How to evaluate Sonic City

Evaluating *context-aware computing for creative purposes* from a cognitive science point of view

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Sara Lerén, 780421-4901

Supervisors: Pierre Gander from SSKKII and
Staffan Björk from PLAY Research at Interactive Institute

SSKKII center for interdisciplinary research
The IT university of Göteborg
Göteborg university

Abstract

When new types of interaction between humans and computers begin to emerge in the shape of new computer systems, new types of demands are placed on the cognitive resources of the users of these systems. Evaluation is an efficient way of finding out how computer systems affect users' cognitive behaviour, and research made within cognitive science can be used both when designing and developing interactive systems as well as when evaluating them. When deciding which evaluation method to use to evaluate a specific system, aspects that need to be considered are: the nature of the system, what questions are to be answered by the evaluation and how this can be done with a minimum of cognitive stress for all parties involved. This paper suggests a combination of observations and interviews as a framework for evaluating a context-aware system with a creative purpose, namely Sonic City, in order to discover possible changes in both perception and behaviour of the users.

Keywords

Sonic City, human-computer interaction, cognitive science, context-aware computing, spatial cognition, - the psychology of hearing, soundscape composition, evaluation methods.

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1. Introduction

The technological development of computer systems is moving towards new and more advanced technology with different kinds of interaction and moving away from standard interaction paradigms such as GUI (graphical user interface) and WIMP interface (windows, icons, menus and pointers). This puts new kinds of demands on both the users as well as the designers of these systems. A trend within this development is to make the technology into a more natural part of people's everyday life by incorporating it into the actions and behaviours that normally takes place in a person's daily activities. One example of such a system is *Sonic City*, which is a wearable system that is aware of both the user's movements and the changes in the environment as a result of these movements. Based on the activities of the user, Sonic City will create music as a representation of the user's movements in an urban environment.

1.1. Questions

The questions I wanted to answer in the process of working with this paper are mainly involved with how new kinds of interaction with technology can influence the user's cognitive processes. I chose Sonic City as an example, and wanted to find out how such as system can affect the way the user perceives the environment surrounding him/her. I also wanted to find out how it affects the user's behaviour when it comes to making decisions about what actions to take when moving around in the environment.

But asking these questions isn't enough since there are many different ways of finding out the answers. Also, which answer you will get depends on how you ask the question.

- Which evaluation technique/techniques are best suited for finding out how new ways of interaction affect the user's cognitive behaviour?
- What different aspects are important to take into consideration when deciding which evaluation technique to use?

1.2. Purpose

The purpose of this paper is to observe and analyse Sonic City as an example of new kinds of interaction with technology from a cognitive science point of view, and to consider which evaluation methods might be suitable in regards to the interaction that Sonic City provides. In particular the purpose is to study the effects that a system of this fashion might have on the users' perception of their environment as well as on their cognitive behaviour when it comes to decision-making, and how these effects can be acknowledged by using different evaluation methods.

1.3. Delimitation

The scope of this paper has been constrained in the sense that the focus is on one of many systems using new kinds of interaction with technology. Although some of the fields of research and theories presented in this paper are fairly general and can be applied to many different kinds of interaction they are primarily chosen because of their suitability to the task which is the purpose of this paper: to look at Sonic City from a cognitive science point of view.
Another restriction of this paper is that it is based on information about the project Sonic City and relevant theories that relate either to the nature of Sonic City or to the evaluation of interactive systems, neither of which have been empirically tested within the range of this paper.

1.4. Sonic City

Sonic City is a project developed in conjunction between PLAY Research at Interactive Institute and Future Applications Lab at Viktoria Institute. Involved in the project are Lalya Gaye and Lars Erik Holmquist from Future Applications Lab and Ramia Mazé from PLAY Research.

The aim of the project is described in Sonic City's Mission Statement:

"In the project *Sonic City,* we are developing an application that enables people to create music by walking through a city, in this way 'playing' it as a musical instrument. Using wearable technology and context-aware computing, music is generated in real-time as a result of sensor-based information about a user's movement and the multiple contexts they pass through. We thus consider the urban environment as an interface for music creation and explore mobility as a composition parameter."
(Gaye, Holmquist and Mazé, 2002, p. 1)

The initial prototype of the system consists of a portable computer and biometric and environmental sensors which assemble data about the state of the user and his/her environment. Multi-sensor data from the sensors is processed in real-time by an interactive programming environment which transforms the data into audio content that reaches the user through earphones.

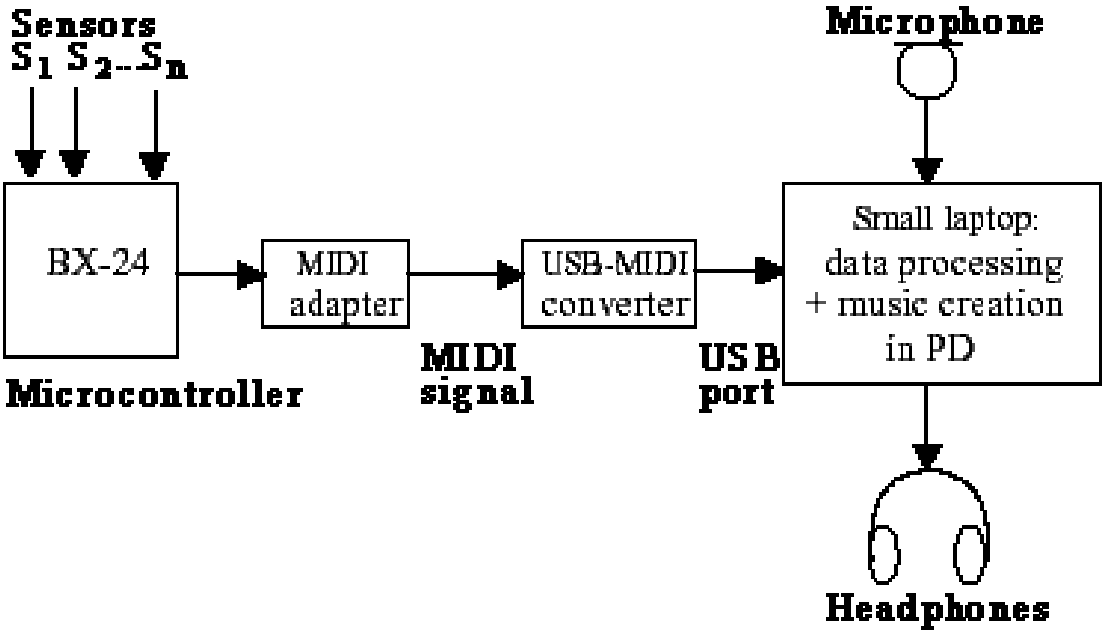

Figure 1.1 The dataflow within Sonic City. The sensor data is collected by a BasicX-24 microcontroller, which sends them via a USB-MIDI converter to a laptop computer. The data is then reconverted and processed on different levels, and created into music by a program in the interactive music environment within the laptop. The music then reaches the user via the headphones. (Available at http://www.viktoria.informatik.gu.se/groups/play/projects/soniccity)

The current prototype of Sonic City uses sensors that are worn onto the user's body and clothes which measure light, sound pressure level, air pollution and blood pressure. The sensors also keep track of the user's location and movements by using ultrasonic distance sensors and a digital compass. The sensors are designed to be flexible enough to allow the user to move them around, because the way they are worn and where they are positioned can influence what they sense and thus affect how the music will sound. In this way the user gains more control over the use of the system and he/she is able to customise it by moving the sensors and acknowledging a different musical experience.

In a future prototype an electromagnetic field sensor, accelerometers, GPS (Global Positioning System), a metal detector and pressure sensors will be added to the system. Ultimately, the program is intended to run on a PDA (such as a pocket PC or a Palm Pilot) or as a wearable device instead of being run on a laptop which is currently the case with the existing prototype.

2. Background

2.1. Fields of Research

2.1.1. Human-Computer Interaction and Interaction Design

The following sections concerning human-computer interaction and interaction design provide an introduction to these fields of research, their background and their relationships to other related academic disciplines, and can be considered an appropriate background to the rest of this paper for those who are unfamiliar with these topics.

2.1.1.1. What is Human-Computer Interaction?

In the western society of today a large part of the information, service and goods that we consider indispensable in our ordinary lives exist as technology in a physical form. To be able to benefit from these resources it is therefore often necessary for us to interact with technology in a physical manner, and one of the most powerful and widespread expressions of technology is the computer. The discipline of addressing this interaction is commonly known as *human-computer interaction*, or *HCI*.

There are several different definitions of what HCI exactly is, here follows some definitions that addresses the discipline from slightly different points of view:

"HCI is concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."

(Hewett et al., 1992, p. 6)

"Human-Computer Interaction (or HCI) is, put simply, the study of people, computer technology and the ways they influence each other. We study HCI to determine how we can make this computer technology more usable by people."

(Dix et al., 1993, p. xiii)

"HCI is a multidisciplinary subject. The student has to embrace theories of human behaviour as well as the principles of computer system design."

(Preece et al, 1994, p. v)

Taking these different definitions into consideration, one can come to the conclusion that HCI is a discipline concerned with the effects and the nature of the interaction between human and computer technology. This of course produces quite a wide range of areas in which HCI can be useful, and the fact that the discipline of HCI gathers inspiration from several other main disciplines facilitates the use of HCI in different areas.

2.1.1.2. The history of Human-Computer Interaction

The study of HCI initially evolved from work on ergonomics concerned with the design and usability of equipment. In the early work of HCI the main goal was to provide interfaces which were better suited for a wide range of users and not only computer specialists. This was done by hiding the low-level operations of the computer and instead creating an interface which contained more intuitive methods of interaction than writing detailed instructions in a computer language (Sharples, 1995). For example using metaphors for familiar items that the user can relate to such as calculators and word-processors.

The scope of HCI has broadened since then and is now an interdisciplinary field which, among other things, covers:

"...interface design, formal models of users and their interaction with computers, evaluation of computer systems, computer-mediated human to human communication and computer-supported cooperative work."
(Sharples, 1995, p. 1)

The interdisciplinarity of HCI is something that has evolved and increased with time. It wasn't until the mid '90s that many companies realised that they had to create multidisciplinary design teams that covered people with various backgrounds in order to be able to compete on the market (Preece et al., 2002). There is a great advantage to multidisciplinary teams since each member of the team has his/hers unique perspective on the task at hand which can lead to many more creative and original ideas being produced.

Interaction design is a subject which has sprung from the ideas of HCI, and is concerned with designing interactive products which take human limitations and potential into consideration. In the book "Interaction design - beyond human-computer interaction", the authors makes the following definition of what Interaction design is:

"In essence, it is about developing interactive products that are easy, effective and enjoyable - from the user's perspective."
(Preece et al., 2002, p. 2)

This book also contains the following image, which explains the relationship between interaction design, human-computer interaction, and other approaches which have and has had influence on the disciplines concerning interactive systems.

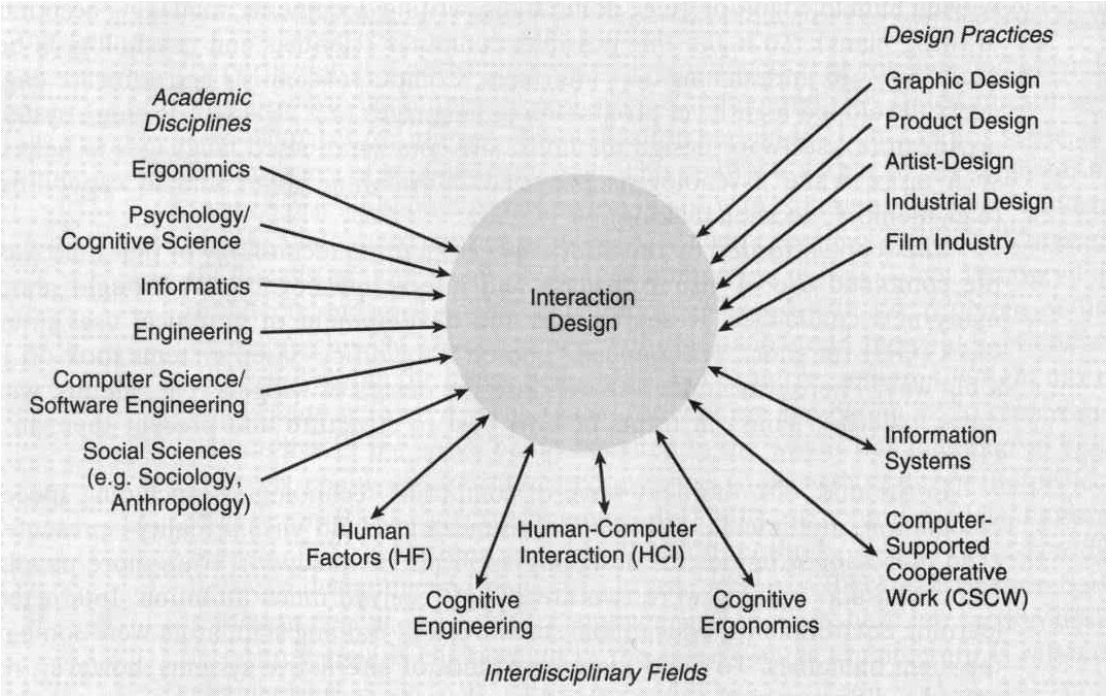

Figure 2.1 Relationships among contributing academic disciplines, design practices, and interdisciplinary fields concerned with interaction design. (Preece et al., 2002, p. 8)

2.1.1.3. The benefits of Human-Computer Interaction

Because computer technology has evolved into something not only suited for computer specialists but for the common man and woman, it becomes increasingly important to focus on making the systems easy-to-learn and easy-to-use. Early computers were often designed merely for technical users who could accept largely obscure command-line interfaces, but computer users of today are more demanding when it comes to interface design.

But dissatisfied users is not the only disadvantage of poorly designed computer interfaces. Computer systems are now available for almost all areas of life, and since they are developed to increase productivity it is of course crucial that they perform adequately. Poorly designed systems (with poor user interfaces) can lead to decreasing efficiency, increasing expenses and potential breaches of safety.

This is where HCI comes in. A large part of the work within HCI is concerned with evaluation and testing of computer systems, and it has been discovered

that repeated testing with a small number of typical users of the system performing typical tasks has turned out to be very successful in finding flaws and getting inspiration for improving the design. Well designed user interfaces can lead to increased productivity, reduced fatigue and error, reduced learning times, better human retention over time and higher subjective satisfaction and creativity (Shneiderman, 1993).

HCI is of course not only concerned with testing and evaluation, but also with research on theories of the psychology of computer use. In this area cognitive psychology plays an important part since the purpose of most interactive computer systems is to assist tasks which engage the mind. If and when you understand how the human mind works when interacting with technology it will be a lot easier to understand how to design interactive systems which takes into consideration the psychological potential and limitations of the user.

Apart from the aspects of performance and productivity, HCI is also concerned with the subjective satisfaction of the user. This is an issue that is growing increasingly important since the usage of computers is consuming more and more time. It's not unusual that a person interacts with computer at work eight hours a day and then comes home and works or plays with his/her personal computer a few hours more. In this scenario it is of course important that the user's experience of the interaction is enjoyable and satisfactory, or else the main part of his/her day will be unpleasant.

2.1.2. Cognitive Science

Cognitive science is an important field of research which has had influence on both human-computer interaction as well as on different evaluation methods used to evaluate interactive systems, and i therefore consider the next two sections concerning the subject to be a crucial part of this thesis.

2.1.2.1. What is Cognitive Science?

Cognitive science is a highly interdisciplinary field of study which essentially deals with the human processes involved in turning perceptual input from the outside world into knowledge inside the mind and using this knowledge to think, reason and communicate etc. These processes can be analysed from many different perspectives, for example philosophical, linguistic, computational, biological, anthropological and psychological. Each of these different fields have their own way of looking at the issues involved in explaining and understanding cognition and each have their own answers to the questions involved. Examples of questions that researchers within the field of cognitive science are trying to answer are "what is the nature of thought?", "what is consciousness?", "how do we interact with our environment?" and "how do we reason and make decisions?".

2.1.2.2. Cognitive Psychology

Cognitive science in general has had great influence on the work done within HCI and interaction design, and one field within cognitive science that is perhaps especially significant is *cognitive psychology*. There are many topics within cognitive psychology that are important for HCI such as perception, attention, memory, learning, thinking and problem solving (Preece et al., 1994). These topics are important since they are human factors that must be considered in order to design and build functional and usable systems.

The work that has been accomplished within the field of psychology has primarily concerned the understanding of human behaviour and the mental processes that underlie it (Preece et al., 1994). The results of this work is the foundation of cognitive psychology, but within this field of research the psychological principles are used to discover how - the human cognition works. Some of the benefits of this kind of research are that you can find out how to use the cognitive resources more efficiently and how you can minimise cognitive stress.

The field within HCI that is concerned with evaluation of interaction between humans and technology has benefited greatly from the research made within cognitive psychology in characterising cognitive processes in terms of their capabilities and limitations. The results of this research has been applied to HCI by using different methods such as guidelines, models of human cognition and empirical methods, all of which can be useful and practicable when evaluating the use of interactive computer systems of many kinds.

2.1.3. Context-Aware Computing

A very important aspect of Sonic City is its' context-awareness, and to better be able to understand the properties of such a system the following sections provide an introduction to context-aware computing featuring an example of another context-aware system called Nomadic Radio.

2.1.3.1. What is Context-Aware Computing?

The word *context* refers to the environment that surrounds people or things in different aspects, it concerns a wide range of attributes surrounding him/her/it. The context consists, not only of the immediate physical environment, but also of the resources nearby and of the social conditions (Schilit et al., 1994). Examples of factors that should be considered when observing the context are where you are geographically, who you are with, the lightning conditions and the sound environment.

Context-aware Computing Applications are systems that examine the properties of the context and take these into consideration when deciding

what input and output the system should handle and at what specific time (Moran and Dourish, 2001). The purpose of Context-Aware Computing is to make computing fit in with peoples' ordinary lives and the activities they devote themselves to. For example, the execution environment of a person moving around is constantly changing, and a system that is supposed to support the person in this activity has to adapt to the changes in location and react accordingly.

2.1.3.2. An example of Context-Aware Computing: Nomadic Radio

In "*Nomadic Radio:* Scaleable and Contextual Notification for Wearable Audio Messaging" the authors explain the need for context-aware wearable computing by stating the following:

"Mobile workers need seamless access to communication and information services on portable devices. However current solutions overwhelm users with intrusive and ambiguous notifications. In this paper, we describe scaleable auditory techniques and a contextual notification model for providing timely information, while minimising interruptions. User's actions influence local adaptation in the model. These techniques are demonstrated in *Nomadic Radio,* an audio-only wearable computing platform."

(Sawhney N. and Schmandt C., 1999, p. 1)

Nomadic Radio is a wearable system for personal messaging and communication. It provides an audio-only interface to remote services and messages such as mail (in electronic or voice form), news broadcasts and calendar events. When messages of these types reach the system they are downloaded to the device and the user can browse through them at any time during the day using voice commands or tactile input.

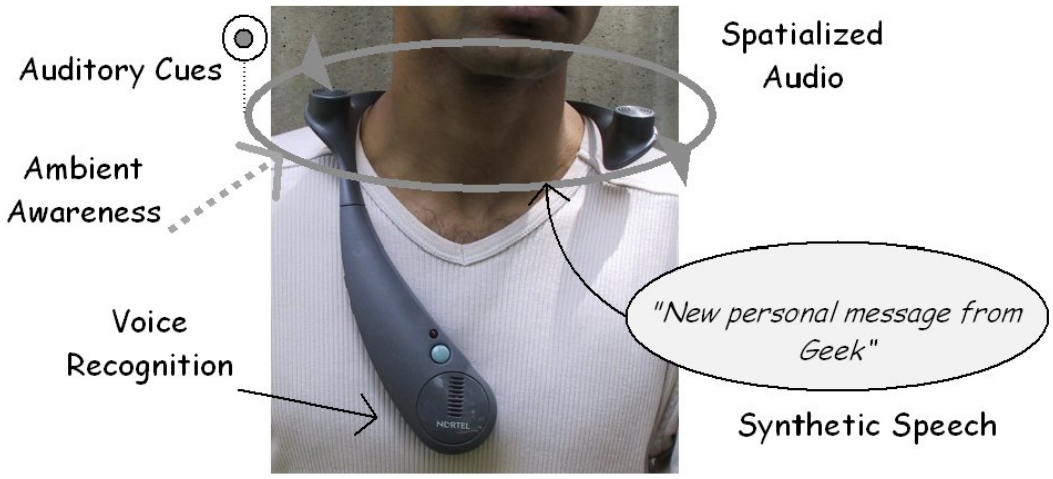

Figure 2.2 The SoundBeam Neckset used as an interface for the Nomadic Radio. (Sawhney and Schmandt, 1999, p. 2)

Unlike most other systems supporting similar activities, Nomadic Radio takes a number of - different factors into consideration concerning the context when deciding what action to take. When the system receives an e-mail it will measure its level of importance before deciding if the user will get any notification of the e-mail and in what shape and intensity. For example, if you're in an important meeting you probably don't want to be disturbed unless it's something important the matter.

The reason mentioned in this paper for developing a system that primarily operates as an audio-only device is that the ambient auditory cues used by the system to provide awareness of the system's status minimises the cognitive effort. In Nomadic Radio the sound of flowing water is used to indicate that the system is active, such a sound does not distract the listener and tends to fade into the perceptual background after a while. If the system receives a short e-mail this will sound like a short splash, while a larger transfer of information will sound like faster flowing water. Because of this the listener gets an idea of the size of the message before it becomes available and can quickly decide whether the message should be read at that time or saved for later.

2.2. Theories

2.2.1. Spatial Cognition

One of my theories concerning how the use of Sonic City might affect the user's behaviour relates to the activity that the user will devote him/herself to while using the system: walking around in an urban environment. The following sections relate to the mental processes involved in moving around to give an understanding of how humans operate when it comes to these matters.

2.2.1.1. What is Spatial Cognition?

In the field of *spatial cognition* one looks at the perceptual and cognitive processes that are involved when people find their way in different environments and how the perceptual input of these activities create coherent representations of these environments. Spatial cognition is also concerned with how people acquire information about the spatial layout of the environment and how they use this information for orientation and navigation (Gärling, 1995).

2.2.1.2. Cognitive Maps and Travel Plans

Cognitive maps are mental representations of different environments which contain information about the properties of different places and the spatial relations between them (Gärling, 1995). We use these cognitive maps to decide how to get to a certain location and by what means, usually in order to reach the desired location in the quickest and easiest way.

We also use cognitive maps to create *travel plans* which are detailed sequences of the actions necessary to reach a certain location (Passini, 1995), for example: in order to get to the elevator; enter the main door, turn left, follow the corridor to the end and then turn right. The more detailed the travel plan is the easier the orientation is for the person. But the more accurate the cognitive map is the less detailed the travel plan has to be for the person to find his/her way (Gärling, 1995). This is because less observation is required from the person in order to maintain orientation.

2.2.1.3. Wayfinding

As stated in "Spatial representations, a wayfinding perspective":

"Wayfinding describes a person's ability, both cognitive and behavioral, to reach spatial destinations."

(R. Passini, 1995, p. 140)

When people are involved in *wayfinding* they make large quantities of decisions deciding what actions to take in order to reach the desired location (according to Passini, 1995, tests have shown that an amount of 50 or more decisions over a period of 20 minutes is not unusual.) A wayfinding decision consists of two major parts: a behavioural part (for example "entering" or "turning right") and a physical part which usually is an object or a place (for example "the door" or "the end of the corridor") which specifies at what location and with what object the behaviour should occur (Passini, 1995). These decisions are then transformed into actions (for example "entering the door" or "turning right at the end of the corridor".)

Even though these decisions are executed at an essentially unconscious level people are normally able, to some extent, to recall the wayfinding decisions they made in the process of moving from one place to another. How much and how detailed information about way-finding decisions a person can account for depends, among other things, of how familiar the environment is. The more often you follow a certain route the more familiar it becomes and the less attention you have to pay to the operations involved (Passini, 1995). Therefore it can be more difficult to account for a familiar route (for example going to work every morning) simply because you know the road so well that you can find your way without having to claim any conscious mental activities for the task.

2.2.1.4. Spatial Decision-Making

When making wayfinding decisions both spatial and non-spatial attributes are accounted for. Spatial factors that can influence the decision-making are distance to the desired location, how much time it would take to get there and how much energy the activity of going there would require. Non-spatial factors include the attractiveness of the location, the activity going on in the location and the danger or threat that the move could result in. The attractiveness of going to a certain place can offset the cost of moving there provided that the utility is great enough. According to the same principle the place can be avoided if the cost is small enough to avoid the disutility of the place, for example danger or threat (Gärling and Golledge, 2000).

2.2.2. The Psychology of Hearing

Sonic City uses an audio interface to provide the user with a representation of the urban environment and his/her movements within these surroundings. Since interfaces that communicate exclusively with sound are quite uncommon, it is interesting to examine the psychological effects that this type of interaction might have on the user. Hence, the following sections concern the psychology of hearing featuring what principles affect the perception of sound and how people are able to share their attention between more than one perceptual impression at a time.

2.2.2.1. Perception and Shared Attention

In everyday life people constantly perceive information via their different senses, they see things, smell things, taste things, feel things and hear things. When there are lots of things happening in a person's environment, he /she has to share his/her attention between the different events to be able to interpret the different perceptual signals. What determines how many different tasks a person is able to get involved in at a time depends on the difficulty of the tasks, the similarity of the tasks and whether the person is used to performing the task.

When performing more than one different task at a time, another factor that has to be taken into consideration is the cognitive resources that each of the tasks claim to be performed. It is easier to perform different tasks if they claim different cognitive resources. For example a person is usually able to share his/her attention between listening to music and reading a book, but it is much more difficult to try to listen to two things at once. Because of this fact, and because most of the information we perceive in our everyday environment is in visual form resulting in overburdening the visual system, there are strong motivations for exploiting sound to its full potential.

2.2.2.2. General principles of Perceptual Organisation

According to cognitive psychology humans strive to find meaningfulness, patterns and similarities in what they perceive in order to minimise the cognitive effort and use the cognitive resources efficiently. The gestalt psychologists claimed that there are *rules of perceptual organisation* which determine how the perceptual input is used to achieve perceptual grouping of same input (Moore, 1997). These rules were mostly described first in relation to vision, but they generally apply to both vision and hearing.

Similarity

Auditory elements will be grouped together if they are similar in regard to closeness in tone, pitch, loudness or subjective location, but the basis of similarity seems to be tone rather than pitch. Single perceptual streams are formed of tones that are similar and closely spaced in frequency, tones which are widely spaced form separate streams (Moore, 1997).

Good continuation

The principle of good continuation exploits the fact that changes of a sound source in frequency, intensity, location or range tend to be smooth and continuous rather than abrupt. The nature of the change in any of these aspects indicates what has caused the change. A smooth change indicates change within a single source, a sudden change indicates that a new source has been activated (Moore, 1997).

Common fate

Different frequency components that originate from the same sound source usually vary in a highly coherent way. They tend to start and finish together and change in intensity and frequency together. This fact is exploited by the perceptual system in the way that two or more sound-components are grouped and perceived as part of the same source if they undergo the same kind of changes at the same time (Moore, 1997).

Disjoint allocation

The theory of disjoint allocation is also known as "belongingness" and states that a single component in a sound only can be assigned to one source at a time. A component cannot be used in the formation of a new sound-stream if it has already been used in the formation of previous stream. A problem with this theory is that there is more than one way to interpret certain auditory input if they are ambiguous. If a sound-component which might belong to one of many streams exists, the percept may alter depending on the stream in which the component is included (Moore, 1997).

Closure

If a sound from a given source is temporarily obscured by one or many other sounds, there may be no way for the hearer to determine whether the obscured sound has continued or not. Under these conditions the obscured sound may still be perceived as continuous, although it is not. In other words when a sound A is alternated with a sound B, then A may be heard as continuous, even though it is interrupted (Moore, 1997).

Figure-ground phenomenon

Even though we may think that it is possible to observe and compare different components in a complex sound, people are generally not capable of consciously attending to every aspect of the auditory input. Rather, it appears that the complex sound is divided into streams and we can only consciously attend to one stream at a time. For example when we listen to music, we attend primarily to one melodic stream at a time while the rest of the music is less prominent (Moore, 1997).

2.2.3. Soundscape Composition

Soundscape composition is a method which is used by Sonic City to represent the urban environment by using sound. To better understand the nature of Sonic City, here follows an introduction to what soundscape composition is, how it works and what effects it might have on people exposed to it.

2.2.3.1. What is Soundscape Composition?

Soundscape composition is a way of exploiting the surroundings by recording environmental sounds and using them as "instruments" to compose a sonic representation of the environmental context. Since a soundscape composition is always rooted in themes of the sound environment it is never abstract, and it can consist of either unprocessed or processed sounds, or a combination of the two (Westerkamp, 1999).

The only way to be able to hear a soundscape composition is by using sound equipment such as microphones and loudspeakers, since the acoustic environment exists exclusively in the electroacoustic realm. One way of creating a soundscape composition is by recording the electroacoustic sounds of an environment with one or more microphones, running these sounds through a system which enhances and/or exploits them in a specific way and then playing the output from the system on a pair of loudspeakers or headphones (Westerkamp, 1999). In this way audio technology allows us to extract information from environmental sounds by creating a type of language which meaning depends on the context and on the placement within a composition.

2.2.3.2. The nature and effects of Soundscape Composition

Soundscape composition can be used for different reasons, for example to enhance the listener's awareness of sounds in the environment, to comment on essential characteristics of a sonic environment or to exaggerate the sonic contours of the surroundings. The main effect of these different changes in the way we interpret our sonic environment is that they can enrich our perception of our daily sound environment and also change our attitudes towards it. Simply because soundscape compositions can make us more aware of the contours of sound, its colours and its details and therefore give us a new experience of it.

Another way of seeing soundscape composition is as a new way of listening which highlights both the world around us as well as the relationship between the environmental sound sources which surrounds us and our mental representations of these sounds. Or, as Hildegard Westerkamp writes:

"By riding the edge between real and recorded sounds, original and processed sounds, daily and composed soundscapes it creates a place of balance between inner and outer worlds, reality and imagination."

(Westerkamp, 1999, p. 4)

2.3. Evaluation

As stated in section 1.2 (Purpose), the aim of this thesis is (among other things) to consider which evaluation methods might be suitable for evaluating Sonic City in acknowledging the effects that the use of it might have on the users' perception and behaviour. To be able to do this, I had to explore the process of evaluating and what different methods can be used. The results of these explorations are presented in the following sections.

2.3.1. Reasons for Evaluation

There are many reasons for evaluating computer systems, for example to get a better understanding of the environment in which the system will exist and to be able to follow up earlier stated goals of the system's functionality and usability. In the book "Interaction design: beyond human-computer interaction" the authors explain the need for evaluation by stating the following:

"Just as designers shouldn't assume that everyone is like them, they also shouldn't presume that following design guidelines guarantees good usability. Evaluation is needed to check that users can use the product and like it."

(Preece et al. 2002, p. 319)

Evaluation is an activity that system designers should dedicate themselves to during the whole process of designing and building a new system, since it's an efficient way to make sure that potential users are able to use the system in the intended way. By taking the results of the evaluations into consideration in the design process you can fix the problems before the product reaches the market, in this way minimising the risk that the system is misunderstood, incorrectly used and disliked by the users.

2.3.2. Evaluation methods excluding users

The main advantages of using evaluation methods which do not involve the users are that there are less practical and ethical issues to be considered when administering the evaluations, and that there is money to be saved. The main disadvantage is that you are unable to get the "real" users' opinions about the system. Although you can use experts or members of the design-team to act as users, it can never be the same thing as letting real users try out the system and comment on its pros and cons.

Heuristic Evaluation

A *heuristic evaluation* is performed by an expert who will test the system taking a number of usability principles known as *heuristics* into consideration. If the expert finds a violation of any of these heuristics he/she will identify it and decide how critical the violation is in relation to the heuristic (Wang 1998). Based on these violations and their seriousness the design-team will decide whether the system needs to be altered in order to avoid them or not.

Which heuristics to use depends on what kind of system you want to evaluate, and selecting appropriate heuristics are very important since they will focus the experts' attention on specific issues. The heuristic evaluation was developed by Jakob Nielsen and his colleagues, and some of the heuristics they recommend are system visibility, mapping between the system and the real world, user control, consistency, error prevention and flexibility.

An advantage of using heuristic evaluation is that it is a good technique for identifying usability problems, in Preece et al. (2002) the authors refer to Nielsen (1994) when stating that empirical testing conducted by Nielsen et al. suggests that around 75% of the total usability problems can be identified by using five different experts as evaluators. One disadvantage of using this evaluation technique is that you have to select the right heuristics to be able to identify the critical usability problems, if you select the wrong ones the result of the evaluation will not be of any help in improving the system. The result of a heuristic evaluation also depends on the person who conducts the evaluation, and mainly on his/her expertise. Evaluators with sufficient knowledge in all the necessary fields of expertise can be hard to find, and that's another disadvantage of the technique (Preece et al, 2002).

Cognitive Walk-through

A *cognitive walk-through* is accomplished by letting a member of the design-team take on the role of a potential user of the system. He/she then performs a walk-through of the different tasks that can be carried out within the system and tries to identify the different usability problems that can be encountered when using the system (Wang, 1998). The characteristics of the typical users of the system needs to be taken into consideration before performing the walk-through, and every single step of it has to be documented thoroughly in order to identify which parts of the system works and which don't (Preece et al., 2002).

A big advantage of cognitive walk-through as an evaluation technique is that it gives a very detailed view of the possible difficulties that the users may encounter in the system, without present users or a fully functional prototype. Disadvantages are that it has quite a narrow focus which isn't beneficial for all types of systems, and that it can be very time-consuming and complex to perform if done properly.

2.3.3. Evaluation methods involving users

An advantage of involving potential users of the system to be evaluated in the evaluation process is that you have a chance of obtaining the users' subjective opinions about the properties of the interaction with the system, which can be very valuable information for the system developers. Disadvantages are that there are practical and ethical issues to be considered when acquiring information from users and later publishing it in a paper, magazine or book. These issues can be both time-consuming and difficult to administer.

Controlled Experiment

Controlled experiments generally take place in an artificial environment such as a laboratory, and not in the kind of environment where the system tested normally would be used. In these types of settings neither the participant nor the administrator of the test will get disturbed or distracted by sound or movement that are commonly a natural part of the context when using different types of systems in everyday life.

A controlled experiment can be performed in many different ways, for example you can test two or more systems against each other in order to compare their performance when it comes to usability and efficiency, or you can let two or more participants test the same system in order to compare how well they master the system (Preece et al., 2002).

The main advantage of controlled experiments is that you can get a very detailed understanding of the individual participants' cognitive and perceptual

behaviour because you can focus on the participants' behaviour without being disturbed by external sources (Wang, 1998). However, this type of evaluation does not take into consideration the social and communicational factors that have effect on individuals when part of a group, and since the evaluation does not take place in the natural environment of use it's not certain that the test results are fully accurate.

Think-aloud Technique

When using the *think-aloud technique* in evaluation the test-administrator/administrators are present during the entire test and instructs the participant to say out loud everything he/she is thinking and trying to do. Usually you have two administrators attending at the test, one that guides the participant and one that observes the participant's behaviour and records these observations in a think-aloud protocol. It is the test-guide's task to give instructions to the participant without disturbing or influencing his/her actions (Preece et al, 2002), for example if the participant becomes silent the guide can ask him/her "what are you thinking right now?" in order to make the participant start talking again.

The think-aloud protocol technique was developed by Eriksson and Simon (Eriksson and Simon, 1985) as a way of examining people's problem-solving strategies by externalising their thought processes (Preece et al. 2002). Advantages of this technique are that you directly can identify problematic areas within the system and that you can get a view of the participant's mental representation of the system. Disadvantages are that some participants have difficulties communicating their thoughts to the test-administrators, and that the processes involved in thinking-aloud might affect the interaction with the system in regards to speed and efficiency.

Observation

Observation as an evaluation technique is achieved by observing the participant using the system to be evaluated, collecting data about the participant's behaviour and then analysing the data (Preece et al., 2002). There are many different observation techniques to use from such as personal observation, photographing, video-recording or event logging. Which technique to use will depend on the nature and the context of the system and what kind of behaviour it is you want to observe.

The analysis of the observational data often take a lot more time than the observation itself, it is therefor important to plan these activities well before starting them. The first thing to do when analysing observational data is to try to locate patterns that can answer the questions you want answered or show support for a certain theory. These patterns are then analysed in relation to the goals of the evaluation with the purpose of producing a convincing report with powerful examples that help to confirm the main points (Preece et aL., 2002). The more participants you observe and the more obvious the patterns

in the data, the more powerful the points are that you can verify, which is an advantage of this method. A disadvantage is that it can be difficult and time-consuming to find these patterns.

Interview

An *interview* can be seen as a "conversation with a purpose" (Kahn and Cannell, 1957) and to what extent an evaluation interview will resemble a conversation depends on how it is executed (Preece et al. 2002). Before carrying out an interview the interviewer has to decide what questions are to be answered, how the interview will be arranged and how much control he/she will have on the conversation. An interview can be more or less structured when it comes to the interviewer's control of it, and how rigid you choose it to be depends on which questions you want answered and how much freedom you want to give the participant in answering these questions.

An advantage of interviews is that they are adaptive in the sense that the interviewer at any time can change the course of the interview, for example by asking the participant to elaborate on a certain subject or posing counter-questions. Another advantage is that the participant can supply information that the interviewer had not expected. Disadvantages are that the participant cannot be anonymous and that the results from an interview can be difficult to quantify.

Questionnaire

Using *questionnaires* to gather demographic data and users' opinions is a traditional and widespread technique. When designing a questionnaire it is important to put effort in writing the questions to ensure that the participants will understand them and give suitable answers and that the results of the questionnaires will be easily analysed (Preece et al., 2002). For example, you can choose between closed (such as yes/no questions) and open questions (such as "elaborate on..." questions) depending on what questions you want answered by the questionnaire.

Advantages of questionnaires are that they are cheap and easy to quantify and that they offer anonymity. A disadvantage is that the results of a questionnaire very much depends on the questions posed in it in the way that people tend to answer them in the way they think are expected of them and that there is no way for the participants to answer questions that do not appear in the questionnaire.

2.3.4. Evaluation methods for new types of interaction

Verification through User Value

As the interaction with computers grows more complex and finds new circumstances in which to take place, it becomes increasingly difficult to know what 'correct behaviour' is in regards to the usage of a certain system. Miller and Funk (2001) suggests that instead of looking at classic attributes commonly used in evaluation such as efficiency and usability one should focus on *user value*. They define user value as something that can be achieved either through a more satisfying user experience, improved task performance or an expanded range of task performance. Evaluation should be performed by using well-chosen scenarios for which appropriate and inappropriate behaviour has been established in regards to user value. If the evaluation indicates enhanced user value this means that the quality of the system has been verified.

Broadening the Scope of Evaluation

According to Arnstein et al. (2001), new kinds of interaction presents a challenging evaluation problem partly because the user's experience of a computer application doesn't start with the user running the application but instead starts when a hardware or software artefact is envisioned by a developer. Because of this Arnstein et al. suggest that the scope of evaluation should be broadened to include both the users' experience of the system as well as the experience of developers, system administrators and even people who may want to abuse the system. This can be seen as a supplement to standard HCI techniques that can give a better understanding of how the properties of the entire system are perceived by all parties involved.

Evaluating the Predictability of Systems

Some of the new types of computer interaction differ from standard applications in the way that they operate over greater physical space, have a greater availability of the system over time and support interaction between larger a larger number of people. Because of this these types of interaction are more difficult to evaluate, and Dey (2001) suggests that focusing on the system's predictability is an effective way of evaluating an important metric of all types of systems, both new and old. A system is predictable if the user can anticipate what effects will come of the user's actions, and this is a characteristic that is significantly important to new kinds of computer systems because they often adapt their behaviour according to the context of use. As a result of this flexibility there is a risk that the user doesn't understand why the system behaves the way it does and gets confused because of it.

3. Method

The main part of the preparative work made before the writing of this paper consisted of gathering background information concerning the different fields of research and theories in section 2 (background). The two main sources used to gather this information are the Göteborg University Library and the Internet. I've used the Internet as a source mainly when I have not been able to find information elsewhere, which has been the case with context-aware computing, soundscape composition and evaluation methods concerning new types of interaction. I've also used information found on the Internet to compare with information that I've found elsewhere in order to receive more than one point of view on a specific matter when this has been possible.

Some of the subjects explored in the background section I've chose because I consider them essential to this paper if it is to be enjoyable and understandable even to those who are not familiar with all of the issues dealt with in it. These subjects include the fields of research covered in the background section: human-computer interaction and interaction design, cognitive science and context-aware computing. Also, section 1.4 (Sonic City) of the introduction is beneficial to understanding the rest of the paper because it explains the idea of Sonic City and how it works.

The subjects in the theory part of the background section are not essential for the reader to understand this paper, but are rather subjects that I've found interesting because they can provide a deeper understanding of the different properties of Sonic City and what effects it might have on the users' cognitive behaviour that can be interesting to evaluate. These subjects include: spatial cognition, the psychology of hearing and soundscape composition. Section 2.3 (evaluation) gives an introduction to evaluation and presents different evaluation methods which can be used to measure the effects that an interactive system might have on its users.

In the result section of this paper I've analysed the information gathered in the background section in order to find out what different properties of Sonic City would be interesting to evaluate and how this could be done in a suitable way. I would have wanted to use the framework for evaluation presented in section 4.3.2.4 to evaluate Sonic City, but because there is currently only one functional prototype which is not robust enough to evaluate, this has not been possible.

The only empirical element of this paper is the interview in section 4.1 where I carried out two separate interviews with Lalya Gaye and Ramia Mazé, both asking them the same four questions (with Lalya in person and with Ramia over the phone). The interview with Lalya was in Swedish, I have therefore translated her answers to English, and the interview with Ramia was in English. Both the interviews eventually turned into more of a conversation which I think was good since the purpose of these interviews was to receive

some of their reflections on cognitive resources, perception, behaviour and evaluation in relation to Sonic City and letting them speak as freely as possible. Later I compared the results of the interviews with the conclusions I've come to myself in the process of working on this paper.

4. Result

4.1. Interview with Lalya Gaye and Ramia Mazé

- In the development of Sonic City, have you considered and taken into consideration the cognitive resources of the users?

Lalya: We have taken some consideration but not a lot, for example when we thought about how much the control the user should have over the system and whether the same route taken by the user should sound the same every time, because that might be boring.
Ramia: Not really, we started thinking about ourselves as possible users and used ourselves and our previous experience as reference. Our plan was to create something first and then test it on other users than ourselves.

- Have you thought anything about evaluation of Sonic City, and if so, which evaluation method(s) do you think would be best to use?

Lalya: We have though more about how the system would fit in the user's lifestyle and made scenarios with a number of potential users. We are also planning to have workshops, both for evaluation and inspiration purposes, but since the current prototype is a bit messy with lots of wires it's difficult to use that one in evaluation purposes. We are considering to let people use the sensors and comment on the different sounds that can be created by the system.
Ramia: Since the current prototype is just an initial prototype and is not meant to be the final product it's hard to evaluate. Rather than evaluating we want to involve users in evolving the design using workshops where people will be encouraged to share their lifestyles.

- Do you think that the use of Sonic City will alter the way the user perceives his/her environment and the way he/she behaves?

Lalya: We are hoping that people will take different routes and discover new things that they haven't seen before. When you're using something in a creative way you perceive new things in a more personal way.
Ramia: The explicit goal of this project is to transform people's relationship to their city in changing their individual perception of it. Thus, we have made no assumptions about what effects Sonic City might have on users, we want the use of it to be a playful and entertaining experience.

- In what way do you think you could measure these effects on the user's perception and behaviour most efficiently?

Lalya: We are considering carrying out continuous evaluations which will progress for about a month where we will let the user test the system, ask questions and document the activities. But we won't control the users in this process but let them play without giving them lots of instructions, because we think this way it will be more fun and give more interesting feedback.
Ramia: We are not very interested in quantitative evaluation but rather in qualitative evaluation. We think workshops can be a good way of obtaining ideas and emotions from users by using role-playing and imagining activities. In this way we might also be able to uncover subliminal behaviour involved in wayfinding among other things.

4.2. Analysis of Sonic City

Seen from a cognitive science point of view, Sonic City is interesting because it introduces a new kind of interaction with which differs quite a lot from classic interaction with computer systems. Distant from the aspects that are considered crucial for a well-designed system in classic HCI, Sonic City has new types of objectives regarding user experience and cognitive behaviour in reaction to an urban environment, and factors such as efficiency and timesaving are considered irrelevant.

More specific, the characteristics of Sonic City that I've found most interesting and therefore focused on in this paper are:

- The context-awareness of the system and its effects on the users.
- How the usage of Sonic City possibly will alter the user's spatial cognition in inspiring the user to modify his/her wayfinding behaviour.
- The audio interface of the system and the issue of shared attention between visual and audio perception.
- The idea of using the city as a musical instrument and encouraging creativity in the user's behaviour, and how this might influence the way the user perceives the city that he/she lives in.

Context-awareness

Sonic City is context-aware in the aspect that the audio output of the system is created by processing input from biometric and environmental sensors which collects data concerning the state of the user and his/her environment. Changes in these data result in changes in the music produced by the system.

The purpose of context-awareness is generally to make computer systems into a more natural part of peoples' everyday life by making the technology

more flexible and attentive. However, when it comes to Sonic City the reason for context-awareness is rather to make users more attentive of their environment than for the system to blend in with the users' everyday activities.

The effects of the context-awareness in Sonic City might vary from user to user depending on factors such as age, interests, background, physical and psychological condition, and some of the effects that I consider possible to emerge from using Sonic City are:

- Increased awareness and sensitivity regarding the urban surroundings.
- Increased consciousness of urban behaviour.
- Increased creativity and inspiration to explore the environment in a new way.
- Decreased attention towards other components of the context not emphasised by the system.

Spatial cognition

The user's spatial behaviour is reflected by Sonic City in monitoring the user's movements in relation to the spatial environment and representing these movements sonically in the shape of music. There are many different factors which have influence on a person's wayfinding behaviour, both spatial and non-spatial, and the use of Sonic City may affect it in different ways:

- Tendency to make unconventional wayfinding decisions in order to experiment and find out how the system responds to different routes.
- Increased attention devoted to making wayfinding decisions.

Audio interface

The users of Sonic City will experience new kinds of perceptual representations of their physical environment in a sonic appearance, which most of them will never have encountered before. When the audio output from the system is perceived by the user it will compete for the user's attention and cognitive resources along with every other input, be it sonic, visual or tactile, that is perceived by him/her. The effects that might be expected following these facts are:

- Difficulty to separate the sounds of the system from the natural sounds of the environment if they are too similar (the principle of similarity) or if the sounds of the system obscure the natural sounds (the principle of closure).
- Tendency to recognise the distinctions of the environment in a new way based on the variations of the audio output of the system (the principle of good continuation).
- Difficulty to consciously listen to both the sounds of the system as well as the sounds of the environment (principle of figure-ground phenomenon).

The city as a musical instrument

In Sonic City the soundscape of the urban environment is exploited and transformed into music, in this way playing the city like a musical instrument and utilising the changes in its physical properties to create variations in the musical composition. This might affect the users in the following ways:

- Increased awareness of the soundscape of the urban environment and its variations.
- An enriched perception of both the environment as well as the relationship between environmental properties and the users' mental representations of them.

4.3. Evaluation of Sonic City

Because there is no prototype of Sonic City available for testing at this point, I haven't had the opportunity of evaluating the system and finding out whether my assumptions about its effects on the users' cognitive behaviour are correct or not. However, if I had been able to carry out an evaluation of Sonic City I would have based it on the assumptions stated in the following sections.

4.3.1. What to evaluate

Initiated on the hypotheses made in section 4.2 (Analysis of Sonic City), the questions I would have wanted answered in the process of evaluating Sonic City are the following:

- Will the use of Sonic City alter the way in which the user perceives his/her urban environment and its characteristics, and if so, in what way?
- Will the user acquire an increased consciousness of his/her behaviour involved in moving around in an urban environment and the wayfinding decisions involved herein?
- Will the user be inspired by using Sonic City to explore his/her environment in new ways and make unconventional wayfinding decisions?
- Will it be difficult for the user to share his/her attention between Sonic City and the outside world, risking that less attention is devoted to important features of the outside world such as traffic?
- Will the use of Sonic City lead to an enriched understanding of the relationship between the environment and the user's mental representation of it?

4.3.2. How to evaluate

When considering how to evaluate a certain system, not only do you have to take into consideration the nature and the properties of the system, but you also have to consider the resources and limitations of the user from a cognitive perspective. In order for the evaluation to provide substantial and valuable information, you have to facilitate the process of sharing and mediating thoughts and opinions for the user and avoid making it more difficult than necessary, both for the user and the evaluator.

4.3.2.1. Considering evaluation methods excluding users

Depending on the resources available to the design-team, essentially regarding time and money, choices are made concerning how extensive the evaluation should be and whether it should involve users or not. If the resources needed for involving users in the evaluation process are unavailable, the cognitive walk-through method can be a beneficial alternative since it doesn't require a lot of preparation or a fully functional prototype.

Another alternative is the heuristic evaluation technique, but this requires more preparation in selecting the appropriate heuristics to establish the evaluation and also calls for a fully functional prototype. Based on these facts, I consider cognitive walk-through superior to heuristic evaluation when excluding users from the evaluation procedure. Thus, I believe evaluation methods which involve users can highly improve the outcome of an evaluation because they give access, not only to the design-teams', but to the users' subjective opinions of the system evaluated.

4.3.2.2. Considering evaluation methods involving users

In regards to the nature of Sonic City, some of the evaluation methods considered in section 2.3.3 (Evaluation methods involving users) immediately appear inappropriate for evaluating a system of this sort.

- Using *controlled experiments* would be unsuitable because they exclude the natural environment of the system, and since a highly important and significant aspect of Sonic City is its context-awareness, the effects of this feature wouldn't be accounted for by using this technique.
- The *think-aloud technique* would not be appropriate because it wouldn't be realistically manageable for the test-administrator to ask the participant questions while he/she is walking around using Sonic City. Also, it would probably put too much stress on the participant to try to devote attention to walking, talking and listening, both to music and to the test-administrator, all at the same time.
- *Questionnaires* could be useful to the evaluation of Sonic City in providing quantitative data, but the disadvantage of the method concerning rigidity and the fact that participants tend to answer the way they think they

should makes it an inappropriate evaluation technique. Also, in evaluating a system like Sonic City, you tend to appreciate qualitative data higher than quantitative data because it can provide a more detailed view of the user's subjective opinions.

The two evaluation methods remaining after excluding the ones above are the *observation* method and the *interview* method, which I both consider to be appropriate tools for evaluating Sonic City. When using observation as an evaluation method in classic HCI, it's normally used to locate patterns in the users' behaviour in order to show support for a certain theory. However, if the observation method was used on Sonic City I would suggest that it was used not only to locate patterns but to locate diversity and alterations in the users' behaviour. The reason for this is that Sonic City is intended to provide a special and unique user experience in relation to the user's personality and lifestyle. By observing the user moving around in his/her city both with and without using Sonic City, any changes in his/her behaviour can be detected.

The main advantage of interviewing is that it is a very adaptive and flexible evaluation method, which makes is suitable for finding out how the user's subjective opinions and perceptions of his/her environment might have changed by using Sonic City. The less fixed and inflexible the interview situation is, the more it can become a two-way communication between the interviewer and the interviewee. This will endorse a flexible conversation that encourages the interviewee to share his/her thoughts and feelings about the system evaluated, with some aid from the interviewer.

4.3.2.3. Considering evaluation methods for new types of interaction

In section 2.3.4 (Evaluation methods for new types of interaction) I've discussed three different new evaluation methods especially agreeable with new types of interaction paradigms. Out of these three, I find *verification through user value* to be an interesting evaluation method in regards to Sonic City, because user value would be an interesting and suitable factor to consider in the system. Of course, when you don't have any other system of the same type to compare with, you will have to look at whether using Sonic City results in an increased user value as opposed to not using the system.

To *broaden the scope of evaluation* would also be an interesting evaluation method because you would get opinions on the system from people that you normally wouldn't include in the evaluation process, and who probably views it from a more or less different point of view. After collecting the opinions on the system from different people which have different relations to it, it would be even more interesting to compare them amongst each other to find out to what degree the thoughts about the system depend on what kind of relationship you have to it.

The idea of *evaluating the predictability* of Sonic City seems somewhat unsuitable since it is not the purpose of the system to be predictable, but quite the opposite. If the system was to be predictable, a lot of the fun and excitement involved in trying the system would have disappeared. You could of course evaluate the *unpredictability* of the system, but I don't think that should be the main focus of the evaluation.

4.3.2.4. A framework for evaluating Sonic City

For the evaluation of Sonic City, I suggest involving users in the process by using a combination of interviewing and observing because I think this method will be able to provide answers to all the questions stated in section 4.3.1 (What to evaluate), if conducted in the right way. The evaluation could commence by observing users moving around in the city without using Sonic City, and later observing them using Sonic City while moving around in the same areas, taking the same routes. In this way you could observe any changes in wayfinding behaviour as well as whether the user seems to be able to share his/her attention between Sonic City and the environment surrounding him/her. If the observed user should find it unpleasant to be observed by a person you could instead monitor his/her movements using GPS (Global Positioning System) and conduct a more thorough interview.

When it comes to the interview, you should query the user about the experience of using Sonic City and ask him/her whether his/her perception of the urban environment changed after walking around using Sonic City, whether he/she thinks that his/her wayfinding behaviour got influenced and whether there was any problem sharing attention between Sonic City and the urban environment. You could conduct a series of interviews and compare their results based on how long experience the user has had with Sonic City, how many times he/she has used it and for how long periods at a time. In these interviews you could also introduce the concept of user value by asking the user whether Sonic City in some way increased the quality of his/her experience of moving around in an urban environment.

An evaluation method, which perhaps is not crucial for finding out how well the system is received by its users, but could give an interesting view of the whole design and development process as opposed to the user experience is the idea of broadening the evaluation scope to include other people than the users of the system. An example of how this could be achieved is by letting people who have not been involved in the making of the system administer and lead the evaluation of it. The administrators of the evaluation could then follow the same evaluation framework as stated above, not only observing and interviewing the users of the system, but also people involved in the design, development, administration and maintenance of the system and compare the different evaluation results from the different groups of people with different relation to the system.

5. Analysis

A disadvantage of the assumptions made in the result section is that they are based on facts about Sonic City and theories about evaluation, and not empirically tested in any aspect. This is a disadvantage because there is no may of telling whether the framework for evaluating Sonic City presented in section 4.3.2.4 will be able to answer the questions stated in section 4.3.1 (What to evaluate). Of course, this is most definitely a common problem involved in choosing evaluation frameworks for new systems which introduce new kinds of interaction. In spite of this, I think that here are ways of benefiting from previous theories about evaluation, although you may have to adapt them to better suit the nature of the system to be evaluated.

When I've considered which evaluation methods would be best suited for evaluating Sonic City, I've both considered classic evaluation methods that have been used for a long time, as well as new ones which have not yet been used to the extend that you can analyse their advantages and disadvantages. These evaluation methods come from different backgrounds in concern to academic disciplines and have been developed by different people. Because of this, these evaluation methods cover a wide scope of opinions on evaluation. I consider this to be a great advantages - since I believe that interdisciplinarity can bring out the best qualities of all disciplines involved.

In relation to the interviews with Lalya Gaye and Ramia Mazé in section 4.1, some of the conclusions I came to in the result section regarded issues that they had already considered. For example, when they used themselves as possible users in the beginning of developing Sonic City, they used a somewhat modified and limited model of the cognitive walk-through method, and they consider the goal of the Sonic City project to transform people's relationship to their city in changing their individual perception of it. When it comes to evaluation methods involving users, they are planning to have workshops with the purpose of both evaluating as well as involving users in the evolution of the design, which is an evaluation methods that I haven't considered. A main priority for them when it comes to evaluating is that they want the experience to be fun and pleasant for the participants, and that they don't want to control the users in this process. I agree with this goal because I think that the result of an evaluation will be far more interesting, and perhaps even surprising, if you avoid restraining the participants by giving them too many instructions which might stifle them.

6. Discussion

Since I didn't have the opportunity to try out the framework presented in section 4.3.2.4 by using it to evaluate Sonic City, I put more effort into exploring different evaluation methods and their applicability in regards to new types of interaction such as context-aware computing. I also conducted interviews with Lalya Gaye and Ramia Mazé (see section 4.1) with the

purpose of finding out how much they had thought about the cognitive aspects of using Sonic City and how to evaluate the system, and then compare their thoughts and beliefs on these matters with my own.

In practice, the only thing I had any problems with in working on this paper was finding relevant and beneficial information concerning the nature of Sonic City, especially information on context-aware computing and how to evaluate the new kind of interaction that the use of Sonic City might result in. My goal was to primarily use books or other authenticated written material as references, but since some of the information I found indispensable for the work on this paper is available only through the internet, some of the references direct to academic papers that originates either from a conference, curriculum or university.

If I would be given the chance to write this paper all over again, there are some issues that I would have wanted to investigate further:

- The idea of broadening the scope of evaluation presented in section 2.3.4 (Evaluation methods for new types of interaction) is an interesting and unexplored way of involving other people than the users in the evaluation process which I would have liked to have seen the results of.
- Since I considered interviewing to be an appropriate evaluation method for obtaining the user's subjective opinions and perceptions (see section 4.3.2.2 Considering evaluation methods involving users), I would have liked to study specific interviewing techniques to a larger extent to better learn how to create an enjoyable interviewing situation where the person interviewed feels comfortable sharing his/her feelings and emotions.
- Apart from the questions stated in section 4.3.1 (What to evaluate), it would also have been interesting to evaluate issues such as whether the users feel that they have control over the music-creation and whether they recognise the system as a sort of musical instrument or not.
- As opposed to soundscape composition, Sonic City also exploits the movements of the user, and not only the changes in the environment, when creating music. Using movements as a way of interacting is known as *gestural interaction*, which is a topic that I would have wanted to explore in order to get a better understanding of how it can affect the user's cognitive behavour.

Hopefully, the conclusions made in this paper will be of use to the people involved in evaluating Sonic City once a sufficiently robust prototype is built, and I also believe that the results I've come to in this paper might also be of use to other work in related areas such as other research made on context-aware computing and the use of computers in creative purposes, as well as sonic interfaces and evaluation of new ways of interaction between humans and computers.

7. Conclusion

In this paper, my purpose has been to observe and analyse Sonic City from a cognitive science point of view, and regarding the role that cognitive science plays in this situation I would say that it is an important one. Cognitive science can provide useful information both when designing and developing a system as well as when evaluating it, the main purpose of this is to take advantage of previous research so that you don't have to make the same mistakes as the people before you.

When it comes to new types of interaction such as context-aware computing, not a lot of research has been done on how to evaluate systems of this kind, but I still believe that you can benefit from work made within cognitive science concerning evaluation even if you might have to alter it to better suit the system you want to evaluate. Even though people's interaction with technology may have changed radically over the last couple of years, peoples cognitive limitations and resources haven't by far changed to the same extend, and thus the research made within the field of cognitive psychology still holds.

To find out how new kinds of interaction with technology might affect the users' cognitive processes you must evaluate how the users react to the situation of using the system, and how they utilise the different properties of the system. The evaluation technique I find best suited for evaluating how Sonic City affects the users' cognitive behaviour is a combination between observations and interviews, to be able to discover changes in both perception and behaviour with the users. Aspects that are important to take into consideration when deciding which evaluation technique to use are the nature of the system to be evaluated, what different questions you want answered by the evaluation and the cognitive resources of both the participants and the test-administrators.

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