to the participant's current task or some task in the immediate future. In addition, participants struggled to imagine the type of data that might be useful to them later, which added a cognitive burden when new media arrived in the staging area. One participant commented that, 'it seems like I have to stop and think about every new piece of information that comes in'. Ultimately, participants expressed a need for a glanceable interface that could help them to launch new tasks.

3 Prospective prototype

Based on a brainstorming session with 15 participants, we designed the prospective system – *Kartta* – to provide a guide for users in the field based on location-based feedback by other users (Perttula et al., 2009). In this way, the system can be thought of as a Digg for locations. Kartta is composed of a server and a mobile application built using Mobile Python. The mobile application can capture content and context data which are sent to the server automatically. The server uses this information to create a map of the immediate region around a user, highlighting points-of-interest as well as landmarks to help the user to navigate. The mobile application polls the server regularly for a new map and set of landmarks (Figure 3).

Figure 3 Data flow in the Kartta system



Note: Using the mobile application, participants upload media, positive or negative votes for specific locations, and associated metadata to the server. Synchronously or asynchronously, other participants request a map from the server, optionally sending location and orientation information. The server finds and ranks clusters, selects media within each cluster, generates routes and sends the updated information back to the mobile client.

Figure 4 Kartta in a field setting

Note: (Left) The application showing the user's current location as well as votes. (Right) A zoomed-in view showing the user's current location, votes and tags.

The mobile application visualises not only the augmented map returned by the server but also the users' current location (Figure 4). Users can configure the interface either to show media captured by an explicit list of friends, or to show only their own captures. Because, as Fleck et al. (2002) point out, mobile users often feel that capturing media is too distracting, the application includes a simple, one-button interface for recommending that other users visit an area (a positive vote) or avoid it (a negative vote). A positive vote is represented on the map as a green dot and a negative vote a red dot. Overtime, votes implicitly create an interest-map of a place.

Mobile users can also launch media capture applications with another button. The mobile application sends media to the server along with context information (if available) including phone tilt (up, level or down), compass orientation, time-of-day and location. Context data can also be recorded continuously. The application currently senses location information via either embedded or attached GPS devices. While GPS currently affords only a gross estimate of location, we believe that it is sufficient since our application depends on aggregated data (votes). Furthermore, users can add tags to disambiguate areas of interest. Finally, media captured at a location automatically corresponds to a positive vote for that place (similar to the approach in Jaffe et al. (2006)).

The server ingests media and votes sent from mobile devices, finds clusters of media, selects representative captures for each cluster and generates routes from averaged and smoothed GPS traces. The server saves mobile media in a database, and a set of ingest and access services produce multiple downsampled representations of uploaded media: thumbnails of photos, keyframes and lower resolution copies of videos, and copies with lower sample rates for audio clips. The mobile application can use these different representations to provide tiered access to media.

To organise captured media, the server first finds and ranks clusters of interest areas, ranks media within each cluster and then generates route information.

3.1 Scenarios of use

Consider a group of researchers who are attending a conference with a few thousand attendees. Bob sees an interesting poster and wants to notify others. He takes a photo of it and tags the photo. After that others' devices download his photo automatically. Also, all of the group members can see a highly positive vote on the map indicating the place of the poster. Marcia zooms in and sees an interesting tag next to the vote. She presses one key and a photo pops up on the screen. She thinks that she must see that poster and checks out the map. She is already almost in the correct place but she cannot find the poster. So Marcia sends a message to Bob and asks about the poster. Bob can see Marcia on the map and he replies, 'it is behind the corner next to the stairs'. Marcia finds the poster and she thinks it is fascinating. She wants to give a positive vote to the poster and does it just pressing one key. A vote appears on the map and the rest of the group can see that there must be something interesting at that location since there are now two positive votes.

Later, Bob is sitting through an uninteresting talk. He gives it a negative vote, which is sent automatically to the others' maps. Bob also sends a message to everyone about the topic of the talk and writes that there is nothing new. Now everyone can look for something else. Marcia is at a different talk that is more interesting. She gives a positive vote to the talk and takes a photo, tagging it with the topic of the talk. Bob and others decide to move to that talk.

3.2 Experience

We first built a simulation tool to tune weights in our ranking algorithm. After running a series of simulations, we ran a pilot field experiment following (Massimi et al., 2007) scavenger hunt approach for evaluating mobile collaborative systems. In our initial pilot, four users recruited from our lab were divided into two teams of two, and we gave every user a device running our system. We used a simplified version of the mobile application that did not include route information, showed one tag per capture rather than several per cluster, and inferred orientation from a GPS trace rather than relying on an external sensor. The system came preloaded with a map of the campus near our building, which includes buildings, several flights of stairs, parking lots, a fountain, etc. The goal of the exercise was to find coloured balls (30 in total) that had been scattered around an office complex. Two researchers followed participants during the study, taking notes and helping if users were completely stuck. Also, we held a focus group session with all participants after the study focusing on potential features.

Participants collectively captured 66 total targets and submitted 45 tags over 1 hr. While the interface was not yet at a stage to judge its usability for groups, but participants provided a host of recommendations in the focus group. Participants, overall, felt that the interface required too much attention, and requested vibratory and auditory alerts. They also suggested that the map may not be necessary at all, and that the visual interface might consist only of hotspots as well as paths to those spots. They also suggested audio tagging, list views of recorded tags and orientation controls and views.

Overall, though, participant interest was high, and they were motivated to use an interface that helped them to explore an environment. Participants were much more engaged because the tool 'helped [them] uncover new opportunities' rather than only documenting their actions. They also appreciated that the glanceability of the vote display required little thought ('I can see immediately where to go').

4 Comparisons of the two prototypes

Our retrospective prototype helped the users to put their media captures in context with other media captured nearby, while our prospective prototype used media to indicate areas of potential interest. Through our pilot testing, we found that users are more likely to do *post hoc* organisation than *in situ* organisation, and that it is more important that the mobile application itself provide information but otherwise not require intense focus, or worse, get in the way of users' real-world tasks. This reinforces previous work that has found that most people would rather pay attention to the events around them than to navigate through a phone's interface (Oulasvirta et al., 2005). Furthermore, *post hoc* organisation could be accomplished using either system since the process of capturing metadata is relatively streamlined. Also, given that mobile users want to focus on *now* and *next*, it is not as useful to provide a full timeline on the mobile application for most capture tasks.

Overall, then, we found that the prospective prototype provided both *in situ* and *post hoc* value, and we decided to expand and test it in a more realistic setting.

5 Follow-up evaluation of Kartta

After improving the usability of the interface, we designed another, more focused experiment to evaluate Kartta. Furthermore, inspired by Baus et al. (2007) finding that audio can be useful for navigation tasks, we wanted to include a variety of media types. In this experiment, six single users recruited from our lab were asked to use Kartta to find and record objects of interest in a semi-familiar, semi-urban environment. We pre-recorded objects using a mixture of media – four photos (two tagged), two audio with no tags, two video with no tags, two tagged negative votes and two tagged positive votes. Participants were given a device with the Kartta application and all but three of the votes and media pre-loaded were asked to take a photo of the object they thought was being recorded or tagged at each location (e.g. one hotspot was linked to an audio clip of the chimes of a clock, of which participants were to take a photo). Media captured by participants was saved to the device locally and uploaded to the server in a separate thread. A few minutes into the study, the application downloaded and displayed the remaining votes (we added a vibrated alert to signal updates). Participants were also asked to avoid areas marked with negative votes.

One researcher shadowed the participant both to record behaviour and to answer questions about the interface in case the participant had difficulties. Since the task took place in an uncontrolled environment we did not incentivise participants to complete the study quickly. Instead, we asked them to signal to the shadower when they believed they had completed the task. At the end, we asked participants several follow-up questions designed to determine which media was most helpful for navigation, the ease of navigating the map and their ability to avoid negative areas.

5.1 Results

Despite there being no incentive, all participants completed the study in the time allotted. However, only one participant successfully captured photos of all objects, and one captured only five. On average, participants captured eight out of ten objects. Media in the set that only appeared after the start of the experiment were those most likely to be left out. All

participants chose photos as either the first or second most useful media for navigation. Four chose tags as the first or second most useful. One participant commented that it was easier to find those media that he could at least 'roughly make out from a distance'. Overall, participants found it useful that the interface reflected their orientation as well as location (four on a five-point scale on average), and they found it easy to navigate the map (also four out of five).

Participants had few questions for the shadower during the task. Though it did not affect participant's ability to complete the task, network reliability was also an issue, and we relied on media retrieved from the device for analysis. In general, participants had fun with the task, one noting that it was 'like virtual geocaching'.

6 Related work

Past work includes a variety of methods to capture data for retrospective exploration. Similar to Notelinker, Fono and Counts (2006) Sandboxes system displays collaboratively captured multimedia on mobile phones. However, this work does not address organisation (i.e. it does not utilise context to structure captures). Furthermore, it does not provide any video recording or other video-related support, such as keyframe generation. Erol and Hull (2003) describe a system to index into a presentation using an image captured with a camera phone. Their access interface displays the original captured slide and the video recording at the time it was presented (a similar system using scanned images appears in Chiu et al. (2000)). Fink et al. (2006) describe a system that senses TV audio to automatically recognise the programme the user is currently watching. They use this technology to support social viewing applications. Fleck et al. (2002) conducted an iterative deployment of a mobile capture tool in a museum setting. They quickly found that the capture application they had designed required an attentional shift away from the activity being captured that was unacceptable to users. In the end, they embedded capture technology into the environment itself and used the mobile device only to initiate an automated capture process (by swiping an RFID over a reader). In most mobile situations, though, it is not possible to instrument the environment in this way. Overall, these systems do not address collaboratively recorded media and are designed primarily for retrieval rather than *in situ* organisation and synthesis.

Some map-based interfaces are used for retrospective purposes, and in many cases they can also be used for long-term planning. One example is EveryTrail (http://www.everytrail.com/) which allows users to upload GPS tracking information as well as GPS-tagged photos. The system automatically plots that information on Google maps and offers a variety of social interactions around uploaded media (comments, ratings, etc.). However, the tool is not designed to collate and redisplay automatically information from multiple users.

Past work in prospective mobile location-based media has focused on creating summaries of collected media, descriptions of static environments or non-spatial visualisations of user-generated content. Jaffe et al. (2006) built a system that uses location and other contextual information to select key photos from a collection. However, their work focuses on summarisation rather than navigation. Grabler et al. (2008) developed a prototype that automatically generates maps based using building textures, road geometry and external landmark information. In this work, the authors focus on static structures and landmarks rather than temporary environments. Studies by Baus et al. (2007) showed that audio landmarks can aid navigation tasks, but their work did not involve user generated content.

GeoNotes (Espinoza et al., 2001) supported user generated place annotation, but was focused on text.

Of course, many applications can be used for both retrospective and prospective purposes. For example, a geonote can archive an experience (retrospective) or remind the user to complete a task (prospective). Still, both our work and past work suggest that users typically want to offload retrospective tasks from the mobile device as much as possible, focusing instead on prospective tasks.

7 Conclusions and future work

We found that attentional demands dominate and mobile media applications should distract as little as possible and provide as much information as possible peripherally or using no visuals at all. To this end, we intend to extend our prospective system further to support glancability and eyes-free notification. In particular, the phone should vibrate when a user is very close to an interesting area or when someone within walking distance votes up an area. We also plan to add audio notifications, such as the name of a user who just made a capture. Finally, we plan to deploy our prospective system to a realistic environment in which people overlap in time while exploring a new space, such as a conference.

Acknowledgements

This work is based on an earlier work: 'Kartta: using multimedia and context to navigate unfamiliar environments, in the *Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era*. Tampere, Finland (September/October 2009). ©ACM, 2009. We would like to thank our pilot users for their patience.

References

Baus, J., Wasinger, R., Aslan, I., Krüger, A., Maier, A. and Schwartz, T. (2007) 'Auditory perceptible landmarks in mobile navigation', *IUI*, pp.302–304.

Chiu, P., Foote, J., Girgensohn, A. and Boreczky, J. (2000) 'Automatically linking multimedia meeting documents by image matching', *ACM Hypertext*, pp.244–245.

Churchill, E., Nelson, L., Denoue, L. and Girgensohn, A. (2003) 'The plasma poster network: posting multimedia content in public places', *Interact*, pp.599–606.

Denoue, L., Hilbert, D., Adcock, J., Billsus, D. and Cooper, M. (2005) 'ProjectorBox: seamless presentation capture for classrooms', *E-Learn*, pp.1986–1991.

Erol, B. and Hull, J.J. (2003) 'Linking presentation documents using image analysis', *Signals, Systems and Computers*, pp.97–101.

Espinoza, F., Persson, P., Sandin, A., Nyström, H., Cacciatore, E., and Bylund, M. (2001) 'GeoNotes: social and navigational aspects of location-based information systems, *Ubicomp*, pp.2–17.

Fink, M., Covell, M. and Baluja, S. (2006) 'Social- and interactive-television applications based on real-time ambient-audio identification', *EuroITV*, pp.138–146.

Fleck, M., Frid, M., Kindberg, T., O'Brien-Strain, E., Rajani, R. and Spasojevic, M. (2002) 'From informing to remembering: ubiquitous systems in interactive museums', *IEEE Pervasive Computing*, Vol. 1, No. 2, pp.13–21.

Fono, D. and Counts, S. (2006) 'Sandboxes: supporting social play through collaborative multimedia composition on mobile phones', *CSCW*, pp.163–166.

Grabler, F., Agrawala, M., Sumner, R.W. and Pauly, M. (2008) 'Automatic generation of tourist maps', *Siggraph*, pp.1–11.

Grabner, M., Grabner, H., Bischof, H. (2006) 'Fast approximated SIFT'. *Asian Conference on Computer Vision*, pp.918–927.

Greenburg, S. and Buxton, B. (2008) 'Usability evaluation considered harmful (some of the time)', *CHI*, pp.111–120.

Jaffe, A., Naaman, M., Tassa, T. and Davis, M. (2006) 'Generating summaries and visualization for large collections of geo-referenced photographs', *Multimedia Information Retrieval*, pp.89–98.

Klemmer, S. (2002) 'A pervasive computing framework supporting collaboration in documentary history projects', *DIS*.

Massimi, M., Ganoe, C.H. and Carroll, J.M. (2007) 'Scavenger hunt: An empirical method for mobile collaborative problem-solving', *IEEE Pervasive Computing*, Vol. 6, No. 1, pp.81–87.

Oulasvirta, A., Tamminen, S., Roto, V. and Kuorelahti, J. (2005) 'Interaction in 4-second bursts: the fragmented nature of attentional resources in mobile HCI', *CHI*, pp.919–928.

Perttula, A. and Carter, S. (2008) 'Retrospective vs. prospective: a comparison of two approaches to mobile media capture and access', *Social Mobile Media Workshop*.

Perttula, A., Carter, S. and Denoue, L. (2009) 'Kartta: using multimedia and context to navigate unfamiliar environments', *MindTrek*, pp.120-123.

Shrage, M. (2000) *Serious Play*. Boston: Harvard Business School Press.

Trevor, J., Hilbert, D. and Schilit, B. (2002) 'Issues in personalizing shared ubiquitous devices', Workshop on user centered evaluations for ubiquitous computing systems: best known methods. *Ubicomp*.

Publication 2

Multisilta, J., **Perttula, A.**, Suominen, M., & Koivisto, A. (2010). Mobile Video Sharing: Documentation Tools for Working Communities. Proceedings of the EuroITV 2010, 8th European Conference on Interactive TV and Video. June 9-11, 2010, Tampere, Finland, pp. 31-38. ISBN: 978-1-60558-831-5.

Mobile Video Sharing: Documentation Tools for Working Communities

Jari Multisilta, Arttu Perttula, Marko Suominen, Antti Koivisto
Tampere University of Technology
PL 300, 28101 Pori
Finland
+358 3 311 511
{jari.multisilta, arttu.perttula, marko.suominen, antti.t.koivisto}@tut.fi

ABSTRACT
Although video sharing in web is used in learning, most video sharing services are not originally designed to be used as a learning application. In addition, most of these systems were designed to use via computer and with a web browser. Our solution, MoViE (Mobile Video Experience), is designed to be used in learning applications especially with mobile devices. MoViE is a social media service that enables users to create video stories using their mobile phones. Service's web interface is light and it works with all modern mobile phone browsers. In order to support automatic tagging of videos we designed a specific client for Symbian S60 platform that uses gps and cell tower data for creating tags for location, place and weather. In addition, MoViE's mobile client application makes uploading process even faster and makes possible to utilize smart tagging suggestions. The S60 MoViE client was used by the staff of Pori Jazz festival organization during the festival in summer 2009 for documenting the festival arrangements. They tried to capture unsuccessful, broken and bad things around the festival area. The aim was to use the videos for learning how to do things better next year.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: Miscellaneous

General Terms
Documentation, Design, Experimentation

Keywords
Mobile, Video Sharing, Tagging, Social Media

1. INTRODUCTION
Video sharing is becoming to an important role in current social media applications. We have seen a huge growth in the amount of videos in services like YouTube [2]. For generation Y or Net Generation [15], it is natural to acquire information and communicate with social media and video.

EuroITV2010, June 9-11, 2010, Tampere, Finland.

Most mobile phones have nowadays a digital camera that can also record video. The image quality of mobile phone cameras has also been growing rapidly. The best cameras already have 7 megapixel and in daylight situations they produce better images than digital cameras a few years ago.

We are seeing a change in how we use images and video and what they mean to us. From formal family portraits a hundred years ago we are in a situation where we do not print our images for albums anymore. Instead, our images and videos are mostly for single-use, maybe for showing them once to our friends, and delete them or forget to our computer's hard disk. Users are also sharing their experiences with others by uploading the images and videos to a social media service, such as Flickr, Picasa, or YouTube [10, 11].

Sharing status updates, images and videos with others is more generally called as life publishing, which includes all the means people willingly use for publishing the occasions of their life on the Internet [16].

Figure 1. MoViE homepage in Nokia N95.

In this paper, we discuss a mobile social media service MoViE (Mobile Video Experience) [12, 13] and present the client for the MoViE service that works in Symbian S60 phones. We have earlier presented how MoViE can be used in a mobile browser. In this paper, we discuss how special client software can be used in a learning application, where Pori Jazz festival staff used the

softeware and MoViE platform for documenting the festival arrangements. The idea of the MoViE is that users can upload video clips they have shot using their mobile phones to the service (Figure 1). When uploading the clips to the MoViE the author can also tag the clips. In the MoViE, users can watch clips and create remixes of video clips they find from the service. Users can use their own clips and clips from other users in their remixes. In addition, users can utilize tagspaces for adding new tags to video clips.

2. RELATED WORK

The first camera phones appeared just about nine years ago, and their development has been rapid. There has been quite a lot of research on how people use mobile phone cameras in imaging or as a replacement of a traditional camera. However, shooting a series of video clips and creating a story out of series of video clips is conceptually totally different activity. In this section we try to compare research results from mobile imaging to our problem space (i.e. shooting and sharing a series of video clips).

2.1 Mobile Imaging

In one of the first published studies about the use of camera phones Okabe and Ito [14] wrote: "unlike the traditional camera, the camera phone is an intimate and ubiquitous presence that invites a new kind of personal awareness, a persistent alertness to the visually newsworthy that makes amateur photojournalists out of its users." It seems that people record and share small stories with their camera phones [4, 8]. Based on Koskinen [9] images are captured with mobile phones just for fun or information only for a moment. We think that mobile videos may have similar role, but the production process of a video clip requires more time and thinking, and thus the process of doing a clip may be the most important outcome to the person creating the clip. We also think that it is possible to collectively co-create stories that have significance and sense of dramaturgical tension to the viewers.

Van House and Davis [4] have defined four higher-order social uses of personal photography, namely creating and maintaining social relationships; constructing personal and group memory; self-presentation; and self-expression. In addition, based on their research they found three interpretations of camera phones: as memory-capture devices, communicative devices, and expressive devices. We would like to add the storytelling as an additional interpretation, special for mobile video device.

For example, Koskinen [9] have studied how people use camera phones in communication and action. Koskinen defines mobile multimedia as a "set of technologies that enable people to capture, send, and receive photographs, sounds, and sometimes video."

Jacucci, Oulasvirta, Salovaara and Sarvas have studied about shared experience on large-scale events [5] and found out that spectatorship is about co-experiencing the event because it has an active nature, sociality and interactional character. Based on their work, mobile technologies can provide on-site support for groups of spectators. As an application, Jacucci et al. have designed a mobile application for creating shared digital memories (shared media albums) using mobile phones. Their application had a story-based structure and it supported also automatic album creation of selected media.

Yahoo has introduced a ZoneTag service that support geotagging and tag suggestions for images [1]. In ZoneTag, a user takes an image, and based on the location information, ZoneTag suggests tags that the user or other users have used in that area. ZoneTag posts tagged images to Flickr. Another mobile tagging system is MobiTags [3], a mobile social system that helps people to tag "open storage" museum collections. MobiTags integrates social tagging of museum objects, an interactive map, and information about the art to help visitors collaboratively organize and explore these open storage collection.

2.2 Mobile Video

Jokela, Karukka and Mäkelä [6] have designed video editing tools to be used on a mobile phone. They have created a set of editing tools that enabled users to create short video presentations by changing the order of the clips, cutting a video clip and inserting an audio track to the clip. Based on their study, video editing on mobile devices is feasible despite of small displays and limited input devices. In addition, Jokela et al. [6] suggest that there is a true need for a video editing application on mobile devices. In our system, the simple editing and remixing of video clips can be done in the server with the mobile phone.

Social video services can be divided to real time sharing systems and offline sharing systems. In real time systems the user has a special client in her mobile device that uploads the video stream to the server in real time. Others can watch the video from the web in real time. An example of such a system is Qik. YouTube is an example of offline video sharing system.

In some cases, the live sharing of videos from a mobile device is practical and useful, but in many cases users may not be in network coverage, or their data plan may not support real time sharing (or it simply is too costly).

Existing mobile video sharing systems present videos to users as channels (f. ex. JuiceCaster, Floobs, YouTube, LiveCasting) or by classifying them to videos, people and events (f. ex. Qik). JuiceCaster supports mobile image and video sharing and watching videos using a mobile device but does not include remixing of videos.

Geotagging is also supported in some of the current video sharing sites (such as Qik, YouTube). Google has also integrated the geotagged YouTube videos also to Google Earth. Mobile devices with a GPS receiver can include geotags to image files automatically. Geotags for video clips are typically uploaded to the server as a separate event – this is done automatically for example by posting to Ovi.com with a Nokia device or by using special uploading software in the mobile device. For example, ShoZu, available for many brands and devices, can include geotags to videos posted to Flickr and YouTube.

JayCut (www.jaycut.com) supports remixing videos on a browser by simple drag and drop user interface. This is designed to be used in a large screen with full-featured browser. It is not possible to use a mobile device for remixing in JayCut.

2.3 Features of Video Sharing Systems

Video sharing service refers to website where users can distribute their video clips. Usually services have options for private, group or public video sharing. In this study, we do not discuss websites that are solely search engines and do not provide the hosting of the video content. We did a video sharing service survey during the spring 2009 and selected the most popular and notable video services for the study. The main focus of the survey was to list

Table 1. Selected features of the popular online video sharing web services have been surveyed during the spring 2009. Please note that video sharing web sites are improving or changing their features constantly.

	Blip.tv	Break.com	Dailymotion	Google video	HD share	imeem	Metacafe	Ovi	Revver	Sevenload	Spike	Veoh	Vimeo	Yahoo video	YouTube
Mobile interface	-	X	X	-	-	X	X	X	-	-	X	-	-	-	X
Video downloading	X	-	X	X	-	-	-	-	X	-	-	X	X	-	-
Share a video link	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Video rss/podcast	X	X	-	X	-	-	X	-	X	-	X	-	-	-	-
Possibility to earn	X	X	-	-	-	-	-	-	X	-	-	-	-	-	-
Tag own videos	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tag other users' videos	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-
Tag cloud	X	-	-	-	X	-	-	-	-	X	-	-	X	-	-
Location data	-	-	X	-	-	-	-	X	-	-	-	-	-	-	X
Video comments	X	X	X	-	X	X	X	-	X	X	X	X	X	X	X
Video scores	-	X	X	-	X	X	X	-	X	X	X	X	X	X	X
User comments	X	X	X	-	-	-	-	-	X	X	-	X	-	X	X
User scores	-	X	X	-	-	X	-	-	X	X	-	X	-	-	-
Private messages	-	X	X	-	X	X	X	X	X	X	X	X	X	X	X
Forum	X	-	X	-	X	X	X	X	X	-	-	X	X	-	X
Groups	-	X	X	-	X	X	X	X	-	X	X	X	X	X	X
Add friends	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X
Multilingual	-	-	X	-	X	-	-	X	-	X	-	-	-	-	X

important functionalities and features of the existing video sharing services (see Table 1). The features list surveyed is not exhaustive but instead reflects the features we believe could be useful in learning applications. We were also interested in carrying out this video service review to find out what kind of tagging methods are available and if there are some other objectives of the service beside an entertainment intention.

Our overall experience with video sharing services indicate that there is still need for a video service which is designed for mobile phones, includes smart or automatic tagging, geo-data information and possibility to use a mobile client application. In particular, all of these video sites have been created for entertainment purposes. There are no particular video sharing sites to support learning activities. However, video sharing web sites are improving or changing their features all the time. Our experiments revealed a lack of video editing possibilities on the web. For example, it is not possible to remix two clips to the one video file. In many services, it is not possible to reply to the video by a video. We

were also surprised that users have to always tag videos manually. Video sharing services do not have any tag suggestions methods except geo-tagging, which is supported by some services. However, these do not provide place conditional tag suggestions. Also, tagging is done always by typing words. That is maybe because of there are no service specific or general mobile client applications. For example audio or image tagging is not allowed. In addition, smart phones' sensors could provide different and faster tag creating or selecting methods.

3. MoViE Service

In this chapter we present the design principles of MoViE service and discuss the Symbian client software. In general, MoViE was designed for a research platform for studying how people can create stories, share and learn with mobile social media service.

3.1 Design Principles

MoViE (Mobile Video Experience) is meant for mobile video sharing. MoViE does not support real time video sharing such as for example Qik (www.qik.com) or LiveCast (www.livecast.com) or sharing media from a PC to the mobile device such as MyCasting with Orb (http://www.orb.com/mobile/).

Many existing video sharing services are designed for computer use. The users can post videos to these sites using their mobile devices but cannot perform other activities in these sites with their mobile devices. This is because of the sites use JavaScript features that are not supported in current mobile browsers or include complex screen design.

Varied limitations of mobile devices and their Internet browsers are taken into consideration in the MoViE design. Also, the layout in MoViE is as simple and light as possible. Operations are very much done on the server side and the input from a user is simplified. For example, tagging a video can be done by just ticking suitable tags from a selection. Besides the usual Flash video player the videos are also available in 3gp format. To make the upload and download times bearable with slower connections the video size is limited to 20 MB.

MoViE has the usual activities of a video-sharing site. Users may upload videos, watch videos, rate videos and reply to a video with own video. Video lists may be sorted by date, how many times videos have been watched or videos' score. Video search uses two variables. First one contains the search words, which may be directed to a specified field with a prefix. Specified fields are username, title, description, tags and geotags. Second variable defines the sorting of the results. In addition to list the search results in traditional best match first order, they may be sorted as video list in general in MoViE.

3.2 MoViE Client

MoViE can be used with a mobile phone browser in all phones that support web browsing. However, we wanted to design a system that would support the tag creation by collecting automatically context data as much as possible. The MoViE mobile client is a video capturing, tagging and uploading tool for Symbian S60 mobile phones. It uses GPS (Global Positioning System) and GSM cell information as automatic context to videos. This information is used to find the most appropriate words for tag suggestions. The typical usage scenario is presented in Figures 2, 3 and 4. First, when the client is executed it asks for which network is used to upload videos (Figure 2). After that the client starts automatically phone specific camera module. GPS and GSM cell information are stored as a background process during the video capturing. With this information the database can perform queries to the MoViE server and determine where the video was captured. Using this data, the MoViE server provides video related weather information. Also, MoViE server tries to suggest some tags that could be appropriate with particular video.

GSM cell information is used to locate approximately the place where the video was captured. This is done by calculating signal strengths of nearby cell towers. The MoViE client performs this computation automatically in background. After that, if available GPS information is used to determinate the exact place from where the video was sent to the MoViE server. In any case, GSM cell provides at least some location information if the GPS module does not work for some reason, for example if the user is inside a building.

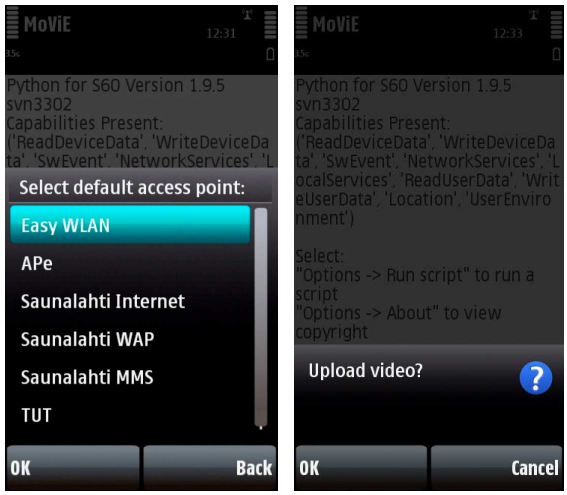


Figure 2. User selects default access point for the internet connection, and uploads video after video capturing.

When the video has been uploaded, the user is asked to enter the video title and description (Figure 3). The previously used description is always suggested since the user may be shooting several videos in one "session".

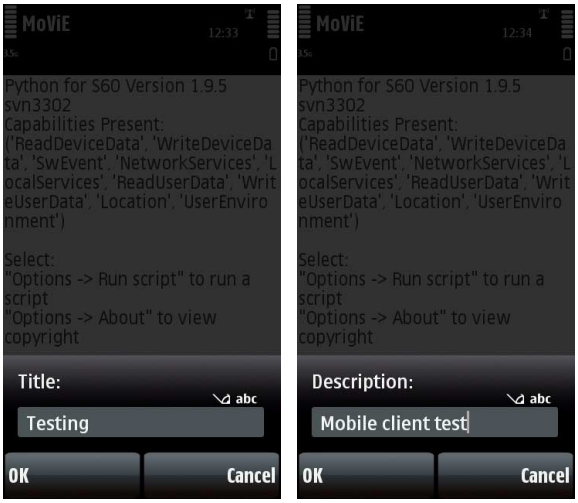


Figure 3. User enters the title, and the description.

Finally, the user can enter the tags (Figure 4). User tags the video using provided tags (her tagspace) and optionally gives some new tags to the uploaded video.

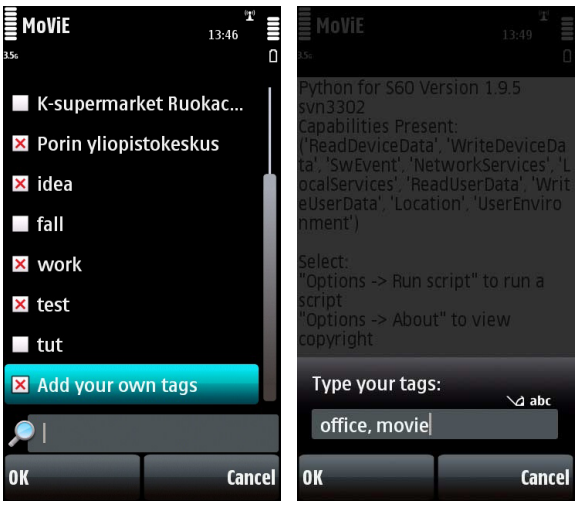


Figure 4. User tags the video using provided tags and optionally gives some new tags to the uploaded video.

The MoViE server gives tag suggestions to the user. If tag suggestions have suitable tags user can select those tags to the video. In this version, tag suggestions for the video include:

- Geo place: mobile client users generated tags in the specific place.
- Weather: tags fed to the client by users in the specific place and at the specific time.
- Recent: five latest tags typed by a user.
- Places: the database has about 25 000 places from all over Finland (sights, buildings, monuments etc.).
- Events: events that are in the same town as a user (in the future version of MoViE).

These categories are almost all based on GPS information except recent tags. If GPS information is available, the MoViE server can easily suggest all kinds of places or events nearby the user or ongoing happenings in the same town at the moment. The MoViE server makes these queries from the specific database.

The MoViE client sends the GSM cell and GPS information to the MoViE server, which runs queries from the Yahoo and the Google server (see Figure 5). The Yahoo server returns the place related information and Google server returns the place and weather information. In Yahoo server the GSM cell is used with the "cellLookup" service to get country and city names. If this query does not return the appropriate city and country as a result, the MoViE server runs a backup query to Google Map API. In Google server, longitude and latitude values are used to get the location information. In addition, Yahoo's TagMap API is used to determine the name of the place where the video was captured. Google server uses this information to produce weather details. All of this can be seen as context information in the MoViE homepage (see Figure 6).

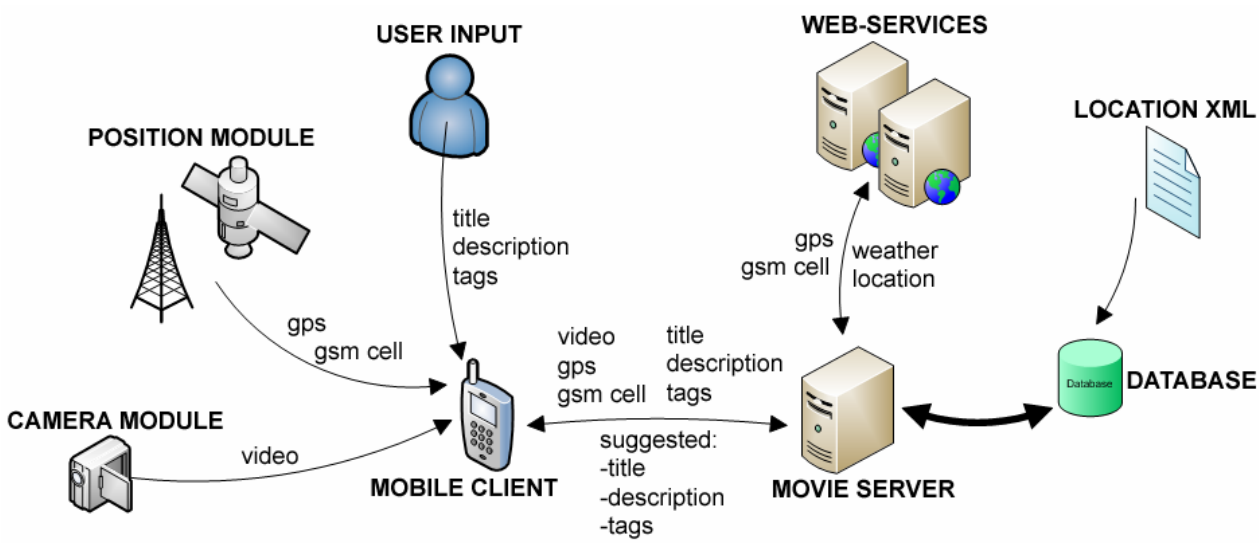


Figure 5. Simplified MoViE architecture diagram.

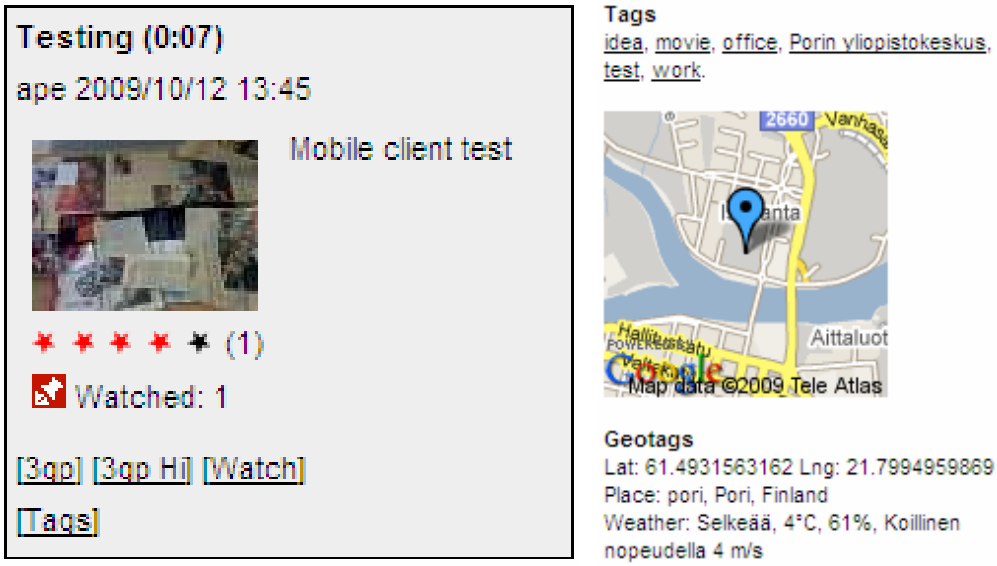


Figure 6. The MoViE web service showing a mobile video and metadata after successfully uploading and tagging the video via mobile client.

4. REMIXING

Videos uploaded to MoViE are meant to be shared with everybody - even with the unregistered users. However, it is possible to create private groups and mark videos private, but as soon as user shares her private video in a group, other members in the group may figure out the location of the video file in the server or simply download it and use other means to share it. This in mind it may appear unnecessary to prevent private videos to be used in remixes. A collaborative aspect of MoViE is making remixes i.e. merge several videos into one new video (see Figure 7). Not just users own, but all videos in MoViE with the mentioned exception are free to be used in a remix.

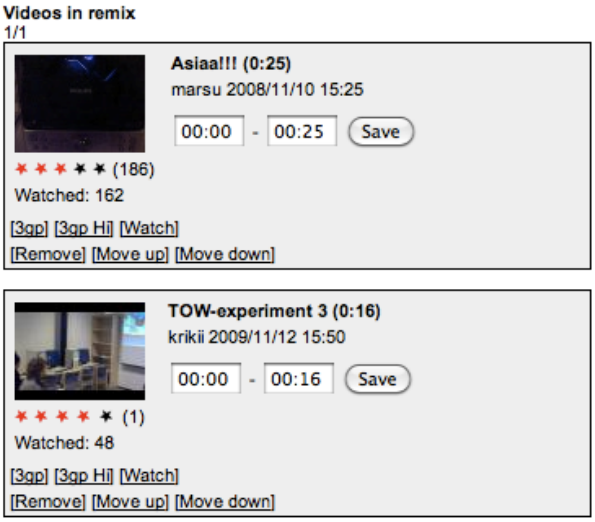


Figure 7. Selected videos in a remix.

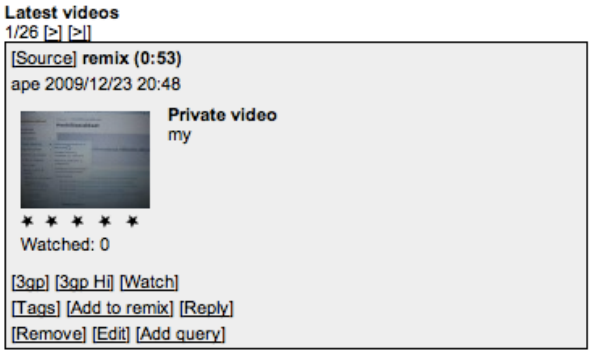


Figure 8. The remix generated by MoViE

There is two ways and their combination to make remixes. The first one is to select the videos one by one and adjust their order and their start and end cues. The second one is to use search as an aid. Search works as previously explained with the addition to possibly limit search into one group the user has access. In the remix search is only interested in the first hit. User may do several searches at one time and think of each search as a scene in a remix's manuscript. Remixes are easy to distinguish from other videos in MoViE as there is a source link before the title (see Figure 8). Source lists all videos used in remix.

5. FIELD PILOT: LEARNING IN THE WORK

Eight users were recruited from the staff of Pori Jazz festival organization and they were given a Nokia mobile device running our MoViE mobile client (four Nokia N95 and four 5800 phones). The participants used only mobile clients and they also had the access to web service using their computers. The goal of the pilot was to capture and tag as much videos as possible during nine

days at the jazz festival (July 11th to 19th, 2009). The participants tried to capture specially unsuccessful, broken and bad things around the festival area. Purpose of this was to document these things better and learn from the video "memory" so that the quality of arrangements could be improved.

We adapted this approach to test our system, focusing on understanding how well the mobile client helps users to upload videos to the service as well as how much faster and easier tag suggestions from the server makes the whole process. We used a simplified version of the mobile application that did video default access point selecting and video uploading automatically. In this case, our server side application suggested to user the specific tag list, which consists of the latest tags and place conditional tags.

We held a focus group sessions with all the participants and personal interviews after the festival focusing on the user experience.

Participants collectively captured 113 total videos and submitted 47 tags over one week. 10 of the tags were selected from tag suggestions. Ultimately, we found that the mobile client application was not yet at a stage to provide fast enough data transfer via 3G-network. In WLAN network the uploading is much faster. Uploading should be implemented as a background process because of participants felt uncomfortable to wait tens of seconds to complete the uploading.

Participants overall felt that the tagging required too much attention, and requested for example simple voting system for important and less meaningful videos. They also suggested that tagging could be done by using pre-made list(s) including user created main themes like different places, situations or daily activities. This feature is implemented in the MoViE system but was not utilized in the this experiment. The list of previously used tags appeared as a useful option because of it makes tagging faster. They found that the geo-tagging is a significant feature when videos are explored later because of it is otherwise troublesome to remember the exact place of the captured video.

Common opinion among participants were that capturing videos is the fastest and the best way to record and save notes in this kind of work environment The participants found adding audio comments to videos useful way to avoid typing tags or notes. But sometimes even video capturing and especially tagging required too much attention because of the hectic work situations during the festival. Participants also requested a feature that would send the videos directly to the large public display which is located in their office. So they could immediately fix up the problem that is described in the particular video. In this case, geo-tagging is significant feature and tagging should also include scale of importance of the attention. After repairing the problem described in the video, the user could just select and remove the video from the office screen by using the mobile client software. Overall, participants were confident that video sharing system offer extra value to the Pori Jazz organizers and can be utilized to improve the next year festival.

6. DISCUSSION

In this paper we have discussed about the MoViE social video sharing service and it's Mobile Python Symbian S60 client software. We have tried to support automatic tagging by collecting contextual information based on the location of the device. MoViE is designed to be used with a mobile device and it supports mobile social video sharing and remixing and can be used in different learning applications. In this paper, we explained an experiment where MoViE was used with Pori Jazz festival staff for documenting the festival arrangements, and using this information for learning to fix things not working very well during the festival.

7. ACKNOWLEDGEMENT

We thank Ville Kairamo from Demola as well as our study participants for their time and feedback. Jari Multisilta would like to acknowledge the Academy of Finland for the Researcher Mobility in Working Life Grant for 2008 and 2009.

8. REFERENCES

[1] Ahern, S., Davis, M., Eckles, D., King, S., Naaman, M., Nair, R., Spasojevic, M., Hui-I Yang, J. (2006). Zonetag: Designing context-aware mobile media capture to increase participation. PICS '06, p. 3.

[2] Cheng X., Dale C., and Liu J. (2008). Statistics and Social Network of YouTube Videos. Proc. of IWQoS200

[3] Cosley D., Baxter J., Lee S., Alson B., Nomura S., Adams P., Sarabu C., Gay G. (2009) A Tag in the Hand: Supporting Semantic, Social, and Spatial Navigation in Museums. CHI 2009, April 4–9, 2009, Boston, MA, USA.

[4] Van House, N., and Davis M. (2005). The Social Life of Cameraphone Images. In Proceedings of the Pervasive Image Capture and Sharing: New Social Practices and Implications for Technology Workshop (PICS 2005) at the Seventh International Conference on Ubiquitous Computing (UbiComp 2005).

[5] Jacucci G., Oulasvirta A, Salovaara A, & Sarvas R. (2005). Supporting the Shared Experience of Spectators through Mobile Group Media. In Proceedings of GROUP'05, November 6–9, 2005, Sanibel Island, Florida, USA. ACM, New York, NY, 207-216.

[6] Jokela T., Karukka M., and Mäkelä K. (2007). Mobile Video Editor: Design and Evaluation. In J. Jacko (ed.): Human-Computer Interaction, Part II, HCI 2008, LNCS 4551, Springer-Verlag Berlin Heidelberg, pp. 344-353.

[7] Kiili K., Multisilta J., Suominen M., Ketamo H. (2009). Learning Experiences on Mobile Social Media. Proceedings of the 17th International Conference on Computers in Education, ICCE 2009, Hong Kong.

[8] Klastrup L. (2007). Telling & Sharing? Understanding Mobile Stories & Future of Narratives. pertDAC 2007 The Future of Digital Media Culture. 7th International Digital Arts and Culture Conference, Perth, Australia 15-18th September.

[9] Koskinen I. K. (2007). Mobile Multimedia in Action. Transactions Publishers, New Brunswick, London.

[10] Milrad M. and Multisilta J. (eds) (2009) Sharing Experiences with Social Mobile Media. Proceedings of the International Workshop in conjunction with MobileHCI 2009. Tampere University of Technology, Pori, Publications 13.

[11] Multisilta, J. and Milrad, M. (2009) Sharing Experiences with Social Mobile Media. In Proceedings of the 11th international Conference on Human-Computer interaction with Mobile Devices and Services (Bonn, Germany, September 15 - 18, 2009). MobileHCI '09. ACM, New York, NY, 1-3.

[12] Multisilta J., and Mäenpää M. (2008). Mobile Video Stories. In Proceedings of the 3rd International Conference on Digital interactive Media in Entertainment and Arts (Athens, Greece, September 10 - 12, 2008). DIMEA '08, vol. 349. ACM, New York, NY, 401-406.

[13] Multisilta J., Suominen M. (2009) MoViE: Mobile Video Experience. In Lugmayr A., Franssila H., Sotamaa O., and Vanhala J. (eds.) Proceedings of 13th International Academic MindTrek Conference: Everyday Life in the Ubiquitous Era, Tampere, Finland, October.

[14] Okabe D., and Ito M. (2004). Camera phones changing the definition of picture-worthy. Japan Media Review. Annenberg School for Communication, USC, http://ojr.org/japan/wireless/1062208524.php [11.05.2008].

[15] Tapscott D. (2009) Grown Up Digital. McGraw-Hill, New York.

[16] Östman, S. (2008). Elämäjulkaiseminen – omaelämäkerrallisten traditioiden kuopus (Life publishing – youngest child of autobiographical traditions). ELORE, vol. 15 – 2/2008. Suomen Kansantietouden Tutkijain Seura ry. [http://www.elore.fi/arkisto/2_08/ ost2_08.pdf] (in Finnish)

Publication 3

Perttula, A., Koivisto, A., Mäkelä, R., Suominen, M., & Multisilta, J. (2011). Social Navigation with The Collective Mobile Mood Monitoring System. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. September 28-30, 2011, Tampere, Finland, pp. 117-124. ISBN: 978-1-4503-0816-8.

Awarded prize: Certificate of Honor, Academic Papers - Special Mention.

SOCIAL NAVIGATION WITH THE COLLECTIVE MOBILE MOOD MONITORING SYSTEM

Arttu Perttula, Antti Koivisto, Riikka Mäkelä, Marko Suominen, Jari Multisilta

Tampere University of Technology
PL 300, 28101 Pori
Finland
Tel. +358 3 311 511

{arttu.perttula, antti.t.koivisto, riikka.makela, marko.suominen, jari.multisilta}@tut.fi

ABSTRACT

At large-scale events, people could benefit from the experiences of others to help find interesting areas. Also, more and more pervasive and ubiquitous mobile devices could be utilized for navigation in different situations. In this paper, we will present a manual input mobile computing platform for monitoring and collecting information about people's moods at a large-scale public event. In addition to places and venues, moods are represented in real time on a public map as a social navigation recommendation system. Furthermore, as a step towards future work, we utilized consumer-level brainwave measurement equipment to build a mobile prototype research application for semi-automatic mood monitoring. The aims of the field pilot study and the follow-up examination were to explore the usefulness and effect of the mobile mood sharing system that was developed on event visitors. In particular, the study focuses on benefits of the social aspects, in addition to spatial and semantic navigation. With today's available technology, we have to balance in the comfort zone between required user attention and user experience. In any case, the results of the study broaden the field of social mobile applications and facilitate the diffusion of these into different large-scale public events.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation (e.g., HCI)**]: Group and Organization Interfaces—Collaborative computing; H4.3 [**Information systems applications**]: Communications applications.

General Terms

Documentation, Experimentation

Keywords

Mobile Device, Mobile Social Media, Social Navigation, Experience Sharing, Co-creational Space, Mood, Emotion, Event

MindTrek'11, September 28-30, 2011, Tampere, Finland.

1. INTRODUCTION

In public places and at events, people observe the behavior of others all the time in order to determine where to go or what to do. However at large-scale events, without the traces they leave behind, people cannot benefit from what others are experiencing. Nowadays, mobile devices are part of everyday life and as they become more pervasive and ubiquitous, we find ourselves asking questions about how to use these devices for navigation in different situations. [13] Characteristics of large-scale events include their spatial distribution, their extended duration over days, and such events as are set apart from daily life. [18] This simultaneously creates several options and choices about ongoing venues and places for event visitors.

Also, by monitoring our surroundings and people, we are probably able to envision the atmosphere, collective emotional states and activities. On the other hand, sharing emotions is crucial to the creation and maintenance of social bonds. Emotion sharing can also be used in the creation of a collective spirit. Nowadays, mobile devices are exceptionally suitable tools for conducting social as well as psychological experiments in an unobtrusive way. Therefore, they represent the ideal computing platform for monitoring and collecting information about people's emotions, moods, attitudes, views and opinions. Knowledge about people's emotions is used for designing consumer products, analyzing political issues and for designing enriching and entertaining experiences and applications for people. Much of the work in affective computing focuses on ways in which computers can become aware of, and process data about, these human emotional states [35, 1, 29, 11].

In this paper, we are presenting a manual input mobile computing platform for monitoring and collecting information about people's moods at a large-scale public event. In addition to places and venues, collective mood climate is represented in real time on a public map as a social navigation recommendation and guidance system. It is worth noting that the proposed system is not only for extending the feeling of participation at a large-scale event and transforming passive bystander spectatorship to a more active form of engagement as other solutions are usually designed for (e.g. [31]). Furthermore, as a step towards future work we utilized consumer level brainwave measurement equipment to build a mobile prototype research application for semi-automatic mood monitoring. After all, the purpose of the developed system is to produce extra value for event participants by using themselves as sensors.

A goal of social navigation is to utilize information about other people's behavior for our own navigational decisions [8]. When Dourish and Chalmers [9] introduced the concept of social navigation, they defined it as "navigation towards a cluster of people or navigation because other people have looked at something". In social navigation, people watch the activity of other people to make choices about what is popular, what paths to follow, and to find links to related information [16]. Social navigation can potentially transform different spaces by encouraging people to explore the spaces that might otherwise be ignored or overlooked [13].

2. RELATED WORK

Building technologies for sharing mood or emotional reactions is not new. However, there are few designs that allow users to share their own moods or enhance their social awareness of others. [2] Affective computing proposes applications that understand and meaningfully react to the emotions of their users [35]. These applications usually contain a component that measures one's emotional state, and reflects that to the user in some way. In general, two types of emotion measurement methods are deployed: facial expression detection and measurement of physiological responses by using camera images have the advantage that no body contact with the user is needed. The drawback, however, is that the user needs to be confined to a specific location in view of the camera. [41]

Thus, especially for the majority of mobile measurement applications, developers often revert to physiological measurement techniques, like skin conductance response or heart rate. Most of the physiological techniques require sensor bodily contact, which might reflect negatively on the wearing comfort; however they allow users to move freely. [41] In mobile settings, three main methods are used for collecting information about users' moods: self-reporting, physiological measurements and social media related analysis. In addition to these three, we try to compare research results from social navigation to our problem space.

2.1 Self-reporting – Manual Input

The most traditional, relatively feasible and lightweight method used is self-reporting. Self-reporting instruments consist of verbal scales and protocols or they can be non-verbal, like SAM [21] and Emocards [7]. Self-reporting always requires manual input from the user. In mobile settings, emotions are often communicated by the user through various multimedia possibilities, such as MMS or specially designed smilies in SMS systems.

Sample applications that use moods obtained by manual input mechanisms are already available commercially. In particular, the iPod application, Moody, uses manual input to tag tracks with mood information. Similarly Nokia, in the context of the MOBILIFE project, developed a ContextWatcher application [20] that also tags mood information to content.

Several kinds of free mood tracker applications are available for health and entertainment purposes. For example, the Mood Tracker is a simple application designed for patients with depression or bipolar disorder to track their moods and medications. With the Mood Panda application a user is able to keep a mood diary by rating his/her own moods, sharing them with friends and viewing global moods via the Internet or with a mobile phone.

Research has been done on designing special systems for mobile emotional communication, such as ExMS - an animated avatar-based messaging system [32] and eMoto – based on emotion-gestures, rendering a message background of colours, shapes and animations expressing the emotional content [40]. Both systems are based on a user's own description of what he/she feels.

MoodJam is a web-based application that provides a palette of colors from which users can choose one to best reflect their mood. Additionally, users can supplement their color selections with words or notes and post the selection to a publicly available site. Visitors can mouse over colors and see comments or tags. LinkMood is another web-based application that allows users to choose from an extensive list of words to let others know how they are feeling, and also provides a brief space for users to leave a short note or description to discuss why they are in the mood they are in. Furthermore, moods are archived so users can track how their moods have changed over time.

A mobile application, Aurora, encourages patients to share their current mood and comfort levels with others. Users can choose graphics, photos or colors to represent their current mood, rate their current comfort levels and provide a short textual description of their status. This information is also available for social group members, as well as an aggregate mood and comfort display for the entire population of users. In addition, users are able to send text messages to one another through the interface. [13]

2.2 Physiological Measurements

The measuring of physiological, vocal and facial reactions has been associated with emotions in many studies. For the majority of mobile measurement applications developers often revert to physiological measurement techniques, like skin conductance or heart rate. Most techniques require bodily contact with sensors and therefore, easy-to-wear sensor platforms that are wirelessly connected to mobile devices have been developed [41, 14]. Perttula et al. [34] monitored and presented collective heart rates of an audience with heart rate belts and mobile phones at ice-hockey games in order to enhance and deepen the collective feeling of the audience.

The EmotionSense platform, developed for experimental social psychology research, is used to integrate information gathered through different features of the phone – location through GPS, movement through an accelerometer, proximity to Bluetooth devices, as well as excerpts of conversation – create an impression how someone's feeling [36].

Finally, users of the eMoto mobile system carry a special stylus fitted with pressure sensors and an accelerometer with them. When sending a text message to another user of the system, the user squeezes and shakes the stylus in a manner befitting their mood. The eMoto device recognizes these actions through the sensors in the stylus and uses an algorithm to generate a background image for their text message composed of colors and shapes. Users can alter the pressure applied to the stylus and their movements to generate an image they find consistent with their mood [40].

2.3 Social Media Tracking

An emerging trend in analyzing people's emotions is an attempt to measure collective moods by gathering inputs from different social media platforms. Social media provides a rich source of information for marketing professionals, social psychologists, and

others interested in extracting and mining opinions, views, moods and attitudes. Social media research uses sentiment-based text analysis, i.e. classifying opinionated texts or sentences be they positive or negative, a technique that itself goes a long way back [15, 6, 19].

Mishne and de Rijke [26] developed algorithms, later evolving to MoodViews - a set of online tools [25], for estimating global mood levels in blog posts. They showed that at an aggregate level, predicting the intensity of moods over a span of time could be done with a high degree of accuracy even without an extensive engineering feature or model tuning.

Twitter is a popular micro blogging service in which users post messages which are very short: less than 140 characters averaging 11 words per message. It is easy for a user to use with a mobile phone and convenient for research, because there are a very large number of messages, many of which are publicly available, and obtaining them is technically simpler than scraping blogs from the web [28]. It was found that already with a relatively simple sentiment detector based on Twitter data, consumer confidence and presidential job approval polls could be replicated [28]. For example, Nokia's Internet Pulse analyses Twitter tweets and seeks "Nokia" words. Tweets are categorized into positive and negative messages. In addition to those, the website presents automatically generated keywords.

2.4 Social Navigation

The relationship between a location or an activity and mood has been the subject for lots of research projects, for example Sorin Matei's mental maps of Los Angeles [24]. When navigating through a space, people use the physical layout, the relationships between different informational objects, and their own actions and activities.

Systems such as Cooltown [12] and PEACH [39] support spatial navigation and physical orientation, as well as semantic information about objects, and social recommendations about art and others' experiences. Similarly, MobiTags' primary goal is to support social, spatial, and semantic navigation through the integration of art information, social tags contributed by visitors, and map-based representations of museum space [5]. Another museum application, based on movement, activity, and density, took the form of an emotional climate map. Color-coding areas of the museum's floor plan suggested different atmospheres in various areas of the gallery [3].

Moodlog tourist service is implemented with a location-aware orientation-aware camera mobile device held by the user during a tour. Moodlog allows all users to augment their feelings relating to the visited place, tag their mood with mood tags and digital media such as music, photos and videos taken there, thus creating an inner mood of the place for tourists [4]. Mislove et al. [27] created the Pulse of the Nation, a cartogram, based on Twitter feeds, which presents a collective mood through the day in the different parts of the USA. SimpleGeo presents FourSquare, Gowalla, Twitter, Flickr, Bump, Brightkite, BlockChalk and Fwix messages on the map of the USA, but it does not analyze those messages.

Connecto is a mobile location-sharing application. Although researchers set out to gain a better understanding of how users might apply location sharing and location awareness to improve coordination and foster social connection, they discovered that the system was instead widely used for sharing mood and emotional status [2].

Perttula et al. [33] presents the Kartta mobile application, which provides users with a map showing them nearby areas they are likely to find interesting. To do this, it gathers and analyzes both explicit and implicit recommendations of specific locations. In addition to the media-capturing option, the application includes a simple, one-button interface for recommending that other users visit an area (a positive vote) or avoid it (a negative vote).

3. MOOD MONITORING MAP

In this section we will describe a system, Mood Monitoring Map, which derives points-of-interest and associated landmarks from user-generated moods captured onsite. With this approach, it helps users navigate standard environments, as well as temporary events, such as festivals and fairs in particular. In general, the research platform application is a social mobile service where users can send their current feelings to be shown on a map and that can then be utilized for social navigation. A typical large-scale event use case scenario is that a user is curious and wants to see where other users are located or what are the best and worst places to visit at the event. Another scenario is that a user wants to inform about a positive or negative place to other users by inputting the mood.

3.1 Design Principles

The Mood Monitoring Map is meant for emotion capturing, sharing and viewing. It does not support media sharing or messaging such as Kartta [33], for example. Many existing mood tracker applications are designed for mobile use but those do not include collective mood capturing or sharing options. Usually applications are personal diary-like solutions or they do not support geo-location of moods. Instead of common colors or words for mood inputting, we utilize symbolic happy, neutral and unhappy smiley faces (Figure 1.). Visualization of moods is based on an augmented Google Maps solution (Figure 2.), because it is already familiar to the most of the users and it provides suitable API to prototype our system.

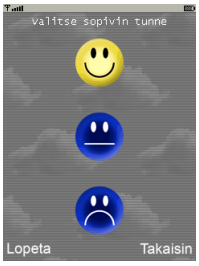


Figure 1. Manual mood selection is the main view of the custom-made mobile application.

Varied limitations of mobile devices and their Internet browsers are taken into consideration in the Mood Monitoring Map design. Also, the layout is as simple and light as possible. For mood inputting, a user can download a mobile client application or use a website. Operations are very much done on the server side and the input from a user is simplified. For example, just selecting the suitable mood from the list can do mood capturing. To avoid possible mobile data transfer problems, moods and locations are transferred via text messages (SMS) if the purpose-built mobile client application is used.

The Mood Monitoring Map has some unusual activities for a mood tracker application. All the moods collected on the map are anonymous. When a user inputs a mood, it can be tagged or stored with a message. These description texts are also visible to all users. Users may browse collective moods by selecting a timeframe and zooming the map. For example, an event visitor can observe moods given on one day in a specific place. In addition to manual mood inputting, the Mood Monitoring Map system automatically analyses moods from an event or location-related Twitter messages and provides the possibility of representing them close to the map.

3.2 Technological Solution

The Mood Monitoring Map system consists of three main components (Figure 3.): A) input mechanisms, B) the server side solution and C) visualization. The system includes different options for mood input methods and output visualization. Thus, it is available to more users and it can be used as it enriches the collective experience at an event the most. The core of the system runs automatically. Users' activities form the content of the service.

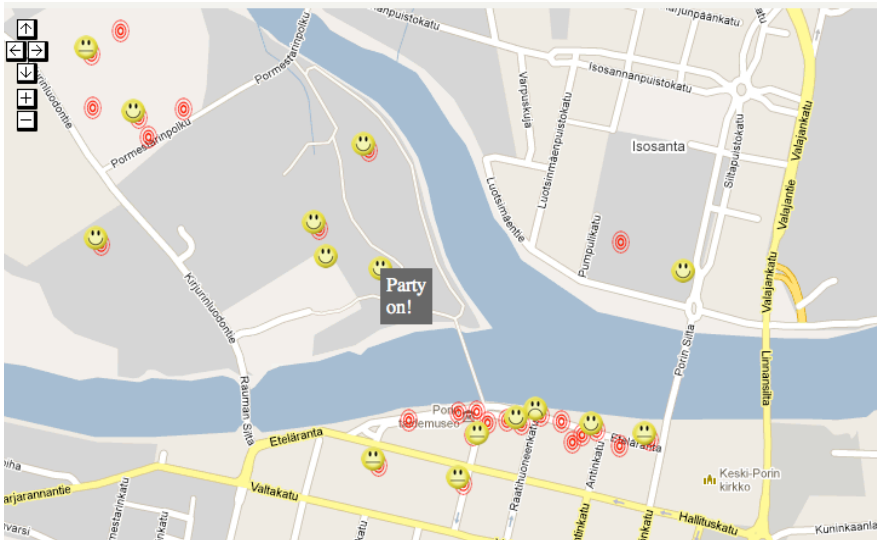


Figure 2. The Mood Monitoring Map website presenting moods, preconfigured event areas and one tagged mood.

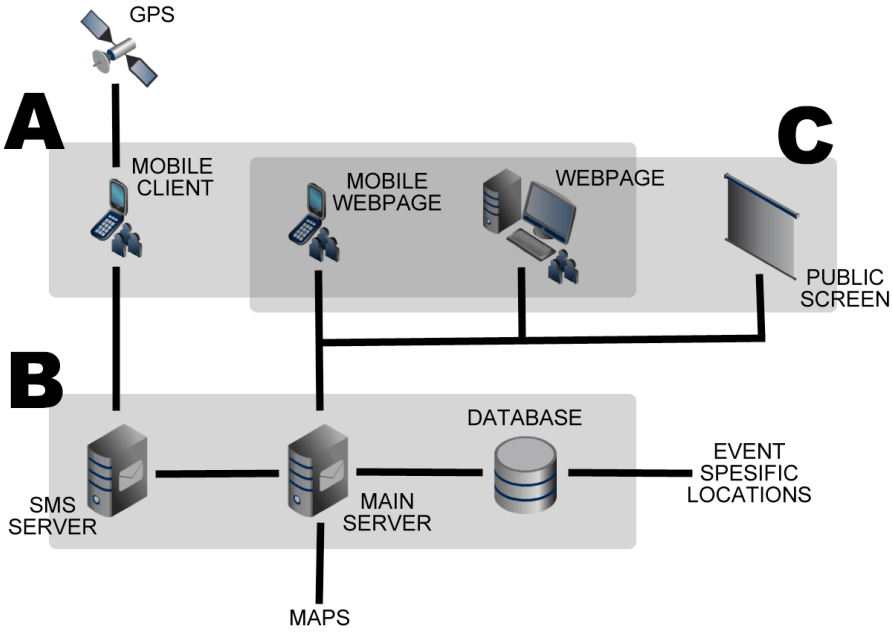


Figure 3. The main components of the Mood Monitoring Map are divided into three sections: A) input mechanisms, B) server side solution and C) visualization.

Input mechanisms include custom-made Java or Mobile Python mobile client applications. This client has three functions: an automatic geo-location based on GPS. If there is no GPS signal or a device does not support this feature, location can be selected from a premade list of places. The next step is to select the mood from three smiley faces (Figure 1.). Optionally, a user can also add a text description to the current mood. Manual mood inputting can also be done by using a website designed for mobile devices or a computer browser version of the website (Figure 2). In this case, a user drags a pin on the map and selects the mood from the list and adds the optional tag.

The server side solution consists of a text message server and a main server. Mobile clients send information to the text message server via SMS and the data is delivered to the main server, which stores moods, locations and descriptions in a database. The main server generates static map images for different kinds of visualization purposes and provides data to a website that utilizes Google Maps. The Mood Monitoring Map can be presented, for example, on a public display, a mobile device's screen or a computer screen. The main server has also a Twitter message analyzer component that seeks relevant messages from selected Twitter channels.

4. PILOT STUDIES

The aims of the field pilot study and the follow-up examination were to explore the usefulness and effect of the developed mobile mood sharing system on event visitors. In particular, the study focuses on the benefits of the social aspect, in addition to spatial and semantic navigation. The field pilot included in this project was realized in the summer of 2010 at the Pori Jazz Festival. The nine day long event gathers about 80 000 visitors. During the field pilot, the system stored about one hundred manually inputted moods. The use of collective mobile mood monitoring and its effects on the event participating experience were empirically evaluated. The follow-up examination was conducted in research laboratory circumstances during the spring of 2011. 16 volunteers tested the custom-made mobile semi-automatic mood tracker.

4.1 Field Pilot

The field pilot participants were partly research fellows and the actual pilot study was also executed through public audience participation. We placed ourselves among the audience near a public screen and tried to record behavior, information retrieval and the social interactions. Three observers from the research group followed some participators during the pilot study. Finally, the participators were asked to fill in a questionnaire during the festival or afterwards. The observation results and participants questionnaire answers were analyzed. Unfortunately we got only six filled-out questionnaires, thus the results are mainly based on observations.

The Mood Monitoring Map was also advertised on a festival radio station, on a main area screen and in a newspaper article. Despite that, the system stored only one hundred moods produced by 10 to 20 separate users. It appears that most of the people are not ready to install any applications on their mobile devices, or they do not use or have a mobile web browser for this kind of purposes. It seems that most of the users were more familiar with sending only a mood SMS than utilizing the mobile client application or website. Also, the website address should be more easier to remember. Because of high usage, the GSM-network provided relatively low data connection rates or then a connection was not even able to be established sometimes during the pilot test and it negatively affected the user-experience. Someone suggested that every significant area inside the event should have a large public screen and there should be a custom-made remote controller nearby for mood inputting.

The test would naturally be much more significant to the whole audience if the majority could actually take part in the collective mood sharing experience. So, the mood map was visualized on a large public screen. This encouraged people to participate in our experiment. When one's own or others' mood appeared on the public screen without any delay, users appreciated the system. Unfortunately sunlight made it useless during the daytime. In any case, this enabled almost everyone in the audience to take part in the experiment just by monitoring collective moods. The festival area was so extensive (about 1 km) that to obtain the best visibility, more than one public screen would have been essential.

One of the main things as to why the system stored only one hundred moods during the festival, was that it took too much attention to focus on the mobile device while at the same time enjoying festival performances and shows. Even though manual mood inputting included only a couple of steps, people more than likely just observed other users' moods and, based on the collective mood map, they made social navigation decisions.

4.2 Follow-up Examination

The field pilot encouraged us to study the possibilities of creating as automatic an emotion capturing system as possible. We decided to integrate wireless consumer-level brainwave sensor measurement equipment (NeuroSky MindSet headsets) into mobile devices via a custom-made Android application. These kinds of headphone-like headsets are not perhaps proper in real life public event situations, but in this examination in research laboratory circumstances, the user-experience is not so relevant. Maybe these devices will be less obtrusive and slimmed down in the future, or brainwaves will be measured some other way.

It is difficult to instruct people to be happy, neutral or unhappy. Some things make others happy while others might not feel anything special. In addition, if study participants have to think of something to generate predetermined emotions, those feelings are not real, and study results are not generalizable. So, instead of monitoring feelings, we focused on capturing brainwaves produced by facial expressions. In this way, the study produced the most reliable data. In Figures 4, 5 and 6 the captured brainwaves readings' mean values are presented. Anyway in this case, the shape of the figure is meaningful. In this initial study we did not take into consideration how a study participant's different thoughts, body movements, activities and other actions affected the collected brainwave signals. In field situations, those things might generate more noise in the sample data, but we assume that facial expressions can still be identified from readings provided by the headset.

A separate prototype brainwave mobile application has minimal functions. A study participant selects the mood similarly to that of the mobile client application (Figure 1.). Then a two second time phase follows to perform the chosen facial expression related to the mood. The brainwave data was stored automatically in the

database during the examination. Every participant performed all the mood-related expressions once.

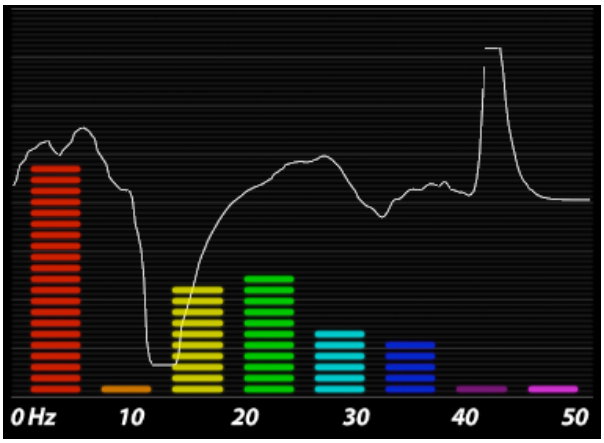


Figure 4. Captured brainwaves when study participants smiled.

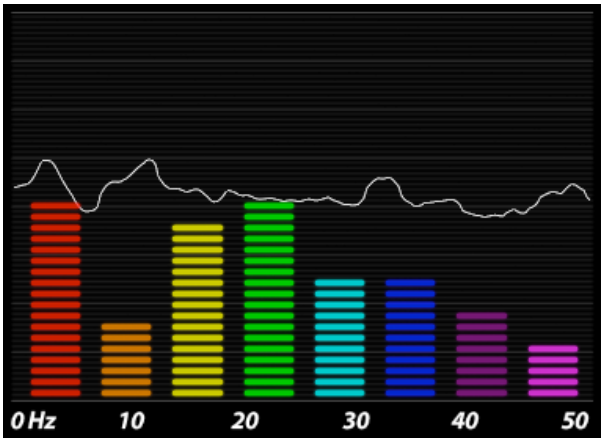


Figure 5. Captured brainwaves when study participants had a neutral facial expression.

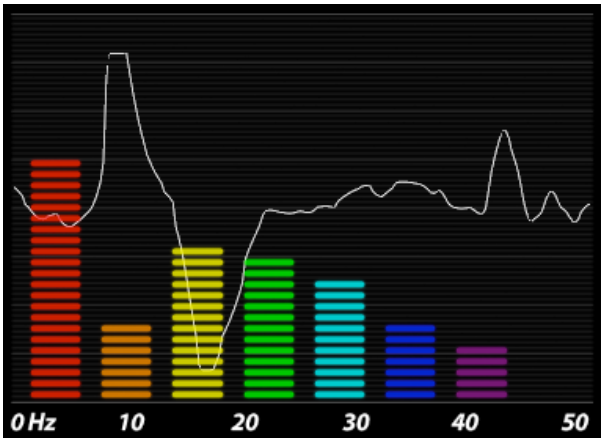


Figure 6. Captured brainwaves when study participants had a negative expression on their face.

People's facial expressions are a little bit different and this causes variation in the data. Anyway, by comparing Figures 4, 5 and 6, it is clearly visible that it is possible to detect these three facial expressions by using consumer-level brainwave headsets. Mood inputting by moving facial muscles is faster than selecting a mood from a mobile device's touchscreen. It also might be an automatic procedure if a person expresses feelings via the face, for example, if someone is happy and smiles at the same time without thinking about making the smile expression. It is easily possible to integrate the brainwave feature into the Mood Monitoring Map system as a replacement for manual inputting.

5. DISCUSSION

Large-scale events are an important domain for research on groups and computational media. While current services target individual spectators, our research evidenced how spectatorship is about co-experiencing the event. Moreover, the increasing availability of mobile computing provides new opportunities to support on-site groups of spectators.

Even though the emotions have been extensively studied for a long time in psychology, there still is controversy on how human emotions could be presented and described. For example, there is controversy on whether facial expressions are perceived categorically (e.g. [37]), or if a set of emotions, which can be called basic emotions, exists [30]. While our understanding of emotions and their presentation is still incomplete, it is difficult to define methods, which would succeed in capturing information about them [17].

Persons indicate moods slightly differently in this study. So, it is troublesome to create a brainwave emotion-capturing system that is suitable for all. Instead, a personalized version with a calibration function would work more reliably.

In addition to our brainwave examination, some new research questions arose during the field pilot. Is it possible to detect users' moods through heart rate measurement? Does it make any difference how a person walks or moves? In other words, could we use mobile devices' acceleration or motion sensors to measure emotion-related data? If there are a lot of decibels in some area, is there a better collective mood climate? Could we use mobile devices' microphones to capture decibels or perhaps separate sounds that indicate the different moods of nearby users?

When it comes to devices used in our follow-up examination, there is a limited amount of related work in this area. A number of groups [10, 22, 42] use professional-quality brainwave devices that offer higher quality signals but they are expensive and based on wired headsets. In contrast, consumer-oriented versions of these EEG-headsets (EmotivSystems, NeuroSky and OCZTechnology) are considerably cheaper and noisier, but at the same time are more geared toward gaming applications rather than the types of classification we have used them for. Typically, these headsets are wireless, enabling mobile uses. [23]

6. CONCLUSION AND FUTURE WORK

Well-established psychophysiological techniques bear promise, but so far have mainly been validated in laboratory situations. [41] To apply them in real-life situations also, we built the Mood Monitoring Map platform. This system shows that emotional experiences can be stored and visualized in a relatively unobtrusive way, while at the same time enabling us to gather

knowledge on emotional experiences and social navigation at large-scale events. Moreover it offers the opportunity to prototype emphatic application concepts and test them in relevant situations. Furthermore, by presenting our system, we have shown our attempts to increase awareness of shared interests and experiences among communities. We believe that building a context-aware social navigation system will facilitate community formation based on shared interests and knowledge exchanges within communities.

In summary, mobile applications should cause reflection on social presence, and create greater awareness and interaction with a space. Applications should also be open to interpretation (e.g. the primary goal is to have people reflect on social presence and create greater awareness, but they may reflect on other things such as computer surveillance, privacy, using social recommender systems to change visitors' experiences). Additionally, applications should be enjoyable and engaging. In many of these systems, the user had the ability to select a representation for their mood without too much effort or interpretation, and the resulting representation had enough ambiguity to allow for creative representations and interpretations. -But not so much that the user would feel that what they are sharing will have no relevance to other users [38].

While our experiments are limited, we have shown that it is possible to enrich user experience at public events from user-generated data. Also, because of our focus on this kind of environment, we made design decisions that allow users to derive some value from the system with only minimal input. All functions are as automatic as possible. Anyway, as a result of this study, we still have to balance between the user-experience and automatisation from a technological point of view. All in all, the evaluation results indicate that most of the study participants appreciated this sort of experiment. It seems that the Mood Monitoring Map or a corresponding system could be used to increase positive large-scale public event experiences when designed properly.

Additionally, we found observations to be a critically valuable tool in prototyping this social mobile application. After running more complex pilots, the next step for this work is a full-fledged field experiment with a group of friends or colleagues in an unconstrained environment that could be a large-scale exhibition area, for example.

As a future work, the map-view should be enhanced to meet the demands of fluent mobile social navigation. A heat map could be a relevant solution to provide this kind of collective social navigation information on mobile device screens. [33] Also, event areas could be presented as a mobile device friendly list that is sorted by the rate of the users' moods. In addition to mood monitoring, mobile brainwave detection devices offer other interesting research opportunities, such as how they could be used to control mobile devices as an input method, or could they improve mobile media tagging, for example.

7. ACKNOWLEDGMENTS

We thank our study participants for their time and feedback. Also, we would like to acknowledge Tekes – the Finnish Funding Agency for Technology and Innovation for funding this project.

8. REFERENCES

[1] Ark, W., Dryer, D., Lu, D. (1999). The emotion mouse. In Proceedings of HCI'99, pp. 818–823, Munich, Germany.

[2] Barkhuus, L., Brown, B., Bell, M., Sherwood, S., Hall, M., Chalmers, M. (2008). From aware-ness to repartee: Sharing location within social groups. In Proceedings of SIGCHI'08, pp. 497–506, Florence, Italy. doi:10.1145/1357054.1357134.

[3] Boehner, K., Sengers, P., Medynskiy, Y., Gay, G. 2005. Opening the frame of the art mu- seum: Technology as art and tool. In Proceedings of DACC'05, pp. 123–132, Copenhagen, Denmark.

[4] Chen, Z., Chao, Y., Chang, J., Chan, L., Hsu, Y., Hung, Y. 2008. Moodlog: Touring in mood of place. Ubi-Media Computing, 2008 First IEEE International Conference 2008.

[5] Cosley, D., Baxter, J., Lee, S., Alson, B., Adams, P., Sarabu, C., Nomura, S., Gay, G. 2009. A tag in the hand: Supporting semantic, social, and spatial navigation in museums. In Proceedings of CHI'09, Boston, MA.

[6] Das, S., Chen, M. 2001. Yahoo! for Amazon: Extracting market sentiment from stock message boards. In Proc. of the 8th Asia Pacific Finance Association Annual Conference (APFA 2001).

[7] Desmet, P., Overbeeke, S., Tax, S. 2001. Designing products with added emotional value; development and application of an approach for research through design, The Design Journal 4 (2001) (1), pp. 32–47.

[8] Dieberger, A. 1999. Social connotations of space in the design for virtual communities and social navigation. In Munro, A., Hook, K., and Benyon, D. (Eds.), Social Navigation of Informa- tion Space. Berlin: Springer-Verlag.

[9] Dourish, P., Chalmers, M. 1994. Running out of space: Models of information navigation. In Proceedings of HCI'94, Glasgow, Scotland.

[10] Farwell, L., Donchin, E. 1988. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalography and clinical Neurophysiology, 70(6):510–523, 1988.

[11] Fernandez, R., Scheirer, J., Picard, R. 1999. Expression glasses: A wearable device for facial expression recognition. In Proceedings of CHI'99, p. 484, Pittsburgh, PA.

[12] Fleck, M., Frid, M., Kindberg, T., O'Brien-Strain, E., Rajani, R., Spasojevic, M. 2002. From informing to remembering: Ubiquitous systems in interactive museums. Pervasive Computing, 1(2), pp. 13–21. doi:10.1109/MPRV.2002.1012333

[13] Gay, G. 2009. Context-Aware Mobile Computing: Affordances of Space, Social Awareness, and Social Influence. A Publication in the Morgan & Claypool Publishers series Synthesis Lectures on Human-Centered Informatics. ISBN: 9781598299915.

[14] Gluhak, A., Presser, M., Zhu, L., Esfandiyari, S., Kupschick, S. 2007. Towards Mood Based Mobile Services and Applications. EuroSSC 2007: 159-174.

[15] Hearst, M. 1992. Automatic acquisition of hyponyms from large text corpora. In Proceedings of the Fourteenth International Conference on Computational Linguistics.

[16] Hook, K., Benyon, D., Munro, A. (2003). Designing Information Spaces: The Social Navigation Approach. Berlin: Springer-Verlag.

[17] Isomursu, M., Tähti, M., Väinämö, S., Kuutti, K. 2007. Experimental evaluation of five methods for collecting emotions in field settings with mobile applications. International Journal of Human-Computer Studies. 2006 Elsevier Ltd. All rights reserved. doi:10.1016/j.ijhcs.2006.11.007

[18] Jacucci, G., Oulasvirta, A., Salovaara, A., Sarvas, R. 2005. Supporting the Shared Experience of Spectators through Mobile Group Media. GROUP'05, November 6–9, 2005, Sanibel Island, Florida, USA.

[19] Kemp, C., Griffiths, T., Tenenbaum, J. 2004. Discovering Latent Classes in Relational Data. 2004 - MIT AI Memo.

[20] Koolwaaij, J., Tarlano, A., Luther, M., Nurmi, P., Mrohs, B., Battestini, A., Vaidya, R. 2006. Context Watcher - Sharing Context Information in Everyday Life, Web Technologies, Applications, and Services, WTAS 2006, Calgary, Canada (2006).

[21] Lang, P. J. 1980. Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, J. H. Johnson, & T. A. Wil- liams ~Eds.!, Technology in mental health care delivery systems ~pp. 119– 137!. Norwood, NJ: Ablex.

[22] Li, K., Sankar, R., Arbel, Y., Donchin, E. 2009. P300 Based Single Trial Independent Component Analysis on EEG Signal. Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience, pages 404–410, 2009.

[23] Lin, C., Ko, L., Chang, C., Wang, Y., Chung, C., Yang, F., Duann, J., Jung, T., Chiou, J. 2009. Wearable and Wireless Brain-Computer Interface and Its Applications. Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience, pages 741–748, 2009.

[24] Matei, S., Ball-Rokeach, S., Qiu, J. 2001. Fear and misperception of Los Angeles urban space: A spatialstatistical study of communication-shaped mental maps. Communication Research, 28(4), 429-463.

[25] Mishne, G., Balog, K., Rijke, M., Ernsting, B. 2007. MoodViews: Tracking and Searching Mood-Annotated Blog Posts. In: Proceedings Int. Conf. on Weblogs and Social Media (ICWSM-2007), March 2007.

[26] Mishne, G., Rijke, M. 2006. Capturing Global Mood Levels using Blog Posts. In: AAAI 2006 Spring Symposium on Computational Approaches to Analysing Weblogs (AAAI-CAAW 2006), March 2006. Also presented at the 16th Meeting of Computational Linguistics in the Netherlands (CLIN 2005).

[27] Mislove, A., Lehmann, S., Ahn, Y-Y., Onnela, J-P., Rosenquist, J. 2010. Pulse of the Nation - U.S. Mood throughout the Day inferred from Twitter. [Online]. http://www.ccs.neu.edu/home/amislove/twittermood/ (2011, Apr.).

[28] O'Connor, B., Balasubramanyan, R., Routedge, B., Smith, N. 2010. From Tweets to Polls: Linking Text Sentiment to Public Opinion Time Series. In Proceedings of the Fourth International AAAI Conference on Weblogs and Social Media (ICWSM). Washington, DC, May 2010.

[29] Ortony, A., Clore, G., Collins, A. (1988). The Cognitive Structure of Emotions. New York, NY: Cambridge Press. doi:10.1145/238218.238344

[30] Ortony, A., Turner, T.J. 1990. What's basic about basic emotions? Psychol Rev 97 (3), 315–331.

[31] Peltonen, P., Salovaara, A., Jacucci, G., Ilmonen, T., Ardito, C., Saarikko, P., Batra, V. 2007. Extending Large-Scale Event Participation with User-Created Mobile Media on a Public Display. MUM'07, December 12-14, 2007, Oulu, Finland.

[32] Persson, P. 2003. ExMS: an Animated and Avatar-based Messaging System for Expressive Peer Communication, Proceedings of GROUP 2003 conference, Nov. 9-12, 2003.

[33] Perttula, A., Carter, S. and Denoue, L. (2009) Kartta: Using Multimedia and Context to Navigate Unfamiliar Environments, MindTrek 2009, pp. 120-123.

[34] Perttula, A., Tuomi, P., Suominen, M., Koivisto, A., Multisilta, J. 2010. Users as Sensors: Creating Shared Experiences in Co-creational Spaces by Collective Heart Rate. MindTrek 2010, October 6th-October 8th 2010, Tampere, FINLAND.

[35] Picard, R. (1997). Affective Computing. Cambridge, MA: MIT Press. doi:10.1016/S0953-5438(98)00056-3

[36] Rachuri, K., Musolesi, M., Mascolo, C., Rentfrow, P., Longworth, C., Aucinas, A. 2010. EmotionSense: A Mobile Phones based Adaptive Platform for Experimental Social Psychology Research. In Proceedings of UbiComp '10, 2010.

[37] Schiano, D., Ehrlich, S., Sheridan, K. 2004. Categorical imperative NOT: facial affect is perceived continuously. In: Proceedings of CHI04, ACM Press, pp. 49–56.

[38] Sengers, P., Boehner, K., Mateas, M.,Gay, G. 2008. The disenchantment of affect. Journal of Pervasive and Ubiquitous Computing, 12(5), pp. 347–358.

[39] Stock, O., Zancanaro, M., Busetta, P., Callaway, C., Krüger, A., Kruppa, M., Kuflik, T., Not, E., Rocchi, C. 2007. Intelligent presentation of information for the museum visitor in PEACH. User-Modeling and User-Adapted Interaction, 17(3), pp. 257–304.

[40] Sundström, P., Ståhl, A., Höök, K. 2007. In Situ Informants Exploring an Emotional Mobile Messaging System in Their Everyday Practice, In a special issue of IJHCS on Evaluating Affective Interfaces, vol. 65, issue 4, pp. 388--403.

[41] Westerink, J., Ouwerkerk, M., Vries, G., Waele, S., Eerenbeemd, J., Boven, M. 2009. Emotion measurement platform for daily life situations. Affective Computing and Intelligent Interaction and Workshops, 2009. ACII 2009. pp.1-6, 10-12 Sept. 2009. doi: 10.1109/ACII.2009.5349574.

[42] Xu, N., Gao, X., Hong, B., Miao, X., Gao, S., Yang, F. 2004. BCI competition 2003-data set IIb: enhancing P300 wave detection using ICA-based subspace projections for BCI applications. IEEE Transactions on Biomedical Engineering, 51(6):1067–1072, 2004.

Publication 4

Kiili, K., **Perttula, A.**, & Tuomi, P. (2010). Development of Multiplayer Exertion Games for Physical Education. IADIS International Journal on WWW/Internet. Vol. 8, No. 1, pp. 52-69. ISSN: 1645-7641.

IADIS International Journal on WWW/Internet
Vol. 8, No. 1, pp. 52-69
ISSN: 1645-7641

DEVELOPMENT OF MULTIPLAYER EXERTION GAMES FOR PHYSICAL EDUCATION

Kristian Kiili. *Tampere University of Technology, Pohjoisranta 11 A, 28101 Pori, Finland. kristian.kiili@tut.fi*

Arttu Perttula. *Tampere University of Technology, Pohjoisranta 11 A, 28101 Pori, Finland. arttu.perttula@tut.fi*

Pauliina Tuomi. *Tampere University of Technology, Pohjoisranta 11 A, 28101 Pori, Finland. pauliina.tuomi@tut.fi*

ABSTRACT

The potential use of serious games in educational settings is huge, because a large and growing population is familiar and engaged with playing games. However, the popularity of games has aroused also problems. For example, obesity has recently become a big problem in many countries. The development of motion-based controllers and the concern over the high levels of obesity has facilitated the new coming of exertion game genre that involve physical activity as a means of interacting with the game. In this paper a design framework for exertion games is proposed. Based on the framework three mobile multiplayer exertion games were developed and empirically evaluated in a junior high school (n = 105). The results indicated that mobile phones and heart rate belts were experienced as appropriate exertion game controllers and simple motion detection can be used to design engaging exertion games. The results showed that motion-based games and team play motivate children a lot and games could be an effective 'weapon' in the fight against the growing problem of obesity. Furthermore, the results indicated that exertion games could have also educational value and educational content could be embedded in to exertion games. Generally, it seems that exertion games could provide meaningful and cost-effective solutions for physical education and other educational contexts. In spite of promising results more research, particularly in the area of exertion game design is needed.

KEYWORDS

Exertion game, mobile phone, physical education, heart rate, multiplayer, flow experience.

1. INTRODUCTION

The development of new educational methods is necessary to accelerate learning, develop new skills for the knowledge economy and to reach learner groups that are currently unreached by conventional techniques of learning. The potential use of serious games in educational settings is huge, because a large and growing population is familiar and engaged with playing games. However, the popularity of games has also aroused problems. For example, obesity has recently become a big problem in many countries. According to Gorgu et al. (2009) the reasons for obesity include a high calorie diet and a serious lack of physical activities in the daily lives of children. It has been argued that video games are one of the main reasons for physical inactivity (Vandewateret et al., 2004; Luepker, 1999; Parizkova & Chin, 2003; Riviere, 2004; Sothern, 2004). The exertion game genre tries to change this by encouraging players to perform physical movements during gameplay. According to Mueller, Agamanolis, Vetere and Gibbs (2009) exertion games (also referred as exergames) are an emerging form of computer games that aim to leverage the advantages of sports and exercise in order to support physical, social and mental health benefits. An exertion game is controlled with an input mechanism that requires a player to intentionally invest physical exertion (Mueller, Gibbs & Vetere, 2008). Exertion can be defined as an act of exerting, involving skeletal muscles, which results in physical fatigue, often associated with physical activity and sport. The overall hope is that the sense of enjoyment that traditional video games produce can be harnessed to engage children in greater physical activity.

Basically, exergaming is not a new phenomenon. It was introduced with the Atari 2600's footpad controller in the early 1980's and popularized with Konami's Dance Revolution product in the 1990's. However, in recent years, the development of motion-based controllers has facilitated the advent of the exertion game genre. Currently, exertion games are specifically associated with Nintendo Wii game console and recent research has used it as a test-bed in many different contexts (e.g. Graf, Pratt, Hester & Short, 2009; Graves, Stratton, Ridgers & Cable, 2007). The research has shown that exertion games can be an effective form of exercise (e.g. Papastergiou, 2009; Graf et al., 2009). On the other hand Daley (2009) has criticized the previous studies and calls for more extensive and methodologically robust research. He argues that although studies have produced some encouraging results regarding the energy expenditure of exertion games, active gaming is no substitute for real sports. For example, in the Wii Sports games, players are required to move their bodies to control their virtual characters in the game, but the movements are quite small and intensity is usually low. However, research and tryouts have been also conducted in order to make the gaming more active with the help of heart rate measuring devices. The use of heart rate measurement immediately brings more intensity to the gaming experience and makes it automatically more energy requiring. For example, Nenonen, Lindblad, Häkkinen, Laitinen, Jouhtio and Hämäläinen (2007) have used heart rate as a control method in their game called Pulse Masters Biathlon. The objective of the game was to get through the track as fast as possible. The gameplay consisted of two states: cross-country skiing and target shooting. (Nenonen et al. 2007, 853) According to Nenonen et al. (2007) players felt that heart rate was a fun and interesting way to interact with the game. They were also able to show that heart rate interaction could be used with any exercise method. Most importantly, the players also reported that this could be a reason to exercise since the game was addictive, and it felt like a good exercise (Nenonen et al. 2007, 856).

In spite of criticism, previous research indicates that exertion games can provide a means to motivate, at the very least, persons who are less active. Thus, exertion games might have some potential use in the fight against youth overweight and obesity. However, more research is needed to distinguish between exertion games that contribute to increased fitness and those that only offer novel ways of controlling games. Thus, we need systematic research, particularly in the area of game design. One of the biggest challenges is the need to make the game attractive to players and at the same time effective as an exercise. The aim of this study is to provide design principles that facilitate the development of high quality exertion games for children and youth. In fact, we propose a design framework for exertion games and consider ways to implement exertion games into schools. Furthermore, we report the results of two pilot studies in which we tested three novel exertion games that are based on the framework. Finally, the evaluation results of the used exertion games and players' opinions about exergaming are presented and discussed.

2. DESIGN FRAMEWORK FOR EXERTION GAMES

The flow theory (Csikszentmihalyi, 1991) forms a foundation to design exertion games, because it provides a universal model for engagement (Sweetser & Wyeth, 2005; Kiili & Lainema, 2008). Flow has been applied in several different domains including sports, digital games and education. These domains are partly parallel with exertion games and provide several aspects to consider. For example, Jackson and Csikszentmihalyi (1999) have stated that sports can offer such rewarding experiences that one does it for no other reason than to be part of it. Furthermore, they argue that a sport setting is structured to enhance flow. Although, winning in sports is important, flow does not depend on final outcomes of an activity, and offers athletes something more than just a successful outcome. In fact, an optimal experience usually occurs when a person's body or mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile (Csikszentmihalyi, 1991). Such experiences are not necessarily pleasant when they occur, but they still produce enjoyment. This is true also in exertion games. However, exertion games should not be too intensive because they are mainly targeted to persons whose fitness level is low or to persons who are not interested in regular and heavy physical exercises.

We constructed a design framework for exertion games by combining previous research results about flow and exergaming (see figure 1). The framework can be divided into five main elements: Player, flow antecedents, gameplay, flow state and social context.

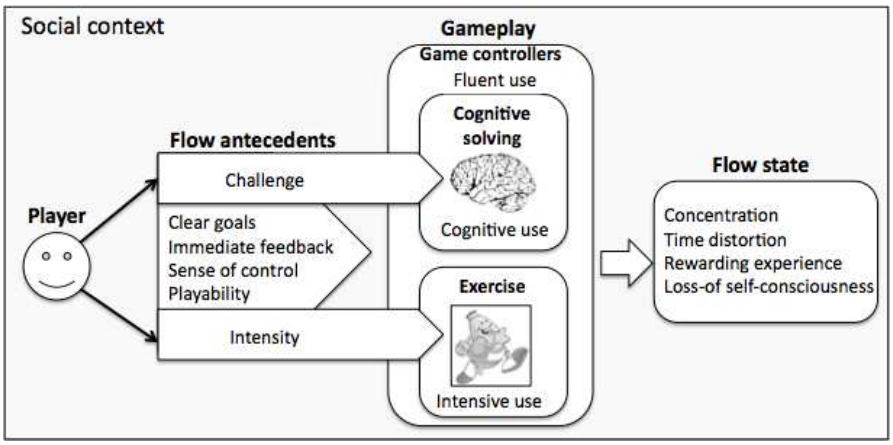


Figure 1. Design framework for exertion games

2.1 Player and Social Context

Exercising can be boring alone. For example, Paw et al (2007) found out that children seem to prefer multi-player and group game play to individual exercise. Teamwork and competition are good motivators that engage players. However, the multiplayer approach is not a magic bullet alone. Several player characteristics should be taken into account when designing exertion games in order to create enjoyable and effective experiences. For example, in what ways the game can adapt to the player? Does the game controllers work similarly for different people sizes? Could the handicapping system motivate low fitted players?

2.2 Flow Antecedents and Gameplay

Gameplay is the core of the game and its significance should not be underestimated. According to Costikyan (2002), good gameplay keeps a player motivated and engaged throughout an entire game. Game designers Rollings and Adams (2003) have defined gameplay as one or more causally linked series of challenges in a simulated environment. In fact, gameplay also includes the actions that players can take to meet the challenges. Thus, the implementation of game controllers that enable interaction with the game is crucial. Generally, the game controllers (player's movements) should be easy to adopt and the whole user interface fluent to use.

The flow antecedents are factors that facilitate flow experience through engaging gameplay. The antecedents can be divided into two dimensions: static and dynamic. Clear goals, immediate feedback, sense of control and playability are quite static antecedents and we do not consider them in this paper. In contrast challenge and intensity are dynamic antecedents that should be adapted to players' skill and fitness levels (Sinclair, Hingston, & Masek, 2007). In order to optimize the engagement and effectiveness of exertion games Sinclair, Hingston, and Masek (2007) have proposed a dual flow model that extends the original three-channel flow model with an effectiveness dimension that reflects an intensity-fitness balance.

Furthermore, in a recent study, Kiili and Perttula (2010) extended the dual flow model with a team flow dimension (Figure 2).

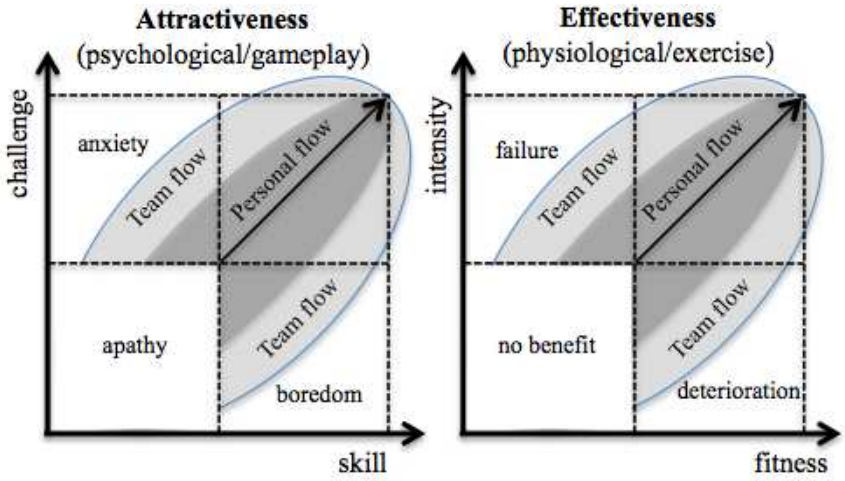


Figure 2. An extended dual flow model for exertion games (Kiili & Perttula, 2010)

According to the dual flow model the challenge-skill balance determines the attractiveness of the game. If the challenge is too low, a player tends to feel boredom and when the challenge is too high, a player tends to feel anxiety. Similarly the intensity-fitness balance determines the effectiveness of the game. If the game is too intensive, a player will fail to play the game and is unable to continue exercising. On the other hand, if the intensity is too low compared to player's fitness level, a player will enter a state of deterioration. The optimal exergaming experience can be achieved when both the attractiveness and effectiveness dimensions are in balance and a player is in the flow zone.

However, the balancing of exertion games is not as straight forward as the balancing of traditional computer games. The basic balancing principle suggests that the difficulty level of a game can be gradually increased, because it is assumed that a player's skill level increases with playing time. Thus, for example, playtesting can be used to balance the challenges for a certain target audience. Such a solution does not work properly in exertion games. Although, a player's skills may increase during playing, in lengthy playing sessions the gradually increasing intensity will lead to exhaustion and failure. To overcome this problem, Sinclair, Hingston, and Masek (2007) have suggested that exertion games should adapt dynamically to a player's performance, or they should be based on simple mechanics that focus more on input devices and exercise movements than on complex gameplay. In general, the dual flow model provides a good starting point for designing exertion games, but more detailed design principles are still needed.

2.3 Flow State

According to Kiili and Lainema (2008), whenever people reflect on their flow experiences, they mention some, and often all, of the following characteristics: concentration, time distortion, rewarding experience, and loss of self-consciousness. In flow a person is totally

focused on the activity and is able to forget all unpleasant things. Because flow-inducing activities require complete concentration of attention on the task at hand, there are no cognitive recourses left over for irrelevant information. Thus, self seems to disappear from awareness during flow. In other words, in flow there is no room for self-scrutiny Csikszentmihalyi (1991). This is very important in exertion games, because some of the players may have low self-esteem and they are afraid to exercise publicly. According to Csikszentmihalyi (1991) during the flow experience the sense of time tends to bear little relation to the passage of time as measured by the absolute convention of a clock; Usually time seems to pass really fast. Time distortion facilitates the physical gains. Rewarding experience refers to an activity that is done, not with the expectation of some future benefit, but simply because the doing itself is interesting and fun. Thus, experienced flow works as a hook that engages players and get them to play games again and again.

3. MOBILE EXERTION GAME PLATFORM

Following is a short description of the exertion game platform that is used in the research reported in this paper.

Mobile game controller. As game controllers we use the Nokia 60 series smart phones tat have a built-in 3-axis accelerometer sensor. To exploit this feature we have a custom made Mobile Python application. The mobile client sends every properly done player movement to the game server via a network socket by the WLAN connection. To determine this movement we store the accelerator sensor readings x, y and z to separate vectors. The mobile software observes approximately 35 times per second the accelerometer readings for stream sensor data. We use these vectors to compose the normed difference between old and new accelerator data. And the result presents our magnitude vector. We do not have an absolute position of the certain phone in a virtual space or an estimate of the tilt angle of the device relative to the gravitational field. In this case we are only interested in to detect the magnitude of the movement. When this value exceeds the certain margin, the mobile client software recognizes this as a squat or a jump movement. It also waits the value of the magnitude vector to fall below this margin before new movements are sent to the server. This prevents multiple sending procedures occurring during the one movement.

Although our solution detects movements, it cannot distinguish a jump from a squat, for example. In spite of that, our games are designed for certain movements. However, before starting to play players can decide what kinds of movements they will use in the game. Such an approach makes it possible to use same client-software in a variety of games and for exercising purposes.

Server side solution. Our exertion games are running in classic client-server architecture (figure 3), but the server is only a simple socket server, which echoes all received messages to all clients. The game engine is one of the clients. This way it is possible to use the same server without modifications for different games. As a drawback this solution causes unnecessary traffic between clients, which are used as controllers and game session is vulnerable to disturbance. In future versions socket server will distinguish game engines from controllers and address messages to right clients.

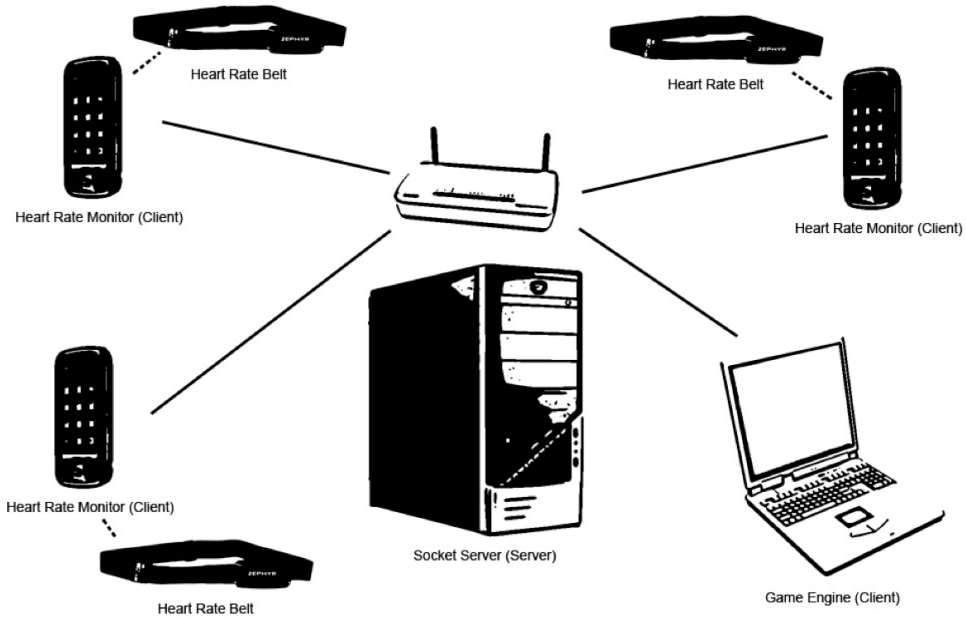


Figure 3. Mobile client-server architecture

4. STUDY 1 – ACCELERATION BASED GAMES

4.1 Method

Participants. The pilot testing was conducted in fall 2009 at the school of Kasavuori in Finland. The participants were 7th-9th graders (n = 45). The gender distribution was almost even. The school of Kasavuori provided appropriate settings for the study because it is profiled to be one of the most advanced Finnish schools in usage of new media.

Test beds: Tuck of War and Diamond Hunter. Both of these real-time mobile multiplayer games can be controlled with the mobile client software presented above. A mobile phone is kept in a pocket or alternatively on the hand during the game session. The game scene is presented by using a large public display or a video projector.

Tuck of War, ToW (see Figure 4) is designed for two teams that consist of one to five players. Players' characters are selected randomly. The goal of the game is to pull other team players one by one to the gap that is located between the teams. When the game starts players should perform squat movements as frequent as possible. One squat equals to one point to the team. The sum of the squats is the pulling power of the team. One game takes about from 30 seconds to two minutes depending on the amount of the players and fitness balance of the teams.

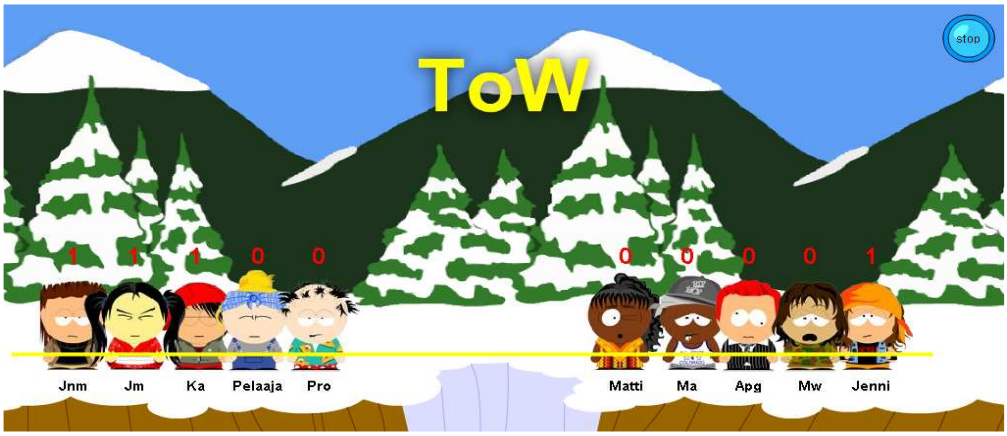


Figure 4. Tuck of War (Game characters were created with SP-Studio, www.sp-studio.de, for this prototype.)

Diamond Hunter (see Figure 5), a 2D-platform game, can be played by one to four players simultaneously. Game characters move automatically all the time and change direction as a result of collision to the wall. Players attempt to jump in a correct place and collect all the visible diamonds. They can also collect magic shoes to double their jumping power for few seconds. The best diamond collector is the winner of the game. One game takes usually from 30 seconds to two minutes depending on the amount of the players but the exercise is not intensive as in the Tuck of War game. It is noticeable that either of these current versions of presented mobile exertion games does not take into account player's physical condition.

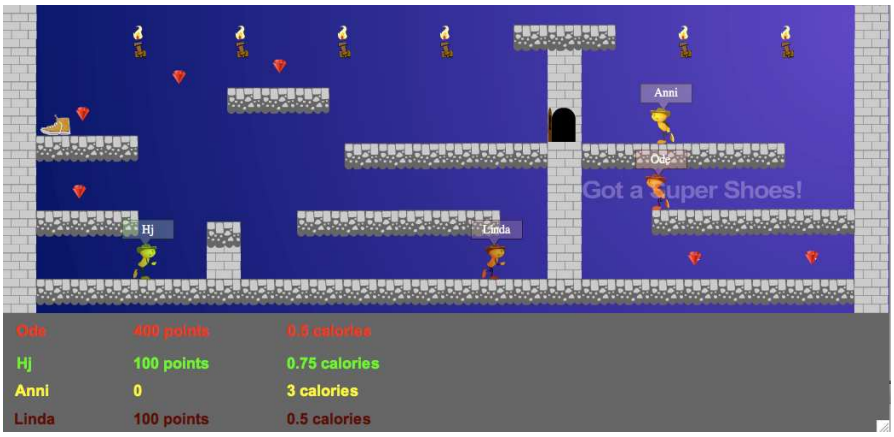


Figure 5. Diamond Hunter (Game graphics are derived from examples of ActionScript 3.0 Game Programming University book, for this prototype.)

Instruments. The evaluation of the games was mainly based on a 9-item questionnaire delivered through MoViE (Mobile Video Experience), which is a social mobile service that enables users to create video stories using their mobile phones. We used video based questionnaire in order to increase validity by avoiding interpretation problems of statements. The items of the questionnaire were from following themes derived from the proposed design

framework: usability of game controllers, usefulness of exercises and the meaning of multiplayer approach. Each video question had three multiple answer possibilities; I agree, I disagree and No opinion. The questions were both spoken in the video clips and presented textually after each video. We did not include any background questions because that did not serve the main intention of this pilot study. Finally, 32 of the participants filled in the questionnaire properly.

Procedure. 1) At first, the participants played ToW and Diamond Hunter exertion games. Three observers followed the players during playing sessions and wrote down notes with respect to player-environment, player-devices, player-to-player, and player-actor interactions (Lindt et. al, 2007). 2) After the gaming sessions observers discussed briefly with players. 3) Then players filled in the video based questionnaire within 15 minutes.

4.2 Results

Overall, the players really appreciated the tested game concepts. For example, some of the players said that This was an amazingly fun game.", "This was really made in a cunning and interesting way!", and "Where can I download this?". One of the most positive aspects of the tested exertion games was that they did not represent any traditional sport games or events like track and field events, for example. This was one of the reasons why these exertion games were interpreted as being fun and suitable for a large group of pupils. Furthermore, randomly decided game characters appealed to players surprisingly a lot and lowered the threshold to start playing.

The games engaged the players in a way that they truly shared the experience of team play, which was seen in yells, screams, cheers and laughs. The pupils from 7th and 8th grade we experienced as the most enthused group of participants, which pinpoints the fact that children and youth really are the most convenient target groups for these kinds of exertion games. The players exercised with an adequate speed and reacted constantly, which indicates high player immersion and concentration. Furthermore, players got quite intensive workout during the playing session and they seemed to enjoy the physical activities.

4.2.1 Usability and Game Controller

The players seemed to understand the meaning and the use of the mobile phone as a game controller. However, there were slight problems with the use of phone's touch screen that was a new feature for most of the participants. For example, part of the participants needed assistance on how to fill in their nicknames and to get started. When the game was on, players seemed to realize the connection between their squatting or jumping and the feedback illustrated on the screen. Furthermore, mobile phones were considered, as appropriate devices for exertion games and participant would have liked to use their own phones as game controllers. The questionnaire results strengthen these observations – 70 percent of the players emphasized that the game controllers should be intuitive and easy to use. Furthermore, it came out that the motion detection has to be fast. Overall, the results clearly indicated that it is possible to design engaging exertion games with only simple motion detection.

In this research we used games that were based on simple gameplay mechanics that supported low-level motion detection. In fact, the movements that players made were simple gross motor skills and were easy to perform. Based on the observations, we argue that one does not have to know exactly what movements a player makes – the main thing is that the

player is moving and is having fun. On the other hand, the study revealed that the threshold for cheating is quite low, at least for very competitive players. Players noticed very quickly that by holding the phone in one's hand instead of in a pocket, they could carry out movements more quickly and easily. Furthermore, possibilities of cheating clearly disturbed some of the players, because they tended to concentrate more on observing performances of other players than on their own. In spite of that, peer judging worked well in most of the playing groups – cheating was avoided and players could concentrate on playing.

For all practical purposes it is very hard to weed out all cheating possibilities from multiplayer exertion games. One solution is to utilize more sensors. For example, strain sensors (Merilampi, et al., in press) might be helpful in the prevention of cheating in exertion games. By adding a strain sensor on joints (knees, for example) it is possible to monitor that the player actually moves the part of the body that is meant to move. Currently, we are developing such strain sensor solutions for our exertion game platform. In spite of the possibilities that strain sensors provide, such solutions do not exclude all possibilities of cheating – for example, one can wear textiles differently than they are meant to be worn. Unfortunately, to some extent we just have to accept the fact that cheating is almost always possible.

4.2.2 Usefulness of Exertion Games

Both pupils and teachers experienced exertion games as useful applications. The majority of the participants (63%) felt that exertion games could motivate young people to move more and gain health benefits. According to the observation results, participants invariably showed signs of physical effort such as getting out of breath, sweating and symptoms of exhaustion. Like stated by one of the participant: "Hey cool! You are actually sweating!" However this did not affect the willingness to keep on playing or starting another round. Over 70 percent of the participants would like to play exertion games in schools, if such games were available. This is the most promising result for this pilot study. Furthermore, the participants also thought that the games could be integrated also to other subjects than physical education.

4.2.3 The Meaning of Social Context

The collaboration between the players worked well. The players liked to communicate and collaborate within their teams as well as compete against the opposite teams. The results revealed that teamwork motivated and engaged players a lot. This supports Jackson´s (1996) finding where interactions among teammates help individuals to attain flow. Although, neither flow nor team flow was measured directly in this study, observations and discussions with players indicated that most of the players reached a flow state during the playing sessions. In fact, in team condition teammates can support one another to overcome more challenging problems than they could overcome in a single player mode. Similarly in team condition players can divide the exercise burden among teammates. For example, in the ToW game, the team feature enabled players to vary their physical intensity once in a while without immediately losing the game. Basically, this shows that the possibilities for self-regulation are also very important in exertion games.

The competition seemed to be the striving force of playing for most of the participants. It was clear that it was desirable to win the game. For example, one player said that "Yes, let's play the game where we play together against the other group". Another player was very disappointed with their team's performance and required unyieldingly the rematch with the same teams. The meaning of social aspect was also seen also in communication during

playing. Players tried to courage each other by shouting “Don’t give up. We can win this!”. Questionnaire results verified this aspect because almost all of the participants felt that the social side of the game was an important part of the experience itself and players undoubtedly enjoyed the game because of the presence of the other players.

5. STUDY 2 – HEART RATE BASED GAME

5.1 Method

Participants. The study was conducted in fall 2010 at the school of Kasavuori in Finland. The participants were 7th-9th graders (n = 60). Each class (16 altogether) selected four students that stand for their class in the exertion game tournament.

Test bed. The game played in the tournament is called Speeding (figure 6). In the game two teams compete against each other by racing top fuel cars. The objective of the game is to accelerate the car to the top speed by raising team’s collective heart rate as much as possible. Car speed is directly proportional to team’s collective heart rate, so they also had to maintain the top heart rate for a while. Players are allowed to decide the physical movements that they prefer to be the best and most efficient. One game takes approximately one to three minutes.

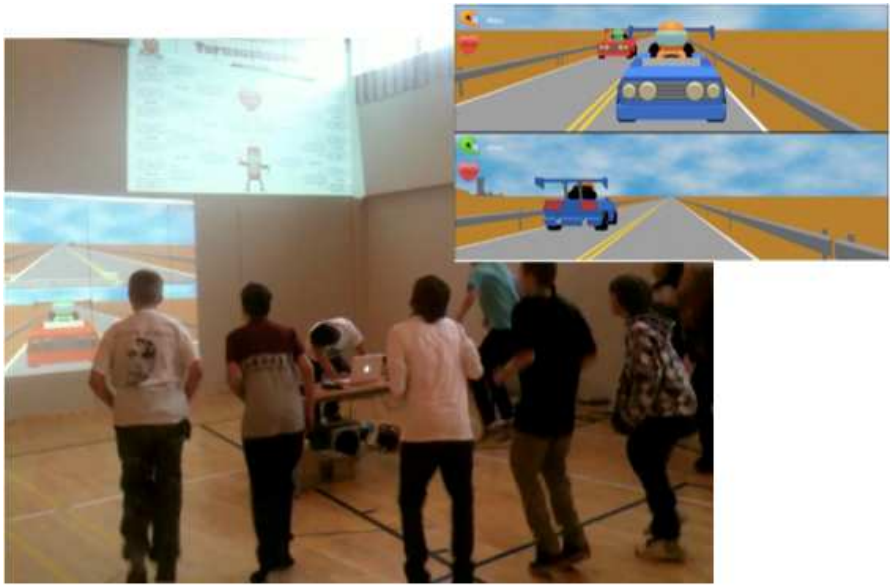


Figure 6. Students playing Speeding in the exertion game tournament

The game utilizes Panda3D game engine that allows implementing different camera angles to the game. For example, if competing teams were close to each other they were viewed by side angle. On the other hand, if the opponent is overwhelming, the game situation is presented from the first person perspective that creates a feeling of chasing.

Instruments. The evaluation of the game tournament was based on digital questionnaire including 27 items, heart rate recordings and observation. Nine of the items measured flow experience and rest focused on the usefulness of the used game controller, attitudes towards exertion games, and educational use of exertion games. The included flow dimensions were challenge-skill balance, clear goals, sense of control, immediate feedback, concentration, time distortion, rewarding (autotelic) experience, action awareness merging and loss of self-consciousness.

Procedure. 1) At first, the participants played Speeding game. The teams that reached to the final played four games during the tournament. Three observers followed the players and wrote down notes with respect to player-environment, player-devices, player-to-player, and player-actor interactions (Lindt et. al, 2007). 2) After the gaming sessions observers discussed briefly with players. 2) A day after the tournament players filled in the digital questionnaire.

5.2 Results

5.2.1 General Experiences about the Public Exertion Game Tournament

The tournament was a success and players as well as audience liked the event a lot – "Quite nice, we could have these sort of games more often.". The results indicated that a large percentage of the players would be willing to play exertion games in public spaces like schools (78 %). Players got a very insensitive workout during the tournament and 72 % reported that they gave all to win the tournament. Players used different strategies to increase their heart rate. They performed for example squats, presses, jumps and running in place. The players reported that their attention tended to focus mostly on their activity and functioning of the body as well as assessment of the opponents' physical state. Because the game involved quite heavy exercise, some of the players did not have time to draw attention to realization of the game graphics. Thus, it seems that in intensive exertion games the players do not require necessarily so-called high-tech graphical outlook. On the other hand the situation of the game needs to be clearly expressed because it is challenging to focus attention to details, when exercising. Overall, team play was experienced as fun. Only 4 % had a dissenting view of this. In addition, 64 % of the players believed that teammates made them perform better. However, opinions of the meaning of the audience varied and 25 % had no opinion of this at all.

5.2.2 Flow Experience

Table 1 shows that the flow level experienced by the players was quite high ($M = 3.70$, $SD = 1.01$), but experiences varied among players. Players' stamina did correlate with flow experience ($r = .09$, $p > .001$), which indicates that everyone could enjoy the playing. However, most of the players stated that they were in good physical shape ($M = 4.33$, $SD = .82$). The results showed that team play was appreciated a lot ($M = 4.08$, $SD = .93$) and it facilitated also the flow experience ($r = .32$, $p < .05$). Furthermore, results also revealed that flow experience was related to feeling of learning ($r = .40$, $p < .05$). Based on these findings we argue that the proposed exertion game framework and flow dimensions should be considered when designing exertion games.

Table 1. Means and standard deviations of flow dimensions and flow construct

Dimension	Mean	Standard Deviation
Challenge-skill	3.91	.84
Action-awareness	3.73	1.02
Clear goals	3.93	.92
Feedback	3.72	.99
Concentration	3.95	.96
Sense of control	3.45	.98
Loss of self-consciousness	3.67	1.23
Time distortion	3.50	1.05
Rewarding experience	3.48	1.08
Flow construct	3.70	1.01

5.2.3 Heart Rate Monitor Belts as Game Controllers

Heart rate monitoring was a new subject to players and they were eager to play games controlled with heart rate. Although heart rate monitors that were used in the experiment were not optimally designed for our purpose, players considered them as suitable game controllers (M = 3.62, SD = 1.11). In used HRM belts a separate transmitter part is attached to the belt with two poppers and it detached too easily. Users tended to improve the proper point of the heart rate belt just before a game and sometimes this caused separation between the belt and the transmitter. A fixed heart rate monitor belt would have been much more reliable solution at least for players with minor practice and knowledge about heart rate monitors. Furthermore, some of the girls experienced the use of the heart rate belt uncomfortable as one of the girls stated. “The game was neat and fun but it was a bit awkward and uncomfortable for the girls to use the heart rate monitor-belt, the big black square in the middle kept falling off constantly.”. Players commented also on other technical difficulties. “It was otherwise good, but it would have been nice, if all the heart rate monitors would have worked, everyone would have been able to take part and the teams would have been equal.”

Despite of these technical problems, only 18 % thought that the heart rate monitor was not compatible as an exertion game controller. The correlation ($r = .48$, $p < 0.01$) between the willingness to play similar games again and the suitability of the heart rate monitor as a game controller was significant. This may be partly affected the fact that the use of heart rate belt was unprecedented to most of the students, so the novelty may have influenced the results. In fact 86 % of the players would have liked to also see their own heart rate in addition to their team’s collective heart rate during the game. The expression of own heart rate would have supported the selection of exercising strategy – it would have been easier to perceive the causes and consequences.

Figure 7 visualizes heart rate data of the tournament’s final game. As we can see the initial heart rate values of both teams (Team 1: 139 bpm; Team 2: 126 bpm) were quite high. We assume that the excitement of final game affected this. Anyhow, both teams ended up to quite high values – over 190 bpm). This indicates that players exercised very intensively. The team 2 that had a lower starting rate won the match.

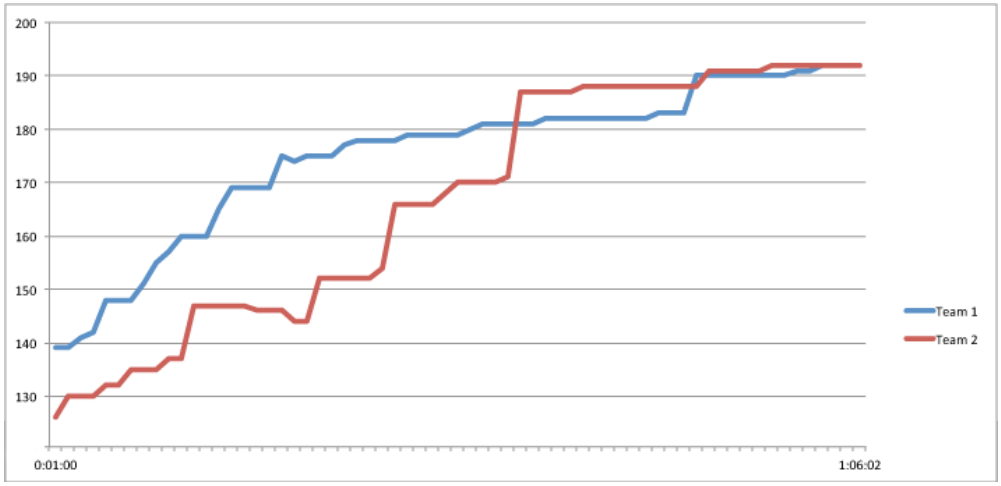


Figure 7. Both team's collective heart rate values during the final game.

Players criticized also the way in which the heart rate data was transformed to the speed of the car. Some of the players felt that they were treated unfairly. For example, one player stated that "I think the game was useful/functional, but it should not be based on how the heart rate is rising, instead it should measure how low one can actually keep one's heart rate during the exercise. In such case the players who are in better shape would succeed better than the players that are in poor shape and whose heart rate will rise up to 200 even before the actually exercising begins.". In fact fairness, perplexed surprisingly many players as following comments shows. "There should have been longer pauses and resting periods in order to get the heart rate come down." "It would have been nicer if there had been longer breaks between the games, since we had two games in a row.". Such discussions indicate that players really thought and analyzed the gameplay, which supports also the learning of body functions.

5.2.4 Educational Value

The opinions about educational value of Speeding varied among players (M = 3.02, SD = 1.25). 42 % of players felt that they learned new things about behavior of their heart. On the other hand 37 % reported that they did not learn anything new from playing the game. The expression of each player's own heart rate would have facilitated learning. In such case it would have been possible to play game more strategically. It seems that some of the players would have needed guidance in order to maximize the learning outcomes. As Mayer (2004) has pointed out, guided discovery learning is much more effective than pure discovery learning. Guidance, structure and focused goals cannot be ignored when trying to promote appropriate cognitive processing. Triggers, clear goals and guidance are vital at the least to learners with low metacognitive abilities and in informal context. Furthermore, players did not appreciate the idea of embedding educational content into exertion games (M = 2.82, SD = 1.242). However, it is possible that players could not imagine the way how educational content could be embedded to exertion games. Thus, research on that theme is needed.

6. GAME BALANCING ISSUES

Game balancing means the adjustment of game elements so that the game delivers a desirable experience to the player. Although balancing varies a lot between different games, common balancing principles can be distinguished. Some balancing methods that came out during this research are considered next.

Challenge-Skill Balance. In exertion games the quality of the playing experience arises from interplay between the psychological and physiological balance (extended dual flow model, Figure 2). Thus, balancing should begin by determining the desired balance between physical activities and mental activities. In any case, the aim of challenge-skill balancing is to deliver rewarding experiences to players by providing them with an appropriate amount of challenges and successful experiences. Generally, the aim is to avoid experiences of anxiety, exhaustion and boredom.

The results of this research clearly showed that the eagerness of players dropped very rapidly if the physical endurance of players differed significantly. For example, if the opponent team was very overpowering in the Tow game or in the Speeding game, the underdog team easily gave up without trying their best. In such competitive games a handicapping system could be a useful balancing method. A handicapping system could be implemented, for example, in terms of dynamic adjustment. For example, heart rates, player profiles or the performance of players could be used to create teams and in that way facilitate the experiences of players. The challenge of game design is to implement such adaptation solutions that are harmonious and transparent to players. For example, heart rate monitoring could be used to determine a player's fitness level and the intensity of exercising during the game. For example, a player with a high heart rate could earn more points from performing a single movement than a low pulse player. On the other hand, based on heart rate monitoring, a cheering system for low pulse players could be implemented. Such a system could motivate certain players to exercise more intensively. Furthermore, personal trainer type of elements could be implemented based on heart rate data.

Playing Time. In exertion games it is very important to balance the length of the gameplay. The length of the game should be based on desired fitness aims: is the game designed to develop stamina, speed, flexibility, muscular strength etc.? For example, the ToW game is designed to develop stamina and muscular strength. In ToW the relationship of squat movements performed and pulling power of the team is adjusted so that one game last approximately 30 to 120 seconds. However, the playing time of each player varies, because the weakest players are removed from the game (fall into the gap or pit) during the match. Furthermore, the significance of a players' fitness level plays an important role in balancing. Designers should pay attention to the fact that usually when the playing time increases, the performance of players also gets weaker, at least in high intensity games.

Embedded educational content. According to previous research engagement in a physically loading work (gameplay) affects attention focus (Tenenbaum, 2001). The research has shown that when the physical workload increases, attention allocation shifts from dissociation to association (e.g. Tenenbaum, & Connolly, 2008; Hutchinson & Tenenbaum, 2007). Association can be defined as turning focus inward and toward bodily sensations, while dissociation is focusing outward and away from body sensations (Scott, Scott, Bedic, & Dowd, 1999). Thus, the integration of learning content and exertion interfaces raises new game design challenges. Generally, if educational content is embedded into the game, the

intensity of exercising should be balanced so that perception of content is possible and player can voluntarily invest cognitive effort on processing of content. If intensity of exercising is too high player may miss relevant content or processing is only superficial, which does not lead to deep learning.

7. CONCLUSION

The results of the presented studies were very positive. The concepts of tested exertion games were successful although they were only low-fidelity prototypes. It seems that there is certainly space for physically activating games in schools. This is especially important because obesity and the lack of exercise seem to be big problems with youngsters. Overall, the results indicated that exertion games could motivate pupils to move more and improve their health through gaming. In fact, players got quite intensive workout during the playing sessions and they seemed to enjoy the physical activities. The results revealed that students are willing to play exertion games as a part of physical education or during lesson breaks. We did not find any difference between genders or age groups – both sexes were equally interested on playing. However, when interpreting the results, we have to take into account the novelty effect of tested games. It is possible that the games engaged students because they had never played such games before. Thus, in future we are going to conduct long-term studies in order to explore the playing experiences more deeply and reveal the real impacts of exertion games in players' health.

The results also showed that mobile phones and heart rate belts can be used as exertion game controllers and games can be played on large public screens in schools and other public places. Based on the results, we argue that the use of mobile phones as game controllers could broaden the field of exergaming tremendously and facilitate the diffusion of exertion games in general. Young people have increasingly smart phones that include built-in acceleration sensors. In other words, they already have a game controller in their pocket all the time – also in school. On the other hand, the use of mobile phones might be prohibited or restricted in certain schools that can disturb the diffusion of the mobile exertion games. The use of heart rate belts as game controllers is more challenging and requires resources from schools. Furthermore, a set of heart rate belts could be used as game controllers in physical education lessons, but in guided manner. However, it seems that mobile phones provide more sustainable solution for exertion games targeted for school contexts.

Generally, smart phones provide several advantages for exergaming. Firstly, it is rapid to create client software prototypes. Secondly, an information related to the game can be displayed on a screen of a phone, which is not possible using some other game controllers, like Wiimote or Blobo for example. As a result of this, it is real two-way communication during the game and players can receive information that is not visible to other players. Also, individualized gaming information can be displayed on the screen of a phone or voice feedback can be utilized. Thirdly, a smart phone's internal memory allows saving research data to log-files. And moreover, a player can scope out her progress and history in exertion games from the client software. Fourthly, the overwhelming feature in smart phones is a WLAN-connection, which allows the high amount of simultaneous players, fast data transfer and wide area connectivity, which is important in school settings. Especially, a large number of players turned out to be very motivating factor in tested exertion games.

Overall, exertion games seem to motivate children a lot and they would like to play exertion games in their free time as well as in schools. In the future, there could be one large public screen at a schoolyard and for example 50 students could attend simultaneously the game during the breaks. Other scenario is that the schools could have game rooms designed especially for this purpose where mobile exertion games could be played. In this case the schools could provide phones for game controllers as well. Additionally, we assume that exergaming could motivate also sedentary adults to move more and have positive impact on the whole society's healthiness – exergaming could be an effective 'weapon' in the fight against obesity that is a growing problem in western society. However, more research is needed in order to distinguish between exertion games that contribute to increased fitness and those that only offer novel ways to control games. Furthermore, the area of educational exertion games is totally unexplored field. The results of this paper indicated that exertion games could have also educational value. However, more research is needed to distinguish design principles for educational exertion games.

REFERENCES

Costikyan, G., 2002. I have no words & I must design: Toward a critical vocabulary for games. *Proceedings of the Computer Games and Digital Cultures Conference*. Finland, Tampere. pp. 9-33.

Csikszentmihalyi, M., 1991. *Flow: The Psychology of Optimal Experience*. New York City, NY: Harper Perennial.

Daley, A.J., 2009. Can Exergaming Contribute to Improving Physical Activity Levels and Health Outcomes in Children? *PEDIATRICS*, 124(2), 763-771.

Jackson, S. A., 1996. Toward a conceptual understanding of the flow experience in elite athletes. *Physical Education, Recreation and Dance*, 67, 1, 76-90.

Jackson, S.A. & Csikszentmihalyi, M, 1999. *Flow in Sports: the keys to optimal experiences and performances*. Champaign, IL; Human Kinetics.

Gorgu, L., et al, 2009. Towards Mobile Collaborative Exergaming. *2nd International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services*. Porto, Portugal. pp. 61-64.

Graf, D.L., Pratt, L.V., Casey N., Hester, C.N, & Short, K.R. 2009. Playing Active Video Games Increases Energy Expenditure in Children. *PEDIATRICS*, 124(2), 534-540.

Graves, L., Stratton, G. Ridgers, N.D. & Cable, N.T. 2007. Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: cross sectional study. *BMJ*, 335, 1282-1284.

Hutchinsona, J.C. & Tenenbaumb, G. 2007. Attention focus during physical effort: The mediating role of task intensity, Psychology of Sport and Exercise, 8(2), 233-245.

Kiili, K. and Lainema, T., 2008. Foundation for Measuring Engagement in Educational Games. *Journal of Interactive Learning Research*, 19(3), 469-488.

Kiili, K. and Perttula, A., 2010. Exergaming: Exploring engagement principles. *In the proceedings of the Serious games for sports and Health*, Game Days 2010. Darmstadt, Germany. pp. 161-172.

Lindt, I. et al, 2007. A Report on the Crossmedia Game Epidemic Menace. In *Computers in Entertainment*, 5(1):8.

Luepker, R., 1999. How physically active are American children and what can we do about it? *International journey of Obesity*, 23, 12-17.

Mayer, R., 2004. Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, 59,14-19.

Merilampi S. et al, in press. Embedded Wireless Strain Sensors based on Printed RFID Tag, Sensor Review.

Mueller, F., Agamanolis, S., Vetere, F. & Gibbs, M. R. 2009. A Framework for Exertion Interactions over a Distance. ACM SIGGRAPH 2009. ACM, pp. 143-150.

Mueller, F., Gibbs, M. & Vetere, F. 2008 Taxonomy of Exertion Games. OzCHI '08: Proceedings of the 20th Australasian Conference on Computer-Human Interaction. Cairns, Australia. ACM, 263-266.

Nenonen V. et al, 2007. Using heart rate to control an interactive game. *Proceedings of the SIGCHI conference on Human factors in computing systems*, April 28-May 03, 2007, San Jose, California, USA. pp 853-856.

Papastergiou, M., 2009. Exploring the potential of computer and video games health and physical education: A literature review. *Computers & Education*, 53, 603-622.

Paw, M. et al, 2008. The motivation of children to play an active video game. *Journal of Science and Medicine in Sport*, 2008. 11(2), 163-166.

Parizkova, J. and Chin, M., 2003. Obesity prevention and health promoting during early periods of growth and development. *Journal of Exercise Science and Fitness*, 1(1), 1-14.

Riviere, D., 2004. Metabolic functions and sport. *Bulletin de l'Académie Nationale de Medicine*, 188(6), 913-922.

Rollings, A. and Adams, E., 2003. *Andrew Rollings and Ernest Adams on Game design*. USA: New Riders.

Scott, L.M., Scott, D., Bedic, S.P. & Dowd, J. (1999). The effect of associative and dissociative strategies on rowing ergometer performance. The Sport Psychologist, 13, 57–68.

Sinclair, J. et al, 2007. Considerations for the design of exergames. *Proceedings of GRAPHITE 2007*. Perth, Australia. pp 289-295.

Sothern, M., 2004. Obesity prevention in children: Physical activity and nutrition. *Nutrition*, 20(7-8), 704-708.

Sweetser, P. and Wyeth, P., 2005. GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment*, 3(3), 1-24.

Tenenbaum G. 2001. A social-cognitive perspective of perceived exertion and exertion tolerance. In: R.N. Singer, H. Hausenblas and C. Janelle, Editors, Handbook of sport psychology, Wiley, New York (2001), pp. 810–820.

Tenenbaum, G. and Connolly, C.T. 2008. Attention allocation under varied workload and effort perception in rowers. *Psychology of Sport and Exercise*, 9(5), 704-717.

Vanderwater, E.A., Shim, M.S. & Caplovitz, A.G. 2004. Linking obesity and activity level with children's television and video game use. *Adolescence*, 27(1), 71-85.

Publication 5

Perttula, A., Tuomi, P., Kiili, K., Suominen, M., Koivisto, A., & Multisilta, J. (2013). Enriching Shared Experience by Collective Heart Rate. International Journal of Social and Humanistic Computing. Vol. 2, Nos. 1/2, 2013, pp. 31-50. ISSN online: 1752-6132.

Enriching shared experience by collective heart rate

Arttu Perttula*, Pauliina Tuomi, Kristian Kiili, Marko Suominen and Antti Koivisto

Tampere University of Technology,
PL 300, 28101 Pori, Finland
E-mail: arttu.perttula@tut.fi
E-mail: pauliina.tuomi@tut.fi
E-mail: kristian.kiili@tut.fi
E-mail: marko.suominen@tut.fi
E-mail: antti.t.koivisto@tut.fi
*Corresponding author

Jari Multisilta

University of Helsinki,
P.O. Box 9, FI-00014 University of Helsinki, Finland
E-mail: jari.multisilta@helsinki.fi

Abstract: The last decade has witnessed a growing interest in design information technologies and interfaces that support rich and complex user experiences, including satisfaction, joy, aesthetics, and reflection. It is high on the agenda to extend and intensify the overall (user) experiences with the help of appropriate technology. This paper presents two pilot studies in which mobile devices were used to enrich shared experiences by measuring user generated collective heart rate. It is visualised in the indoor ice rink and utilised in exertion games to bring intensiveness into the audience experience. The aim of the study was to explore the usefulness and affect of the developed collective heart rate system and to evaluate it as one of the new features that could enhance the shared experience among the audiences in co-creational spaces. In particular, the study focuses on studying the significance of the technological equipment in creating a sense of collectiveness and togetherness of the participants. This research is important because it introduces a new idea of user involvement with the techniques of mobile phones and heart rate measurement belts. The results, positive and negative, of the study widen the field of physiological sensing technologies and facilitate the diffusion of these techniques into different public events.

Keywords: mobile sensors; mobile social media; collective heart rate; sharing experiences; co-creational spaces; experimentation; documentation.

Reference to this paper should be made as follows: Perttula, A., Tuomi, P., Kiili, K., Suominen, M., Koivisto, A. and Multisilta, J. (2013) 'Enriching shared experience by collective heart rate', *Int. J. Social and Humanistic Computing*, Vol. 2, Nos. 1/2, pp.31–50.

Biographical notes: Arttu Perttula is a Researcher at the Tampere University of Technology in Pori, Finland. He received his Master of Science (MSc) degree from the Tampere University of Technology in 2007. His research is related to mobile human computer interaction. He has been working in different

research projects concentrating mainly on mobile social media, mobile learning and mobile games. In the year 2008, he spent six months with Fuji Xerox Palo Alto Laboratory, Inc. as an intern. In the year 2010, he spent three months as a Visiting Researcher at Stanford University, H-STAR Institute.

Pauliina Tuomi is a PhD student in Digital Culture at the University of Turku and works as a Researcher at the Tampere University of Technology, AMC. Her doctoral thesis is set to define the different characteristic elements of participatory and intermedial TV culture in the 21st century. She has been working in various research projects concentrating on mobile learning, game-based learning and exergaming.

Kristian Kiili works as a Senior Research Fellow and Adjunct Professor at Tampere University of Technology. His research focuses on game-based learning, exergaming and game design issues. Results received from his studies has been published in several scientific publications as well as applied in commercial e-learning products.

Marko Suominen is a Researcher in Tampere University of Technology in Pori, Finland. He received his Master of Science (MSc) degree from the Tampere University of Technology in 2000. He has been working in various research projects concentrating in recent years on mobile social video applications, game-based learning and exergaming.

Antti Koivisto is a PhD student at the Tampere University of Technology in Pori, Finland. He currently works at Satakunta University of Applied Sciences as a Researcher and as a Teacher. His research interests are exergames and exergame controllers. He is currently researching how games suit for elderly and mentally disabled people.

Jari Multisilta is the Director of Cicero Learning Network in the University of Helsinki, Finland and a Professor of Multimedia in Tampere University of Technology, Finland. He received his MSc from the University of Tampere in 1992 in Mathematics and his DrTech degree at Tampere University of Technology in 1996. His research interests include networked and mobile learning, mobile social media, mobile storytelling and mobile social video applications. He was a Visiting Fellow at Nokia Research Center from 2008 to 2009, and a Visiting Scholar at Stanford University, H-STAR Institute on 2007, 2008, 2010 and 2012.

This paper is a revised and expanded version of a paper entitled ‘Users as sensors: creating shared experiences in co-creational spaces by collective heart rate’ presented at 14th International Academic MindTrek Conference – Envisioning Future Media Environments, Tampere, Finland, 6–8 October 2010.

1 Introduction

During the recent years we have experienced an increase in use of mobile communication support (Armstrong, 2007; Dahlbom, 1996). In events, concerts and sports competitions audience get experiences that enrich their lives. The experience is an entity that is formed by the event, the person, physical environment, people sharing the experience and services provided to the audience. The aim of this paper is to describe a project that

explores an implementation of supporting co-creation in a public space, study users as sensors, and study the space for sharing experiences, the service concept and service in this space and users' perceptions of the service in such a space. The user interface to the space for sharing experiences is mobile devices.

Researchers in the domain of human factors have been concerned with optimising the relationship between humans and their technological systems. The quality of a system has been judged not only on how it affects task performance in terms of productivity and efficiency, but on what kind of effect it has on well-being of the user. The increasing availability of physiological sensing technologies is opening a real-time window into users' internal states. Evidence from physiology has shown that physiological measurements [e.g., galvanic skin response (GSR), heart rate (HR), blood volume pulse] reflect autonomic nervous system (ANS) activity and can provide key information regarding the intensity and quality of an individual's internal experience (Andreassi, 2000); moreover, physiological response is involuntary and thus is difficult to 'fake' (Andreassi, 2000). There are many examples of the use physiological metrics in the domain of human factors [see Mandryk et al. (2006) for an overview]. Monitoring the HR can be considered as a one way to measure audience excitement and empathy. In other words, the audience is a sensor that produces a collective HR. The purpose of this study is to find out do this collective HR and the developed system affect and enrich the experience of public events. This paper presents two studies on using mobile device enabled collective HR. The second one is the follow-up study.

Study 1 Ice hockey pilots included in this project are realised in hockey matches of a Finnish National Hockey League team Porin Ässät during the spring 2010. The group of volunteer first attended two try-outs in two different hockey games and at the actual pilot study the audience was invited to take part in the HR measurement. 10 participants from the audience actually wore the rate measurement belts and part of the audience was asked to fill in a questionnaire.

Study 2 Based on the results of the first study we implemented an approach to add activity to the audience. The HR-based multiplayer game study was conducted in fall 2010 at the school of Kasavuori in Finland. 60 students participated in the exertion game tournament. Players were observed during the game session and afterwards observers discussed briefly with players. A day after the tournament players filled in the digital questionnaire. In this study players can be seen also as an active audience because of the game itself is the main event.

In both cases (studies), the use of collective HR and its affects on the event experience were empirically evaluated. Traditional evaluation methodologies in human-computer interaction (HCI) are rooted in the productivity environment; however, for an entertainment technology, the interest lies in the quality of experience and to what degree this experience is facilitated by the entertainment technology, regardless of performance (Pagulayan et al., 2003). Currently, the most common methods of assessing user experience are through subjective self-reporting, including questionnaires and interviews, and through objective reports from video observation and analysis (Lazzaro, 2004). Subjective evaluation through questionnaires and interviews is generalisable, and is a good approach to understanding the attitudes of users (Marshall and Rossman, 2006).

To collect HRs from individual users can be implemented by using HR belts as external sensors for mobile phones via Bluetooth. To transfer this data to the server mobile phones are connected to a local network (Wlan). The server utilises HR values to produce the collective HR. Both individuals' HRs and the collective HR can be visualised in a real time. In addition, mobile devices can be utilised to measure sensor readings and detect user inputs as in the Study 2.

2 Related work

The aim of the study was to explore the usefulness and affect of the developed collective HR system to the collective experience in public events. To solve this multidimensional research problem we take into consideration several earlier approaches. Related research has been conducted from HR measurement, audience and technical point of views (Khoo et al., 2008; Armstrong, 2007). Based on earlier studies mobile devices can be used to enhance audience experience during sport events (Nilsson, 2007). Also, use of physiological measurements in order to evaluate and enhance audience experience has been studied widely. However, audience is rarely studied as an active part of an event. This chapter provides the background information about the field of the study.

2.1 HR measurement

Probably the first research on audience's HR measurement was conducted already in the 1960's in Freiburg, Germany. The short article in the official Finnish Football Yearbook 1967–1968 states that three German doctors executed a research on intense football fans HRs at the time something significant happened on the football field. They decided to inspect their own HRs during the final games in World Champion tournament, summer 1966. Game events had an affect to these doctors. For example their HR rose significantly when the home team scored. During the overtime, the HR of one of the doctors actually rose to 196 beats per second, which was counted already lethal for some people. Reason for this study was actually the sudden deaths of sport followers and this experiment seemed to back up the fact that true sport fans really immerse themselves into the gaming situations in a way that it could be dangerous for some (Honkavaara, 1968)

There are also other studies on measuring breathing- and HR data for example with distribution over wireless IP networks (Khoo et al., 2008). For example the Könberg's et al. (2003) study was conducted in order to enhance a sport event and it was tested to provide online sensor data from athletes directly to the internet. For the purpose two internet enabled sensors measuring pulse and breathing rate, to be worn by hockey players, was designed. A sensor networking approach with full TCP/IP suite capability at the sensor was used. The sensors worn by the player was networked and data provided to spectators via hand held computers and IEEE 802.11b communication. The sensors were tested for a full Swedish Hockey League game. The main intention was to enhance an event for the audience using this type of sensor systems. The study was also executed in Luleå's hockey arena. Könberg's at al. study chose to measure breathing and HR on hockey players on a team to make it possible for the audience and the team coach to get real-time information about the players' status. In brief, the implemented system was placed on the hockey players. It consists of sensors for measuring breathing and pulse

rate and a wireless system for transmitting data from the hockey player to the rink side where it is received for distribution to the audience. The audience had access to the data through handheld computers (PDAs) connected through WLAN.

Kiili et al. (2010a) tested the usefulness of HRs for controlling an exertion game. Two teams compete each other and the objective of the game was to accelerate the car to the top speed by raising team's collective HR as much as possible. Results indicated that HR monitors were considered as suitable game controllers.

In Lin et al.'s (2008) study they subjectively and physiologically investigated the effects of the audiences' 3D virtual actor in a movie on their movie experience, using the audience-participating movie DIM as the object of study. They, based on the existing literature, chose to collect GSR and electrocardiogram (EKG) signals to evaluate audience experience. These physiological data were gathered using ProComp Infiniti hardware and Biograph software from Thought Technologies TM. HR was computed from the EKG signal. EKG records the electrical activity of the heart over time. Cardiovascular measures such as HR, heart rate variability (HRV) and interbeat interval (IBI) can be computed from EKG signals. Lin et al also chose to focus on the measure of HR in the study.

2.2 Audience experience

Lots of the audience research that utilise HR measurement technique consists of people presenting for example a speech in front of the audience. For example probably one of the first studies on the matter, the study of Bassett et al. (1973) already from the year 1973 investigated the effects of visible audience responses on the HR of students presenting an informative speech. The results indicated that speakers receiving negative audience responses had higher HRs than speakers receiving positive audience responses. These findings suggest that speaker experienced stress is greater under negative than positive conditions of audience response. This is called an audience effect by Robert Zajonc's (1965) drive theory. The subject is still studied for example especially in the field of public speaking as well as in the field of competitive sports (Bray and Martin, 2003).

The audience research concentrates also on the consumption of the media for example. One good example is Gantz's and Wenner's study on Men, women, and sports: Audience experiences and effects. The study examined gender differences in the audience experience with televised sports. Men and women were expected to approach, observe, and respond to sports programming in different ways (Gantz and Wenner, 1991).

However, the audience is rarely studied as an active piece of different events. Like mentioned before, audience is usually interpreted passive either as a counter part in a public situation or as a consumer of mass media products. In this study the audience is seen as an active part of the hockey game and the exertion game event. One of the intentions of this study is to increase and enhance the interaction between the audience and the happenings on the events. We see audience members as sensors, not just consumers but producers and content creators as well. With the concept of collect HR we are able to invite the audience to participate in different arena events with different ways for example competitions on guessing the correct HR or when comparing HRs. The chapter Results and Findings covers more of these different ways to activate the audience.

2.3 Technological solution

Our research platform is based on a client – socket server architecture. These kinds of solutions are utilised usually in games. For example Kiili et al. (2010b) have designed an exertion game solution to be used on a mobile phone. They have used a real time socket server system that enables multiple simultaneous mobile phone connections. A solution of the Study 1 to transfer HRs to the server presented in this paper uses a simplified version of this kind of game platform. Instead of acceleration sensor data, our solution includes HR belts providing heart beat values. In addition, all game features like inputting a player name and selecting a game etc. are removed. The main differences concerns about visualisation. In the follow-up study (Study 2) in this paper we combine the HR feature with the game platform thus it recognises HRs and game commands (movements in this case).

Nowadays smart phones include several sensors and lots of research has been done based on those mobile sensors like an acceleration sensor or for example a GPS. For instance, Essl and Rohs (2007) have presented a sensor-based integrated mobile phone instrument that can be used to play virtual drums. It utilises an acceleration sensor. In addition, several external sensors can be attached to a smart phone for example via Bluetooth connection. A HR belt is concerned as an external sensor in this study.

More general, for example Nilsson (2007) has exploited Mobile IT in his research in order to amplify event audience experience. His study introduces how mobile IT can be used to enhance audience experience and constitute an alternative information and media resource during sport events. The study explores how handheld and alternative media and information channels provide the audience with information and news during the event.

3 Research platform

This chapter describes operation of the research platform. It consists of mobile clients and server side solution. The main features are HR measurement and visualisation. For the follow-up study (Study 2) we added necessary game controlling features but the platform is same in both cases.

3.1 Mobile client

As HR measurement equipment we used Nokia 5800 XpressMusic smart phones and Zephyr HxM Bluetooth HR belts. Once a Bluetooth connection has been established with the HxM, the connecting mobile device can receive the data packets. The Nokia 5800 receives a data packet that includes a HR value from the HxM at one-second intervals.

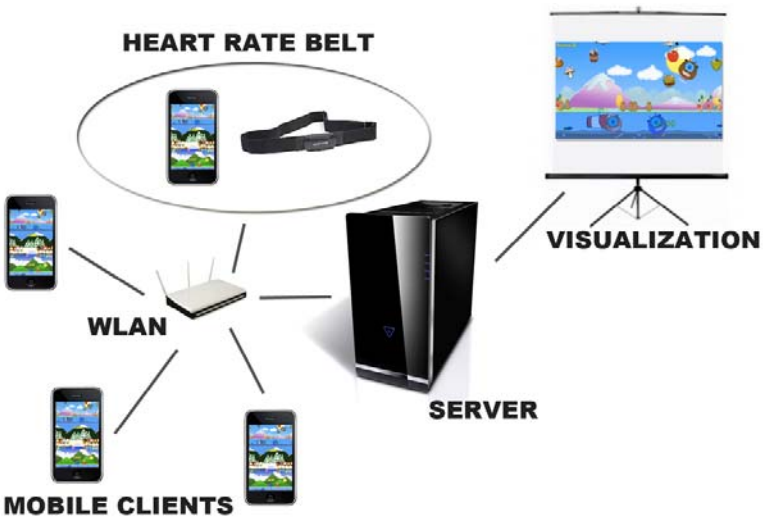
After analysing a received data packet, the mobile client can visualise user's current HR on the mobile phone screen in a real time, if this feature is activated (see Figure 1). At the same time, it sends every captured HR value to the server in a specific XML scripting language format via a network socket by the WLAN connection. The HxM has wear-detect circuitry, which switches on data output. The mobile client application establishes the Bluetooth connection with the HxM and the WLAN connection to the server automatically when these are available.

Figure 1 The mobile client represents user's HR (see online version for colours)

3.2 Server side

The server (a part of Figure 2) has a socket-server made in Java, which directs messages sent by the mobile-client in XML format to the main application made in Flash. In principle, the main application can be on any given computer of the same wireless network but in this experiment the main application was in the same laptop as the socket-server.

Figure 2 The research platform (see online version for colours)



For the socket-server to be able to forward the messages of the mobile-clients to the main application, it must quite first send socket-server a XML-message about its existence and that it is waiting for mobile-clients to join. After this, the socket-server answers the inquiries of the mobile-clients that the main application is hosting and the mobile-client can be connected to the main application. The socket-server also transmits messages the other way round.

4 Methods and arrangements

The follow-up study differs from the first one because of it was more realistic to implement it in a different pilot environment. The first study was suitable for ice hockey matches. The follow-up version is more activating solution and it was not anymore proper for commercial ice hockey matches. Due to this, the second version was implemented without the ice hockey context. However, both studies were designed to find out do the collective HR and the developed system affect and enrich the experience of a public event.

4.1 Study 1 – collective HR in ice hockey matches

The pilot testing was conducted in spring 2010 with the cooperation of Porin Ässät Hockey Team and the group of volunteers that were recruited to attend two try outs before the actual pilot study (Table 1). The participants of the try out groups were staff and students of the University Consortium of Pori (n = 20). The participators of the final test (n = 10) were recruited from the audience before the hockey game.

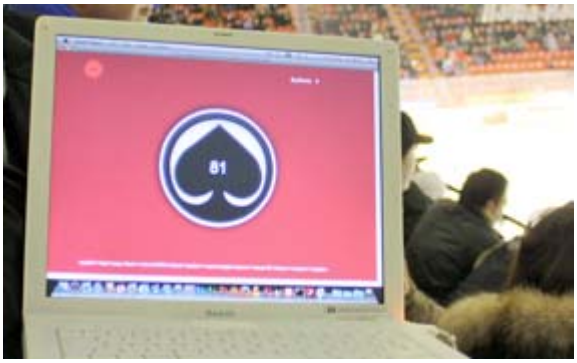
Table 1 The ice hockey pilots

Ice hockey matches	*Participants*
1st try out: March 2, 2010 (Ässät-Tappara)	10 volunteers
2nd try out: March 11, 2010 (Ässät-Kalpa)	10 volunteers
Final test: March 16, 2010 (Ässät-Saipa)	10 + audience

At first, two try out – groups in two different hockey games tested the HR measurement experiment. We placed ourselves among the audience and tried to record behaviours and the social interactions as Nilsson (2007) has presented earlier. Three observers from the research group followed the participators during the first round of the hockey game when the HR measurement belts were used. Then the actual pilot study was executed through audience participation with the HR belts, and when attending an arena event, the main media and information support available is the one provided by host (Nilsson, 2007), which is why the collective announcements came from the commentator during the game. This enabled everyone in the audience to take part in the experiment just by listening the average, collective HR. Finally, the audience participators with the HR belts and the rest of the audience filled in a questionnaire during the first break of the game. The observation results and participants questionnaire answers were analysed.

In this case, the main application of our system calculates an average HR from the values of the moment at intervals of one second and transmits the result to the HR animation (Figure 3). In case the test person goes out of reach of the wireless network or the mobile-clients for some other reason stops sending HR information completely or temporarily. The main application counts out all mobile clients from the calculation, which have not sent a new HR in five seconds.

Figure 3 The collective HR visualised on a laptop screen (see online version for colours)



If a test person has an especially low or high HR, the leaving out of calculation is seen from the average especially if there are only few test persons. To take this into consideration would mean that the test persons' normal HR would have to be known beforehand. The main application could calculate a normal HR before the beginning of the hockey game to the test person and the average would be calculated from the change of the normal. However the change in the HR is what interests, not the right HR. Unfortunately a time between the beginning of the game and enlisting of the test persons is short and the people are more or less exhausted after having walked uphill from the parking place to the to the ice-rink and do not necessarily calm down before the beginning of the game. In the actual experiment, all the test persons sent HR information from beginning to end and we did not need to pay attention to this possible distortion.

The main application rounds off the HR average as a whole number and records it with a time stamp in the array whenever the average changes. When there are a hundred cases, the main application will send the contents of the array to the web server in the same laptop and begin collecting the average changes from the beginning. The web server has a program made in PHP, which adds the sent HRs to the database. For this experiment there was an added text field in the main application in which the observer wrote the events of the game and sent them with a timestamp through the same program in the web server to the database.

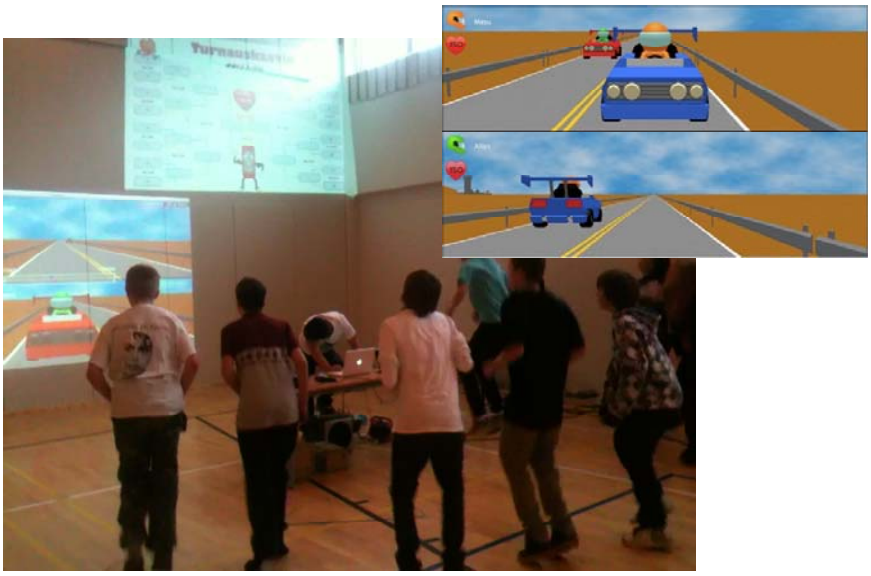
4.2 Study 2 – HR-based multiplayer exertion game event

To deepen the study of the collective HR, we decided to perform another pilot at a totally different public event. The follow-up study was conducted in fall 2010 at the school of Kasavuori in Finland. The participants were 13–16 years old (n = 60). Each class (16 altogether) selected four students that stand for their class in the exertion game tournament.

The game played in the tournament is called speeding (Figure 4). In the game two teams compete against each other by racing top fuel cars. The objective of the game is to accelerate the car to the top speed by raising team's collective HR as much as possible. Car speed is directly proportional to team's collective HR, so they also had to maintain the top HR for a while. Players are allowed to decide the physical movements that they prefer to be the best and most efficient. One game takes approximately one to three minutes. The game utilises Panda3D game engine that allows implementing different

camera angles to the game. For example, if competing teams were close to each other they were viewed by side angle. On the other hand, if the opponent is overwhelming, the game situation is presented from the first person perspective that creates a feeling of chasing.

Figure 4 Students playing speeding at the exertion game tournament (see online version for colours)



The evaluation of the game tournament was based on digital questionnaire including 27 items, HR recordings and observation. Nine of the items measured flow experience and rest focused on the usefulness of the used game controller, attitudes towards exertion games, and educational use of exertion games. At first, the participants played speeding game. The teams that reached the finals played four games during the tournament. Three observers followed the players and wrote down notes. After the gaming sessions, observers discussed briefly with players. A day after the tournament players filled in the digital questionnaire.

5 Results and findings

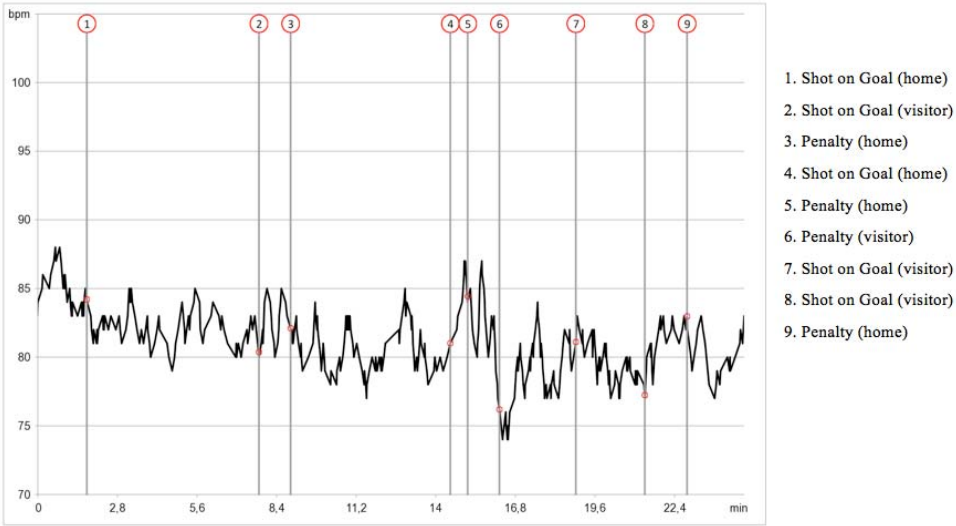
As mentioned already earlier, the follow-up study was conducted because of the first study results. In the second study the audience is more active part of the event than in the first study. Both results are presented in this chapter.

5.1 Study 1 – collective HR in ice hockey matches

The collective HRs from the second try out and the final test during the first periods are presented in Figure 5 and Figure 6. These two periods were selected because we had some technical problems during the first try out. So these figures provide the most reliable data. The HR data was stored automatically to the database during the played

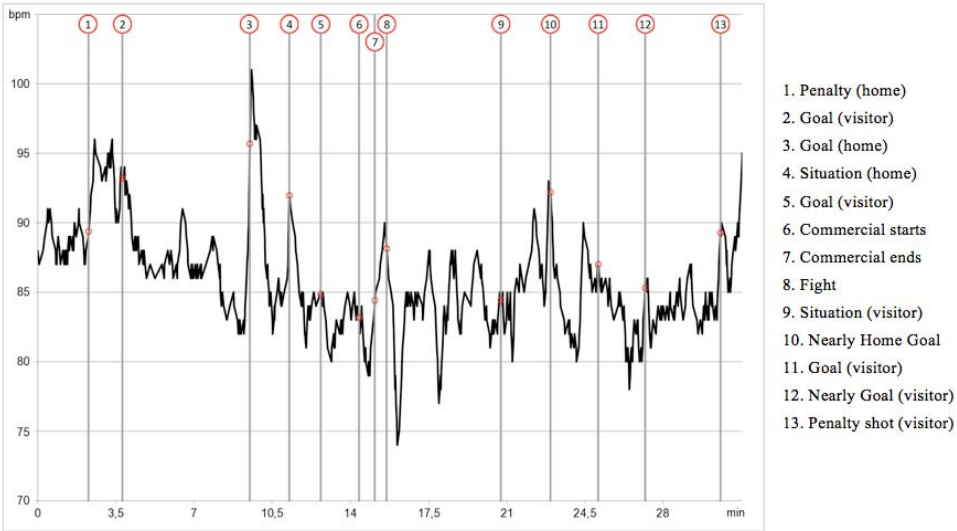
games. In addition, significant game events were added manually to the same database meanwhile. In Figure 5, all participants were located to grandstand seating. In this game, there were 2,924 people.

Figure 5 Ice hockey match (March 11, 2010) Ässät vs. Kalpa (see online version for colours)



Note: The first round significant game events.

Figure 6 Ice hockey match (March 16, 2010) Ässät vs. Saipa (see online version for colours)



Note: The first round significant game events.

On the contrary, in Figure 6 the study participants were in the standing grandstand and the whole audience was 4,007 people. The final test match was also important to the home team because they had a small opportunity to survive to the playoff games. So

these might be noteworthy issues when reviewing these figures. Moreover, Figure 5 does not include a goal. At any rate, it is clearly visible that different situations during the games have an effect to the audience collective HR.

5.1.1 Observation results

Overall, the participators appreciated the HR measurement concept itself. They were enthusiastic to get the experiment started. It seemed that it was really interesting to see your own accurate and real time HR from the screen of your mobile phone. At first the participants looked repeatedly their rate and pretty soon it was seen that the participants started to get an effect on the rate by jumping and so on. This was all normal behaviour since they were adapting the technology for the first time. This was seen in the both try out groups. All of the participants watched their own rate while something exiting happened on the ice but they were also interested what their collective rate was at times.

Generally, the players seemed to understand the logic between the mobile phone, server and HR measurement belt. However, there were slight problems with the use of the belt since it was a new gadget for some of the participants. For example, part of the participants needed assistance on how to put the belt on and locate it (on chest) correctly. There were also feelings of slight awkwardness since the try out groups first came to realise that they were obligated to put the belt, naturally, under their shirts next to the bare skin. They did this in the toilet but still it was seen that for example the wristband would be more pleasant for the test group to use. This was especially seen when the participators from the audience were recruited at the final test. Approximately 25 persons from 30 declined after hearing that they would be asked to attach the belt under their clothes. It took time, a bit more than first expected, to gather the group from the audience mainly because of this. One of the problem areas was the obligatory moisturising of the belt. Some of the belts dried out during the test and due to this no longer were part of the test.

The participators communicated with each other during the tests and compared their own rates and the collective result as well. This emphasises that this sort of an add on – feature had an effect on their watching experience. However it did not seem to have disrupted the following of the game, which is important. In the future HR-feature could especially be designed to bring more sociality to the audiences for example during the breaks.

There was not that much to observe when the commentator announced the collective HRs to everyone in the hall. However it was seen that the people were waiting to hear did the rate change for example when the home team scored. The test would naturally be much more significant to the whole audience if the majority could actually take part in the HR measurement experience and if the collective heart could be visualised on a large public screen. The future developments and research ideas will be presented in more detail in the section future work and places for improvement at the end of the paper.

5.1.2 The questionnaire results

The evaluation of this collective HR study was mainly based on a paper-based 15-item questionnaire, which was dealt to the certain, but random part of the audience by the research group itself. The questionnaire contained questions of respondents' background

for example in their habits of watching ice hockey and using HR belts in their free time. The respondents were also most importantly asked whether they noticed there was an experiment executing and whether the experiment affected their watching experience or not. Most of the questions were multiple-choice questions (based on the Likert scale), and each question had multiple answer possibilities suitable to the questions. There were also four scenario-based questions that introduced four different ways to utilise the HR measurement in order to enhance the audience experiment. There were multiple answer possibilities such as not interested, good idea and disturbing. In the end 53 members of the audience answered the inquiry. The members of the research group also observed all the participators in three different sessions. They were observed from the moment they arrived to the ice hockey hall and to the moment they gave their belts and mobile phones back. This way it was possible to monitor the initialisation of the technology from its very beginning.

Fifty three members of the audience (including the ones that also wore the belts) participated in the inquiry. Thirty three were male and 20 female. Most (15) of the respondents were between the ages of 21–30 and the second largest group (12) was between the ages of 41–50. 48 of the respondents declared themselves as fans and supporters of the home team Porin Ässät and 19 went to hockey games now and then and 20 often. Small group (four) stated that they go to see hockey always when it is played. Only five of the respondents use HR measurement belts regularly or always on their free time when 27 state no use of belts. Eight use belts now and then and 13 seldom. Six of the respondents make bets on hockey results often, 15 now and then and 18 seldom. 14 state never. The clear majority (23) follows the results on real-time from the internet, text TV or television (if possible). Also 10 watch at least the results during the game night from the internet, text TV or television. Small amount (four) checks the results from the tomorrow's magazine and five are not interested in the results at all. These background questions were used in order to create a picture of what type of people go to hockey games in the year 2010. The study was especially interested, due to the research subject, of the use of HR measurement belts, the role of the different mediums when checking the hockey results and the background of the audience – a true fan and dedicated hockey follower will have different, more intense, approach to these kinds of extra-features happening during the game.

What is promising is the fact that the clear majority (52) noticed the HR measurement during the game. This time it was not possible to visualise the collective HR on the central screen above the ice but the local commentator of the game was recruited to announce the current rate instead. The commentator announced the average HR for example after the goals or other significant events during the game. The inquiry then asked whether the HR knowledge had any influence on the audience's experiences. No one answered that the final test would have had any negative impact on the game. However 27 stated that it did not have any impact what so ever. One of the good results was the percentage on positive impact since 24 of the respondents stated that the impact was indeed positive.

Finally, we suggested four different scenarios and situations (Table 2, Table 3, Table 4 and Table 5) in which the HR measurement and public display could be used. Based on these tables, the collective HR of the audience should be displayed to everyone during the next pilot study. Also, by adding extra features like competitions the experiment could be more interesting.

Table 2 Scenario A

Would it be interesting to have the possibility to guess the collective rate at the time when the first goal is done?	
Not interested	3
Disturbing	0
Could not care less	12
Good idea	31
Exiting	5

Table 3 Scenario B

Would it be interesting if the home team's supporters and visitor team's supporters collective rates could be displayed at the same time so the data could be compared in real-time?	
Not interested	1
Disturbing	1
Could not care less	13
Good idea	31
Exiting	5

Table 4 Scenario C

Would it be interesting if it would be possible to increase your own heart rate during the game breaks for example by making waves in the audience, even as a competition between the home and visitor teams' supporters?	
Not interested	10
Disturbing	6
Could not care less	13
Good idea	20
Exiting	2

Table 5 Scenario D

Would it be interesting if it would be possible to look up from the internet during and after game the graphical diagram of the heart rate? In a way where also the different game situations could be located with the rates?	
Not interested	11
Disturbing	0
Could not care less	8
Good idea	24
Exiting	8

5.1.3 Discussion

At first, like mentioned before, in the future the collective HR will be visualised on a large public screen that already holds the important information of the game and is situated in the centre of the ice rink itself. This will give all of the audience a possibility to follow the current state of the rate when they feel like it. In this experiment the

notification of the collective HR was more or less based on the rhetoric of the announcer. Secondly, the experiment should be able to offer the necessary technology to a much bigger part of the audience than in this test. The amount of the devices is crucial among the large audiences (Nilsson, 2007). This is of course difficult since the technology is expensive and every participator must be involved in the study by signing an agreement in case of breakage and such. This was done also in this experiment. According to the Könbergs et al. study, there are a lot of demands on sensors and equipment that are to be placed on a hockey player (for example size, weight, placement, low power consumption, resistance to motion artifacts and high humidity). There also certain demands on equipment used with the ice hockey audience as well (Könberg et al., 2003).

When it comes to the technology, it should be stated, that the HR measurement belts that need to be placed under clothes and moistened are not necessarily the best choice since the use of them, according to this study, seems to be interpreted as some sort of a violation of privacy. The successful experiment must offer for example a wristband or such that would not inquire that much trouble from the audience. However, if the test groups got bigger, it would also automatically mean better-organised data gathering from the audience. This time the research group gathered the data just by sharing the inquiry leaflets and collecting them afterwards. The time to act during the break is limited so there should definitely be a bigger group of people collecting the answers. In the future it has been considered that for example the junior hockey team could be used for this purpose.

In this study, significant game events like goals and penalties were added manually to the server by using a custom-made Flash application interface. As a future work, this feature will be automated by merging the heart measurement server data and real time game event information from the official Finnish National Hockey League website. In addition, this feature that visualises the real time audience HR including game events can be implemented to a web page.

Nowadays smart phones include several sensors and lots of research has done based on those mobile sensors like an acceleration sensor or GPS but especially Andrew et al. (2010) have written about ubiquitous sensing, actuation and interaction. Based on their research nanotechnology will revolutionise smart phones' sensor technology. In the future, it might be possible to measure a HR and other body functions without external sensors or sensors could be even a part of a human body.

We have designed several competitions and games to the audience for an entertainment purpose. The audience can guess what the collective HR is when a home team scores. Otherwise, it can be also a coach's HR. In addition, the audience can receive tasks. For example they have to maintain the collective HR between certain margins by doing waves or squats.

5.2 Study 2 – HR-based multiplayer exertion game event

The tournament was a success and players as well as audience liked the event a lot – "Quite nice, we could have these sort of games more often". The results indicated that a large percentage of the players would be willing to play exertion games in public spaces like schools (78 %). However, the results indicated that the games should include only lightweight exercising. Overall, team play was experienced as fun. Only 4 % had a dissenting view o this. In addition, 64 % of the players believed that teammates made

them perform better. However, opinions of the meaning of the audience varied and 25 % had no opinion of this at all.

The flow level experienced by the players was quite high (M = 3.70, SD = 1.01), but experiences varied among players. Players' stamina did correlate with flow experience ($r = .09$, $p > .001$), which indicates that everyone could enjoy the playing. However, most of the players stated that they were in good physical shape (M = 4.33, SD = .82). The results showed that team play was appreciated a lot (M = 4.08, SD = .93) and it facilitated also the flow experience ($r = .32$, $p < .05$).

In this study the students of the school could follow the tournament. The results showed that the audience really enjoyed the event (72%) and the interest remained during the whole tournament. Over half of the audience would have liked to participate in tournament also as players. Audience was interested in both visualisation of the gameplay and players' exercising. For audience the fidelity of the graphics was more important than for the players.

5.2.1 HR data results

HR monitoring was a new subject to players and they were eager to play games controlled with HR. Although HR monitors that were used in the experiment were not optimally designed for our purpose, players considered them as suitable game controllers (M = 3.62, SD = 1.11). However, in used HRM belts a separate transmitter part is attached to the belt with two poppers and it detached too easily and players experienced it as a technical problem. "It was otherwise good, but it would have been nice, if all the heart rate monitors would have worked, everyone would have been able to take part and the teams would have been equal". In practice, users tended to improve the proper point of the HR belt just before a game and sometimes this caused separation between the belt and the transmitter. A fixed HR monitor belt would have been much more reliable solution at least for players with minor practice and knowledge about HR monitors.

Despite of these technical problems, only 18 % thought that the HR monitor was not compatible as an exertion game controller. The correlation ($r = .48$, $p < 0.01$) between the willingness to play similar games again and the suitability of the HR monitor as a game controller was significant. This may be partly affected the fact that the use of HR belt was unprecedented to most of the students, so the novelty may have influenced the results. In fact 86 % of the players would have liked to also see their own HR in addition to their team's collective HR during the game. The expression of own HR would have supported the selection of exercising strategy – it would have been easier to perceive the causes and consequences.

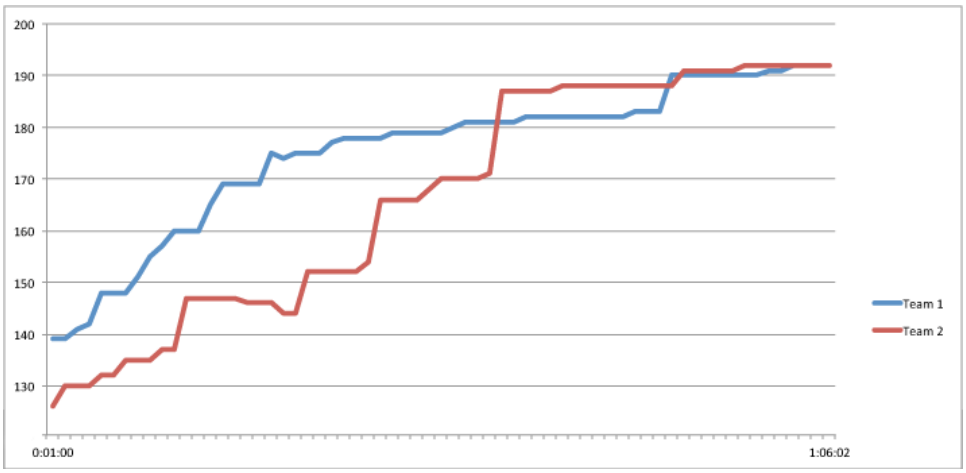
Players used different strategies to increase their HR. They performed for example squats, presses, jumps and running in place. The players reported that their attention tended to focus mostly on their activity and functioning of the body as well as assessment of the opponents' physical state. Because the game involved quite heavy exercise, some of the players did not have time to draw attention to realisation of the game graphics. Thus, it seems that in intensive exertion games the players do not require necessarily so-called high-tech graphical outlook. On the other hand the situation of the game needs to be clearly expressed because it is challenging to focus attention to details, when exercising.

Figure 7 visualises HR data of the tournament's final game. As we can see the initial HR values of both teams (Blue team: 139 bpm; Red team: 126 bpm) were quite high. We

assume that the excitement of the final game affected this. Anyhow, both teams ended up to quite high values – over 190 bpm). This indicates that players exercised very intensively. The red team that had a lower starting rate won the match.

Fairness perplexed surprisingly many players as following comments shows. "There should have been longer pauses and resting periods in order to get the heart rate come down". "It would have been nicer if there had been longer breaks between the games, since we had two games in a row". Such discussions indicate that players really thought and analysed the gameplay, which supports also the learning of body functions.

Figure 7 Both teams' collective HR values during the final game (see online version for colours)



6 Conclusions and future work

In sum, in this paper we have created the research platform in order to study co-creational space experience by utilising collective HR during public events. We conducted two different pilot studies based on the collective HR. The first pilot succeeded in eliciting sense of presence through the commentator's announcements, engagement, and in enhancing interaction and communication between audience and hockey game; in addition, similarly to Lin et al. (2008) study, the study also shows potential of physiological evaluation techniques in objectively evaluating user experience. Furthermore, the follow-up study supports these results. The real-time feedback on a public screen enriches the collective experience.

While our experiments are limited, we have shown that it is possible to enrich user experience in public events with (the use of) user-generated data. Also, because of our focus on these kinds of environments we made design decisions that allow users to derive some value from the system with only minimal input. All functions like network connections and HR monitoring are switched on automatically.

The evaluation results indicate that most of the study participants appreciated this sort of experiment. It seems that HR measurement events could be used to increase the positive experience when designed properly. However, it should be taken into account

that an ice hockey match and multiplayer exertion game tournament are almost automatically social and collective experiences for the participants. Still, the technology enhancing the experience would be there in order to deepen the collective feeling of the audience and participants.

Additionally, we found observations to be a critically valuable tool in prototyping this social mobile application. After running more complex pilots, the next step for this work is a full-fledged field experiment with a group or friends or colleagues in an unconstrained environment that could be a festival area for example.

Also, as a future work we should take into consideration the risk management. International Agency for Research on Cancer has classified radiofrequency radiation possibly carcinogenic (IARC, 2011). Since heart is a delicate, electrical organ, information about possible risks would be worth stating. Already in 1970, it was recommended that "cardiovascular abnormalities be used as screening criteria to exclude people from occupations involving radio-frequency exposures" (Cleary, 1970). Heart problems have been reported with wireless routers and pulsed radiofrequency (microwave) radiation (Havas et al., 2010). Heart problems come up also in epidemiological studies of base stations (Khurana et al., 2011). Having a mobile phone (sending HR data) next to vital organs is another risk area (Avendaño et al., 2010; de Iuliis et al., 2009). However, because of athletes utilise nowadays commonly different kind of (Bluetooth and radio-frequency) HR measurement equipment (Ahtinen et al., 2008) we believe that our system is safe to use and HR results in this study were not due to microwave exposure.

Acknowledgements

The authors would like to thank Jukka Hirsimäki who gave them a possibility to fulfil all the ice hockey pilots as well as their study participants for their time and feedback. In addition, Antero Lindstedt was invaluable assistance during the data gathering process at ice hockey games. Also, the authors would like to acknowledge Tekes – the Finnish Funding Agency for Technology and Innovation for funding the ice hockey part of this project.

References

Ahtinen, A., Isomursu, M., Huhtala, Y., Kaasinen, J., Salminen, J. and Häkkilä, J. (2008) 'Tracking outdoor sports – user experience perspective', in Aarts, E., Crowley, J.L., Ruyter, B., Gerhäuser, H., Pflaum, A., Schmidt, J. and Wichert, R. (Eds.): *Proceedings of the European Conference on Ambient Intelligence (AmI '08)*, Springer-Verlag, Berlin, Heidelberg, pp.192–209, ISBN 978-3-540-89616-6.

Andreassi, J.L. (2000) *Psychophysiology: Human Behavior and Physiological Response*, Lawrence Erlbaum Associates, Mahwah, New Jersey, USA.

Andrew, P., Bailey, M., Ryhänen, T. and Wei, D. (2010) 'Sensing, actuation, and interaction', in Ryhänen, T., Uusitalo, M.A., Ikkala, O. and Kärkkäinen, A. (Eds.): *Nanotechnologies for Future Mobile Devices*, Published by Cambridge University Press.

Armstrong, S. (2007) 'Wireless connectivity for health and sports monitoring: a review', *British Journal of Sports Medicine*, Vol. 41, No. 5, pp.285–289, doi:10.1136/bjsm.2006.030015.

Avendaño, C., Mata, A., Sanchez Sarmiento, C.A. and Doncel, G.F. (2011) 'Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation', *Fertility and Sterility*. Vol. 97, No. 1, pp.39–45.

Bassett, R., Behnke, R.R., Carlile, L.W. and Rogers, J. (1973) 'The effects of positive and negative audience responses on the autonomic arousal of student speakers', *Southern Speech Communication Journal*, Vol. 38, No. 3, pp.255–261.

Bray and Martin (2003) 'The effect of competition location on individual athlete performance and psychological states', *Psychology of Sport and Exercise*, April, Vol. 4, No. 2, pp.117–123.

Cleary, S.F. (Ed.) (1970) 'Biological effects and health implications of microwave radiation', *Symposium Proceedings*, 17–19 September 1969, Richmond Virginia, Sponsored by Medical College of Virginia, Virginia Commonwealth University with the support of Bureau of Radiological Health, U.S. Department of Health, Education, and Welfare, Public Health Service, Environmental Health Service, 275p.

Dahlbom, B. (1996) 'The new informatics', *Scandinavian Journal of Information Systems*, Vol. 8, No. 2, pp.29–48.

De Iuliis, G.N., Newey, R.J., King, B.V. and Aitken, R.J. (2009) 'Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro', *PloS One*, Vol. 4, No. 7, p.e6446.

Essl, G. and Rohs, M. (2007) 'ShaMus – a sensor-based integrated mobile phone instrument', *Proceedings of the International Computer Music Conference (ICMC)*, 27–31 August, Copenhagen, Denmark.

Gantz, W. and Wenner, L.A. (1991) 'Men, women, and sports: audience experiences and effects', *Journal of Broadcasting & Electronic Media*, Vol. 35, No. 2, pp.233–243.

Havas, M., Marrongelle, J., Pollner, B., Kelley, E., Rees, C.R.G. and Tully, L. (2010) 'Provocation study using heart rate variability shows microwave radiation from DECT phone affects autonomic nervous system', *European Journal of Oncology*, Vol. 5, Library [online] http://www.icems.eu/papers.htm?f=/c/a/2009/12/15/MNHJ1B49KH.DTL.

Honkavaara, A. (1968) Jääkiekkokirja 1967–68, Kirjapaino H. Öhrling, p.195.

IARC (2011) *IARC Classifies Radiofrequency Electromagnetic Fields As Possibly Carcinogenic to Human*, The WHO/International Agency for Research on Cancer. Press release, No. 208. URL:http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf.

Khoo, J., Brown, I. and Lim, Y. (2008) 'Wireless on-body-network breathing rate and depth measurement during activity', *30th Annual International IEEE EMBS Conference Vancouver*, 20–24 August, British Columbia, Canada.

Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M. and Ahonen, M. (2010) 'Epidemiological evidence for a health risk from mobile phone base stations', *International Journal of Occupational and Environmental Health*, Vol. 16, No. 3, pp.263–267.

Kiili, K., Perttula, A. and Tuomi, P. (2010a) 'Development of multiplayer exertion games for physical education', *IADIS International Journal on WWW/Internet*, Vol. VIII, No. 1, pp.1645–7641, ISSN.

Kiili, K., Perttula, A., Tuomi, P., Suominen, M. and Lindstedt, A. (2010b) 'Designing mobile multiplayer exergames for physical education', *IADIS International Conference Mobile Learning*, 19–21 March, Porto, Portugal.

Könberg, T., Ohult, C. and Delsing, J. (2003) 'Measuring breathing and heart rate data with distribution over wireless IP networks', *IMTC 2003 – Instrumentation and Measurement Technology Conference*, Colorado, USA.

Lazzaro, N. (2004) 'Why we play games: 4 keys to more emotion', *Proceedings of Game Developers Conference 2004*.

Lin, T., Maejima, A. and Morishima, S. (2008) 'Using subjective and physiological measures to evaluate audience-participating movie experience', *Proceedings of the Working Conference on Advanced Visual Interfaces*, 28–30 May, Napoli, Italy, *AVI '08*, pp.49–56, ACM, New York, NY.

Mandryk, R.L., Inkpen, K.M. and Calvert, T.W. (2006) 'Using psycho physiological techniques to measure user experience with entertainment technologies', *Behaviour & Information Technology*, Vol. 25, No. 2, pp.141–158.

Marshall, D.C. and Rossman, D.G.B. (2006) *Designing Qualitative Research*, 4th ed., Sage Publications, Thousand Oaks, CA.

Nilsson, A. (2007) *Sport Informatics-Using Mobile IT to Amplify Event Audience Experience*, The Mobile Informatics Group, Victoria.

Pagulayan, R.J., Keeker, K., Wixon, D., Romero, R. and Fuller, T. (2003) 'User-centered design in games', in Julie A. Jacko and Andrew Sears (Eds.): *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, pp.883–906, Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey, USA, ISBN: 0-8058-3838-4.

Zajonc, R. (1965) 'Social facilitation', *Science, New Series*, 16 July, Vol. 149, No. 3681, pp.269–274.

Publication 6

Perttula, A. (2012). When a Video Game Transforms to Mobile Phone Controlled Team Experience. Proceedings of 16th International Academic MindTrek Conference: Envision Future Media Environments. October 3-5, 2012, Tampere, Finland, pp. 302-309. ISBN: 978-1-4503-1637-8.

When a Video Game Transforms to Mobile Phone Controlled Team Experience

Arttu Perttula

Tampere University of Technology
PL 300, 28101 Pori
Finland
Tel. +358 3 311 511

arttu.perttula@tut.fi

ABSTRACT

An existing rhythm game is modified to provide a new kind of collective experience. In addition to providing a novel collective experience, this study seeks answers to the following research question; how could the game be modified so that it would enhance social interaction between players? In order to obtain answer to the question, the game modification was based on an extraordinary custom-made user-interface that involves players in cooperation. According to players, the modified multiplayer version of the game was both engaging in action and enjoyable. Totally out of the context of the game, controllers offered amusing game experience. Finally, cooperation through modification of the game was the answer to the proposed research question.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—Collaborative computing; H5.2 [**Information Interfaces and Presentation**]: User Interfaces—Input devices and strategies.

General Terms

Experimentation

Keywords

Experimental Design, Audiovisual Play, User Interface, Mobile Phone, Social Context, Game Testing

1. INTRODUCTION

The computer and video game industry has been recently producing games in a genre called music or rhythm games. The technology used in these games allows for novel interfaces to represent musical instructions. The games themselves have greatly simplified instruments and music is created to the point where the skills learnt are not transferrable to the actual instruments that they seek to recreate. [20] Actually, rhythm-based or beat matching music games have become increasingly popular. The challenge is to usually press, hit, strum or slide on buttons at the correct time. Players are presented with the next required button presses on screen and they are scored on their accuracy of matching their selection with the beat of the music. The simplistic interaction required for rhythm-based games allows the genre to rely less on complex interactivity and gameplay. The focus is the engagement of players. [39]

A rhythm game was selected for this study based on both popularity and simplicity, with focusing to provide a new kind of collective experience for players. The game was played at a public event. Thus, a multiplayer feature and simplicity were important aspects. Because there are no rhythm-games for many players (even up to 20 players) simultaneously, for this experiment an existing game called Frets on Fire (published by Unreal Voodoo 2006) was modified to a cooperative multiplayer version. This game is based on the popular Guitar Hero (published by Harmonix, Neversoft and Vicarious Visions 2005) game, but it is open source software. It can be run on Linux, Microsoft Windows and Mac OS X operating systems. Frets on Fire can be played with a keyboard, an external joystick or even a Guitar Hero controller.

This study will examine ways to create an enjoyable and usable collaboratively controlled game. For the purposes of this study, a game is considered usable if the players are reasonably capable of playing the game without explicit instructions. A game's enjoyability is determined through player feedback. Collaborative control refers to a mechanism that allows multiple users to control a single game entity. A game entity in this case is a virtual instrument. In a conventional multiplayer game, each player has at least one entity that they alone control. In contrast, collaboratively controlled gameplay requires that multiple players provide collective input for an entity or system. Thus a group of players must work simultaneously and in concert with one another to achieve their intended goal.

In the unmodified Frets on Fire game, a player must read the on-screen notation, simultaneously pressing a particular fret button with the left hand and a strum bar with the right hand. Correct playing allows each note to make its way out of the audio playback. In other words, the goal of this game is that the player presses the right button combination, matching the colored dots on the screen, which are moving along with the music (Figure 1). Some dots have lines attached to them, implying that one should

MindTrek 2012, October 3-5, 2012, Tampere, FINLAND.

hold down that corresponding button for a longer period of time, until the end of the line hits the bottom of the screen. The score increases when a player hits the right combination of buttons matching the dots on the screen.

Figure 1. During the Frets on Fire gameplay a player presses buttons in time to colored markers. They are matched to the rhythm of the music.

In the modified version, players work as a team to control a virtual instrument via colored dots. The game prototype piloted during the fall 2011 with a total of 36 players. Results based on observations and interviews are promising and several subjects for future work occurred during the study.

2. RATIONALE

In addition to providing a new kind of collective experience, this study tries to answer the following research question; how could the game be modified so that it would enhance social interaction between players? In order to obtain answer to the question, in addition to the basic game, game modification is based upon a novel user-interface that involves players in cooperation. Cooperation is a part of the persuasion, enjoyment as well as adding more playfulness to the game. McGonical [23] even claims that cooperation always provokes positive emotions and meaning in games. Furthermore, by adding the cooperation element to the game, the hypothesis is that a novel multiplayer user-interface will be the answer to the research question. To understand better this solution, persuasion, enjoyment and playfulness are described in more detail.

2.1 Persuasion

Many people do not need external pressure or rewards to do things like playing the guitar; the rewards are built-in, or intrinsic. [8] Malone and Lepper [22] have outlined seven types of intrinsic motivators that work with games. Three of these motivators are group-level intrinsic motivators: competition, cooperation, and recognition. They involve interaction among people. According to Fogg [8] competition is perhaps the most powerful group-level intrinsic motivator. Not everyone is competitive by nature, but in most situations and for most people, competition is energizing and motivating. Cooperation is another motivator, one that seems to be built into human nature. When people belong to a work group, most of them cooperate. Finally, people are intrinsically motivated by recognition. [8]

The modified game includes competition between teams. Scores are stored on the high score list and teams can watch while others are playing. The high score list tries to motivate teams by recognition. Cooperation is an essential part of the modification through user interface.

2.2 Enjoyment

Games (single-player and multiplayer) use different strategies for enjoyment. According to Lazzaro [18] one main criteria for enjoyment in games is social interaction. Games should support and create opportunities for social interaction. Furthermore, games should support competition and cooperation between players. To support social interaction, games should create opportunities for player competition, cooperation, and connection [18, 27].

Game experiences should be structured to enhance player-to-player interaction and to create enjoyment in playing with others both inside and outside the game [18]. People enjoy interacting with other people, spending time with friends, watching others play. Chatting and talking about the game, seeing other people's reactions and expressions, gloating when beating a friend, or feeling pride when they win [18, 35]. Social competitions are also an important aspect of social interaction [40], as people gain satisfaction from competing against and beating other people. Anyway, it is important to note that games with social interaction are not necessarily the most enjoyable ones although it is one approach to create enjoyment.

2.3 Playfulness

Fullerton et al. [10] propose that a playful approach can be applied to even the most serious or difficult subjects because playfulness is a state of mind rather than an action. Playfulness is a way to motivate and activate a user on creating new approaches for many not-so-exciting tasks [13]. The definition of playfulness in user experience can be constructed from elements that engage people's attention or involve them in activity for the sake of playing, amusement, or creative enjoyment [7]. Playful user experience provides users with opportunities to develop skills through exploratory behavior [41].

Several design methods can be used to evoke playfulness in the user. A playful game can contain elements of experimentation [41] and social interaction [30] such the game modification does. Frivolous interaction such as a component of interactive silliness can be implemented. According to Malone, an enjoyable user interface is based on three aspects: challenge, fantasy and curiosity [21]. Playfulness attracts users and provides enjoyable user experience. It should also inspire and enable users to develop their knowledge and skills. [17] In this case, a novel way to control the game provides elements of playfulness such as experimentation, social interaction, silliness, challenge, fantasy and curiosity.

3. RELATED WORK

There are several studies about persuasion, enjoyment and playfulness in games. The intention of this study is to achieve cooperation with these elements via the novel user-interface. Thus it is more relevant to present game controller modifications based on Guitar Hero or Frets on Fire games. Many of them deal with people with disabilities. Thus, the viewpoint of the design is different and they are not comparable with this study. Anyway, the system presented in this study is designed to be more social paralleled to the following.

Versteeg [38] managed to use a brain computer interface to control simplified Frets on Fire game. He disabled the rhythm button and decreased the number of buttons from five to two. The game is dependent on timing, thus it is important that the brain computer interface software can analyze data quickly and correctly.

Armiger and Vogelstein [1] developed an interface for the commercial video game Guitar Hero using surface electromyography to create a novel training and evaluation device for upper-extremity amputees. Rather than pressing the keys with one's fingers as in the normal game, a user merely flexes his or her index, middle, or ring finger muscles, and the resulting myoelectric activity is recorded using six or more EMG electrodes placed around the forearm. The acquired data is processed in real-time using pattern recognition algorithms to derive intended motion, and the results are used to control the game.

Tilley [37] hacked the Dualshock controllers for the Guitar Hero. The game is normally played with a plastic guitar-shaped controller where one player presses five colored buttons in time to music and two players can compete at the same time. The controllers were modified so that five students can have one colored button each and this allows up to ten students to play at the same time in two-player mode.

Gamers with severe physical disabilities cannot always use traditional input devices. Based on that, Vickers et al. [39] utilized an eye-gaze interaction technique to control a Guitar Hero style game. The experiment concludes with a case study in which a young person with physical disabilities is able to successfully play the game using only eye movements.

Very few video games have been designed or adapted to allow people with vision impairment to play. Yuan and Folmer [43] developed a glove that transforms visual information into haptic feedback using small pager motors attached to the tip of each finger. This allows a blind player to play Guitar Hero successfully and enjoy the challenge.

Friedman et al. [9] presented the MusicGlove for individuals with hand motor impairment as a motivating way to perform hand exercises and to quantitatively assess hand movement recovery. When the user touches the thumb lead to one of the other five electrical leads, a distinct event is sent to the computer through a microcontroller. Frets on Fire interprets these events in the form of musical notes.

4. MODIFIED GAME

The single player game Frets on Fire is modified to a multiplayer version, which is designed in a way that everyone can participate. Actually players are not necessarily controlling a guitar anymore. The original game visualization and user interface modifications can present any imagined instrument. In general, this game modification was designed to provide a new kind of collective experience to players. Via this approach there is an attempt to offer a new way of improving team spirit.

A typical case scenario for use is that a group of friends play the game. To succeed in the game, they have to works as a team and practice cooperation skills. Another scenario is that the game system is available in a public space and people want to try it. In addition to playing, they meet new people.

4.1 Design Principles

This modification is designed for 1-6 players. But even more players can play simultaneously because players use mobile phone flashlights to control the game. One player can also have two flashlights in both hands. A single player game is almost impossible but six players are optimal. In an optimal case, each player controls one color. The sixth player similarly controls the guitar's pick. Basically, players just point their flashlight towards light sensor items (Figure 2).

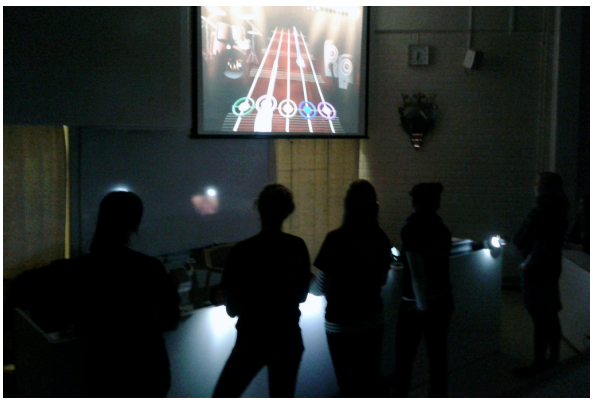


Figure 2. Study participants use mobile phones as flashlights to control the Frets on Fire guitar-playing game.

The design is so simple that anyone can just start to play without any practice. But players have to decide how they will work as a team if they want to experience success in the game, especially if there are less than six players. Simplicity in controlling is one of the key reasons why this study was not carried out with, for example, the multiplayer Band Hero (published by Harmonix, Neversoft and Vicarious Visions 2009). Controllers are even simpler than five button Buzz! (published by Relentless Software 2005) buzzers. Another reason is that this solution does not limit the amount of players. This is why flashlights (Figure 3) are suitable controllers instead of some kind of buttons, for example. There can be, for example, ten players controlling the same color and they can switch positions during gameplay or they can use light as they like. In addition, future work follow-up studies will utilize for example phones' camera sensor (discussed more in Future Work chapter).

Figure 3. Mobile phones are equipped with rear camera led flash (red circle) and it can be controlled by software without using a camera.

This solution utilizes mobile phones also because almost everyone already has a suitable game controller in their pocket. There are no modifications to the original game software. Only the game controlling mechanics is different. In other words in addition to Frets on Fire, this system can also be implemented with the Guitar Hero game. In addition to game software, of course, mobile phone flashlight application is needed. Actually this modification could be used in other kinds of games too, to add an extraordinary multiplayer dimension.

4.2 Technological Implementation

The modification (Figure 4) includes three main points: 1) mobile phones with flashlight applications, 2) custom-made light sensors and 3) the electronics of a keyboard. In general, keyboard buttons are replaced with light sensors. Players use mobile phones as flashlights to control sensors. Points 1-3 are described below.

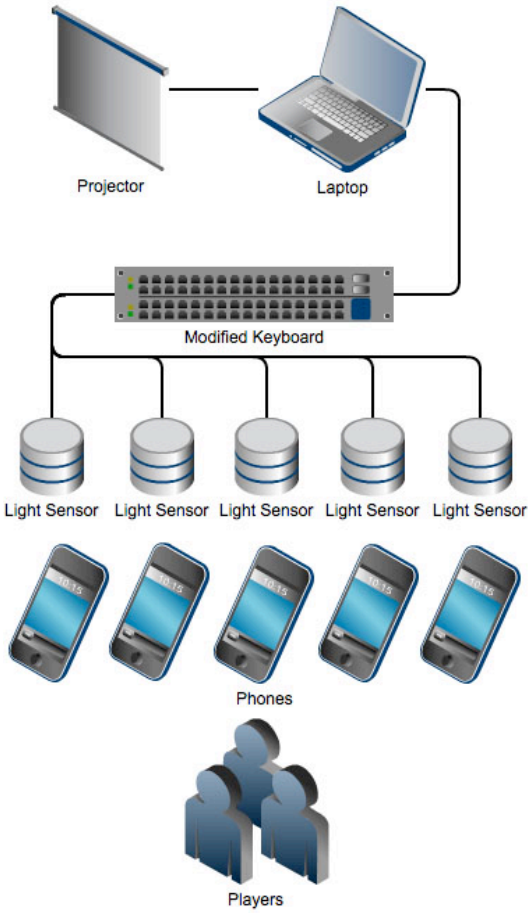


Figure 4. The system architecture of the prototype version.

1) Mobile phones are equipped with rear camera led flash (Figure 3). The flash can be controlled by software without using a camera. The mobile application (Figure 5) is as simple as possible and it acts like a flashlight. There is one on/off slide switch to control a phone's flash led. The switch is visualized on a touch screen. The light produced is bright and illuminative (Figure 2).

Figure 5. The mobile application includes only one on/off slide switch to control a phone's flash led (see Figure 3).

2) A light sensor (Figure 6) includes a high-speed light sensitive switching diode. It is attached to the inside of a tube-shaped container. Its cover is made from transparent plastic and white printing paper. Thus light is able to pass through it. The paper's function is to filter light so it is not too sensitive. This way, a gaming room does not have to be completely darkened. Only intensive light can pass through. When this happens a switch is connected and it replaces a button pressed like in the unmodified version.

Figure 6. Light sensors and mobile phones on a desk during the first try-out. One light sensor corresponds to a certain color in the game. The so-called pick button is also a similar light sensor and it was colored black (not in this picture).

3) All light sensors are wired to a keyboard (Figure 7). Wires are connected and soldered to keyboard's circuit board like certain keyboard buttons. In this modification a USB-keyboard was used. It does not make any difference if it is a Bluetooth-keyboard or it can even be a game controller like a gamepad or a guitar-controller. Light sensors just replace necessary buttons. There was no significant delay, even though connectors between the keyboard and light sensors were five meters long.

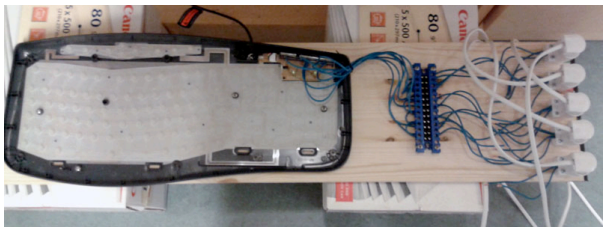


Figure 7. In this initial prototype, all light sensors are wired to a keyboard.

The first attempt to create the game was to utilize phone's (Nokia 5800 XpressMusic) ambient light sensor instead of diodes. It turned out that the sensor worked too slowly. The second attempt to fulfill this solution was using real flashlights with colored lenses attached. Colors would match the game's colors. One or

more mobile phones were utilized to observe flashlights via the camera function. An image detection mobile application would recognize players' actions. In other words in this case, players would play with different colored flashlights and they would point towards mobile phones (or a phone) that capture colors (compare with Future Work chapter). This kind of solution would need more work but it is still an alternative method of implementing this modification. Furthermore, the delay between the game and players could be a problematic issue if real-time mobile image detection application is not efficient.

5. STUDY

The study was conducted in the autumn of 2011 with the cooperation of Insomnia XIII LAN gaming event (Pori, Finland). In addition, a group of volunteers was recruited to attend one try-out (October 7, 2011) before the actual study (October 28, 2011). The participants of the try-out group were college students from the Meri-Porin lukio (Pori, Finland, n = 8, 2 teams, 4 female and 4 male, age 15-18). The participants of the final test (n = 28, 7 teams, 11 female and 17 males, age 15-20) were attendees of the Insomnia event. Team size varied from 3 to 6 players. The purpose of the try-out was mainly to test and simulate the upcoming gaming situation and discover possible bugs. So the following findings and results are mainly based on the actual study. During it, volunteer participants played the game by forming teams, which competed against one another. Scores were saved on a high score list.

5.1 Research Methods

Traditional evaluation methodologies in human-computer interaction are rooted in the productivity environment; however, for entertainment technology, the interest lies in the quality of the experience and to what degree this experience is facilitated by the entertainment technology, regardless of performance [27]. Currently, the most common methods of assessing user experience are through subjective self-reporting and through objective reports [18].

In this study, objective reports are based on real-time and video observations. This method was selected because it enabled observation of participants while playing and confronting them with the game session recordings afterwards. One observer captured on video and another wrote down notes during the event. Especially, we tried to record behaviors and social interactions. Self-reporting included informal on site conversations with study participants. All study participants provided feedback immediately after playing the game. Questionnaires were not used in a situation where people came and went all the time. Too much interference might negatively affect the overall experience.

5.2 Findings and Results

It was a surprise to participants how much attention playing required. In the case of every team, the first round was a tricky one because successful gaming requires practiced reactions, in spite of the fact that all teams were briefly instructed before playing. Almost everyone had also played Guitar Hero earlier so they were familiar with the idea of the game. Players noticed that it is hard to be good, but the game is easy enough anyway so that everyone could participate. In every case, players wanted to try more than once and they played even same songs several times. Actually a couple of players did not want to stop gaming at all.

Some players used their feet to tap the beat to concentrate and some did it because of a good music listening and playing experience. These players said that in order to catch the rhythm, playing needs whole body interaction. According to Miller [16], playing Guitar Hero is deeply theatrical and the affective experience of making music is bound up with embodied performance. The same kind of action happened even with mobile flashlight controllers; some players acted like rock stars. The sound volume has an effect on the players' moods. Some players even said that the experience was like partying. According to them, in addition to the music the light controllers provided unseen user-controlled light show for the event.

It turned out that the mobile flashlight application's on/off slide switch was too slow for accurate gaming. Because of that, some players tried real flashlights as game controllers but they were also too clumsy. The best solution for controlling the game was to keep the mobile phone flashlight on all the time. Players only pointed towards light sensors at the appropriate moment. One player controlled one or two light sensors (colors) depending on the number of players on a team. They did not try to control the same colors together.

Communication between team members was important because of based on observations and discussions, cooperative teams managed to earn more points than others. A good team was encouraging and positive minded. Actually the sociality of the game formed particularly from the players' encouragement and guidance of others. Anyway, the nature of game is not too social because it does not include necessary communication between players. Also, shy ones dared to participate and play. In any case, players unknown to one another beforehand met new people. It did not have an effect on the final results if a team was formed of friends or random participants. Teams competed a little bit against one another but mainly a team tried only to improve its own scores.

Some players acted as leaders of the team and they encouraged and assisted others more than other players. This behavior just happened in some teams. It probably depends on the personality of players. Also, the most skilled person usually became a leader. These leader players also usually controlled the color that included the most action during a game. Leaders helped unskilled players adjust with a suitable amount of anticipation. Players who missed colored dots all the time, were advised that they should take action about half second beforehand. Teams with this kind of person played better and in a more organized manner. However, no one acted as a pure coach-like player on a team; all participants wanted to play the game.

Only a couple of people asked about the implementation of the game. However, they did not call it into question. All participants just enjoyed playing. This could mean that the game modification was convincing and it offered a good experience. Gender did not affect skills, progress or results. Also, based on the feedback females and males liked the game similarly. The audience seemed to enjoy the music show also. Players indicated that the modified version was better than the original one because it was fun to play with others. According to players, collaboration and skill are the main factors of performing well. They also mentioned that this version could be a commercial success among other so-called party games.

Last but not least, one player told that she does not like Guitar Hero because of the guitar-like controller, but she would like to play this modified multiplayer version. According to players this version was easier to try because it is simpler than the instrument-like controller. Players also told that the flashlight solution is better than a keyboard. All players said that game controllers used in this study were fun to use and it was fun that mobile flashlights are not related at all to music playing. This indicates that a game controller does not have to always remind or simulate its real world counterpart.

6. DISCUSSION

At first, it looks like the game controller solution used in this study offers a good gaming experience. It is obvious that the appropriate guitar-like controller offers good gaming experience too. If these are compared to a keyboard, players prefer to use the previously mentioned ones. The keyboard and flashlights are not directly related to the music playing game. What causes the difference? Is the keyboard too traditional input method? Or does it depend on the multiplayer possibilities? Should the controller be simple enough or somehow entertaining? This study does not answer these questions but it would be useful to study more affects of different kind of game controllers on the experiences of players. Also the light interface seems to be less embodied than the original guitar interface - so is less embodiment part of a more social interaction design?

Ryan and Siegel [31] stated that when users experience a device as ready-at-hand, the focus of their attention is on the activities they are doing and not consciously on the device itself. In a sense, the device becomes an extension of the user. When they experience the device as present-to-hand, however, they focus specifically on the device, which goes from being an extension to being a hindrance as they try to resolve whatever is preventing readiness-at-hand of the device. This may explain differences between the keyboard and mobile flashlight controllers.

Arsenault [4] argued that Guitar Hero is not about simulating guitar playing and rhythm is the worst simulated dimension. However, can this kind of modification change some people attitudes towards practicing musical skills? Does it lower the threshold to try something unfamiliar like real instruments? During the study, there was significant improvement among study participants' sociality. The game could be also used in this way as persuasive technology to enhance communication, collaboration and social skills between people.

When it comes to the technology, Frets on Fire was a good choice to pair with the game controller modification presented. Although the game is related to music, and good music itself can improve people's feelings and emotions, a new kind of social aspect positively affected the overall experience. Would this kind of modification work as well with other game genres? Even though as mentioned earlier, single player game is almost impossible and six players is optimal with this modification. For a commercial game, this could be a problem if the game cannot cater for situations when there might be just one or two players around, and they need to be physically present.

Selected research methods were well suited to this study. Observations were found to be a critically valuable tool in prototyping this kind of game and studying the experiences related to it. In this study, interviewing that was more like planned chatting with players worked well because it did not interrupt players at all.

7. FUTURE WORK

In addition to further research, the next version of the presented system will work wirelessly using socket server solution (Figure 8). It would be similar to that presented by Perttula et al. [28], but instead of WLAN (wireless local area network), networking will be conducted via the Internet (players will be still co-located). The installation and configuration will be more straightforward without a local network. A computer or a device with Internet connection is needed to view the game.

Figure 8. The system architecture of the planned second version (compare to the Figure 4).

There could be for example colored lights or painted plates according to the colors of the game. A player points the phone towards corresponding color in time to game events. The game will utilize phones' camera to capture the color and thus perform a color detection function. A mobile phone will send captured color as a game command to the server. Thus it is possible to create the game system without light sensors. In addition, this kind of implementation enables also data gathering and monitoring options; phones can collect information about players' performance and accuracy. Phones could vibrate and thus provide feedback to players.

There is a need to arrange more comprehensive study and compare the modified one with the original version in similar

settings. Although some study participants already reported that the modified version was more fun to play compared to the original single-player guitar controller version.

As future work, to deepen this study, it could be re-arranged with a greater number of study participants and research methods could also be based on playability and player experience research [26]. In addition, other game research method approaches like Ribbens and Poels [29] and Järvinen [11] should be taken into consideration. Also, Ian Bogost's [5] persuasive game studies could offer a comprehensive starting point for further research. Anyway, as Nacke et al. [18] suggested, a multi-measure approach enables a fuller characterization of game experience than any single isolated measure. Furthermore to succeed in future work, social play [34, 6], different attitudes for play [33], gamer mentalities [12], playful experiences [42, 14, 15, 16, 2, 3, 19] and ambiguity of play [32] should be taken into consideration.

8. CONCLUSION

All study participants enjoyed the game; even players who do not profess to like or play so-called rhythm games. As Mäyrä [25] has stated, there is plenty of anecdotal evidence available on how people who are not usually players of particular digital games or games at all actually end up enjoying the experience when they have been introduced to such games under suitable conditions. In this case, the suitable conditions were an element of cooperation and fun input devices. By adding these, the proposed hypothesis turned out to true. The user interface that involved players in cooperation enhanced sociality between players significantly. According to players, the modified game was engaging in action and enjoyable. It is interesting that, totally out of context, the game controllers offered amusing game experience.

To sum it up, by adding a novel user-interface, a social element, to this game, people were attracted. In addition, simplified game controller mechanics with extraordinary multiplayer dimension created a new kind of collective experience. Collaborative control could be considered the next step in the emerging trend of socially encouraging games. The potential knowledge gleaned by this study will equip the creators of these games to make novel game design decisions allowing them to create fun gameplay experiences.

9. ACKNOWLEDGMENTS

Niina Tuulivaara was invaluable assistance during this project. Special thanks for helping to build light sensor items and taking notes. I would like to acknowledge Nokia Foundation for financial support. Also, thanks to Aliisa and Tuomas Sinkkonen for asking to implement this kind of solution in the Insomnia XIII event. I am also tremendously grateful to the players who were willing to share their thoughts with me.

10. REFERENCES

[1] Armiger, R. and Vogelstein, R. 2008. Air-Guitar Hero: a real-time video game interface for training and evaluation of dexterous upper-extremity neuroprosthetic control algorithms. BioCAS 2008, Baltimore, MD, USA, pp 121-124.

[2] Arrasvuori J., Boberg M. and Korhonen H. 2010. Understanding Playfulness - An Overview of the Revised Playful Experience (PLEX) Framework. In proceedings of Design & Emotion 2010 conference, Design and Emotion Society 2010. Chicago, USA.

[3] Arrasvuori J., Korhonen H. and Väänänen-Vainio-Mattila K. 2010. Playfulness in the User Experience of Personal Mobile Products. In proceedings of OZCHI 2010. ACM. November, 2010, Brisbane, Australia.

[4] Arsenault, D. 2008. Guitar Hero: "Not like playing guitar at all"? Loading..., Vol 2, No 2 (2008), ISSN 1923-2691.

[5] Bogost, I. 2007. Persuasive Games: The Expressive Power of Videogames. The MIT Press. Cambridge, Massachusetts, London, England.

[6] Caillois, R. 2011. Man, Play and Games. University of Illinois Press. ISBN-13: 978-0252070334.

[7] Draper, S. W. 1999. Analysing Fun as a Candidate Software Requirement. Personal Technology, 3 (1999), pp 117- 122.

[8] Fogg B.J. 2007. Increasing Persuasion Through Mobility. In Mobile Persuasion – 20 Perspectives on the Future of Behavior Change (Eds. BJ Fogg and Dean Eckles), Persuasive Technology Lab., Stanford University.

[9] Friedman, N. et al. 2011. MusicGlove: Motivating and quantifying hand movement rehabilitation by using functional grips to play music. EMBC, 2011, IEEE, Aug. 30 2011 - Sept. 3 2011, Boston, MA, USA. pp 2359 – 2363.

[10] Fullerton, T. et al. 2004. Game Design Workshop. Designing, Prototyping, and Playtesting games. CMP Books, San Francisco, CA, 2004.

[11] Järvinen, A. 2009. Games without Frontiers: Methods for Game Studies and Design. VDM Verlag.

[12] Kallio, K., Mäyrä, F. and Kaipainen, K. 2010. At Least Nine Ways to Play: Approaching Gamer Mentalities. Games and Culture, July 2011, vol. 6, no. 4, pp. 327-353.

[13] Kangas, S. and Cavén-Pöysä, O. 2005. Ambient utility games: connecting utility to play. International Conference on Internet and Multimedia Systems and Applications (EuroIMSA '05), February 21-23, 2005, Grindelwald, Switzerland, pp 18-24.

[14] Korhonen H., Arrasvuori J. and Väänänen-Vainio-Mattila K. 2010. Analysing User Experience of Personal Mobile Products through Contextual Factors. In proceedings of MUM 2010. ACM. December 1-3, 2010, Limassol, Cyprus.

[15] Korhonen H., Arrasvuori J. and Väänänen-Vainio-Mattila K. 2010. Let Users Tell the Story: Evaluating User Experience with Experience Reports. In proceedings of the 28th international conference extended abstracts on Human factors in computing systems, CHI 2010, ACM Press (2010), pp. 4051-4056. April 10-15, Atlanta, GA, USA.

[16] Korhonen H., Montola M. and Arrasvuori J. 2009. Understanding Playful Experiences Through Digital Games. In proceedings of the 4th International Conference on Designing Pleasurable Products and Interfaces, DPPI 2009. October 13-16, 2009, Compiègne, France.

[17] Kuts, E. 2009. Playful User Interfaces: Literature Review and Model for Analysis. DiGRA 2009 – Breaking New Ground: Innovation in Games, Play, Practice and Theory. September 1-4, 2009, London, United Kingdom.

[18] Lazzaro, N. 2004. Why we play games: 4 keys to more emotion. Game Developer's Conference, San Jose, CA, 2004.

[19] Lucero A. and Arrasvuori J. 2010. PLEX Cards: a source of inspiration when designing for playfulness. In proceedings of Fun and Games 2010. ACM. September 15-17, Leuven, Belgium.

[20] Macrae, R. and Dixon, S. 2008. From toy to tutor: Note-Scroller is a game to teach music. NIME08, June 5-7, Genova, Italy.

[21] Malone,T. W. 1982. Heuristics for designing enjoyable user interfaces: Lessons from computer games. Human factors in computing systems, March 15-17, 1982, Gaithersburg, Maryland, United States, pp 63-68.

[22] Malone, T. and Lepper, M. 1987. Making learning fun: A taxonomy of intrinsic motivation for learning. In Aptitude, Learning, and Instruction (Eds. R.E. Snow and M.J. Farr). Hillsdale, N.J., Lawrence Earlbaum.

[23] McGoniGal, J. 2011. Reality is Broken: Why Games Make Us Better and How They Can Change the World. Jonathan Cape, London.

[24] Miller, K. 2009. Schizophonic Performance: Guitar Hero, Rock Band, and Virtual Virtuosity. Journal of the Society for American Music, Vol. 3 (2009), Number 4, pp 395-429.

[25] Mäyrä, F. 2007. The Contextual Game Experience: On the Socio-Cultural Contexts for Meaning in Digital Play. In proceedings of the DIGRA 2007, Situated Play. September 24-28, 2007, Tokyo, Japan.

[26] Nacke, L. et al. 2009. Playability and Player Experience Research. Digra, London, Brunel University.

[27] Pagulayan, R. J. et al. 2003. User-centered design in games. The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, NJ, Lawrence Erlbaum Associates, pp 883-906.

[28] Perttula, A., Tuomi, P., Suominen, M., Koivisto, A., Multisilta, J. 2010. Users as sensors: creating shared experiences in co-creational spaces by collective heart rate. Proceedings of 14th International Academic MindTrek Conference: Envisioning Future Media Environments. October 6th-8th 2010, Tampere, Finland.

[29] Ribbens, W. and Poels, Y. 2009. Researching player experiences through the use of different qualitative methods. Digra, London, Brunel University.

[30] Rosenbloom, A. 2003. A Game Experience in Every Application. Communications of the ACM, New York, NY, USA. Vol. 46, Issue 7, pp 28–31.

[31] Ryan, W. and Siegel, M. 2009. Evaluating Interactive Entertainment using Breakdown: Understanding Embodied Learning in Video Games. Digra, London, Brunel University.

[32] Sutton-smith, B. 2001. The Ambiguity of Play. Harvard University Press. ISBN-13: 978-0674005815.

[33] Stenros, J. 2010. Playing the system: using frame analysis to understand online play. Proceedings of the International Academic Conference on the Future of Game Design and Technology. ACM, New York, NY, USA, 9-16. DOI=10.1145/1920778.1920781

[34] Stenros, J., Paavilainen, J. and Mäyrä, F. 2009. The many faces of sociability and social play in games. Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era. September 30 – October 2, 2009, Tampere, Finland.

[35] Sweetser, P. et al. 2003. Creating engaging artificial characters for games. The Second International Conference on Entertainment Computing, Carnegie Mellon University, Pittsburgh, PA.

[36] Sweetser, P. and Wyeth, P. 2005. GameFlow: A Model for Evaluating Player Enjoyment in Games. ACM Computers in Entertainment, Vol. 3, No. 3, July 2005. Article 3A.

[37] Tilley, T. 2010. Game Controller Hacking for Fun and Profit. The Annual International Conference on Computer Science Education: Innovation & Technology (CSEIT 2010), Research Publishing Services, 2010, pp. 53-58.

[38] Versteeg, R. 2010. Brains on Fire. Radbound University, Nijmegen.

[39] Vickers, S. et al. 2010. EyeGuitar: Making Rhythm Based Music Video Games Accessible Using Only Eye Movements. ACE '10, 17-NOV-2010, Taipei, Taiwan.

[40] Vorderer, P. et al. 2003. Explaining the enjoyment of playing video games. The role of competition. The Second International Conference on Computer Games, Carnegie Mellon Univ., Pittsburgh, PA.

[41] Väänänen-Vainio-Mattila, K. et al. 2008. Now let's do it in practice: user experience evaluation methods in product development. CHI Extended Abstracts 2008, pp 3961-3964. April 5-10, 2008, Florence, Italy.

[42] Walsh R., Boberg M., Arrasvuori J., Korhonen H. and Walsh T. Introducing Game and Playful Experiences to other Application Domains through Personality and Motivation Models. In proc. of IEEE International Consumer Electronics Society's Games Innovations Conference (ICE-GIC). December 21-23, Hong Kong.

[43] Yuan, B. and Folmer, E. 2008. Blind Hero: Enabling Guitar Hero for the Visually Impaired. ASSETS 2008. October 13-15, 2008, Halifax, Canada.

Publication 7

Perttula, A., Multisilta, J., & Tuomi, P. (2013). Persuasive Mobile Device Sound Sensing in a Classroom Setting. International Journal of Interactive Mobile Technologies (iJIM). Vol. 7, No 1 (2013), pp. 16-24. ISSN: 1865-7923.

Persuasive Mobile Device Sound Sensing in a Classroom Setting

http://dx.doi.org/10.3991/ijim.v7i1.2262

Arttu Perttula[1], Jari Multisilta[2] and Pauliina Tuomi[1]
[1] Tampere University of Technology, Pori, Finland
[2] University of Helsinki, Helsinki, Finland

***Abstract*—This paper presents an idea on how to utilize mobile phones to support learning in the classroom. The paper also tries to initiate discussion on whether we can create new kinds of learning applications using mobile devices and whether this could be the way we should proceed in developing 21st century learning applications. In this study, a mobile phone is programmed to function as a collective sound sensor. To achieve an appropriate learning atmosphere, the designed system attempts to maintain the noise level at a comfortable tolerance level in the classroom. The main aim of the mobile application is to change student behaviour through persuasive visualizations. The prototype application was piloted during spring 2012 with a total of 72 students and two teachers. The results, based on observations and interviews, are promising and several subjects for future work arose during the pilot study.**

***Index Terms*—classroom, mobile, learning, persuasion**

I. INTRODUCTION

There has been a lot of discussion and research on mobile learning or m-learning, and learning theories for eLearning, web-based learning, and mobile learning [1, 2, 3, 4, 5, 6, 7]. The first research pilots on mobile learning were based on transferring electronic content to mobile phones. Soon, it was realized that mobile learning should not just copy the "old" practices of eLearning but the strengths of the mobile device should be harnessed in some other way for learning purposes. With the technology developing at a rapid pace, we soon had mobile phones with digital cameras. The mobile phone appeared as a tool for creating digital recordings of learning activities, for example on field trips [8].

The next innovations in mobile devices are sensors [9]. In general, a sensor is a small device that observes its environment and reports back to a remote base station [10]. Many mobile phones already have a GPS[1] feature that can be used to add location information for mobile applications. Some devices have motion sensors that monitor the acceleration and movements of the device in three dimensional space. It is also possible to use a heart rate monitor with a mobile phone for monitoring physical exercise. In addition, mobile phones can observe the ambient light or sound level from the surroundings of the device.

The data collected from the surroundings of the device can be used to determine something about the context where the device and the user are. The context can then be used in personalizing the mobile services we use with our mobile devices. There are already applications that can suggest a good restaurant or store nearby, based on our location. Could context and sensor data be used in creating new kinds of mobile learning applications? Sharples [11] argues that "the main barriers to developing these new modes of mobile learning are not technical but social". According to Sharples [11], we need more understanding of context and the role of new mobile technologies in the learning process.

This paper presents a novel idea of how to utilize mobile phones to support learning in the classroom. The paper also tries to initiate discussion on whether we can create new kinds of learning applications using mobile devices and whether this could be the way we should proceed in developing 21st century learning applications. The 21st century skills and learning applications can be defined in terms of knowledge, skills, attitudes, values and ethics, and they describe the skills that are needed in understanding information in the information society [12]. In this study, a mobile phone is programmed to function as a collective sound sensor. To achieve an appropriate learning atmosphere, the system presents persuasive visualizations to a target group of students. Thus it attempts to maintain noise levels at pleasurable tolerance level in the classroom.

According to Bistrup et al. [13], harmful effects of noise on children consist of both auditory and non-auditory effects. Auditory effects are reduced or impaired hearing or temporary threshold shifts or tinnitus. This is probably not a relevant problem in classroom settings but when it comes to the non-auditory effects of noise, which are mainly cognitive effects, there is something to improve. Noise can negatively affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and reduced ability to carry out more or less complex tasks. Noise may provoke a stress response in children that includes increased heart rate and increased hormone response, and noise may disrupt sleep and hinder the necessary recovery of the body and brain. As an indirect effect of noise, a raised voice may lead to hoarseness and vocal nodules [13]. In other words, noise in classrooms is a problem and furthermore a challenging research problem.

Bistrup et al. [13] have provided guidelines for achieving good classroom acoustics. In addition to these instructions, mobile technology could be used to prevent the noise problem. Instead of traditional mobile learning applications that are learning tools or information providers, this novel solution has a different approach to support

[1] The Global Positioning System provides location information based on satellites.

and enhance learning. The main aim of the collective sound sensing mobile application is to change student behaviour through persuasion. More detailed purposes of the application are: 1) to keep the soundscape in the classroom appropriate for learning, 2) teach students to work as a team, 3) teach them to take others into consideration, 4) teach proper behaviour and 5) provide something fun to create and enrich a positive learning experience. Furthermore, it can be used to teach sound pressure levels. The prototype application was piloted during the spring of 2012 with a total of 72 students and two teachers. The results based on observations and interviews are promising and several topics for future work arose during the pilot study.

II. CONTEXT

This study tries to answer the following research question: how can we reduce noise in the classroom and thus support learning? To attain an appropriate learning atmosphere, the designed system attempts to keep the noise level at pleasurable tolerance level in the classroom. The hypothesis is that through mobile persuasion, learning results will improve. To understand the context of the study better, mobile learning and persuasion are described in more detail below.

A. Mobile Learning

Lonsdale et al. [14] suggested that contextual information should be used in mobile learning to deliver the right content and services to the user. This could help to overcome the limitations of mobile devices related to user interface and bandwidth. A context, according to Lonsdale et al. [14], is understood as a combination of an awareness of current technical capabilities and limitations and the needs of learners in the learning situation.

The concept of context is also related to the concepts of adaptive, pervasive and ubiquitous learning. For example, Syvänen et al. [15] presented experiences of developing an adaptive and context-aware mobile learning system that they also describe as a pervasive learning environment. They define the pervasive learning environment as a single entity formed by the overlapping of "mental (e.g. needs, preferences, prior knowledge), physical (e.g. objects, other learners close by) and virtual (e.g. content accessible with mobile devices, artefacts) contexts."

Sharples et al. [6] explains that computer technology and learning are both ubiquitous. The concept of mobile learning is closely related to ubiquitous learning and context-aware ubiquitous learning. A context-aware ubiquitous learning system integrates authentic learning environments and digital (virtual) learning environments, which in turn will enable the learning system to interact more actively with the learners. This is possible because of current mobile devices and sensors, such as RFID[2]. [16] It can be said that learning in a classroom can be ubiquitous.

Yau and Joy [17] presented three different types of context-aware mobile learning applications: location-dependent, location-independent and situated learning. They also present a theoretical framework for mobile and context-aware adaptive learning. In their framework, they use contexts such as the learner's schedule, learning styles, knowledge level, concentration level and frequency of interruption.

B. Mobile Persuasion

Many people do not need external pressure or rewards to do things like reading books; the rewards are built-in, or intrinsic [18]. Malone and Lepper [19] have outlined different types of intrinsic motivators. Three of these motivators are group-level intrinsic motivators: competition, cooperation, and recognition. They involve interaction among people. According to Fogg [18], competition is perhaps the most powerful group-level intrinsic motivator. However, not everyone is competitive by nature, but in most situations and for most people, competition is energizing and motivating. Cooperation is another motivator, one that seems to be built into human nature. When people belong to a work group, most of them cooperate. Finally, people are intrinsically motivated by recognition. [18]

The system presented in this study utilizes these three motivators in particular. Classrooms can compete against each other to find out the best learning atmosphere. Also, students can challenge each other to obtain positive collective results. To maintain a suitable noise level, cooperation is essential. Students and teachers can discuss the study results together. Thus, by offering public recognition, the system can increase the likelihood that the group of students will adopt the target behaviour.

In addition to group-level intrinsic motivators, the system involves four other mobile persuasion principles: kairos, information quality, social facilitation and social comparison. Mobile devices are ideally suited to leverage the principle of kairos; offering suggestions at opportune moments to increase the potential to persuade [18]. The designed system in this study visualizes the current noise level in real-time with suggestive images. Visualizations also take information quality into consideration; computing technology that delivers current and relevant information has greater potential to create behaviour change. Furthermore, when it comes to social facilitation, people are more likely to display the target behaviour if they know they are being observed via computing technology or if they can discern via technology that others are displaying the behaviour along with them. According to the social comparison principle, people will have greater motivation to display the target behaviour if they are given information, via computing technology, about how their performance compares with the performance of others, especially others who are similar to them. With their ubiquity, mobile phones have already demonstrated their value as a persuasion tool in several cases, for example education and health. [18]

III. RELATED WORK

Several studies have been made about mobile learning [1, 2, 3, 4, 5, 6, 7] and persuasion [18]. The intention of this study is to change student behaviour through persuasion based on the collective mobile sound sensor. Thus it is more relevant to present some related research concerning mobile sound sensing and noise for background information. There are also noise prevention studies, which utilize external sound sensors instead of mobile phones (e.g. [20]). Commonly, noise measurement or prevention studies are conducted in urban environments and are outside the learning context.

[2] Radio-frequency identification is a wireless short distance system that uses electromagnetic fields to transfer data.

Maisonneuve et al. [21] presented an approach called NoiseTube for the assessment of noise pollution involving the general public. The goal of this project was to turn GPS-equipped mobile phones into noise sensors that enable citizens to measure their personal exposure to noise in their everyday environment. Thus, each user can contribute by sharing their geo-localised measurements and further personal annotation to produce a collective noise map.

The MobGeoSens system [22] utilizes built-in microphones and other sensors attached to mobile phones to collect different kinds of pollutant levels in an urban environment. It also adds the dimension of spatial localization to the data collection process and provides the user with both textual and spatial cartographic displays. While collecting the data, individuals can interactively add annotations and photos which are automatically added and integrated in the visualization log.

Within the Nericell project [23], audio recordings from the built-in microphone of a smartphone constitute the input of a honk-detection algorithm, which in turn feeds an estimator of current traffic conditions. Sensors and radios are used to detect bumps and potholes, braking and honking, and to localize the phone in an energy-efficient manner. The authors investigated the influence of background noise and the sensitivity of the microphones on the performance of the honk-detector.

CenceMe [24] combines the inference of the presence of individuals using sensor-enabled mobile phones with the sharing of this information through social networking applications like Facebook and Twitter. The system also captures audio signals. The data is processed on the mobile phone to determine whether it contains voices or just background noise.

Misra et al. [25] present several examples of how mobile phone microphones can be used for music applications. Using simple feature extraction methods, parameters can be found that sensibly map to synthesis algorithms to allow expressive and interactive performance. For example, a blowing noise can be used as a wind instrument excitation source. Also, other types of interactions can be detected via microphones, such as striking.

The BikeNet project [26] presented how average noise levels can be used to influence daily decisions like the choice of cycling route. The prototype derives estimations of the actual noise levels in the immediate vicinity of the cyclist. The system provides quantitative guidance to cyclists about the healthiness of a given route in terms of pollution levels, allergen levels, noise levels, and roughness of the terrain. These measurements, together with data from cyclist performance measurements, are correlated to create a holistic picture of the cycling experience.

Furthermore, in addition to mobile phone sound sensing, for example Bistrup et al. [13] and Klatte et al. [27] have studied the effects of classroom acoustics on performance and well being in elementary school children. According to the authors, the acoustical conditions in classrooms often do not suit the specific needs of young listeners. They found that reverberation had a significant effect on speech perception and short-term memory of spoken items. The results highlight the importance of good acoustical conditions in classrooms.

Based on the background research, this paper presents a novel approach. Different solutions can be compared but currently there are no applications with this kind of implementation and purpose. The following chapter describes the prototype in detail.

IV. PROTOTYPE IMPLEMENTATION AND DESIGN

An initial approach (Figure 1.) was present decibel[3] readings on a television screen (Figure 2.). Basically, it presents the suitability of the current soundscape in a classroom. The solution utilizes one mobile phone for sound monitoring and one external display for visualization (Figure 2.). In this version, decibels were divided into three categories: quiet, tolerable and noisy. Numbers were colored green, yellow or red based on those categories. Threshold limits were adjustable. There were some difficulties with this approach: numbers were delayed couple of seconds, it might take too much attention, there are already commercial solutions like this and probably it is not persuasive enough.

The second version was designed to solve those grievances. Basically, only visualizations (Figure 3.) are different and there is a gamification[4] element; too noisy environment causes "a game over" visualization and sound level measuring ends up. Thus, this custom-made application can be considered also as a persuasive game, data visualization or interactive teaching material. Graphics (Figure 3.) were created to be suitable and entertaining for different age groups from 6 to 18 years. It was also topical with the seasonal Easter time decorations when the pilot study was carried out. Furthermore, any child or young person could draw it. Hence, it was easy to identify with and the design was attractive to the target group.

The Python for S60[5] application processes two sound files simultaneously: it records two seconds of the present soundscape to one WAV-format file (Figure 6.) and meanwhile it calculates decibel readings (Equation 1.) from another file recorded previously. Every two seconds it swaps these files. Thus, there is a two-second delay between the captured sounds and the visualized image (Figure 3.), which is still eligible for this purpose. The view of the mobile phone is transferred in real time from

Figure 1. An initial approach with colored decibel readings based on three categories: quiet, tolerable and noisy

[3] The decibel (dB) is a logarithmic unit that indicates the ratio of a physical quantity relative to a specified or implied reference level. [28]
[4] Gamification enhances non-game contexts by game design elements, thinking and mechanics. [29]
[5] The Python for S60 (PyS60) is Nokia's version of the Python programming language to its Symbian S60 software platform. [30]

the phone's s-video output to a data projector or a large television screen. Thus, everyone in the classroom is able to monitor it.

Without proper calibration, sensor devices produce data that may not be representative or can even be misleading [21]. In this case, for example the length of the s-video cable determines the place of the phone (Figure 4.). The best location would be probably in the middle of the classroom. The application is not able to be aware of the distance of the sound source. Thus it is also more proper to calculate estimate sound pressure values and visualize it in pictures than in concrete numbers. In addition, to ensure decent functioning while a lesson a charger cable should be connected to the phone also.

The prototype version is manually adjustable. Firstly, the main user, in this case a teacher, is able to adjust two suitable decibel-reading limits (Figure 5.) from the options menu. This may vary depending on the mobile phone utilized and the location of the phone in the classroom. If the sound pressure level exceeds the first limit, the second view is visualized (Figure 3.). If the sound pressure level also exceeds the second limit, the visualization ends up in the final phase (Figure 3.) and this is visualized until the sound monitoring is restarted. The initial prototype had only these two decibel reading limits (Figure 6.).

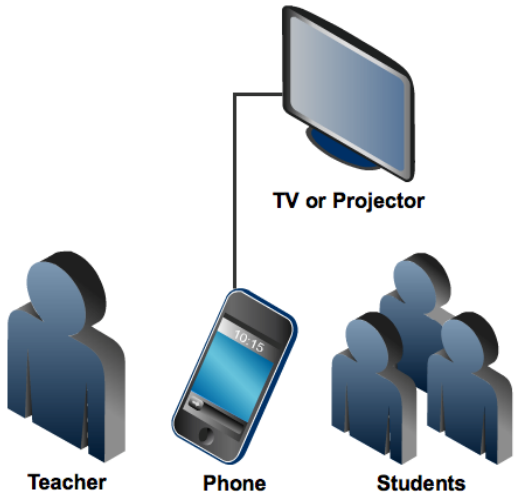


Figure 2. The system architecture of the collective sound sensor

Figure 3. Three views of the prototype mobile application (from left to right): 1) measured sound pressure level is tolerable, 2) the sound pressure level is not appropriate and 3) the sound pressure level has exceeded the tolerable zone

Because one unintentional loud sound could trigger "the game over" event in this case, a manually adjustable limit exceeding option was added. For example, if the second sound pressure level is ten times above the selected limit, only after that will the visualization show the final phase. Once manual calibration is done, a teacher only has to start recording before a lesson by selecting start from the options menu.

Noise level or loudness (Figures 6. and Equation 1.) is generally measured as the equivalent continuous sound level (Leq). Measured in decibels, Leq captures the sound pressure level of a constant noise source over the time interval T that has the same acoustic energy as the actual varying sound level pressure over the same interval. A human ear perceives the loudness differently depending on the frequency of the sound. Standard weighted scale frequency functions have been developed to reflect human perception. [21] The mobile application contains a signal processing algorithm which measures the loudness level of the microphone recording the environmental sound over two seconds at a chosen interval. A commonly used [21] A-weighting filter is applied to the recorded sound and the equivalent sound level Leq, measured in dB(A), is then computed (Equation 1.).

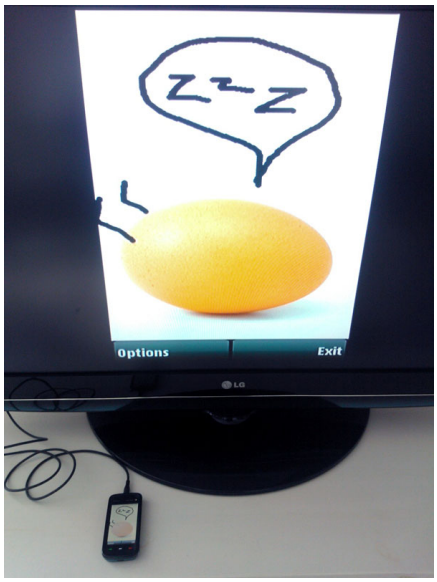


Figure 4. A demonstration setup with a phone and a television

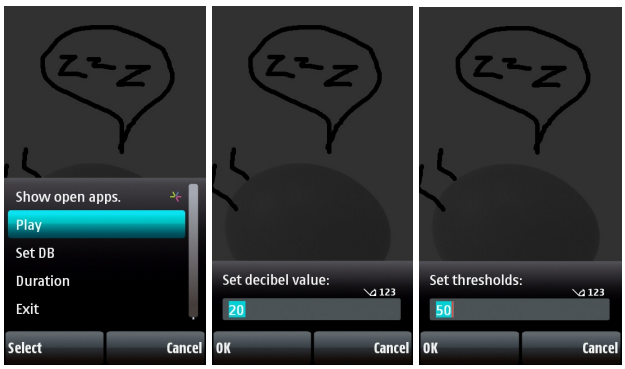


Figure 5. Menu as seen on the screen

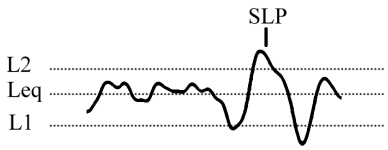


Figure 6. Recorded sound level pressure (SLP) and threshold limits L1 and L2. Presented wave and levels are examples

$$L_{eq} = 10log\frac{1}{T}\int_0^T \frac{p^2}{p_0^2}dt \quad . \qquad (1)$$

The idea is related to the concept of opportunistic sensing, where the data collection stage is fully automated with no user involvement. The benefit of opportunistic sensing is that it lowers the burden placed on the user, allowing overall participation by a population of users to remain high even if the application is not that personally appealing. This is particularly useful for community sensing, where per user benefit may be hard to quantify and only accrue over a long time. [31]

V. PILOT STUDY

A five-day pilot test was conducted in the spring of 2012 (March 26-30) with the cooperation of Meri-Pori (Pori, Finland) upper level school and upper secondary school. Two teachers (mother tongue and physics) and four classes (two secondary schools and two high schools) of students (altogether n = 72, girls and boys, age 13-18) participated in the pilot. The system was installed in the classroom beforehand and the teachers were told to conduct as ordinary a lesson as possible. The teachers did not tell the students what was going on. A mobile phone was connected to a television or a video projector depending on the classroom equipment and the entire system was visible to the students.

A. Research Methods

In this case, the interest lies in the experience. In other words, how the teachers and students experienced the pilot situation. Does the system affect the behaviour of the students and hence the atmosphere of the class? This can be seen as a user experience study. Currently, the most common methods of assessing user experience are through subjective self- reporting and through objective reports [32].

In this study, objective reports were based on observations performed by teachers. This method was selected because it enabled the observation of participants during ordinary lessons. The teachers were interviewed after each lesson. In particular, the teachers tried to observe behaviour and social interaction. Self-reporting included informal conversations with teachers, although the teachers talked to the students and reported back on the students' thoughts. It is difficult to measure the effects on the learning process; hence only teachers provided study feedback.

B. Results and Findings

Based on the observations, high school students (age 16-18) were not excited about the application. All in all, it did not have an effect on them at all. They wondered about the system for a while but then no longer paid any attention to it. According to the teachers, noise is not a relevant problem among this age group hence the application was not meaningful. Also, visualization might be more appealing to younger students. Secondary school students were eager to know about the system. Although there was no animation and the graphics were simple, secondary school students (age 13-15) reported that the visualization was fun and entertaining. However, one teacher indicated that the application did not disrupt the students' learning process because of it did not require a lot of attention. Secondary school students quickly learned the meaning and function of the application.

Students tried to maintain an appropriate sound level in the classroom because they did not want to break the visualized egg. The application clearly had a persuasive effect on the students. They learned the differences between proper and inappropriate sound levels. In fact, they perceived the experiment as a game. If someone was too noisy the others instructed the disruptive student to be quieter. Team spirit improved significantly during the pilot study. They perceived the application as such a challenge that they discussed among themselves during breaks how they could keep the egg unbroken for as long as possible. During the pilot week, the students asked the teacher if they would have the experiment during the next lesson. And if the answer was no, they were disappointed. Other classes would have liked to try the system, too.

The teachers reported that it would be useful and interesting if it were possible to locate the noise more specifically in the classroom because it is not always obvious who the troublemaker is. Using three or more mobile phones to detect noise could fulfill this task, making it possible to locate the sound source approximately; similarly to the way an indoor positioning system utilizes three or more Wi-Fi hotspots. The teachers also had another kind of concern. They became anxious about whether their teaching performance could be recorded and monitored via this system. A class with the most suitable sound levels during lessons possibly indicates a skillful teacher.

Regarding the technology, the study revealed that the phone's (Nokia XpressMusic 5800) microphone or software is probably optimized for speech. For example, sounds from whistling and hand clapping had a random effect on decibel readings, whereas speech and shouting worked more precisely. In other words, the mobile phone utilized and the quality of its microphone might have an effect on the final experience. In any case, in this pilot study case it did not have significant impact on the results.

VI. DISCUSSION AND IDEAS

Based on the study results, it is obvious that the target group should be determined more precisely. In its current state, the application could also be useful among kindergarten (age 2-5) and primary school (age 6-12) students. Students could draw and upload their own character images or animations to the application. In this way, the application could have an even greater impact on the target group.

Actually, various studies have shown that noise levels in day-care rooms and play areas can be considerable and that these may have negative effects [33, 34, 35, 36, 37, 38] In addition to kids, these effects concern teachers as well. Noise levels in day-care centres are occasionally high, possibly resulting in health repercussions: auditory fatigue and stress being the two main negative effects. [33,

34, 38] The stress of the day-care centre employees (in this case caused by the noise) can eventually lead to burnout and work fatigue. Work fatigue can be described as being a serious stress symptom disorder that appears trough physical and mental fatigue, lack of professional confidence and cynical attitude towards work [39, 40]. Overall, stress can be seen as one of the most significant factors behind work fatigue. [41, 42, 43]

Furthermore, high noise levels may lead to irritability, difficulty communicating, reduced intelligibility and even to a reduction in verbal acquisition amongst children [33]. Several solutions have already been identified and implemented in order to reduce noise levels at day-care centres: cutting down on the number of children at each location, placing tennis balls under chair legs and modifying the choice of activities and toys. [33, 36] Another way of reducing noise in day-care centres is by adding absorbent acoustic materials. Presented persuasive mobile device sound sensing system could be utilized as a functional solution to reduce the noise in day-care centres by utilizing children's own motivation to keep quiet. The motivation is triggered by the system and its well-being.

To be even more persuasive, a class of students could receive stamps or awards if they succeed in noise prevention. Another option would be for classes to compete against each other. If students behave properly the application could offer tips and facts for learning besides the sound monitoring. The character could also encourage the students.

Another point of view is that there could be this kind of mascot or game in a classroom that could be taught by the students. The mascot could learn and acquire wisdom based on the classroom noise prevention results. Similarly, Ketamo and Suominen [44] have presented teachable octopuses based on geometry tasks. Basically, students would learn by teaching. Classrooms could compare and compete on their sound environments against other schools, even schools in other countries.

A more advanced version of the application could include a feature of the automatic recognition of different sounds. Selin et al. [45] have studied how harmonic and transient bird sounds can be recognized efficiently. The results indicate that it is possible to recognize bird sounds of the test species using neural networks with only four features calculated from the wavelet packet decomposition coefficients. A modified version of this kind of automatic sound recognition system could also be used in learning environments. It is likely that student voices could be recognized in a similar way to birds.

It should be taken into account that it was not studied during this pilot how noise affects to learning. There were no comparisons between silent and noisy classes or with and without the application. In this case, supposition that disturbing background noise has negative effect to learning is based on actualized references. Studies indicate that learning and teaching in classrooms is often impeded by noise and reverberation. Noise exposure in schools is often above reasonable limits for children. Learning in loud classrooms is especially impeded by poor speech intelligibility and decreased performance of learning. [46, 47, 48, 49] Furthermore, noise especially effects on cognitive performance, motivation and annoyance [50].

Even though there is evidence that noise of classroom decrease performance of learning, Lawrence [51] reported that certain kind of background music (for example classical) in a classroom could allow students perform manual tasks effectively and efficiently. The application presented could be enhanced with three types of background music based on three noise categories; classical music, pop music and hard rock. This might have an affect to the persuasiveness of the application.

As mentioned earlier, during this study, teachers were told to conduct as ordinary a lesson as possible and they did not tell the students what was going on. However the application could be utilized more pedagogically. A teacher could point out events of the application and highlight the persuasive meaning. The teacher and students could discuss together about noise; sources of noise, why there is noise and its affects to learning. In addition, the application could be utilized as a problem-solving task for students. They should understand how to succeed in this persuasive game and furthermore they should realize why it is important for them.

VII. FUTURE WORK

In addition to further research, the next version of the presented system will work wirelessly using socket[6] server solution (Figure 7.). It would be similar to that presented by Perttula et al. [52], but instead of WLAN[7], networking will be conducted via the Internet. The installation and configuration will be more straightforward without a local network. In this second version, it would be possible to place the mobile phone wherever it is the most suitable. This solution also enables multiple phones to perform as a collective sound sensor. A computer or a device with Internet connection is needed to view the visualizations presented on a web page.

The advanced version will also include an automatic sound pressure level limit measurement option by recording average levels for a given period. In practice, a user does not manually set noise limits as presented in Figure 5. Determining the proper settings was time-consuming during the pilot study because the selected readings were not comparable with decibels as mentioned earlier.

The next study will be conducted in day-care centres. They will probably benefit from it as discussed in previous chapter. According to Kyriacou [43] coping strategies

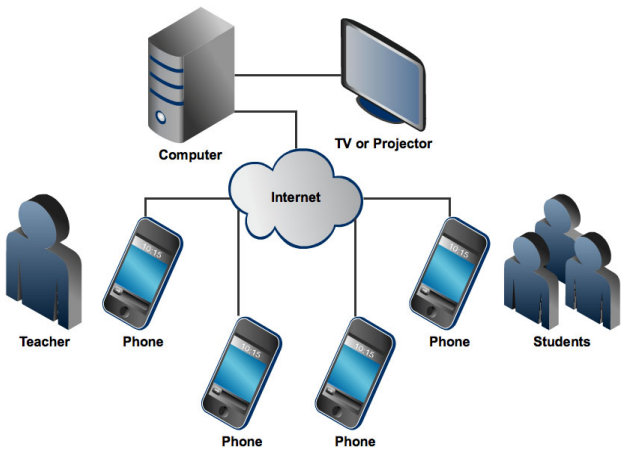


Figure 7. The system architecture of the planned second version

[6] A socket is an endpoint of an inter-process communication flow across a computer network.
[7] WLAN stands for a wireless local area network.

can be divided into direct action and palliative techniques. Direct action refers to strategies teachers can do to eliminate sources of stress. For instance, if time pressures and deadlines are creating stress, a direct action to reduce the problem would be to seek a time extension, or to seek a change in deadline. Palliative techniques do not deal with the source of stress itself, but focus on reducing the feelings of stress from those sources. The presented system basically offers both of the coping methods since it can be used just to reduce the current noise in the room time to time/when needed or it can be used with the perspective that it eventually will drop the noise levels permanently when used regularly in daily basis.

The next study will also pay attention to pedagogically approach described in previous section. Teachers' role will be more active and thus benefits or disadvantages of the application will be studied more comprehensively. Also noise affects to learning will be studied and analyzed. Comparisons to previous studies' results of noise and learning will be conducted.

VIII. CONCLUSIONS

Noise can negatively affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and reduced ability to carry out more or less complex tasks [13]. To reduce noise in a classroom, this article presented a collective sound sensing system in the emerging fields of mobile learning, mobile persuasion and mobile phone sensing. The solution utilizes one mobile phone for sound monitoring and one external display for visualization of the suitability of the current soundscape in a classroom. The custom-made application with entertaining graphics can be considered as a persuasive game, data visualization or interactive teaching material.

Based on the results, the application managed to persuade students to behave more appropriately to create a suitable learning atmosphere in the classroom by reducing noise. As Lane et al. [31] have stated, understanding which types of metaphors and feedback are most effective for persuasion goals is still an open research problem. Building mobile phone sensing systems that integrate persuasion requires interdisciplinary research, combining behavioural and social psychology theories with computer science [31]. The use of large volumes of sensor data provided by mobile phones presents an exciting opportunity and is likely to enable new applications that have promise in enacting positive social changes in mobile learning over the next few years.

The combination of large-scale sensor data together with accurate models of persuasion could revolutionize how we deal with other learning issues in addition to noise in the classroom. Can we create new kinds of learning applications using mobile sensor networks and could this be the way we should proceed in developing learning applications for the 21st century? According to the present study, sensors provide new possibilities for learning applications. In addition, the understanding of sensor-based contextual data and the ability to apply this data to learning could also be considered a new kind of 21st century skill.

ACKNOWLEDGMENT

The authors would like to thank all the students who participated in the study. We also gratefully acknowledge teachers from Meri-Pori Upper Level and Meri-Pori Upper Secondary schools for providing expertise feedback.

REFERENCES

[1] D., Mwanza-Simwami, "Concepts and methods for investigating learner activities with mobile devices: an activity theory perspective," in I. Arnedillo-Sánchez, M. Sharples, G. Vavoula (Eds.), *Beyond Mobile Learning Workshop*, Trinity College Dublin Press, 2007, pp. 24-25.

[2] L., Naismith, P., Lonsdale, G., Vavoula and M., Sharples, "Literature review in mobile technologies and learning," *NESTA Futurelab Series*, Report 11, Bristol, UK: NESTA Futurelab, 2004.

[3] M., Nichols, "A theory for eLearning," *Educational Technology & Society*, 6(2), 1-10, 2003.

[4] K., O'Brien, "New questions over Google's Street View in Germany," *The New York Times*, April 29, 2010, Available at http://www.nytimes.com/2010/04/30/technology/ 30google.html

[5] M., Oliver and C., Pelletier, "Activity theory and learning from digital games: developing an analytical methodology," in D. Buckingham and R. Willett (Eds.), *Digital Generations, Children, Young People, and New Media*. Mahwah, New, Jersey, London: Lawrence Erlbaum Associates, Publishers, 2006.

[6] M., Sharples, J., Taylor and G., Vavoula, "Towards a theory of mobile learning," in proceedings of *mLearn 2005 Conference*, Cape Town, South Africa, 2005.

[7] A., Trifonova and M., Ronchetti, "Where is mobile learning going?," in A. Rossett (Ed.), proceedings of *World Conference on E-learning in Corporate*, Government, Healthcare, & Higher Education, Chesapeake, VA: AACE, 2003, pp. 1794-1801.

[8] R., Yeh et al., "ButterflyNet: a mobile capture and access system for field biology research," in R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, & G. Olson (Eds.), proceedings of the *SIGCHI conference on Human Factors in computing systems (CHI '06)*, New York, NY, USA: ACM, 2006, pp. 571-580.

[9] A., Kansal, M., Goraczko and F., Zhao, "Building a sensor network of mobile phones," in proceedings of the *6th international conference on Information processing in sensor networks (IPSN '07)*, New York, NY, USA: ACM, 2007, pp. 547-548.

[10] R., Bose, "Sensor networks motes, smart spaces, and beyond, pervasive computing," *IEEE* 8(3), 2009, pp. 84 – 90.

[11] M., Sharples, Foreword, "Education in the wild: contextual and location-based mobile learning in action," , in E. Brown (Ed.) *Nottingham: Learning Sciences Research Institute*, University of Nottingham, 2010, pp. 4-6.

[12] J., Voogt and N. J., Roblin, "21st century skills," discussion paper, *Enschede: University of Twente*, 2010.

[13] M., Bistrup, M., Haines, S., Hygge, D., MacKenzie, S., Neyen and C., Petersen, C., "Children and noise – prevention of adverse effects," *National Institute of Public Health*, Denmark, ISBN: 87-7899-056-4, 2002.

[14] P., Lonsdale, C., Baber, M., Sharples and T. N., Arvantis, "A context-awareness architecture for facilitating mobile learning," in J. Attewell & C. Savill-Smith (Eds.), *Learning with mobile devices, Research and development*, London: Learning and Skills Development Agency, 2004, pp. 79-86.

[15] A., Syvanen, R., Beale, M., Sharples, M., Ahonen and P., Lonsdale, "Supporting pervasive learning environments: adaptability and context awareness in mobile learning," *IEEE International Workshop on Wireless and Mobile Technologies in Education*, WMTE 2005, 2005.

[16] H-C., Chu, G-J., Hwang, Y-R., Shi, C-I., Lee and W-W., Chien, "A conceptual map-oriented mindtool for conducting collaborative ubiquitous learning activities," in S. C., Kong et al. (Eds.), proceedings of the *17th International Conference on Computers in Education*, Hong Kong: Asia-Pacific Society for Computers in Education, 2009, pp. 559-563.

[17] J., Yau and M., Joy, M., "A mobile and context-aware adaptive learning schedule framework from a usability perspective – a 'diary: diary-questionnaire' study," in S. C., Kong et al., (Eds.), proceedings of the *17th International Conference on Computers in Education*, Hong Kong: Asia-Pacific Society for Computers in Education, 2009, pp. 512-519.

[18] B. J., Fogg, "Increasing persuasion through mobility," in *Mobile Persuasion – 20 Perspectives on the Future of Behavior Change* (Eds. B. J., Fogg and D., Eckles), Persuasive Technology Lab., Stanford University, 2007.

[19] T., Malone and M., Lepper, "Making learning fun: a taxonomy of intrinsic motivation for learning," in *Aptitude, Learning, and Instruction* (Eds. R. E., Snow and M. J., Farr), Hillsdale, N. J., Lawrence Earlbaum, 1987.

[20] S., Santini et al., "First experiences using wireless sensor networks for noise pollution monitoring," *European Conference on Computer Systems: proceedings of the workshop on Real-world wireless sensor networks (REALWSN'08)*, ACM, 2008, pp. 61-65.

[21] N., Maisonneuve, M., Stevens, M., Niessen and L., Steels, "NoiseTube: Measuring and mapping noise pollution with mobile phones," in *Information Technologies in Environmental Engineering, Environmental Science and Engineering*, DOI 10.1007/978-3-540-88351-7_16, Springer-Verlag, Berlin, Heidelberg, 2009. http://dx.doi.org/10.1007/978-3-540-88351-7_16

[22] E., Kanjo et al., "MobGeoSen: Facilitating personal GeoSensor data collection and visualization using mobile phones," in *Personal Ubiquitous Computing Journal*, vol. 12, no. 8, November 2008, published online: August 2007, pp. 599–607.

[23] P., Mohan, V., Padmanabhan and R., Ramjee, "Nericell: rich monitoring of road and traffic conditions using mobile smartphones," in Proceedings of the *6th ACM Conference on Embedded Networked Sensor Systems (SenSys 2008)*, ACM, 2008, pp. 323–336.

[24] E., Miluzzo et al., "Sensing meets mobile social networks: the design, implementation and evaluation of the CenceMe application," in proceedings of the *6th ACM Conference on Embedded Networked Sensor Systems (SenSys 2008)*, New York, NY, USA: ACM, 2008, pp. 337–350.

[25] A., Misra, G., Essl and M., Rohs, "Microphone as sensor in mobile phone performance," in proceedings of the *8th International Conference on New Interfaces for Musical Expression (NIME 2008)*, Genoa, Italy, June 5-7, 2008.

[26] S., Eisenman, E., Miluzzo, N., Lane, R., Peterson, G., Ahn and A., Campbell, "The BikeNet mobile sensing system for cyclist experience mapping," in proceedings of the *5th International Conference on Embedded Networked Sensor Systems*, Sydney, Australia, 2007, pp. 87 – 101.

[27] M., Klatte, J., Hellbrück, J., Seidel and P., Leistner, "Effects of classroom acoustics on performance and well-being in elementary school children: a field study," in *Environment and Behavior*, September 2010, vol. 42, no. 5, pp. 659-692.

[28] *IEEE Standard 100 Dictionary of IEEE Standards Terms*, Seventh Edition, The Institute of Electrical and Electronics Engineering, New York, 2000, ISBN 0-7381-2601-2, page 288.

[29] S., Deterding, D., Dixon, R., Khaled and L., Nacke, "From game design elements to gamefulness: defining gamification," in proceedings of the *15th International Academic MindTrek Conference: Envisioning Future Media Environments*, Tampere, Finland, 2011.

[30] J., Scheible and V., Tuulos, *Mobile Python: Rapid prototyping of applications on the mobile platform*, Wiley, ISBN: 978-0-470-51505-1, 2007, 348 pp.

[31] N., Lane, E., Miluzzo, H., Lu, D., Peebles, T., Choudhury and A., Campbell, "A survey of mobile phone sensing," in *IEEE Communications Magazine*, September, 2010. pp. 140 – 150. http://dx.doi.org/10.1109/MCOM.2010.5560598

[32] N., Lazzaro, "Why we play games: 4 keys to more emotion," in *Game Developer's Conference*, San Jose, CA, 2004.

[33] A., L'Espérance, A., Boudreau, F., Gariépy and P., Bacon, "Noise reduction in day-care centres by reducing reverberation time: analyses and case studies (Réduction du bruit dans les CPE par la réduction du temps de réverbération : analyses et études de cas)," in *Studies and Research Projects / Report R-463*, Montréal, IRSST, Téléchargement gratuity, 2006, 69 pages.

[34] C., Truchon-Gagnon and R., Hétu, "Noise in day-care center for children," in *Noise Control Engineering Journal*, 30, 1987, p. 57-64. http://dx.doi.org/10.3397/1.2827703

[35] M., Picard and C., Boudreau, "Characteristics of noise found in day-care centers," in *J. Acous. Soc of Am.*, Abstract, 105(2), 1999, p.1127.

[36] M., Picard, "Revisiting speech interference in classrooms," in *Audiology*, 40, 2001, p. 221-244.

[37] A., Moodley, "Acoustic conditions in mainstream classrooms," in *J. Br. Assoc. Teachers Deaf*, 13, 1989, p. 48-54.

[38] E. Sala et al., "Vocal loading among day care center teachers," in *Logoped Phoniatr Vocol*, 27, 2002, pp. 21-28. http://dx.doi.org/10.1080/140154302760146943

[39] W. P., Schaufeli, M. P., Leiter, C., Maslach and S. E., Jackson, *Maslach Burnout Inventory Manual*, California: Consulting Psychologist Press, 1996.

[40] C. L., Cordes and T. W., Dougherty, "A review and an integration of research on job burnout," in *The Academy of Management Review*, 18(4), 1993, pp. 621-656.

[41] J., Blase, "A Sosial psychologian grounded theory of teachers stress and burnout," in *Educational Administration quarterly*, 18 (4), 1982, pp. 93-113. http://dx.doi.org/10.1177/0013161X82018004008

[42] C., Kyriacou, "Teacher stress: past and present," in J., Dunham and V., Varma (Eds.), *Stress in Teachers, Past Present and Future*, 1998.

[43] C., Kyriacou, "Teacher stress: directions for future research," in *Educational Review*, 53, 2001, pp. 28- 35. http://dx.doi.org/10.1080/00131910120033628

[44] H., Ketamo and M., Suominen, "Learning-by-teaching in educational games," in J., Luca and E., Weippl (Eds.), proceedings of *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Chesapeake, VA: AACE, 2008, pp. 2954-2969.

[45] A., Selin, J., Turunen and J., Tanttu, "Wavelets in recognition of bird sounds," in *EURASIP J. Appl. Signal Process*, 1 (January), 2007, pp.141-141.

[46] M., Klatte, M., Wegner and J., Hellbrück, "Noise in the school environment and cognitive performance in elementary school children, part b – cognitive psychological studies," in *Forum Acusticum*, 2005, pp. 2071 – 2074.

[47] D., Shendell, C., Barnett and S., Boese, "Science-based recommendations to prevent or reduce potential exposure to biological, chemical, and physical agents in schools," in *Journal of School Health*, vol. 74, no. 10, 2004, pp. 390 – 396. http://dx.doi.org/10.1111/j.1746-1561.2004.tb06603.x

[48] P., Nelson, K., Kohnert and S., Sabur, "Classroom noise and children learning through a second language," in *Language, Speech, and Hearing Service in Schools*, vol. 36, July 2005, pp. 219 – 229. http://dx.doi.org/10.1044/0161-1461(2005/022)

[49] P., Miller and K., Shannon, "Young children's understanding of the effect of noise and interest level on learning," in *Genetic Psychology Monographs*, vol. 110(1), August 1984, pp. 71-90.

[50] M., Haines et al., "Qualitative responses of children to environmental noise," in *Noise & Health, A Bimonthly Interdiciplinary International Journal*, vol. 5, issue 19, 2003, pp. 19 – 30.

[51] D., Lawrence, "Using music in the classroom," in *Advanced Brain Technologies*, 2001, pp. 9.

[52] A., Perttula, P., Tuomi, M., Suominen, A., Koivisto and J., Multisilta, "Users as sensors: creating shared experiences in co-creational spaces by collective heart rate," in proceedings of *14th International Academic MindTrek Conference: Envisioning Future Media Environments*, Tampere, Finland, October 6th-8th, 2010.

AUTHORS

Arttu Perttula (arttu.perttula@tut.fi) is a researcher at the Tampere University of Technology in Pori, Finland (Tampere University of Technology, Pori Unit, P.O.Box 300, FI-28101 Pori, Finland). He got his Master of Science (M.Sc.) from the Tampere University of Technology

in 2007. His research is related to mobile human computer interaction. Perttula has been working in different research projects concentrating mainly on mobile social media, mobile learning and mobile games. In the year 2008, Perttula spent six months with Fuji Xerox Palo Alto Laboratory, Inc. as an intern. In the year 2010 Perttula was a visiting researcher at Stanford University, H-STAR Institute (three months).

Jari Multisilta (jari.multisilta@helsinki.fi) is the director of Cicero Learning Network in University of Helsinki (University of Helsinki, P.O. Box 9, FI-00014, Helsinki, Finland), Finland, professor of multimedia in Tampere University of Technology, Information Technology at Pori, Finland, Nokia Visiting Professor and Visiting Scholar at Stanford University. He got his M.Sc. from the University of Tampere in 1992 in Mathematics and his Dr. Tech. at Tampere University of Technology in 1996. The title of his doctoral thesis was "Hypermedia Learning Environment for Mathematics". Prof. Multisilta has studied learning and modern communication and information technologies and has taken part in several research projects on this area. Currently, his research interests include networked and mobile learning, mobile social media, mobile storytelling, and mobile social video applications, especially panoramic video. Professor Multisilta has published over 100 international conference papers and journal articles on his research area. He was a Visiting Fellow at Nokia Research Center on 2008-2009. Multisilta has also been Visiting Scholar at Stanford University, H-STAR Institute for 2007 (2 months), 2008 (1 month), 2010 & 6 months) and 2012 (2 months).

Pauliina Tuomi (pauliina.tuomi@tut.fi), Master of Arts, is a PhD student in Digital Culture at the University of Turku and works as a researcher at the Tampere University of Technology (Tampere University of Technology, Pori Unit, P.O.Box 300, FI-28101 Pori, Finland). Tuomi has been working in different research projects concentrating mainly on mobile learning and game-based learning innovations. Her doctoral thesis concentrates on interactive TV and it is set to define the different characteristic elements of participatory and intermedial TV culture in the 21st century. Her research interests include iTV-entertainment, participatory media culture and mediated communication.

This work was supported in part by the Nokia Foundation. Received 11 September 2012. Published as resubmitted by the authors 20 December 2012

Tampereen teknillinen yliopisto
PL 527
33101 Tampere

Tampere University of Technology
P.O.B. 527
FI-33101 Tampere, Finland

ISBN 978-952-15-3192-7
ISSN 1459-2045