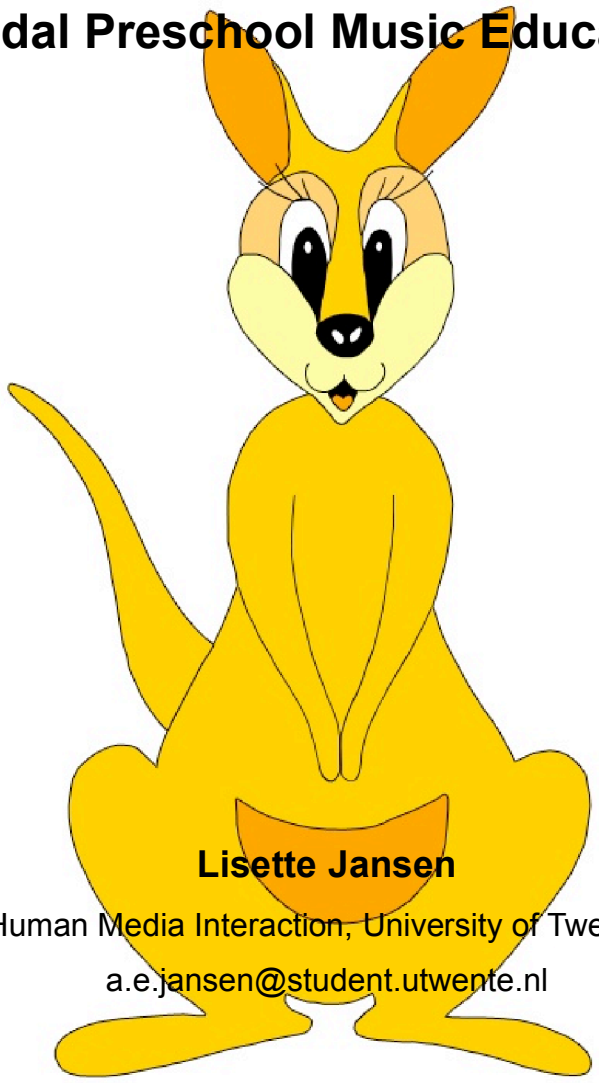
Panze

A Multimodal Preschool Music Education System



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Abstract

This Master's thesis describes a design research project in which an interactive computer system was designed that envisions to contribute to the musical education of children aged two and three years old. The intent was to stimulate the child's inherent musical abilities through active musical interaction with the system. Requirements for the system were formulated based on literature about general child development, human-computer interaction, interaction design & children and Dutch preschool music education. Interactions between children and adults in a Dutch preschool music education method were used as examples for the interaction between the child and the system. The result of the project is the Panze system. It makes use of a pedagogical agent (Panze) that acts as a role model for the child. The child can interact with the system by responding to the music by movement and singing, and by using tangible objects. A Wizard of Oz experiment was done to evaluate the design.

“It's not that children are little scientists,
but that scientists are big children.”

(Gopnik, Meltzoff and Kuhl, 2001, p9)

Preface

In the search for a topic for my computer science graduation project, I was inspired by two personal interests, namely music and children. When I came in touch with a Dutch preschool music education teacher, the idea arose to design a computer system that could contribute to preschoolers' musical education. This teacher, José Retra, became the external supervisor of this project.

My supervisors from the Human-Media Interaction group of the University of Twente were Betsy van Dijk and Anton Nijholt. With their technical background, they had an entirely different point of view than José with her social science background. Furthermore, Betsy was more concerned about Human Factors, while Anton was more interested in the used technology and animated agents. These differences in backgrounds made writing this report an interesting challenge.

Acknowledgements

First of all, I would like to thank my nephews. Carst Meinen for being my main source of inspiration and for thinking up the name of Panze. Tobian Meinen for showing his wonderful infant reactions to music.

Secondly, I would like to thank the following people. The children in the MoL lessons that I observed. Koen Blom and Lennart Boot for putting so much time and effort in the programming of the prototype application and for helping with the tests, without their help, the Wizard of Oz evaluation would not have been possible. Erik Jansen for playing the guitar tracks for the prototype application. Dineke van Aalst for her support during my project and for giving me the opportunity to conduct a pilot test in her home. Dineke's very enthusiastic daughters Mara and Lea for participating in the pilot test. Rita Zeephat, Ine Buigers of pre-school “de Bolleboos” and Eta Steenbergen from pre-school “Pippeloentje”, for giving me the opportunity to conduct the Wizard of Oz test and for the communication about the test to the parents. And of course all children that participated in this test.

And finally I would like to thank my supervisors. Betsy van Dijk, my main supervisor, for her time, help, support and enthusiasm. José Retra for her dedicated supervision, for the insights she gave me into the world of social sciences, for her help with the music for the prototype application, and for our lengthy pleasant conversations over cups of hot chocolate and café delicieux. And of course Anton Nijholt who made it possible that Koen and Lennart could build the Wizard of Oz prototype application.

Contents

1 Introduction

1.1 Motivation

Musical skills can give people, both children and adults, a lot of joy during their lives, for making music and listening to music can be a pleasant activity. There are also indications that the development of musical skills helps children with their general development (Chen-Hafteck, 2004; Hodges, 2002; Young, 2003). These are reasons why it is worthwhile making an effort to contribute to young children's musical abilities.

In this project, an interactive computer system was designed that envisions to stimulate the development of young children's musical abilities through musical interaction with the system. The system is called the 'Panze system'. It consists of a physical input device (called the 'input kangaroo'), that is attached to a television set. At the television screen, the virtual kangaroo called Panze is visible. Panze sings songs and makes movements to the music. A child can interact with the system by singing and moving along with the music and by inserting tangible objects into the pouch of the input kangaroo. Figure 1.1 shows the 'Wizard of Oz' prototype of the Panze system (as described in Chapter 8).

Figure 1.1.WoZ prototype of the Panze system

This Master's thesis reports about the design process of the Panze system. In the Chapters 2, 3 and 4 the theoretical basis of the Panze system is given. The design choices that were made are explained in the Chapters 5 and 6. The conceptual design of the system is described in Chapter 7. Chapter 8 describes the results of a Wizard of Oz test with a prototype of the system. Conclusions, suggestion for further research, and a reflection on the project are given in the final Chapters.

Musical Opportunities in Early Childhood

All children are born with musical abilities (Chen-Hafteck, 2004; Hodges, 2002; Young, 2003). From birth on, babies respond to sounds (Hodges, 2002) and they communicate in a musical way with their caregivers (Young, 2003). According to Young (2003, p14) “it is the experiences and opportunities children receive as they move through

childhood which are the prime influences in determining how competent in music they become, not genetic inheritance." Also according to Chen-Hafteck (2004, p6) the musical abilities of young children have great potential which will be developed if young children "were given the appropriate environment for musical abilities to thrive". Chen-Hafteck believes that it is important to educate children in music during early childhood, because in this period all musical capabilities are readily available and if their intuitive musical responses are not encouraged and developed, they will fade and will be hard to recover on a later age. Regarding this, it is important to start with music education in early childhood. Therefore children in early childhood have been chosen as the intended user group to design for in this project.

Musical Interaction to Contribute to Musical Development

"Musical interactions where the baby is an active participant" can, according to Hodges (2002), be beneficial for the development of the child's brain to make it better equipped for the processing of music. Unfortunately in today's society many parents feel they do not have the time or the skills to musically interact with their children (Young, 2003). To contribute to young children's musical development, in this project an interactive computer system was designed to provide an alternative for musical interactions between parent and child. It has the aim to make the child an active participant in musical interactions between the child and the system.

The system was designed for use at home and for use by the child alone, without help from others. So the parents need time nor skills to let their child benefit from the system. For children a system for use at home has the advantage that they have free access to the system and can play with it whenever they want to (unless their parents tell them otherwise). This form of preschool music education is relatively new, because normally preschool music education involves the parents and/or a real life teacher and typically takes place in groups and outside the home.

Music for young children involves singing and moving (see Chapter 3). Working with a computer mouse and keyboard are unnecessary for this type of music making. In addition, children in early childhood cannot read yet, so textual in- and output are not appropriate. Therefore the interaction between the child and the computer was chosen to take place without the traditional mouse and keyboard input and textual output, but with movement and singing input, and musical output. An additional advantage of these interaction styles is that they do not have the hazards of traditional desktop computer use, like "repetitive strain injury, carpal tunnel damage, [...] the encouragement of sedentary behavior and obesity" (Siraj-Blatchford and Whitebread, 2003).

Target Age Group

The specific age group that was chosen for this project consists of children aged two and three years. Children under four were chosen because they are not yet attending primary school. In the Netherlands children go to primary school at the age of four. This is a major change in their lives. At this time their social environment changes and their daily routines change. Before children attend primary school they may spend more time playing at home, which gives them more opportunities to benefit from a music educational computer system at home.

The minimum age of two was chosen because children of this age are assumed to have the following abilities that are necessary for the intended interaction between the child and the system. First, for effective interaction it is crucial that the user understands that it's own behavior influences the reactions of the system. Children may be able to discover this from the age of eighteen months (see Section 3.4). Second, compared to one-year-old children who begin to be able to play vocally with musical patterns they hear, two-year-olds have an increased ability to take 'characteristic bits' of familiar songs, and sing longer phrases (see Section 3.3). Therefore, detection by a computer system of whether a child sings along, will be easier with two-year-olds than with younger children. Finally, large movements are easier to detect by a computer system than small movements. Because in general two-year-olds can walk, they are better able to make large movements to the music than younger children (see Section 3.2).

As all children differ in their rate of development, an unequivocal age at which children have the necessary abilities cannot be given. To be on the safe side, the minimum age of two years was chosen to be more sure that the users have the abilities necessary for interacting with the system.

1.2 Objectives

The objective of this research project is the design of an interactive music system for two and three-year-old children, with the intent to stimulate the child's inherent musical abilities through the interaction with the system. The system is preferably to be used in a home environment by one child at a time, without the help from adults or peers. The aim is that musical interaction between the child and the system will take place. The system should present its musical output in a way that evokes musical responses of the child. Musical responses are movements and sounds made by the child, like singing, dancing, stamping and clapping with the hands or clapping on the body. Multiple input modalities are used to detect the musical responses of the child. The system adjusts its output according to the detected musical responses. By making the child an active participant in the musical

interaction, the system will hopefully contribute to the child's musical development.

Literature about general child development, human-computer interaction, interaction design & children and Dutch preschool music education has been used to answer the following research questions:

RQ1: What are the requirements for an interactive music educational system for two and three-year-old children?

RQ2: What musical interactions between child and adult that stimulate the child's musical abilities can be used as an example for the system?

RQ3: What interaction styles are eligible for natural musical interaction between the child and the system?

Based on the answers to these questions, the system was designed.

1.3 Approach

In her article “The Researcher's Role in the Design of Children's Media and Technology”, Lieberman (1999) outlines an approach to media development for children. She gives a clear view about what researchers could mean to a design team. Because research is the main part of this design research project, the article is considered an appropriate guideline for this project. Lieberman (1999, p74-75) specifies seven phases of product development. For this small scale research project, five of them are relevant:

- “specifying the product concepts and goals”,
- “designing the product”,
- “testing and revising during production”,
- “measuring outcomes”, and
- “publishing and presenting outcomes”.

The other phases are “funding the project” and “helping team members keep up with the field”. These are considered not relevant for this project because typically a graduation project does not need funding, and this project is carried out by only one person, not by a team.

Lieberman's phases are similar to general phases of interaction design. For example Preece, Rogers and Sharp (2002, p12) define four basic activities involved in the process of interaction design:

- “identifying needs and establishing requirements”,
- “developing alternative designs that meet those requirements”,
- “building interactive versions of the designs so that they can be communicated and assessed”, and
- “evaluating what is being built throughout the process”.

For time reasons it was not possible to develop and build several designs within this graduation project.

By combining this literature from Lieberman and Preece, Rogers and Sharp, it was decided to take the following approach:

- specifying the product concepts and goals,
- designing the musical child-computer interaction system,
- evaluating the design, and
- publishing and presenting outcomes.

These design phases are explained below.

Specifying the Product Concepts and Goals

In the first phase of development, children's needs for learning are identified, and requirements for the system are established. From this, the system's concepts and goals are formulated. In this first phase, the first two research questions are answered.

The Chapters 2 and 3 together answer the first research question (what are the requirements for an interactive music educational system for two and three-year-old children?). The answer to this research question is based on research literature about general child development, interaction design & children, and early childhood music education. Chapter 2 explores children's needs for learning with interactive technology and for learning music. In Chapter 3 the focus is narrowed down to the abilities of two and three-year-old children that were taken into consideration for the design of the system.

Chapter 4 answers the second research question (what musical interactions between child and adult that stimulate the child's musical abilities can be used as an example for the system?). The answer is based on literature about how Dutch Preschool Music Education stimulates children's musical abilities.

The user profile and requirements for the system derived in the Chapters 2, 3 and 4 are used to identify the system's basic concepts and goals. These are described in Chapter 5.

Designing the Musical Child-Computer Interaction System

In the second phase of development, the conclusions of the Chapters 2 to 5 are used to design the system. In Chapter 6 several interaction styles are reviewed for their potential to enable the desired natural musical interaction between the child and the system. This is used to answer the third research question (what interaction styles are eligible for natural musical interaction between the child and the system?). The design decisions made in Chapter 5 and the interaction styles chosen in Chapter 6 are combined to develop the Panze

system. In Chapter 7 the conceptual design of the system is given, in which its characters, interface, navigation, and other features are specifically described.

Evaluating the Design

In the third phase of development, the Panze system is evaluated by a 'Wizard of Oz' (WoZ) experiment. In this kind of experiment a prototype is used that is not fully functional. Children from the target age group interact with the prototype as if it is the working system, but in fact a human 'wizard' watches the children and controls the program from a distance. The WoZ prototype, the experiment and its results are described in Chapter 8.

Publishing and Presenting Outcomes

In the last phase of development the outcomes of this project are given. Chapter 9 describes the conclusions. Suggestions for improvement of the system and further research are given in Chapter 10. Finally, Chapter 11 gives a reflection on this project.

A poster presentation of the results of this research project was held in June 2006 at the conference Interaction Design and Children (IDC2006) in Tampere, Finland. A short paper was published in the conference proceedings (Jansen, van Dijk and Retra, 2006, see Appendix 8).

1.4 Reading Suggestions

This Master's thesis describes the whole development process of the Panze system. For people who plan not to read the whole thesis, here are some reading suggestions. Those who are interested in the theoretical basis of the system, should read the Chapters 2 to 5. People interested in the technical aspects of the system can read the Chapters 6 and 7. To get an impression of how the designed musical interaction works in practice with children, the Chapters 8 and 9 are relevant. And those who are interested in possible future developments of this design, should take notice of Chapter 10 and 11.

2 Children's Needs for Learning

In this Chapter it is described what children need to have an optimal chance to learn. In the science of child development, different theories on how children learn exist (Berk, 2006). For this research project, it is assumed that children have an active role in their own learning. According to Druin and Solomon (1996) this is in accordance with the learning theories of both constructionism and constructivism. However, studies into the different learning theories fell outside the scope of this research project. From literature about children's needs and preferences in their use of interactive technology and from literature about early childhood music education, five main issues were derived:

- play and exploration,
- fun and enjoyment,
- control,
- multiple forms of interaction, and
- interaction with adults.

These main issues are explained in Section 2.1. The requirements that are derived from these main issues are summarized in Section 2.2.

2.1 Main Issues

Play and Exploration

Children are explorers by nature, they have a need to learn. According to Gopnik, Melzoff and Kuhl (2001), this originates from children's strong drive to understand the world around them. Children's play is fundamental for their learning, for by playing they have the chance to experiment and explore the world (Gopnik, Melzoff and Kuhl, 2001; Siraj-Blatchford and Whitebread, 2003). It is therefore, that Wyeth and Purchase (2003) write that “children learn by doing and […] they best construct knowledge in an environment that allows opportunities to explore and play”.

Children also learn about music through play and exploration. In Chapter 3 is described that from a very early age, children play and experiment with sounds. Play and exploration are important for children's musical development, because during play, children “are representing events and exploring materials in order to make better use of their expressive properties.” (Pound and Harrison, 2003, p38).

Fun and Enjoyment

Fun and enjoyment appear to be children's most important motivations for whether or

not they want to interact with an interactive product (Inkpen, 1997; Sim, MacFarlane and Horton, 2005; Read and MacFarlane, 2006). To let the users benefit from the Panze system, it is important that they are motivated to interact with the system. To accomplish this, interacting with the system should be fun and enjoyable.

Also for learning music, fun and enjoyment are important issues. Pound and Harrison (2003, p99) write about this:

> "All learning is enhanced by enjoyment. The chemistry in the brain when children are having fun promotes learning. A music-rich environment must place an emphasis on enjoyment and pleasure. It should be sufficiently safe and supportive for children to feel able to take risks and make mistakes" (Pound and Harrison, 2003, p99)

Control

Children need to be in control of the technology they use. This is twofold. Firstly, children *want* to be in control (Druin et al. 1999; Druin and Solomon, 1996). Thereby, being in control of their own learning is crucial to learn effectively (Siraj-Blatchford and Whitebread, 2003).

Hanna et al. (1999, p16) write that "a successful design gives children control of the computer environment and allows them to set the pace of the interaction" (see also Chapter 5). According to Druin et al. (1999), children have little patience when they are not quickly in control of the technology they use. To make them quickly in control, the system should be easy to learn. Then, "they will quickly become immersed in the experience." (Druin et al.,1999, p67). For the design of an educational system, this indicates that it is important that the child quickly understands the basics of the system. For when the child is not interested in the system, it will not start to join in the activities designed for stimulating the musical abilities, and the system will miss its aim.

Druin (Druin and Solomon, 1996) writes about control that children love repetition and are naturally curious, but only if they choose to do so themselves, not when they are told to by an adult. With respect to technology, this means that children want to choose themselves how to use the technology. A well designed interactive computer system can supply this need, because it can provide feedback, support and help to it's users. This makes children need less help from adults, which makes them feel more in control and more independent in their learning (Siraj-Blatchford and Whitebread, 2003).

Multiple Forms of Interaction

Multiple forms of interaction are important for technology for young children. According to Druin et al. (1999), children are more engaged in the technology when it offers different forms of interaction. They like technology in which they have a choice in the way they interact with it, and spend more time exploring technology when it offers many expressive tools, “like sound, visuals, movement and physical appearance” (Druin et al. 1999, p 65-67).

One form of interaction that seems especially suited for use with children, is the use of 'tangible objects'. These are physical objects, enhanced with technology. According to Revelle et al. (2005, p2051) “exploring and manipulating physical objects is a key component of young children's world and of their learning”. Wyeth and Purchase (2003, p94), who made tangible objects for children aged three to eight, state that “the fundamental implication for resource development is that children need something they can see, touch, hear and feel. It must make provisions for children who learn by directly interacting with their world.”

Music also comprises multiple forms of interaction. To start with, music can be made in various ways: by using the voice, by playing instruments (which are physical objects), or by making sounds with the body, like clapping or stepping. When interacting, one responds to the music that is made, either by singing or playing along or by moving to the music.

Interaction with Adults

Interaction with adults is an important issue for musical development. According to Young (2003) interaction with adults is important for children to view themselves as being musical. When children hear and see adults making music, they will absorb and imitate this. The other way round, if adults take children's spontaneous singing, playing instruments and dancing seriously, it gives children confidence in themselves as musical persons (Young, 2003; Pound and Harrison, 2003). So, children's musical behaviour can be further stimulated by examples and confirmation from adults. In this way, adults act as role models (Pound and Harrison, 2003).

Furthermore, according to Pound and Harrison (2003), adults are important because they are the ones that can create a 'musical atmosphere' for young children. This is an atmosphere in which fun and playfulness are emphasized, where children feel free and are supported and encouraged to experiment, explore, take intellectual risks, make choices and collaborate.

2.2 Conclusion

In this Chapter, five main issues for learning with interactive technology and for learning music were found: play and exploration, fun and enjoyment, control, multiple forms of interaction and interaction with adults. From these main issues, the following requirements were constructed.

1. A play environment that allows children to play and explore, aids their learning. In order to give children an optimal chance to learn from computer based music education, the system should provide the user with an interactive environment in which the user will learn about music by exploring and playing in this environment.
2. To accomplish motivation to interact with the system, and better learning it is important to incorporate fun and enjoyment in the system.
3. To let children enjoy the system, and to promote effective learning, it is important that the user quickly understands the basics of the interaction and feels in control of the system.
4. Active exploration of the system can be promoted by offering the users different forms of interaction. The users should have a choice in the way they interact with the system. Tangible objects will be one of the forms of interaction.
5. Adults can play an important role in the development of children's musical abilities by setting the examples and by taking children's music making seriously. The system has to provide an alternative for the role of adults, because the system is meant to provide children with the necessary musical interaction when their parents do not have the opportunity to do so. In the design a role model for the user has to be provided that has a similar effect.

In Chapter 5 these requirements are incorporated in the design of the Panze system.

3 General and Musical Abilities of the User Group that are Relevant for the Design

In this Chapter the abilities of two and three-year-old children that are relevant for the design of the Panze system are explored. Children aged two and three have very different abilities than adults. Their brains are still developing, and therefore also their motor control. They also have different vocal abilities. However, it is not true that young children are only less capable than adults. Young children have abilities that adults might have lost long ago, because they did not cultivate these abilities. Among these are musical abilities. The innate musical abilities that children have, need to be fostered in order to preserve them. This is what the Panze system aims to do.

The musical child-computer interaction of the Panze system has to be suitable for two and three-year-old children, and has to contribute to the development of their musical abilities. In order to achieve this, it is necessary to look at the musical abilities that children of this target age group usually have. These serve as a starting point for the design. From that starting point, the system has to provide the child with the right material to stimulate further development of these musical abilities (see Chapter 4). According to Langelaar (1980), the choice of the activities for preschool music education should be determined by the children's motor and vocal possibilities. For the musical abilities described in this Chapter, it is assumed that the children have heard music in their home environment, but have had no music lessons from professional teachers. Children's use of instruments will not be mentioned in this Chapter, because making music with musical instruments is not a goal of the Panze system.

The chosen age group of two and three-year-olds is very broad with respect to their abilities. This is largely due to the fast development of their brains. At birth, children's brains are far from fully grown, 75 per cent of the total development of the brains takes place after birth. This development proceeds very fast in the first years of life and has a great influence on children's abilities (Netelenbos, 1998). Consequently there are large differences between the abilities of children aged 24 months and children that are almost four years old. In addition, all children are different and also have some differences in their rate of development. Therefore an absolute definition of the user's abilities cannot be given, they will differ a lot between all users.

This Chapter starts with children's innate musical abilities in Section 3.1 and their early musical behavior in Section 3.2. Section 3.3 discusses children's movement abilities

with respect to music. Section 3.4 describes children's singing and vocal play. Abilities that are relevant for the control of computer systems are considered in Section 3.5. The Chapter is concluded with a user profile and requirements for the system in Section 3.6.

3.1 Innate Musical Abilities

This Section explores the innate musical abilities that all non-disabled children have at, or even before birth, for these provide the basis for further musical development.

Already before birth, a fetus in the womb can hear sounds from the outer world (Hodges, 2002; Berk, 2006; Young, 2003) and is able to react to these sounds (Hodges, 2002; Berk, 2006). In the womb, the unborn child will hear the music the mother hears, and so will already be familiar with music before it is born (Young, 2003). In addition, babies have a memory for music. Very young babies can recognize a recently heard melody (Chen-Hafteck, 2004). And newborns even seem to recognize sounds that they heard frequently during the later stages of pregnancy (Pound and Harrison, 2003; Young, 2003; Netelenbos, 1998).

Babies like to listen to music and seem to have musical preferences. According to Pound and Harrison (2003, p23) “songs with simple musical themes and a strong regular pulse” are their favorites. Many experiments have shown that babies are sensitive to many properties of sound, like pitch (Hodges, 2002; Chen-Hafteck, 2004; Young, 2003), rhythm (Chen-Hafteck, 2004), melodic contour and changes in tempo (Pound and Harrison, 2003).

When babies hear a sound, they can associate it with the object that made the sound (Pound and Harrison, 2003). When they hear a voice, they can turn their head to the source (Hodges, 2002). Babies can also communicate with their caregivers through music. They can express their emotions by vocalizing with variations and contours of pitch and are able to interpret the vocalizations of their caregivers. Other musical abilities that babies use in communication include timing well and matching rhythmically with others. (Young, 2003, p14).

As was said in Section 1.1, it is important to preserve young children's musical abilities, for else they will be lost. The longer children are deprived of musical education, the more they will lose their innate musical abilities. To make sure that children preserve their innate musical abilities, the musical interactions between them and their carers should continue after they have learned to talk. The earlier children get music education, the better. However, not the youngest children were chosen to be the target age group. Because, as was already mentioned in Section 1.1, children from age two are assumed to be able to understand that their own behavior influences the reactions of the system, and their moving and singing will be easier to detect by a computer system than the moving and singing of

younger children, children from age two were chosen as the intended user group. It is hoped that they still have many of their innate musical abilities at their disposal.

Considering that children naturally react to sounds and engage in musical communication as soon as they are born, all children who have had normal child-carer interaction in their first year, have once experienced musical interaction as was described in this Section. The Panze system is envisioned to connect to these experiences. Therefore it is hoped that the users quickly understand the musical interaction with the Panze system.

3.2 Early Musical Behavior

When children grow older, they stay interested in all kinds of sounds around them and they use music as a part of their general play (Young, 2003). For young children, “music is a multimodal experience” (Young, 2003, p103). This means that they experience music with all their senses. According to Langelaar (1980) preschoolers absorb a musical activity as a whole, including the lyrics, rhythm, melody, pitch and movements. Furthermore, music can occur in many ways, merged into many kinds of other activities. Young (2003) writes the following about toddlers (by toddlers, she means children from about one year up to about 2,5 years old).

> “Toddlers like to do all the things we call music and they do them of their own will, weaving them into their everyday play with the things and people around them. They spontaneously vocalise, sing, reproduce songs they have heard, play with words, dance, listen intently to sounds and music, respond to music played by others, find interesting sounds to make and organise their tapping or striking into regularities and patterns” (Young, 2003, p50).

In the previous Chapter it was found that multiple forms of interaction attracts children. The fact that music is a multimodal experience for children is an extra motivation to design the system in a way that its users have the opportunity to interact with the system by responding to the music in multiple musical ways.

Langelaar (1980) distinguishes three phases in which young children join musical activities led by others: observing, making movements and giving vocal responses. When they are offered a musical activity consisting of a song and movements, many children start with listening and looking to the performing person. Young (2003) observed that children as young as one year have the ability to listen focused and intently to music for a long time, especially if they see someone performing. After a number of repetitions (how many

repetitions depends on the child) the child will start to imitate the movements (Langelaar 1980). According to Chen-Hafteck (2004) and Langelaar (1980), making movements is children's primary reaction to music (see Section 3.3), vocal responses usually come later. Most children start singing a few words along only after very many repetitions of the song (Langelaar 1980). For the design of the system, provisions have to be made for all these three phases: the child should have the chance to observe without joining the interaction, and should have the options to interact by giving movement responses and by giving vocal responses.

3.3 Moving to Music

From the first year of life on, children respond to the sounds around them by movements, dances and gestures (Pound and Harrison, 2003). According to Chen-Hafteck (2004), movement to music is so natural for very young children that they respond with movement activities to music without encouragement. If there is enough space to move, children usually respond physically to recorded music (Young, 2003).

As the system has to give the user the option to interact by giving movement responses, it is necessary to look at the motor and movement competence of children in the target age group. Two and three-year-olds have lots of capabilities to move to music in many ways. But because of their rapid development, there are many differences in abilities between children aged 24 months and children that are almost four years old. As they grow older, children gain more control over their muscles. This will affect the number of different movements they make (Young, 2003), and the way they move to music. The system has to provide for the differing abilities of the children in the target age group.

Motor Abilities

The literature about children's motor development provided clues for the movements children will be able to make to music. From the second to the sixth year of life movement patterns like walking, running and jumping develop (Netelenbos, 1998), which makes children more able to make large movements to the music. As two-year-old children generally can walk and even show the minimal form of running (Netelenbos, 1998), it is assumed that the users can play with the system in a standing position. Walking gives them the ability to move freely through the space they have at their disposal. Two-year-olds can kick balls, stand on tip toes and jump with two feet together (Malley, 1991a). This might indicate that their standing is stable enough to be able to make movements like tapping or stamping with one foot while standing. With their hands, two-year-olds are able to make precise movements like throwing balls (Malley, 1991a) and catching them (Netelenbos,

1998).

Spontaneous Movement Responses to Music

To see in practice what movements children make to music, observations were made during three Dutch Preschool Music Education lessons (see Chapter 4 for a description of such lessons). Two of these were recorded on video. The observed children were aged two and three years. In these lessons, the following spontaneous movements from the children were observed:

- jumping,
- jump with the hands in the pockets,
- a movement between jumping and skipping,
- clapping,
- stamping,
- waving the arms,
- waving the arms and turn the torso,
- shake the hair,
- hands on the knees,
- lying on the back, 'cycling' with the legs,
- lying on the back and moving with the legs and the arms to and fro over the floor, and
- rolling over the floor.

Figure 3.1. Jumping

The children made these movements to the music without a direct example from the teacher or adults during the activity. Sometimes the movements the children made were very small, for example they may clap with moving their hands only a little distance from each other.

Eerola, Luck and Toiviainen (2006) also observed movements to music of children aged two to four in an experimental setting, without examples from adults. Based on the types of movement they made, they identified three groups of children: 'hoppers', 'circlers' and 'swayers'. “*Hoppers*, as the name implies, tended to hop or jump up and down to the music; *circlers*, meanwhile, tended to walk around in circles; and *swayers* generally kept their feet stationary, and swung their hips from side to side” (Eerola, Luck, Toiviainen, 2006).

Some of the movements described in this Section are used for the interaction between the user and the Panze system. In the evaluation of the system children were observed to see whether these movements are indeed appropriate for musical interaction (see Chapter 8).

Moving in Time to the Music

Besides knowing what movements children can make to the music, it is also

important to know how well children can move in time to the music. This is necessary to adapt the Panze system to the user's abilities. According to Pound and Harrison (2003), two-year-olds like clapping to express rhythm. Due to still developing motor control, their clapping may not be accurate. Usually this is not because of a lack of understanding, because even in the first year of life children demonstrate an inherent sense of rhythm (Pound and Harrison, 2003). The clapping will most likely become accurate when their motor skills develop by growing older and by training. Three-year-old children usually have enough motor control to engage in activities like marching in time to the music (Pound and Harrison, 2003). But motor control alone is not enough to move in time to the music. Tempo appears to be an important factor. Children under age four are able to synchronize their movements to the beat of the music, provided that the tempo of the music is close to their own preferred tempo (Eerola, Luck, Toiviainen, 2006; Flohr, 2005; Provasi and Bobin-Bègue, 2003). This preferred tempo, called 'spontaneous motor tempo' is a child's preferred rate of moving (walking, clapping, swaying, etc.), independent of music (Eerola, Luck, Toiviainen, 2006). Three-year-olds are slightly better in adjusting their movements to tempo changes than two-year-olds (Eerola, Luck, Toiviainen, 2006). For children aged five and below, Loong (as referred to in Flohr, 2005) found that their average tempo for walking or stepping is 132 beats per minute and for striking 141 beats per minute. Regarding this, the music that the Panze system offers to the child should have a tempo between 132 and 141 beats per minute, in order to give the child the opportunity to move in time to the music. In the next Chapter it is described that under the right conditions it is possible to teach preschoolers to match the beat accurately.

3.4 Vocal Play and Singing

As the system also has to give the user the option to interact by giving vocal responses (see Section 3.2), it will offer songs with which the user can sing along. To provide age-appropriate songs, it is necessary to look at the vocal capabilities of children in the target age group and their ability to sing along with songs.

Young children do not have the same physical abilities for singing as adults. First, their lungs are smaller, therefore they breath more frequently, they may not be able to sing long phrases and they sing softer than adults. Secondly, their vocal cords are immature, softer and shorter and they have less vocal control than adults have (Young, 2003). When children get older their vocal control and stamina increase.

Already in their first year, babies start making vocal music themselves. They babble,

play with vocal sounds (Pound and Harrison, 2003), and experiment with melody and intonation (Hodges, 2002). Through the years this process of vocal play continues. When children get older, the range of spontaneous music making increases (Pound and Harrison, 2002). Young (2003) writes the following about young children's vocalizations.

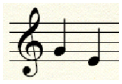
> “It is impossible to draw a dividing line between speech and singing with young children, for they vocalise with words, melodise, intone, chant, whoop and whizz their voices as a continuous sound track to their play. It is richly imaginative and expressive, texturising all they do. It intertwines language and music and blends with movement, play with objects and sociable play with others” (Young, 2003, p88)

While earlier the singing consisted of sliding between ambiguous pitches, in their second, or beginning of the third year of life children become able to sing discrete pitches (Hodges, 2002; Pound and Harrison, 2003). In their second year of life, children start to invent spontaneous songs in which they are exploring and practicing small intervals (an interval is a difference in pitch between two subsequent tones). At first these intervals are small, up to two tones, in musical terms: seconds, minor thirds and major thirds (Gardner, as cited in Pound and Harrison, 2003). Towards two and a half years of age, they will start to enlarge to three and four tones between the pitches (fourths and fifths) (Hodges, 2002).

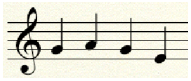
Spontaneous vocal play is the most prolific at the age of three (Young, 2003). But besides spontaneous singing, three-year-old children like to repeat familiar songs. That three-year-olds like singing, becomes apparent form the many ways they use their voice and play with songs. In their spontaneous vocal play they may, for example, sing long rhythmically free-flowing melody lines on open vowel sounds, chant short verbal phrases on simple melody lines as a kind of social call to others or vocalize to accompany their play (Young, 2003). They may also sing songs which they heard in their environment, for example with imitation of the style of performance, or they may make transformations and reworkings of songs (Young, 2003), possibly resulting in 'pot-pourries': spontaneous songs mixed up with parts of conventional songs. In these songs that may last up to several minutes, the child alters and mixes up the words, melodic lines and rhythms of known songs and combines them with its own invented songs (Pound and Harrison, 2003).

The spontaneous singing of young children (from baby's to preschoolers) often includes the following stereotype melody patterns (Langelaar, 1980):

- the basic motive: a melody consisting of only two pitches with a minor third interval (a two tone difference);



– the preschooler tune: the primitive melody with one added tone;



– the preschooler tune changing into speech.

To enable them to sing, the Panze system should provide its users with songs that are tailored to their abilities (Langelaar, 1980). Offering songs with small intervals and/or based on the stereotype melody patterns gives them the chance to practice with material that is appropriate for their age. Also, the songs offered by the Panze system need to be presented in a pitch-range that is appropriate for children. To make sure that all users can sing along, the songs should have a range between d  and b  , as recommended by Langelaar (1980).

As the Panze system will offer songs to evoke vocal responses from its user, it is important to know how capable two and three-year-olds are in singing along with known songs. Children aged one year begin to be able to play with songs or other musical patterns they hear around them and begin to sing 'characteristic bits' of known songs (Pound and Harrison, 2003). When they are two years old, the characteristic bits that they take of familiar songs consist of longer phrases. They often use these to accompany their activities (Pound and Harrison, 2003). From two and a half to three years of age, children extend their playing with familiar songs: they may sing multiple repetitions of characteristic bits or variations. In this way they accommodate to culturally-approved songs (Hodges, 2002). At the age of three, children have more vocal stamina and control than before. Therefore their spontaneous songs get longer and they may be able to reproduce whole songs with accurate overall contour (Hodges, 2002; Pound and Harrison, 2003) and rhythm (Pound and Harrison, 2003). However, it may take a little longer before they are able to sing the accurate pitches (Hodges, 2002). So with age, children's abilities to sing along with known songs increase.

3.5 Abilities for Control of the System

Handling Objects

In the previous Chapter it was found that tangible objects are especially suited for use with young children. Considering that these are to be used with the Panze system, age

appropriate tangibles should be designed that are tailored to the fine motor control children have of their hands.

Children's fine motor skills constantly increase until the age of four, due to developments in the brain (Netelenbos, 1998). This makes that children of almost four years old have a far better fine motor control than children aged 24 months. The fine movements that two year old children can make with their hands, are movements like taking things apart and putting them back together (Malley, 1991a). According to Netelenbos (1998, p70) the development of the brains makes an adequate fine motor control possible at the age of three. They now can handle small objects. They can, for instance, make puzzles (Malley, 1991b).

Several researchers looked into tangibles for children (see also the Chapters 2 and 6). Wyeth and Purchase (2003) enhanced LEGO®Duplo™Primo™ bricks with electronics and found that these worked well for children aged three to eight. This implicates that to design age appropriate tangible objects for use with technology, one could just look at toys that have proven to be age appropriate. In Section 6.6 is described how this was done for the Panze system.

Understanding

For effective interaction it is crucial that the user understands that its own behavior influences the reactions of the system. According to Gopnik, Meltzoff and Kuhl (2001, p77) babies aged 18 months “understand quite complicated things about how objects affect each other” and are able to systematically test objects. This may indicate that from the age of eighteen months, children are able to systematically test a computer system with a tangible user interface and discover that they can influence it by their own actions. Furthermore, before children are three years old, they can appropriately explain cause and effect (Gopnik, Meltzoff and Kuhl, 2001). Regarding these abilities, it is assumed that interacting with a computer system is possible for children aged two and three. This is one of the reasons that they were chosen as the target user group. In the evaluation of the Panze system, children will be observed to see whether they indeed understand the interaction between them and the system.

Speech

As speech recognition is often used for natural human-computer interaction, it was also considered for interaction with the Panze system. Speech recognition is recognition by the computer of human speech. Many children start talking at eighteen months and learn many words in a short time, so two-year-olds are assumed to be able to speak at least

separate words. Before the age of three, they are able to combine words into sentences (Gopnik, Meltzoff and Kuhl, 2001). This may indicate possibilities to use single words spoken by the user for natural interaction with the Panze system. However, Nicol (2004) found that commercial speech recognition systems that are not trained by the child, have a very poor recognition accuracy for speech of young children.

3.6 Conclusion

In this Chapter the abilities of two and three-year-old children that are relevant for the design of the Panze system were discussed. Although all children are different and develop at a different rate, for convenience reasons, within the scope of this research project, it is assumed that the children in the intended user group have the abilities as described in this Chapter.

It was seen that children of almost four years old have more developed motor and vocal abilities than children that are 24 months old. As this whole group is chosen to be the intended user group, the system has to be adapted to the minimal abilities of the youngest children in this age group. Yet it has to be challenging enough for older children with more developed abilities.

Children in the target user group have the ability to hear and have heard music before. They also have a memory for music. Therefore it is assumed that when the Panze system offers a song multiple times, after one or more repetitions they will be able to recognize it.

Young children are interested in all kinds of sounds, are sensitive to sound properties like pitch, rhythm, melodic contour and changes in tempo, they react to sounds and are able to find the source of a sound. Young children like music. They can listen to music focused and intently and use music in many ways in their general play. Through communication between baby and caregiver, they have experienced musical interaction before. So musical interaction will not be something strange to them.

Young children respond to music by movement, even without encouragement. They like to move to music in many ways. Therefore movement is chosen as an important form of interaction for the Panze system. The movement activities of the Panze system should be tailored to the children's abilities. As two and three-year-olds can stand and walk, they are able to play with the system in a standing position and to move freely through the space they have at their disposal. Their standing is probably stable enough to be able to tap and stamp with one foot to the beat of the music. They are also able to jump and to clap their hands.

And indeed, during observations, two and three-year-olds were seen jumping, clapping, stamping, waving, hopping, walking, rolling, swaying, etc. to the music.

The accuracy of moving in time to the music will vary between different children within the user group. They are better able to move in time to the music when the tempo of the music is close to their own preferred tempo. This gives a requirement for the songs that are used by the Panze system to evoke movement responses from it's users: the music should have a tempo between 132 and 141 beats per minute, in order to give the child the opportunity to move in time to the music.

Young children like to sing, therefore singing was chosen as another form of interaction for the Panze system. Two and three-year-olds are able to sing at least small intervals like seconds, minor thirds and major thirds, some may be able to sing bigger intervals. The parts of known songs that they are able to sing, vary between short phrases up to whole songs. This gives a few requirements for the songs that are used by the Panze system to evoke vocal responses from it's users, which should be tailored to their abilities: songs that are offered with the aim to let the child sing along, should exist of small intervals between the tones. Songs based on the stereotype melody types (the basic motive and the preschooler tune) can probably be sang along by all children in the intended user group. The songs should have a range between the tones d  and b  .

Besides children's musical abilities, in this Chapter some other abilities were explored to find possibilities for age appropriate interaction between the user and the Panze system. It was conceived that children aged two and three have the mental capabilities to interact with a computer system.

Apart from controlling the system by singing and movement, interaction with that Panze system will also take place with use of tangible objects. The fine motor control necessary for handling objects varies for children within the target user group. To design appropriate tangible objects it is good to look at toys that have proven to be age appropriate.

Control by speaking was considered not appropriate. Although children aged two and three can say at least separate words, their speech is not clear enough for speech recognition.

Based on the conclusions of this Chapter it was assumed that responding to music by movement and singing, and the use of tangible objects are appropriate forms of interaction for a music educational system for two and three-year-old children. Users who do not wish to

interact (yet), should also be given the option to observe the Panze system and its music without joining in the interaction.

4 Dutch Preschool Music Education: Music on the Lap

The abilities that are present at birth, have the potential to develop when children grow older. But for the abilities to develop well, stimulation from the environment is necessary during early childhood. In this Chapter a method is presented that envisions to stimulate preschooler's musical abilities: the Dutch Preschool Music Education method called 'Music on the Lap' (MoL). It is based on many years of expert pedagogical practice. Musical interaction between child and adult appeared to be important for learning (see Chapter 2). Therefore the musical interaction between child and adult as used in this method to stimulate the child's musical abilities has been chosen to be the example for the interaction design of the system. Making use of an existing method gives the advantage that the design of the new system can profit from the experiences and insights of experienced teachers. The MoL method was chosen because it shares its principles with the main issues of children's needs that were found in Chapter 2 (play and exploration, fun and enjoyment, control, multiple forms of interaction and interaction with adults).

The information about Dutch Preschool Music Education (PME) in this Chapter is derived from articles written by, and through communication with, a PME teacher and researcher, and from observations of MoL lessons from two different teachers.

In Section 4.1 a description of the MoL method is given with an explanation of how it incorporates the important issues found in the Chapter 2. Three musical developmental goals of the method were chosen to be used for the system. These goals, and the approach to achieve these goals, are described in Section 4.2. These approaches served as a guide for the interaction design. Section 4.3 gives the conclusion and additional requirements for the interaction design of the Panze system that are derived from this Chapter.

4.1 The Music on the Lap Method

The MoL method is suited for children aged four months to four years. For the courses, this relatively broad age group is divided into smaller age groups. The groups with the oldest children consist of two and three-year-olds. The children come together with a parent or caregiver to the lessons. The lessons are given by one teacher, in a large room where everyone can move freely. The weekly lessons take an average of 45 minutes. A regular course has 10 lessons.

Dutch PME acknowledges that **interaction with adults** is important in children's musical education, for in the MoL lessons adults play an important role. Each child in the group is accompanied by one parent or caregiver, who participates in the lessons. The teacher and parents or caregivers set the example in the activities and the children interact

musically with the adults. In the MoL method, the aim is that the children imitate the musical behavior of the adults and eventually internalize this behavior. They also have the opportunity to respond to the music in their own ways.

To provide the children with a familiar structure within all the lessons, they all start and end with the same opening and closure activities during the whole course. In these activities every child is addressed individually by the teacher, using a hand puppet. During all the lessons within one course the same hand puppet is used, to make the children become familiar with it. During the welcome activity each child is given the opportunity to say it's name and is given the chance to come to stroke the hand puppet. During the goodbye activity each child is again given the chance to stroke the hand puppet (see Figures 4.1 and 4.2).

Figure 4.1. Closure activity

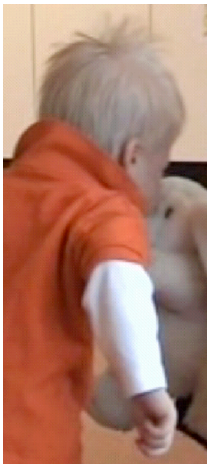


Figure 4.2. Kissing the hand puppet

In the lessons, including the welcome and goodbye songs, an average of ten to twelve activities are offered (Retra, 2005). For each age group the activities in the lessons are adapted to the abilities of the children. All activities offered in the lessons “are based on knowledge about the musical and general development of preschool children” and “are tailored to the needs and capabilities of the children” (Retra, 2005). In all activities the children have the choice to participate or not (Retra, 2006), which gives them **control** over the situation and their own learning. To motivate the children to join in, enjoyment in the offered activities is important (Retra 2005). The method thereby incorporates the important issue of **fun and enjoyment**.

Play and exploration is found in activities that incorporate guided experimentation time. “[This makes] it possible for the children to express their own musical intentions. The PME teacher should observe closely and answer the children musically in the same manner as their performances. This way the children themselves can initiate the movements and will find a confirmed response in the teacher's actions” (Retra, 2005).

In the activities **multiple forms of interaction** are used. An activity consists of a song accompanied by movements and often involves a musical instrument or a toy (Retra, 2006). These forms of interaction are exactly the ones that were found in the previous Chapters: singing and movement are natural musical activities of young children and

tangible objects are important in children's use of interactive technology.

Initially the songs are sung by the teacher and the other adults. During the course the children learn the songs and may eventually join in. Also the movements are made by the teacher and the adults. They actively involve the children in the movements and guide them to make the movements themselves. Movement is the most used form of interaction in the lessons. In the Dutch PME, movement is seen as an important aspect, because all aspects of sound can be experienced through movement. Also, by movement the child's internal rhythm can be synchronized to an external input (Retra, 2005).

4.2 Musical Developmental Goals

Dutch PME has six musical developmental goals. These are: “sense of [beat]: timing, reaction moment; sense of dynamics: loud and soft; sense of form: music versus no music (silence), variations; sense of tempo: fast and slow; voice formation: articulation, resonance; listening skills: attention, directing attention to a sound source” (Retra, 2005). For this project, three of these goals have been chosen:

1. sense of beat and timing,
2. sense of dynamics, and
3. listening skills.

These goals and their approach are explained below.

Sense of Beat and Timing

By sense of beat is meant that the child can feel and perform the beat of the music, for example by clapping or tapping. By timing is meant that the child can perform an action on a prescribed moment in an activity. The approaches for both are largely the same.

To develop a sense of beat in the children, the MoL teacher offers activities in which the children can, for example, tap or clap to the beat of the song. As was mentioned in Chapter 3, an appropriate tempo is an important condition to enable young children to move in time to the music. According to Retra (2006), two and three-year-old children are very well able to match the rhythm when the tempo of the activity is close to their natural tempo and when the child gets ample opportunities to practice.

To further the development of a sense of timing, activities are offered in which the child can perform a movement action on a prescribed moment in the music, called a timing moment. This moment is often announced in the lyrics. An example is an activity in which everyone walks through the room, until the lyrics of the song tell to “lift the leg”. At that

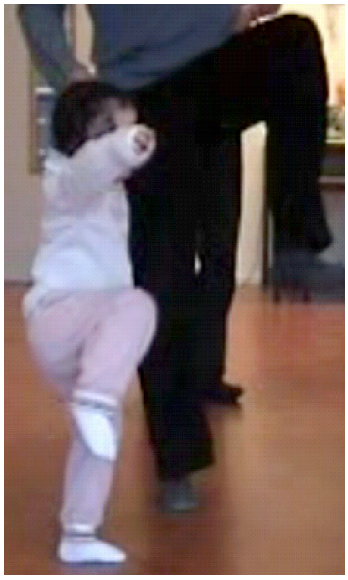


Figure 4.3. "Lift the leg"

moment the children are given the opportunity to lift their leg (Retra, 2006) (see Figure 4.3).

The songs used in the MoL lessons are short. This makes it easier for the children to remember the course of the activity and to "anticipate the right moment to clap, stamp, act" (Retra, 2005).

For both sense of beat and timing, repetition is an important condition. In the MoL lessons "songs are repeated at least 5 [successive] times to give children time to learn the song, to step into the movement and to synchronize their movements to the beat of the song" (Retra, 2005). At first the children imitate the adults, but when the song is repeated multiple times, they will eventually anticipate to the beat or the timing moment. Regarding this, a requirement for the system is that it provides multiple repetitions of the offered activities.

Before children reach the point at which they are able to match the beat accurately and to time well, there is a process of adapting to the beat and to the timing moments. During this adaptation process, the children's movement responses may be ahead of the beat or timing moment, delayed or well timed (Retra, 2005, 2006). However, direct and delayed responses are both musical responses and should be treated as such. Therefore a requirement for the system is that the user needs to get opportunities to respond with movements with varying accuracy. Direct as well as delayed musical responses need to be rewarded by the system.

Sense of Dynamics

By sense of dynamics is meant that the children understand the difference between loud and soft. For this purpose, activities are offered with different volumes: normal, loud and soft. The different volumes are supported by the lyrics and movements. Such activities are first offered with a normal volume. After a few repetitions, variations follow in which the volume, lyrics and movements are changed. In this way the children experience the differences in dynamics. For example, a song could be used that portrays movements of animals. In the low volume verse of the song, a mouse's small, light

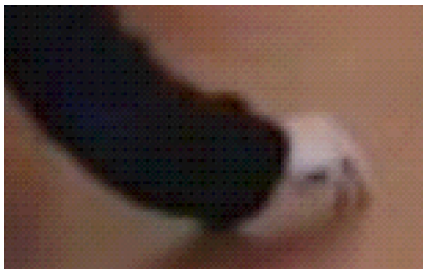


Figure 4.4. Mouse

Figure 4.5. Elephant

movements could be imitated (see Figure 4.4). In contrast, in the high volume verse of the song, an elephant's large, heavy movements could be imitated (see Figure 4.5). In the observed lessons given by one of the teachers (Retra), the low volume version of the song was always placed at the end of the activity to calm down the children after the high energy loud version of the song.

This approach to help children to develop their sense of dynamics was adopted in the design of the Panze system. In Chapter 7 is described how this was done.

Listening Skills

Listening skills include directing attention to a sound source. This is an innate ability (see Chapter 3) and is inherent to all music related activities. For example, to move to the music, one must listen to the beat of the music, and to be able to sing along, one must listen to the melody and the lyrics of the song.

The innate listening skills should be preserved, but can also be enhanced. For the Panze system, the goal 'listening skills' is refined to a specific listening skill: associating timbre with the corresponding musical instrument. The timbre of a musical instrument is the character of it's sound. In the MoL lessons, the children listen to the musical instrument that the teacher plays. Sometimes they play themselves with age appropriate musical instruments like a little drum or a little box containing a sound.

A computer system is perfectly suited to demonstrate instruments that the children can not play themselves. Therefore it was chosen that the Panze system offers it's users the sound and vision of different musical instruments. This will make the children familiar with how the instruments sound and what they look like. Hopefully this eventually leads to the ability to associate the timbre with the corresponding musical instrument.

4.3 Conclusion

The second research question, “What musical interaction between child and adult stimulates the child's musical abilities?”, can be answered based on the practices in the Music on the Lap method. In this Chapter it was seen that adults play an important role in the MoL lessons. The teacher offers activities, provides a familiar structure in the lessons, observes and answers the children's musical performances and gives the children the opportunity to listen to the instrument she plays. The parents and the teacher set the example for the children by singing and moving in the activities. By doing so, they function as a role model for the children. Furthermore, the parents actively involve the children in the movements and guide them in making the movements themselves.

It is impossible to make a computer system take over all these functions of the adults

in the MoL lessons. However, some of the roles of the teacher and the parents can be resembled. A computer system is perfectly able to offer activities, to provide a structure and to give the user the opportunity to listen to musical instruments. The role model that the adults are by giving the example in the activities, can be resembled by the use of a virtual agent, an animated character that is displayed on a screen and audible through loudspeakers. This concept is elaborated in Section 6.1. Observing and answering a child's musical performances is also possible to a certain extend: several methods exist to make computers detect human actions (see Chapter 6). These can be used to follow the musical performances of the system's user. The system can then answer these performances by giving its user rewards of some kind. This concept is also elaborated in Section 5.3.

In the previous Chapters it was found that multiple forms of interaction, in particular observing, moving, singing and playing with tangibles, are important. All of these forms of interaction are also used in the activities of the MoL method. Therefore these forms of interaction are used in the design of the system.

Within the very wide range of musical development, only a few developmental goals were chosen for the design of the Panze system. These are the goals 'sense of beat and timing', 'sense of dynamics' and 'listening skills'. The goal 'listening skills' is refined to the skill to associate timbre with the corresponding musical instrument. To achieve these goals, the Panze system has to offer activities with the following requirements.

- For a sense of beat and timing, a tempo requirement was already given in Chapter 3 (132 to 141 beats per minute). In this Chapter was seen that the system should provide repetitions of the activities, so that the user can slowly adapt to the beat. Short songs should be used to make it easier for the user to remember the course of the activity. Furthermore, direct as well as delayed musical responses need to be rewarded.
- For a sense of dynamics, songs should be offered that have different variations on a normal, low and high volume, with lyrics and movements that properly support the volume of the song.
- For the skill to associate timbre with the corresponding musical instrument, the Panze system should offer the sound and vision of different musical instruments.

5 Goals, Guidelines and Design Decisions

In the previous Chapters, information about the target age group and requirements for an interactive music system were gathered. Recall that the five important issues for children's learning about music are 'play and exploration', 'fun and enjoyment', 'control', 'multiple forms of interaction' and 'interaction with adults'. The conclusions from the previous Chapters were used to formulate the user experience goals and the usability goals for the Panze system. These are given in Section 5.1. In addition to this, general design principles and the user interface guidelines for children by Hanna et al. (1999) are consulted, these are given in Section 5.2. In the final Section is described how the Panze system was designed to meet the goals and the principles and guidelines.

5.1 System Goals

User Experience Goals

User experience goals describe how the users should feel about the interaction with the system (Preece, Rogers and Sharp, 2002). As in the previous Chapters it was found that children need fun and enjoyment to be motivated to join in, the user experience goals for the Panze system are fun and enjoyment.

Usability Goals

Usability is about whether an interactive product is usable from the user's perspective (Preece, Rogers and Sharp, 2002). In the case of the Panze system, the interactions that the children will have with the system, have to enable them to develop their musical abilities. Preece, Rogers and Sharp (2002, p14) break usability down into six goals:

- “effective to use (effectiveness)
- efficient to use (efficiency)
- safe to use (safety)
- have good utility (utility)
- easy to learn (learnability)
- easy to remember how to use (memorability)”

From the findings in the previous Chapters it is derived how each of these usability goals can be achieved for the Panze system.

The Panze system is **effective** to use when, by interacting musically with the system, the musical developmental goals are met. Recall from Chapter 4 that these goals are: 'sense

of beat and rhythm', 'sense of dynamics', and 'learning to associate timbre with the corresponding musical instruments'. The requirements for the activities that should be offered to meet these goals were given in Section 4.3.

Having good **utility** in the case of the Panze system means that the system has to provide an appropriate set of functions that enable children to have musical interaction in the way they want. Recall from Chapter 2 that children naturally want to play and explore the world around them, that they want control over the technology they use, and that they like to have multiple forms of interaction. For the system, this implicates three things.

- The user needs to be given the opportunity to play with the system and explore the system's reactions.
- To give the user control, the systems needs to respond to the user's actions.
- Multimodal interaction needs to be used. Multimodal interaction means that the users have different options (modalities) to interact with the system. The modalities that need to be used for the Panze system, are the ones that appeared to be important for music education in the Chapters 3 and 4: moving, singing and playing with tangibles.

The **learnability** of the Panze system is about how fast and easy a child can learn to play with the system. This is an important usability goal for the design, for the child should be able to use the system without the help of adults. In general, a rule of thumb is that novice adult users of a system should be able to learn it in less than ten minutes (Preece, Rogers and Sharp 2002). For children this time will probably be shorter. Therefore the interaction needs to be very intuitive. To make the interaction intuitive, it needs to be based on what children naturally do. In Chapter 2 it was found that children naturally play and explore and in Chapter 3 it was found that children naturally respond to music. Therefore the musical interaction between the child and the system needs to be based on play, exploration and responding to music.

Memorability means that when a child has played with the system once, it remembers how to play with it a second time, without having to rediscover how it works. As the Panze system is based on exploration, it is not a problem if things are not remembered, for the child can have the joy of discovering them again. Therefore memorability is not an important goal.

Efficiency means that children can reach their goals with minimal effort. When children are novice users of the system, probably their only goal is to explore the system. In

this stage efficiency is not important. When the children become more experienced users, they may know in advance what they want to do with the system. In that stage efficiency becomes important. It can be achieved by minimising the number of actions they have to perform to reach their goal and by making these actions as easy as possible.

By **safety** is meant the chance of making mistakes. As the Panze system is designed for use by the child itself without the help from adults or peers, safety is a very important usability goal. Situations in which the child needs help to overcome the problems that result from making mistakes or from software crashes, are undesirable. To make the Panze system safe to use, it is necessary to have appropriate hardware (see Section 6.2), very stable software and a program structure that promotes exploration and in which all possible actions are good ones, so that making mistakes is not possible.

5.2 Design Principles and Guidelines

General Design Principles

To support the usability of interactive products, many design principles have been formulated in the literature about human-computer interaction, for example by Nielsen, Norman, Shneiderman (all described in Preece, Rogers and Sharp, 2002) and Dix et al. (2004). These are general design principles, that are not targeted to a special user group. Some relevant design principles for the Panze system are described below.

In the previous subsection learnability was considered an important usability goal. Different design principles support learnability. All of the following principles will have to be incorporated in the Panze system.

Visibility and **feedback** are terms that are used differently by Nielsen and Norman, but they both mean that the user should be able to see what is going on: functions and controls should be visible, and feedback needs to be given about actions that have been done (Preece, Rogers and Sharp, 2002). Related to visibility and feedback is **responsiveness**. This means that a system should have a quick response time, so that the users can see that their actions have an effect in the system (Dix et al., 2004).

Some other design principles that support learnability are familiarity, predictability and affordance. **Familiarity** means that the knowledge that the users need for effective interaction with the system should correlate with the user's existing knowledge (Dix et al., 2004). **Affordance** means that the product should have attributes that make clear to the users how to use it. (Preece, Rogers and Sharp, 2002). **Predictability** means that, based on

the previous interactions, the user should be able to predict the behavior of future interactions (Dix et al., 2004).

Two design principles that are associated with the usability goal of safety, are error prevention and recoverability. **Error prevention** means that where possible, it should be prevented that errors occur (Preece, Rogers and Sharp, 2002). **Recoverability** means that when accidentally an error does occur, the user is able to recover from this error (Preece, Rogers and Sharp, 2002; Dix et al., 2004). As for the Panze system it was conceived that it is not acceptable that errors occur, recoverability was not included in the design of the Panze system.

Different design principles support flexibility towards the user's needs. As was said in Chapter 3, these needs will be different for different users. But also the same users will get different needs when they get more experience with the system. Important design principles for flexibility are multi-threading and dialog initiative. **Concurrent multi-threading** means that the user can perform several tasks at the same moment (Dix et al., 2004). In the Panze system, it is probably desirable that the user can move, sing and play with tangibles at the same time. **Dialog initiative** is about whether the user or the system is given the initiative in the interaction. User-driven interaction means that the user has the initiative in the interaction, as opposed to system-driven interaction, where the system has the initiative in the interaction (Dix et al., 2004). According to one of Shneiderman's golden rules of interface design, “users feel more comfortable if they feel in control of the interaction rather than the device being in control” (Preece, Rogers and Sharp, 2002, p266). This issue of control was already found in Chapter 2. As children like to have control over their own learning, the Panze system should have mainly user-driven interaction.

Guidelines for Interaction Design for Children

Hanna et al. (1999) give user interface design guidelines for children. These guidelines are divided into three areas: activity design, instruction design and screen layout design. The guidelines for activity design and instruction design are used as requirements for the Panze system. The screen layout design guidelines are about the use of the cursor and icons. As the mouse and icons are not used in the system, these screen layout guidelines are not useful for this design.

The guidelines by Hanna et al. for designing motivating activities are cited hereafter. Note that two of the important issues that were found in Chapter 2, 'play and exploration' and

'control', appear in the first two sentences of these guidelines.

> "**Activity Design**
>
> The best software, like the best play materials, should provide a tool that allows children to explore the world creatively, using their imaginations to manipulate and assimilate knowledge about the world around them. A successful design gives children control of the computer environment and allows them to set the pace of the interaction.
>
> *Design activities to be inherently interesting and challenging so children will want to play them for their own sake.* The best interactivity models realworld play scenarios that children are most interested in (e.g. for preschoolers, dress-up and fantasy role playing, construction play, drawing and coloring, action figure and doll play, etc.) and uses intuitive, logical, and familiar procedures for accomplishing activities. [...]
>
> *Design activities to allow for expanding complexity and support children as they move from one level to the next in use of the product.* Activities should begin with single-step interactivity, so children do not have to remember several steps in order to complete a problem. As children gain mastery of the activity, steps can slowly be added to increase the challenge and complexity. Support children in mastering the activity by supplying feedback that helps them learn new information. [...]
>
> *Design supportive reward structures that take children's developmental level and context of use into account.* The best method for motivating children to stick with a computer program may be designing intrinsically rewarding activities in which mastering a challenging problem is rewarding in itself [...] Rewards should be given consistently even when children repeat problems or activity levels they have done before. [...] Finally, humor in rewards should take into account the intellectual level of children in the target age range."
>
> (Hanna et al., 1999, p16-18)

The guidelines by Hanna et al. for how to let children benefit best from instructions, are relevant for the learnability. Note that here again the issue of control appears. Their guidelines for instruction design are the following.

> "**Instruction Design**
>
> *Present instructions in an age-appropriate format.* For example, avoid

on-screen text when designing products for young children. [...]

Design instructions to be easy to comprehend and remember. The language should be clear and simple without the use of concepts children have not yet learned. [...] Use on-screen characters that speak instructions. Children pay more attention to characters than to audio alone, [...].

On-screen character interventions should be supportive rather than distracting. [...]

Allow children to control access to instructional information. [...]"

(Hanna et al., 1999, p18-19)

5.3 Meeting the Goals

In this Section it is described how the Panze system will meet the goals formulated in Section 5.1 and will confirm to the design principles and the guidelines that were given in Section 5.2. The details of the design are given in the Chapters 6 and 7.

To meet the user experience goals fun and enjoyment, it was decided to give the system the form of a toy or game: something to play with, not something that just looks like a learning program. It is based on children's need to explore and their tendency to respond to music. Of course, the Panze system contains music to meet the musical developmental goals. But as in Chapter 3 was found that children like to listen to, to respond to, and to make music, it is hoped that the music of the system also provides fun and enjoyment for it's users and that the user will find the musical activities "inherently interesting and challenging", as advocated in the guidelines by Hanna et al. (1999, p16).

The design of the game is discovery-oriented, based on the exploration activities that children naturally perform. By playing with the system, the user can discover its functionality. Because of the very simple structure of the game, the reactions of the system are very predictable, and making mistakes is not possible. The system has a short response time to show the user immediately the effects of their actions. Only single-step interactivity is used: the responses from the system only require a single action from the child, not a sequence of different actions.

For familiarity, the Panze system tries to connect to the user's early experiences with musical interaction between them and their caregivers (see Section 3.1). Furthermore, the user can play with the system in the same way it plays with other toys and can respond to the system's music in the same way it responds to other music. Probably the user will do this without encouragement. Hopefully the familiarity aids in their understanding and the learnability of the musical interaction with the Panze system.

As was written in Section 4.3, the role models that the adults are in the MoL lessons, can be resembled by an animated character that is displayed on screen and audible through loudspeakers. In the Panze system several animated characters will appear. It is assumed that most children are familiar with characters on screen from cartoons and video games.

The main character is the pedagogical agent called Panze (see Figure 5.1). Panze was designed to offer activities to meet the musical developmental goals of 'sense of beat and timing' and 'sense of dynamics'. Like the teacher in the MoL lessons, she does this by singing songs and making movements in time to the music. It is envisioned that in this way, the system provides the user with an alternative role model. Because Panze acts as a role model by setting the example in the activities, she is supportive, as on-screen characters should be according to Hanna et al. (1999). As is the case in the MoL lessons, the aim is that the child will imitate the musical behaviour of the role model and eventually internalizes this behaviour.

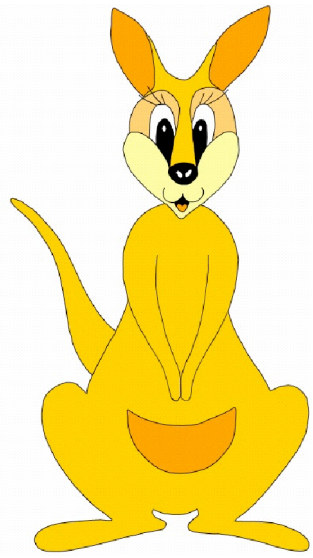


Figure 5.1. Panze

It was tried to keep Panze's communications purely musical, without normal speech. However, some users may need some encouragement to start exploring the system. Because according to the guidelines by Hanna et al. (1999) instructions should be given by an on-screen character, Panze will give some encouraging instructions. She does not tell the user what to do, but encourages the user to experiment with the controls of the system. She only speaks when there is no music, and so does not distract the child while making music. To make the instructions easy to comprehend and remember, Panze repeats the simple encouragements until the user has understood what it can do with the controls.

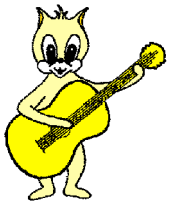


Figure 5.2. Guitar player

Other animated characters are instrumentalists playing instruments that are chosen by the user (see Figures 5.2, 5.3 and 5.4). They accompany the song that Panze sings. Playing an instrument is their only task. These instrumentalists were designed to learn the user to associate timbre with the corresponding musical instruments. The concept for the instrumentalists was chosen because Panze can not sing, move to the music and play instruments at the same time. The only interaction between the user and the instrumentalists is that they appear on screen and disappear from the screen when the user chooses so. Several instrumentalists can be present at the same time.

Figure 5.4. Whistle player

Figure 5.3. Xylophone player

The activities that are used in the Panze system resemble the activities in the MoL lessons. In Section 3.2 it was found that the phases in which young children join in musical activities led by others are first observing, then imitating the movements and finally singing along. As is the case in the activities in the MoL lessons, the Panze system provides for all three phases in every activity: there are no different activities for observing, moving or singing. The user can choose to do any of these during the same activity. The user has the opportunity to observe and listen to Panze without actively participating, to imitate Panze's movements to the music, and to sing along with Panze. Because the system provides for concurrent multi threading, the user can also choose to sing and move at the same time.

According to the guidelines of Hanna et al. (1999), the activities have to support and to allow for expanding complexity. This is incorporated in the design as follows: the user can itself expand the complexity of its interaction, by choosing to only observe, or to move along, or to sing along, or both. To support the users when they move into another phase of joining the activity, they are given different rewards for different interaction styles.

It is hoped that the users like the singing and dancing with a virtual character even without rewards. But to encourage and motivate the users when they imitate Panze, they will get rewards. These rewards are simple funny visual and sound effects, that hopefully do not distract the children from the music. These are hoped to have a similar effect as the adult's answering to the children's musical performances in a MoL lesson.

To give the user the opportunity to play with tangible objects as one form of interaction, the Panze system has a tangible user interface (TUI). This TUI gives the user control over the Panze system. It provides for user-driven interaction. With tangible objects the user can choose the activity that Panze offers, and the instrumentalists that play along with the activity. The users can play with the objects and explore their functionality. To give the user control, the system will not stop making music until the user tells it to, or until the user has left the system.

For good affordance of the system, the TUI was designed to look and function like a toy that is common for young children. Tangible objects that represent instruments have clear pictures of instruments that the user can recognize from the real world, as advocated in the guidelines by Hanna et al. (1999). For visibility and feedback, the choices that the user has made by using the tangible objects are always visible at the screen. The pictures shown on the screen are the same as the pictures on the tangible objects.

In the evaluation of the Panze system (see Chapter 8) children were observed to check whether they indeed view the system as being fun and enjoyable. The utility and

learnability goals of the system were also evaluated. The other usability goals could, because of time constraints, not be tested within the scope of this project. This is left to further research (see Chapter 10).

6 Natural Interaction

Natural interaction between human and computer means that the communication between them takes place in a way that is natural for humans. In the case of musical interaction for young children, in the previous Chapters movement, singing and tangibles were found to be natural interaction styles. Keyboard and mouse, for example, are not. Multimodal interaction refers to interactive technologies that use natural modalities of interaction and operate several communication channels in parallel. This makes the interaction even more natural, for humans also use different forms of communication in their interaction, for example verbal combined with non-verbal communication. As in Chapter 2 was found that active exploration of the system can be promoted by offering the users different forms of interaction and by giving them a choice in the way they interact with the system, multimodal interaction is considered perfectly suited for young children.

In the game industries, games with natural input modalities begin to appear. Some natural input modalities exist for use at home. Examples of these are speech recognition software, dancing mats, Sony's EyeToy® (Eyetoy, 2007), and Nintendo's Wii™ (Wii, 2007), some of which will be treated in Section 6.3. However, most multimodal systems are still found in research and art projects.

In this Chapter, the technology that is necessary for the implementation of the Panze system as described in the previous Chapter is explored. In Section 6.1 the choice of the animated characters is described. In Section 6.2 an appropriate system is proposed with the input modalities sound, movement and tangibles, and the output modalities sound and vision. The equipment that can be used for the detection of movement and sound is explored in paragraphs 6.3 and 6.4. In Section 6.5 an input device with all necessary equipment is designed. For time reasons, the animated characters, the equipment and the detection techniques need to be elaborated in further research (see Chapter 10). The final Section concludes with an overview of the elements and techniques that were chosen for the Panze system.

6.1 Animated Agents

The easiest and most low cost way to make characters that move to the music and play instruments, is to display animated characters on a screen. Animated agents are computer controlled characters with a virtual body, that interact with their environment.

Three examples of animated agents that move to the music or play instruments are the Virtual Rap Dancer (Reidsma et al., 2006), the Virtual Conductor (Bos et al., 2006) and

the Virtual Drummer (Kragtwijk, Nijholt and Zwiers, 2001). These are projects from the Human Media Interaction Group at the University of Twente in the Netherlands. The Virtual Rap Dancer is a character that dances to the beat of music and can interact with a human dancer. The Virtual Conductor is a character that can conduct human musicians. It reacts to the tempo and volume of the musicians. The Virtual Drummer is an animated virtual character that can play drums along with previously imported music.

Reeves and Nass (1996) showed that people, children as well as adults, react to media characters in the same way as to real people. They also interact with them in the same way. Not much is needed for a character to be perceived as a real personality. They don't even need to be visually present, they only need to have some human traits and a consistent personality. A consistent personality means that the different characteristics of the character need to form a consistent, believable whole. For example, a dominant character with a strong voice should not behave shy (Reeves and Nass, 1996).

Bartneck (2003) argues that the appearance of an embodied agent should match the characters abilities. Because limited technology makes that an agent can not do everything that the user expects from a human, an embodied agent can better have an animal appearance than a human appearance. People expect less of animals and are more willing to accept that the agent sometimes makes mistakes. Still, anthropomorphic animal agents are perceived as emotional, believable and human-like (Baylor, 2007b). In addition, Kim and Baylor (2007, p27) found that social interaction can even be achieved with animated agents whose “functionality and adaptability are limited”. According to Baylor (2007b), people prefer agents with a human voice over agents with a computer-generated voice.

Much research has been done into how embodied agents should behave to be most believable and effective (for example Baylor 2007a; Baylor 2007b; Kim and Baylor, 2007; Johnson, Rickel and Lester, 2000; Lester et al., 1997; Lester et al., 2000). Most of this research focuses on conversational skills and non-verbal communication during conversations. However, the aim of the Panze system is to make the users interact with Panze in a musical way, not by conversation. And although research about conversational skills and non-verbal communication could be used to make Panze a more believable role model, in this research project the focus is on the musical interaction. For time reasons, other communication skills are left out of the scope of this research project and are left for further research.

Pedagogical Agents

Animated agents can be used for educational purposes. Animated agents that are

designed to help people with learning, are called pedagogical agents. In the recently published special issue of the Educational Technology magazine about pedagogical agents, many examples of pedagogical agents are described (Educational Technology, 2007). The use of pedagogical agents in educational systems has several benefits. Firstly, pedagogical agents are able to “interactively present instructional or motivational messages in a human-like manner” (Baylor, 2007b, p12). They can also demonstrate physical actions (for example Rickel and Johnson, 2000), which make these easier to learn than when they are only described. Secondly, from several studies was found that animated agents can enhance learners attitudes, motivation and engagement (for example Kim and Baylor, 2007; Dehn and van Mulken, 2000; Lester et al., 1997). This is important, because in Chapter 2, fun and enjoyment were found to be beneficial for learning. For the long term, Lester et al. (1997, p359) suggest that, “by creating the illusion of life, the captivating presence of the agents can motivate students to interact more frequently with agent-based educational software. This in turn has the potential to produce significant cumulative increases in the quality of a child's education over periods of months and years.”

Panze differs from most pedagogical agents in two ways. Firstly, with most pedagogical agents, the verbal aspects are very important. However, with the Panze system these are not. An agent that resembles Panze's function more, is the reactive virtual trainer (Ruttkay et al., 2006). This is an animated agent that presents physical exercises to the user and monitors the user's imitation of these exercises. Secondly, pedagogical agents are mostly used to scaffold the learner. This means that the agent helps the learner where needed and gradually decreases the help when the learner learns to do it on it's own. Panze is a pedagogical agent, but she will not scaffold the learner, nor will she tell whether the user does something right or wrong, she is meant to be a role model that provides the example and will not stop singing or moving when the child can do it on it's own. This is like the adults in the MoL lessons, they also do not stop when the children can sing and move themselves, instead they enjoy making music and moving together.

The Character Panze

For the appearance of the animated agent Panze, the concept of the hand puppet is borrowed. Panze is a metaphor of a combination of the hand puppet and the role models that the teacher and the parents are. It will sing, dance and talk to the child. For the reasons mentioned before, it was chosen to make Panze not a human character. Instead, Panze became a cartoon kangaroo. As the hand puppets that are used in the MoL lessons

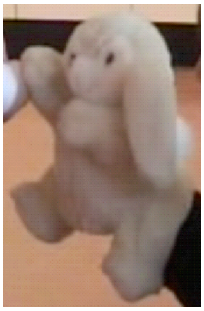


Figure 6.1. Hand puppet 'Bobo'

are usually adorable animals (see Figure 6.1), the aim was to make Panze an adorable animal as well.

A kangaroo was chosen because it has a pouch and large feet. The pouch can be used to put things in and out. The large feet can make Panze's tapping well visible for the users. As kangaroos are known to jump, Panze can jump to the music, the same as many children (the 'hoppers', see Section 3.3) will do spontaneously. Panze became a female, because male kangaroos do not have a pouch, and because the MoL teacher who was willing to sing and speak the voice of the prototype Panze is female.

Children as informants for the design of Panze

For the appearance and the name of Panze, children were used as informants (Druin, 2002). The name 'Panze' was invented by a three year old boy, who was asked to think of a name for a kangaroo that was drawn on the computer and could dance and sing very well. For the appearance of Panze, four drawings were made with different drawing styles and colors. It is common knowledge that children like primary colors and that characters with a large head look more like babies and are therefore more adorable. These were the features that were varied between the different drawings. The drawings were shown to four children in a MoL course.

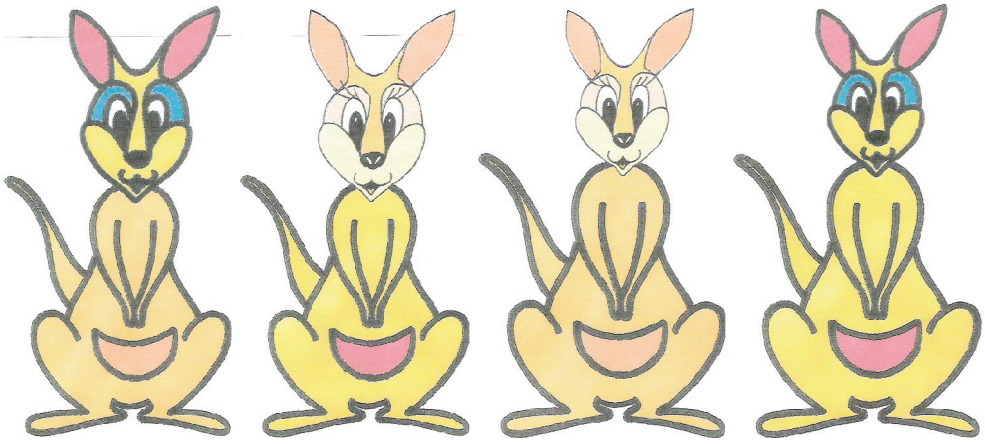


Figure 6.2. Kangaroo 1 *Figure 6.3. Kangaroo 2* *Figure 6.4. Kangaroo 3* *Figure 6.5. Kangaroo 4*

Kangaroo 1 (Figure 6.2) had an orange body and a large head in primary colors, drawn with thick lines. This kangaroo was chosen by one of the children. Kangaroo 2 (Figure 6.3) had a body in primary colors and a large head in orange, drawn with thin lines. This kangaroo was chosen by none of the children. Kangaroo 3 (Figure 6.4) had an orange body and a small head in orange, drawn with thin lines. This kangaroo was chosen by three of the children. Kangaroo 4 (Figure 6.5) had a body in primary colors and a small head in primary colors, drawn with thick lines. This kangaroo was chosen by none of the children. So all children chose the orange body, and most of them chose the combination with the small

orange head. Therefore, kangaroo 3 was used for the design. It is remarkable that this is the kangaroo with the most realistic colors and proportions.

6.2 System

The natural interaction styles movement, singing and using tangibles, and the pedagogical agent Panze, need to be united within a single system. Of course, to display Panze and the instrumentalists and to sound the music, a screen and speakers are needed. Furthermore the equipment that is necessary for the detection of movement and sound (see paragraphs 6.4 and 6.5) and tangibles need to be attached to the system. For inspiration how to do this, commercially available systems and other design research projects were looked at.

Examples for the Panze System

The following devices can be used at home and are commercially available, for example in toy stores.

- Dvd-kids® is a DVD controller designed for young children (Dvd-kids, 2007). The system is to be used with a television set and a DVD player. With the controller and special interactive DVDs, the child can play educational games. The DVD controller has a touch panel on which an activity card, belonging to the game, should be placed. As soon as an activity card is inserted into the controller, instructions appear on the TV screen.
- A dancing mat is a mat with embedded sensors that can be laid on the floor. It is divided into nine squares. Some of the squares contain sensors that trace on which squares the user is standing. A dancing mat can be connected to a game computer, PC or television. Usually, the mat is used in combination with music and software that shows on which squares the user should place the feet and checks whether the user does it right. A new sport called 'fitgames' appeared around the dancing mat (Fitgames, 2006).
- The Sony PlayStation2 uses a USB camera called the EyeToy® (Eyetoy, 2007) to track movements from the user to play games.
- The V.Smile™ TV Learning System (VTech, 2007) is a video game platform for children aged three to seven years. The system consists of a game console that is to be plugged into the television and large joystick with large colorful buttons.

There are several design research projects that combine animated agents with natural interaction. For example, Höysniemi and Hämäläinen (2005) designed a “full-body-interactive mixed-reality martial arts game” (Höysniemi and Hämäläinen, 2005, p2) with a multimodal user interface. It was originally designed for teenagers and adults, but also

children from age 2 enjoyed playing the game. In this game, the players can fight against virtual enemies. Their movements are tracked by camera's and their shouting - to empower their attacks - is detected by a microphone.

Another design by the same researchers is the “QuiQui's Giant Bounce game” (Höysniemi, Hämäläinen and Turkki, 2004). In this game children control the movements of a dragon character by their upper body movements and can make the character breath fire by using their voice. Höysniemi, Hämäläinen and Turkki claim that their game “is the world's first computer vision and hearing based action game that is based on child-centered design and research on children's physical development” (Höysniemi, Hämäläinen and Turkki, 2004, p2). For the detection they use a low-cost web camera and a microphone. The game runs on a Windows PC.

Also Johnson et al. (1999) designed a system that gives the user direct control over the movements of an animated agent. They designed a physical plush toy that is embedded with sensors. By manipulating the head and the limbs of the plush toy, the user can control the animated agent on the screen.

A system that makes use of a pedagogical agent and is, like the Panze system, based on an understanding of how children develop particular skills, is the Sam system (Cassell, 2007). The agent Sam is a “virtual peer” that aims to scaffold children in developing their literacy skills. The system consists of a life-size projection of Sam and a physical toy castle with several RFID tagged (see Section 6.5) figurines. In turns, the user(s) and Sam tell a story while playing with the small figurines in the castle, which can virtually be exchanged between the users and Sam.

The Virtual Rap Dancer (Reidsma et al., 2006), the Virtual Conductor (Bos et al., 2006) and the Reactive Virtual Trainer (Ruttkay et al., 2006) were already mentioned in the previous Section. The system of the Virtual Rap Dancer can detect the beat either from recorded music or from movements or sounds made by the user. The sounds from the user are detected through a microphone, the users' movements are detected through a video camera and a dancing mat. The system of the Virtual Conductor can detect the volume and the tempo of music made by human musicians, detected by a microphone. The system of the Reactive Virtual Trainer makes use of a “single, every-day camera” for optical motion tracking, and a microphone for the detection of acoustic signals.

System used for the Panze System

It was considered that a single device that contains the different input modalities would be the most suitable for the Panze system. This device should contain all necessary hardware and software, other than the screen and the loudspeakers. It should be tangible

and easy to use for two and three-year-old children. It should contain the motion and sound detection sensors and something to turn on the system. For this purpose, a tangible input device was especially designed for the Panze system (see Section 6.5). The motion tracking and sound detection technology that have to be integrated in this input device are described in the Sections 6.3 and 6.4.

The input device needs to be attached to a screen and loudspeakers. For the Panze system, a television set was considered the most appropriate, because almost every household has at least one television. Often, maybe after removal of a small table, there is sufficient space for a child to dance in front of a television. From the dvd-kids® system, the V.Smile™ TV Learning System and the dancing mats it was seen that this is possible and that people are apparently willing to buy such systems.

Other systems that were considered are PCs and game computers. A PC was considered not suitable for the purpose, because: (1) the keyboard and mouse need to be removed to prevent erroneous actions from the child, (2) a PC is less likely to be in a room where parents like their children to play, (3) parents may not like their two or three-year-olds to play with the PC without supervision, and (4) the set up of the PC workplace may not provide the user with sufficient space to move freely to the music. Game computers like the Xbox (Xbox, 2006) and the PlayStation2 (PlayStation, 2006) may be suitable for the purpose, but in most homes of preschoolers probably more television sets than game computers are present. And, more importantly, game computers are closed systems, which means that outsiders cannot write new applications for them.

6.3 Motion Tracking

Techniques used to detect an interpret human movements are called motion tracking, motion capture or gesture recognition. For the Panze system, these techniques are necessary to see whether the child imitates Panze's movements and whether it moves in time to the music. As children can use their whole body when they move to music, the interaction modality for movement can be called full-body interaction. From the observations described in Chapter 3, the parts of the body that were considered most important for the detection of the children's movements are the head, the hands, the hips, the knees and the feet. To gather data about the movements of these parts of the body, three options that were also mentioned in the descriptions of the systems in Section 6.2, were considered: computer vision, a dancing mat and wearables.

Detection of movement with use of a video camera is called vision based motion tracking or computer vision. For their virtual rap dancer, Reidsma et al. (2006) use a video

camera to recognize beats in hand and face movements from adults.

The advantage of the use of a camera is that is is unobtrusive. It does not limit the user in its movements. However, from personal communication with Reidsma it became apparent that it would be very hard to detect the small movements that children may make (see Figure 6.6).

Figure 6.6. Small ticking movements

Another problem with vision based detection is that important parts of the body like the hands and the feet are often not visible through the movements children make: like sitting on the knees, so that their feet are below them, putting their hands in their pockets, and turning around so that the hands are behind the body from the viewpoint of the camera. For these two reasons a video camera was considered not appropriate to detect all children's movements to music.

Dancing mats were already described in the previous Section. The advantages of dancing mats are that they are relatively cheap (from about €15,-) and that they are easy to install. However there are some major disadvantages for use with two and three-year-old children. In the observations in the MoL lessons (see Section 3.3), stepping forth and back and to the sides was not found to be an intuitive response to the music in the MoL lessons. Using the dancing mat may be too difficult for them. Moreover, it was seen that two and three-year-old children often roll over the floor and sit or lie on the ground while making movements to the music. This may cause erroneous detection by the dancing mat. Another disadvantage of the dancing mat is that not all squares are sensitive area's. If the user stands on non-sensitive area's of the mat, their movements are not detected. For these three reasons the dancing mat was considered not appropriate for movement detection of two and three-year-old children.

Wearables are devices that can be worn on the body. When the body moves, these devices move along. This offers possibilities for detection of the movements. Wearables

come in different forms. They can contain different kinds of sensors, or they can have colors or lights to help vision based motion tracking.

A motion capture suit is a suit with sensors that can track the movements of its wearer. However, for two and three-year-old children, making a fitting dancing suit is almost impossible, because children in the age range between 24 months and almost four years largely differ in height. A better alternative for children is to use bracelets, anklets and other bands with sensors to measure only the positions of important parts of the body.

Westeyn et al., (2003) used accelerometers worn on the body in addition to vision based motion capture. “The accelerometers will capture information that is difficult for the vision system to obtain, such as rotation (when the hand shape looks similar) and vertical movement in the direction of the camera. The camera will provide information not gathered by the accelerometers, such as hand shape and relative position” (Westeyn et al., 2003, p90). This combination of camera and accelerometers might also be valuable for the detection of the small movements and hidden parts of the body of the two and three-year-olds.

Wearables can also be provided with colors or reflectors to help detection with a camera. For example, Eerola, Luck and Toiviainen (2006) used a motion capture camera that can register the positions of reflective markers on the body (Qualisys, 2006) for a study to children's movements to music. With only one marker, attached to a headband, they were able to analyze periodicity of the children's movements. In the Panze system, a technique like this could be used to analyze whether the user moves in time to the music.

A disadvantage of wearables is that they may be too obtrusive. For the Panze system, the movements of the head, the hands, the hips, the knees and the feet have to be captured. This requires many wearables. During the observations of children in the MoL lessons, many children did not like to wear bracelets with bells. Also Eerola, Luck and Toiviainen (2006) reported that wearing more than one marker was distracting to many children. Furthermore, sensors for motion tracking easily break (Höysniemi, Hämäläinen and Turkki, 2004).

All considered movement detection methods have serious drawbacks: a video camera will likely perform not well enough to detect small movements; a dancing mat was considered not appropriate for the movements made by two and three-year-old children; and wearables may perform well, but may be too obtrusive for two and three-year-olds.

Further research is necessary to find the most suitable motion tracking method. Solutions may lie in a combination of the foregoing methods, or in improvements in video based motion capture, in more advanced dancing mats and/or in attractive non-obtrusive

wearables that are comfortable to wear and easy to put on and off.

From the gathered data, movement patterns need to be recognized. This can be done by using Hidden Markov models (HMMs) (Westeyn et al., 2003; Mäntyjärvi et al., 2004).

6.4 Sound Detection

For the goal 'sense of dynamics' the user should be given feedback about the dynamics of the sounds it produces. Furthermore, even though voice formation is not a goal of the system, it was considered that singing by the child is worth a reward. Therefore, sound detection to detect the child's singing is necessary.

Children's singing is usually soft (see Chapter 3). It is probably hard to detect the singing and distinguish it from other sounds including the sound of the system itself. To get a good signal, it should be considered to use a microphone array in combination with a method for tracking where the child is. With this combination, the sound produced by the user can be selected. Yang et al. (1998) used this setup to enhance their signal for speech recognition. In addition, the characteristics of children's voices (high pitched) can be used to make a filter that extracts other sounds. To give the user feedback about the dynamics, the sound detection should be combined with intensity detecting software.

Sound detection may also be useful to detect movements that produce sound, like clapping in the hands or stepping on the floor. This is also proposed by Ruttkay et al. (2006) for their Reactive Virtual Trainer. However, the sounds that children make may not always be loud enough for this. To detect even the soft clapping and stepping, sound detection should be combined with movement detection.

Concluding, for the sound detection, one or more microphones are needed in the design of the Panze system. Further research is necessary to find the best sound detection techniques.

6.5 Tangible Input Device

For the Panze system, it was chosen to use tangibles to give the user control over the system (see Section 5.3). With the tangibles the user will be able to turn on the system and to choose activities and instruments. Together with all other necessary hardware and software for the Panze system, the tangible user interface is incorporated in the input device attached to the television set.

Tangible User Interfaces

A 'Tangible User Interface' (TUI) is an interface in which digital information is coupled to physical objects (Ishii and Ullmer, 1997). These objects are referred to as 'tangibles'. In 1997, Ishii and Ullmer proposed TUIs as a means to conform human-computer interaction better to the multimodal way in which people interact with the real world, thus making it more intuitive.

The tangible objects can be equipped with 'Radio Frequency IDentification' (RFID) tags and readers. RFID tags are electronic labels with a microchip containing digital information. They can be read from a distance by an RFID reader. When the tag comes within the reach of the reader, it is activated by radio signals from the reader and sends its information to the reader.

Oh and Woo (2004) used RFID embedded tangible objects with pictures that gave the users information about the control functions of the objects. In their study they compared the use of their TUI to the use of a traditional desktop environment. They found that the TUI provided “an effective interface to those who are not familiar with keyboard or mouse” (Oh and Woo, 2004, p66). In their research these were people around age fifty. Although some children aged two and three may be familiar with keyboard and mouse, they are not very well able to use them (Revelle et al., 2005; Hourcade, 2006).

Fails et al. (2005) did a similar study with children aged four to six. The results of their study suggest that children are more interested and engaged and learn more when they play with a TUI, than when they play with a desktop environment. So also for young children a TUI is a better option than the traditional desktop interfaces with keyboard and mouse.

According to Revelle et al. (2005, p2051) “Embedding interactivity into physical objects [...] allows the “best of both worlds” - supporting traditional exploratory play with physical objects that can be extended and enhanced by the interactive power of digital technology”. So the important issue of 'play and exploration' can be met by a TUI. However, to engage children in the interaction, the interface should not only be tangible, its design has to suit the task (Marshall, Price and Rogers, 2003).

Several researchers successfully developed and tested TUIs for children. Wyeth and Purchase (2003) made electronic enhanced LEGO®Duplo™Primo™ bricks for children aged three to eight. They found that the children playing with the bricks had a “high level of enjoyment and engagement” and understood the functionality of the bricks. Price et al. (2003) designed a game with tangible objects for children aged 6 to 10 years old. Their findings were that “The combined use of physical artefacts and physical action means that

the children themselves become a central part of the activity (rather than just watching something evolve like in computer games), which has a quite different form of immersion and engagement. [...] The use of tangibles appeared to increase the children's propensity to explore and wonder, through the provision of unexpected events causing them to find out new or other ways of achieving their goals." (Price et al., 2003, p183)

Design of the Input Kangaroo

In Chapter 3 was concluded that to make age appropriate tangible objects for use with technology, one could look at toys that have proven to be age appropriate. This will enhance the affordance of the system. Examples of such toys are activity boards and boxes of blocks.

The input device was chosen to represent Panze, to make clear to the children that the tangibles had something to do with the character on screen. The device is called the 'input kangaroo'. For this input kangaroo, two paper prototypes were made. One was based on the concept of an activity board and the other was based on the concept of the Philips 'iCat' and a box of blocks.

The first paper prototype was based on the concept of an activity board. An activity board like the one depicted in Figure 6.7, is a common toy for young children. It is a board with buttons, slides, sounds and lights. The paper prototype based on this concept shows a board with the picture of a kangaroo (representing Panze), buttons and slides (see Figure 6.8). Slides with pictures of different instruments can be slided in or out of the pouch of the depicted kangaroo. Buttons with pictures represent songs. In the board are holes for a microphone and a camera. The advantage of this concept is that it prevents the loss of loose tangibles.

Figure 6.7. Activity Board (source: http://all4kids.ru)

Figure 6.8. Paper prototype based on activity board concept.

The second paper prototype was based on the concept of a box of blocks. In Figure 6.9 an example of a box of blocks is depicted. The blocks have different shapes. In the lid of the box are different holes through which the different blocks can be put in the box. The depicted box of blocks is advertised for children aged six months to three years.

Figure 6.9. Box of blocks (source: www.toysrus.com)

Figure 6.10. The Philips 'iCat' (source: van Breemen, 2005)

As a box of blocks has no interactivity, it was combined with the concept of the Philips 'ICat'. The Philips iCat is a robot user interface (see Figure 6.10). It has the head of a cat and is a 38 cm tall. The head position, eyes, eyelids, eyebrows and lips can be controlled for facial expressions. The iCat is equipped with a webcam, microphones, a loudspeaker, touch sensors, a proximity sensor and several LED's (van Breemen, 2005).

The paper prototype based on the concepts of the box of blocks and the Philips iCat shows a 3D kangaroo (representing Panze) with a large pouch and several loose tangibles (see Figure 6.11). There are two kinds of tangibles: there are tangibles in the form of CDs with a picture on it which represent songs, and tangibles in the form of instruments. These tangibles can be put into the pouch. In the head of the input kangaroo are holes for a microphone and a camera. The advantage of this concept is that, when it is covered with fabric, it looks and feels like a cuddly toy. This makes it more like the hand puppet from the MoL lessons and probably makes it more adorable and attractive to the user.

Figure 6.11. Paper prototype based on box of blocks and iCat

Because the prototype based on the box of blocks and the iCat is more special than an activity board like device, it was considered more interesting to research how two and three-year-olds would interact with such an input device. Therefore this last prototype was elaborated.

The tangibles will be referred to as the 'tangible CDs' and 'tangible instruments'. In the real product, the tangible CDs and instruments will be made of foam, because this was considered a nice and safe material for two and three-year-old children. They will be given RFID tags to make detection possible. In the game, several instrumentalists can be present at the same time, but Panze can only offer one activity at a time. Therefore it needs to be possible to have several tangible instruments in the pouch at a time, but only one tangible CD. To achieve this, The tangible instruments will be thicker than the tangible CDs, and different slots will be made: one for a CD and several for the instruments. This makes that the instruments do not fit in the slot for the CD. The input kangaroo will get a touch sensor and eyes that can be opened or closed. It will blink its eyes when a CD or instrument is inserted and when the child touches it.

6.6 Conclusion: The Elements of the Panze System

The Panze system will make use of multimodal interaction. This means that several modalities of natural interaction are used in parallel. The main aspect of the Panze system is the pedagogical agent named Panze, a virtual kangaroo. This musical pedagogical agent is accompanied by other agents that play instruments. These agents are shown on a TV screen. Attached to the TV set is a physical device that contains the input modalities. The input modalities that were chosen are motion tracking, sound detection and tangibles. In this Chapter only a small review was done to motion tracking and sound detection techniques. To detect the user's movements to the music, probably a combination of computer vision and wearables or dancing mat needs to be used. For the detection of singing, one or more microphones and intensity detecting software are needed. These may, in combination with motion tracking also detect sound-producing movements of the user.

The physical device containing the input modalities is called the 'input kangaroo'. It is a 3D kangaroo with a large pouch in which tangible CDs and instruments can be inserted. These tangible CDs and instruments will be embedded with RFID tags. The input kangaroo will be equipped with:

- eyes that can be opened and closed;
- the hardware and software necessary for the motion tracking;
- one or more **microphones** and intensity detecting software to detect singing of the child;
- a **touch sensor** to detect that the child touches the input kangaroo;
- an **RFID reader** to detect the tangible CDs and instruments when they are in the pouch;
- all other hard- and software necessary for the Panze system, except the screen and loudspeakers, for these are provided for in the television set.

In Figure. 6.12 the arrangement of the elements of the Panze system is represented in diagram form. For further development of the Panze system, the agents and the technology to be used that were mentioned in this Chapter have to be elaborated (see Chapter 10).

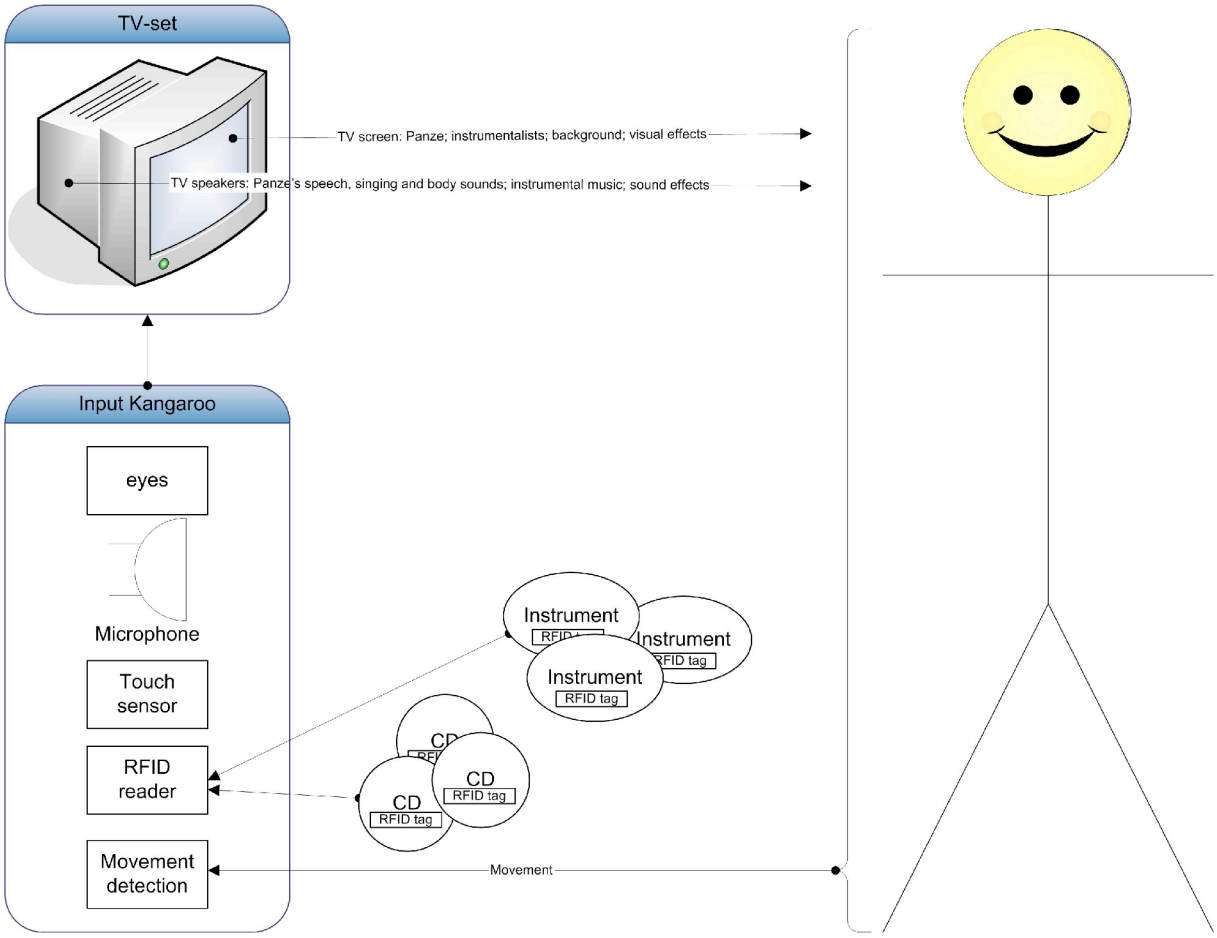


Figure 6.12. Elements of the Panze system

7 Conceptual Design

This Chapter describes the conceptual model of the Panze system. In Section 7.1 a scenario is given that shows the intended interaction between a child and the system. In Section 7.2 the dynamic model of the system is given.

7.1 Scenario

Imagine a three-year-old child, called Emma. She is at home, in the living room, where the input kangaroo is connected to the TV. Both the TV and the Panze system are standby. Emma touches the input kangaroo, this activates the system. The input kangaroo opens its eyes to indicate that the system is now switched on. On the TV-screen Panze appears and greets Emma. Panze sings a welcome song and tells Emma how to choose a song.

Emma is curious and wants to hear a song. There are several tangible foam 'CDs' with a picture on it that represent different songs. She takes the CD with a picture of a helicopter and inserts it into the pouch of the input kangaroo. At the screen a helicopter appears in the background and Panze starts to sing the song 'Helicopter'. Emma likes the song and sings along. She sees a funny effect on the screen. Panze repeats the song until Emma ejects the CD. Panze stops singing. Emma chooses another song, one about a windmill. She inserts the CD with a picture of a windmill. A windmill appears in the background and Panze sings the song.

While Panze sings the song, she also makes movements to the music. Panze repeats this again and again. At first, Emma only watches and listens. After a while she joins in the movements. However, for this first time, she moves not in time to the music. Emma is rewarded for imitating Panze by a visual effect: the sails of the windmill start turning.

After a few repetitions, Emma starts to move in time to the music. Besides the visual reward, she now also hears a sound effect. Emma enjoys herself and as she manages to move in time to the music for most of the time, Panze now starts to sing a variation to the lyrics of the song and changes the movements she makes. Again, when Emma imitates Panze, rewarding visual effects appear. And when she imitates Panze in time to the music, also rewarding sound effects are audible.

Emma also has several foam 'musical instruments'. She is interested in the guitar and puts it in the pouch of the input kangaroo. Behind Panze appears a virtual character that plays a guitar. Emma likes this and puts another instrument in the pouch of the input kangaroo, this time a xylophone. A second virtual character with a xylophone appears next to the guitar player. Together they accompany the song. But Emma does not like the xylophone

and takes the xylophone out of the pouch of the input kangaroo. The xylophone player disappears from the screen and only the guitar player is left.

By now Emma is tired. She stops moving to the music and starts playing with something else. Panze continues singing and making movements, but when the system detects no movement or sound from Emma for ten minutes, it switches automatically to standby.

7.2 Dynamic Model

In Figure 7.1 the basic dynamic model of the Panze system is depicted. The states *Wait* and *Activity* have sub states, these are depicted in Figures 7.3 and 7.4. The next Subsections describe the individual states and sub states.

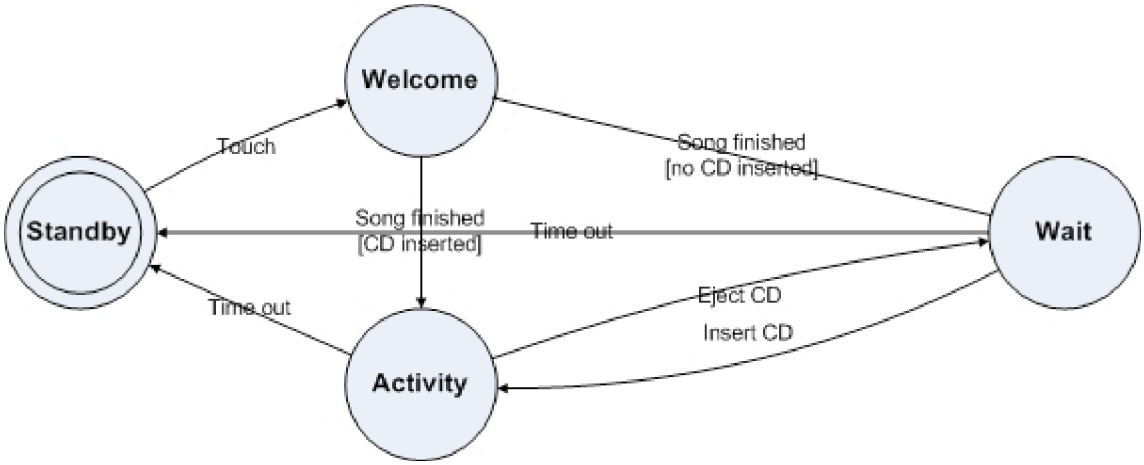


Figure 7.1. Basic dynamic model

Concurrent with the basic dynamic model is the dynamic model of the *Instruments*, depicted in Figure 7.2. Each instrument has its own state diagram. An instrument is either in or out the pouch of the input kangaroo. When an instrument is inserted or ejected, the input kangaroo blinks its eyes. In the states *Wait* and *Activity*, as soon as an instrument is inserted in the pouch, an instrumentalist playing the chosen instrument appears behind Panze on the screen. It disappears from the screen when the user takes the tangible instrument out of the pouch. If more instruments are in the pouch at the same time, the instrumentalists together form a band. In the state *Welcome* the instruments do not sound and do not appear on the screen.

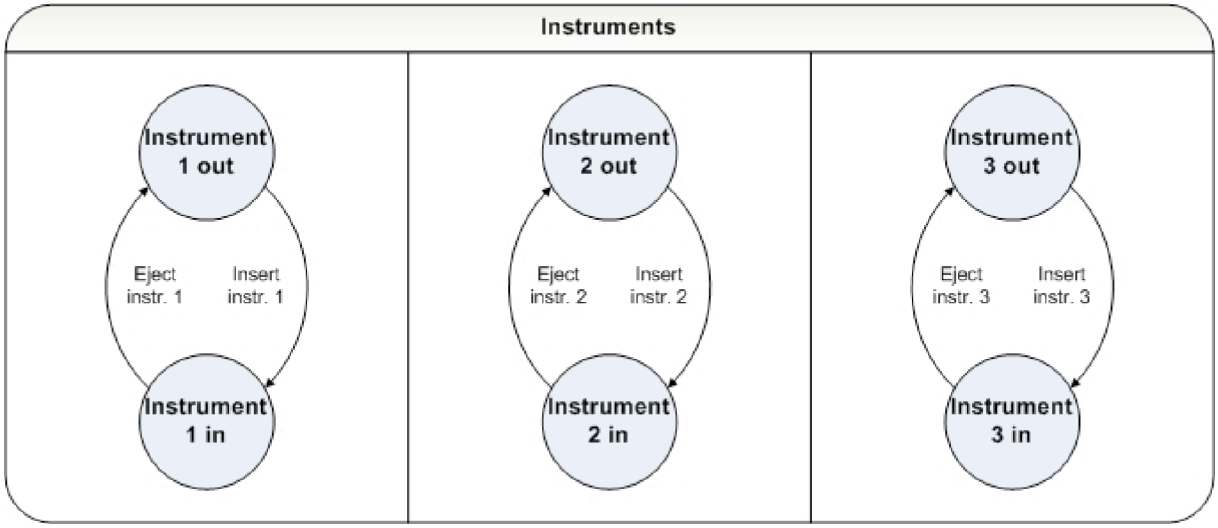


Figure 7.2. Dynamic model Instruments

Standby

When the system is standby, the eyes of the input kangaroo are closed and the TV is standby. When the user touches the input kangaroo, it opens its eyes and the system enters the state *Welcome*. In all other states, touching the input kangaroo only causes it to blink its eyes and has no other effects.

Welcome

eyes input kangaroo	open
Panze	sings Welcome song
Instrumentalists	none
Background	standard

When the system enters the state *Welcome*, the eyes of the input kangaroo are opened and Panze appears on the screen, she sings a welcome song. During the welcome song Panze does not make movements to the music and there will be no response to movement and singing of the child. No instrumentalists will appear when instruments are inserted in the pouch. The song is played once and cannot be interrupted.

After the welcome song has finished, the system enters the state *Activity* if there was a CD detected in the pouch, or it enters the state *Wait* if no CD was detected in the pouch.

Wait

When the system is in the state *Wait*, it waits for a CD to be inserted. When a CD is inserted, the input kangaroo blinks its eyes and the virtual Panze says the name of the song

that corresponds with the CD. If for a long time the system detects no activity from the child, it assumes that the child is not interested anymore. The input kangaroo closes its eyes and the system returns to S*tandby*.

The state *Wait* has three sub states: *Explain CD*, *Explain instrument*, and *Demonstrate instruments*. These are shown in Figure 7.3.

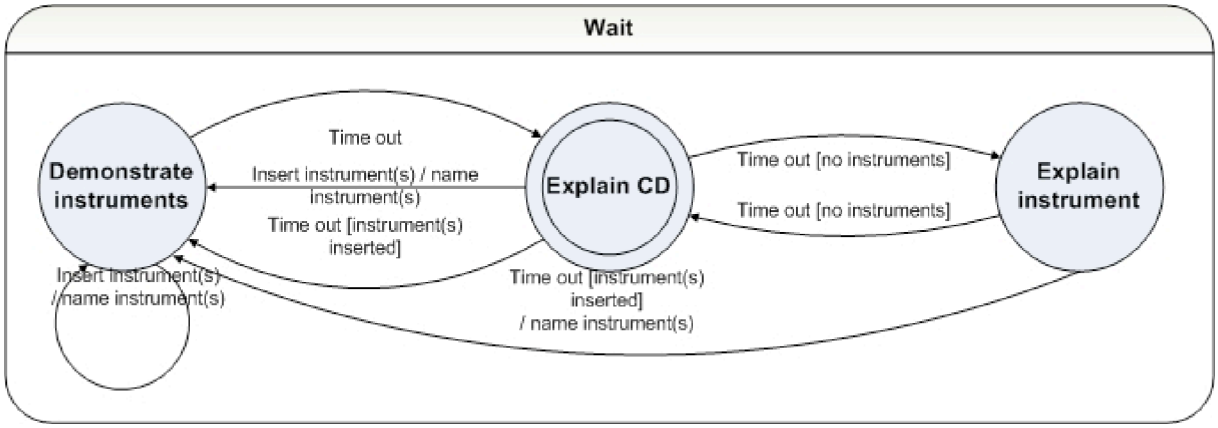


Figure 7.3. Dynamic model Wait

Explain CD

eyes input kangaroo	open
Panze	speaks: “If you put a CD in my pouch, we can sing and dance.”
Instrumentalists	Instrumentalist(s) with inserted instrument(s) are visible, but not moving and not sounding.
Background	standard

When the system is in the state *Explain CD*, Panze tells the child to put a CD in the pouch. If there are any instruments detected in the pouch, the corresponding virtual instrumentalists are displayed behind Panze. After Panze has explained the CD, the system will enter the state *Demonstrate instruments* if there are any instruments detected in the pouch, or *Explain instrument* if there is no instrument detected.

Explain Instrument

eyes input kangaroo	open
Panze	speaks: “If you put a musical instrument in my pouch, you will hear its sound.”
Instrumentalists	none
Background	standard

When the system is in the state *Explain instrument*, Panze tells the child to put an

instrument in the pouch. After Panze has done so, the system will enter the next state. If there is an instrument inserted during this state, Panze says the name of the instrument and the system will enter the state *Demonstrate instruments.* If there is no instrument detected the system will return to *Explain CD*.

Demonstrate Instruments

eyes input kangaroo	open
Panze	looks at instruments – silent
Instrumentalists	instrumentalist(s) with inserted instrument(s) on screen play(s) one chord
Background	standard

When one or more instruments are detected in the pouch while the system is in the *Wait* state, the system will alternate between the sub states *Explain CD* and *Demonstrate instruments*. When the system is in the sub state *Demonstrate instruments* the inserted instruments are visible at the screen behind Panze and they play one chord to demonstrate the sound of the instruments. Panze looks at the instrumentalist(s) behind her.

Activity

eyes input kangaroo	open
Panze	sings song and makes movements to the song
Instrumentalists	instrumentalist(s) with inserted instrument(s) accompany song
Background	according to song

As soon as a CD is detected in the pouch during the states *Welcome* and *Wait*, the system enters the state *Activity*. Panze says the name of the song corresponding with the CD and the background is changed to a theme that illustrates the song. The picture that is on the inserted CD is also visible in the background. Panze starts to sing the song and makes movements to the music. To make sure that almost every user will be able to sing along, one of the CDs is corresponding to a song that is based on the primitive motive (see Chapter 4). If there are any instruments in the pouch, the instrumentalists playing these instruments are visible on the screen behind Panze and accompany the song.

If the child imitates the movements Panze makes, it is rewarded by a visual effect on the screen (visual effect 1). If the child manages to imitate the movements in time to the music, the reward also includes a sound effect. If the child sings along with the song, it is rewarded by another visual effect on the screen (visual effect 2).

Furthermore, the user's movement and vocal responses determine the transitions

between the sub states *Version A*, *Version B* , *Version C* and *Version D*. The dynamic model of *Activity* is given in Figure 7.4.

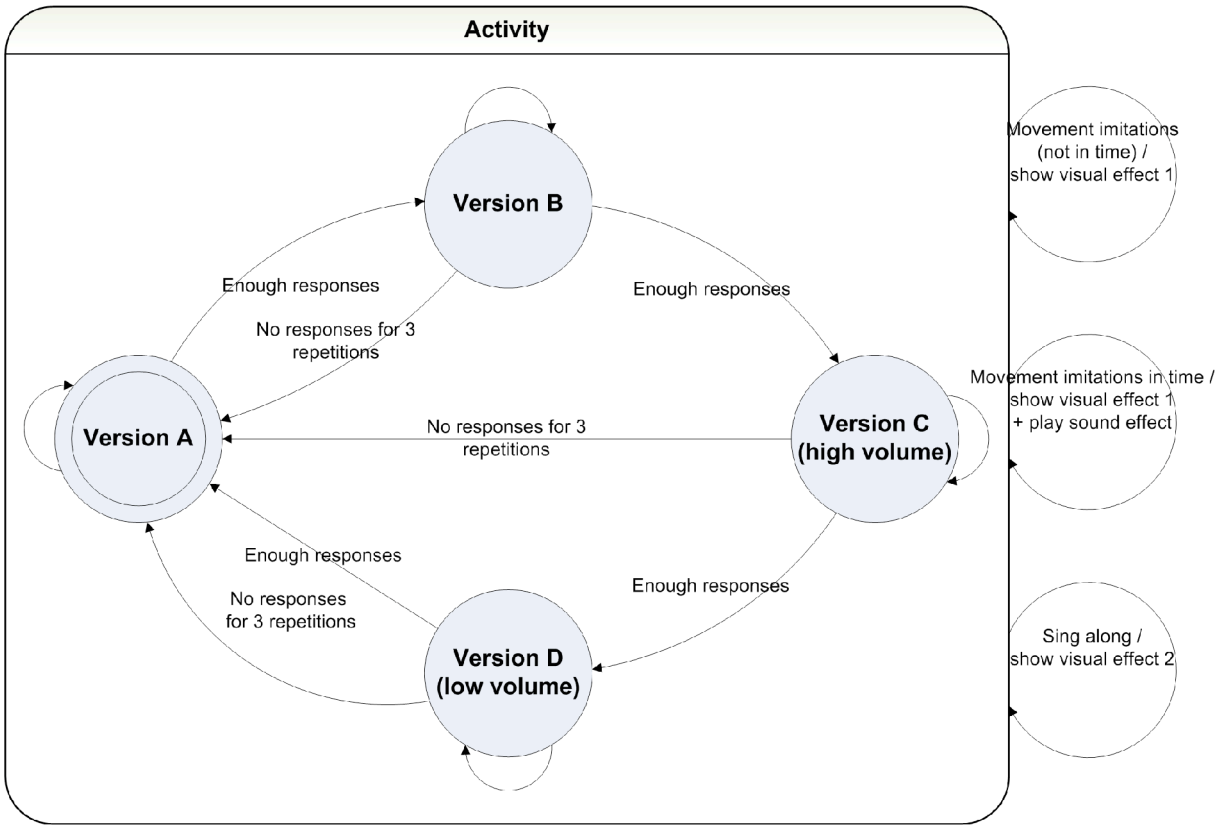


Figure 7.4. Dynamic modal Wait

Every song is repeated continuously, until the user has joined in the activity for sufficient time or until the user gave no musical responses at all during three subsequent repetitions. When the user gave enough musical responses, the system plays the next version of the song. When the user gives no musical responses during three subsequent repetitions of the versions B,C or D, the system returns to version A, for apparently, the user is not ready for a new version. If for another long time the system detects no activity from the child, it assumes that the child is not interested anymore. The input kangaroo closes its eyes and the system returns to S*tandby*.

Version A

When the activity starts, Panze sings the first version (version A) of the song and makes movements to the music. In this version the sound has a default volume. When the child has imitated the movements in time to the music for sufficient time, or sang along for sufficient time, the system enters the next sub state: *Version B.*

Version B

In this sub state Panze sings another version of the song (version B) and makes other movements to the music. The procedure is the same as in the previous sub state, and again when the child has imitated the movements in time to the music or sang along for sufficient time, the system will enter the next sub state: *Version C.*

Version C

In this sub state Panze sings a third version of the song (version C). The volume of both Panze's singing and the instruments are higher than default and Panze makes larger, heavier movements, according to the lyrics of the song. Again the previous procedure repeats itself, but this time the user also has to match the volume of the song. When the user has imitated the large movements in time to the music or sang along firmly for sufficient time, the system will enter the next sub state: *Version D.*

Version D

In this sub state Panze sings a fourth version of the song (version D). The volume of both Panze's singing and the instruments are lower than default and Panze makes smaller movements, according to the lyrics of the song. Again the volume is important. When the child has imitated the small movements in time to the music or sang along softly for sufficient time, the system will return to the first sub state: *Version A*.

8 Evaluation

In general, evaluation of interactive products can take place in different stages of the development of technology. In the different stages, different kinds of prototypes can be used. In an early stage a low-fidelity prototype can be used, that exists for example of paper material like screenshots or sketches of the interface. In later stages higher-fidelity prototypes can be made that look more like a real product (Preece, Rogers and Sharp, 2002; Hanna et al., 1999). Longitudinal tests can be done to assess (nearly) completed products. In these tests, the participants are given the opportunity to use the product over a longer time span, for example days or weeks (Hanna et al., 1999).

Evaluation of interactive products for children can be done with, or without children. When evaluation is done without children, experts are consulted. They inspect the prototype to predict things that children will probably have difficulties with (Preece, Rogers and Sharp, 2002; Hanna et al., 1999; Baauw, Bekker and Markopoulos, 2006). Evaluation with children can be done either by lab experiments or by field studies taking place in a natural setting, e.g. a school (Hanna et al., 1999; Jensen and Skov, 2005).

To find out what the participating children think of the technology, different methods can be used. First of all, the participants should be observed closely while using the product (Hanna, Risden and Alexander, 1997). Furthermore, older participants can be asked to verbalize what they think of the system, using methods as Co-Discovery, Peer Tutoring or Thinking Aloud (van Kesteren, 2003) to encourage them to talk about the product. Also survey methods are often used (Hanna et al., 1999; Read, 2006). However, according to Hanna et al. (1999) it is difficult for children younger than six years to express in words what they do or don't like and Read (2006) points out that survey methods have inherent problems which make them not the best methods to use with children. So for testing with children aged two and three years, it was conceived that only observation of the children while using the system would be appropriate.

This Chapter describes the evaluation of the Panze system. It was evaluated with children. The aim of the evaluation was to see how the children reacted to Panze and how they handled the different forms of interaction. For this, Wizard of Oz (WoZ) prototyping was considered an appropriate method. In this kind of prototyping an application is used, but there is no real interaction between the user and the system. Instead, a person called the 'wizard' operates the application as if the participant interacts with the system (Preece, Rogers and Sharp, 2002; Höysniemi, Hämäläinen and Turkki, 2004). Höysniemi, Hämäläinen and Turkki (2004) did WoZ testing with children to evaluate a full-body

interactive game. From their work it appeared that the WoZ method is suitable to evaluate systems that use motion tracking as an input modality and that it can reveal valuable information about how children interact with a system. In the evaluation of the Panze system, the children were observed to check whether they indeed view the system as being fun and enjoyable. Also the utility and learnability goals of the system were evaluated.

Section 8.1 describes the prototype that was used for the WoZ test. In Section 8.2 the set up for the WoZ test is described. In Section 8.3 and 8.4 the results of the tests are given, on which is reflected in Section 8.5.

8.1 WoZ Prototype

A simple WoZ prototype of the Panze system was made for the evaluation: an application was written and tangible objects were made. The WoZ prototype did not have all features of the conceptual design as described in the previous Chapter. The application ran on an apple laptop which was connected to a computer screen and loudspeakers, instead of a TV set. As no real interaction was used, there was no detection by the system. Instead, the experimenter acted as the 'wizard', who watched the children's actions and operated the prototype accordingly, using a wireless keyboard.

Tangibles

The prototype of the input kangaroo is a 38 cm tall physical 3D kangaroo with a large pouch (see Figure 8.1). It is covered with fabric and its face is made of paper. The face is the same as the face of Panze on the screen. In the pouch are slots into which tangible CDs and instruments can be inserted. The instruments do not fit in the slot for the CD's, and the CD's do not fit in the slots for the instruments.

The prototype has three foam tangible CDs (see Figure 8.2), and three foam tangible instruments: a flute, guitar and xylophone (see Figure 8.3). These instruments were chosen to represent each group of instruments: the wind instruments, the string instruments, and the percussion instruments.

Figure 8.1. The input kangaroo

Figure 8.2. Tangible CDs

Figure 8.3. Tangible instruments

Application

Because of the limited time available for the programming of the application, the prototype Panze was not very movable. A set of only five movements was made for Panze. These movements are clapping with the hands, stepping with the feet, ticking with the fingers, banging with the fists and jumping with both feet.

The experimenter operated the program, according to the actions of the children. A table describing the wizard keys is given in Appendix 2. When a participant touched the input kangaroo, the experimenter pressed the start key to start the animation and the music. As a result, Panze appeared on the screen (see Figure 8.4) and sang the welcome song (see Appendix 1). During this welcome song, Panze made mouth movements and waggled her tail. The welcome song was played once.

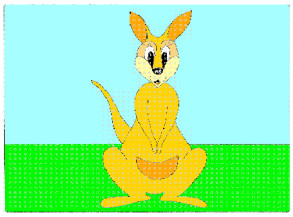


Figure 8.4. Screenshot of Panze during the welcome song.

Figure 8.5. Instrumentalists on the screen

When the welcome song was finished, the application entered the *Wait* state. To explain to the child how to use the tangibles, Panze said: “If you put a CD in my pouch, we can go sing and dance” and “If you put a musical instrument in my pouch, you can hear how it sounds”. When the child inserted tangible instruments in the pouch, instrumentalists appeared next to Panze (see picture 8.5) and a chord played by the instruments was audible.

When a participant inserted a CD, the experimenter made the application enter the state *Activity*. Panze then started the first version of the activity corresponding to the inserted CD. A picture of the inserted CD was shown in the top right corner of the screen.

Activities

From the MoL method, three activities were chosen for the prototype. The limited set of movements gave an important constraint to the songs: the songs should have lyrics that describe the movements, instead of movements that act out the lyrics. As this made it difficult to design a theme that depicts the lyrics of the song, no themes are used. Instead, pictures and colors are used to identify the activities.

The three chosen activities each have four versions (as was explained in Section 7.2). Each one makes use of one of Panze's five movements. The lyrics of the songs were adapted to the movements available. All chosen activities aid in the goals 'sense of beat' and 'sense of volume'. To stimulate children's sense of beat, Panze moves to the beat of the music. The tempo of all songs is 136 beats per minute, as was found to be appropriate in Chapter 3. To stimulate children's sense of volume, the third version of the activity has a high volume, and the fourth has a low volume. The movements of each of these versions match the volume. Two of the activities also aid in the goal 'sense of timing', by providing the child with a timing moment.

The first activity is based on the song 'Klap klap' ('Clap, clap'). This song was chosen because it is based on the basic motive (see Section 3.4). In this way even the less skilled children get a chance to sing along, as it was assumed that all children aged two and three are able to sing the basic motive. The second activity is based on the song 'Wie niet stappen wil' ('Who doesn't want to step') and the third is based on the song 'Klap maar mee' ('Clap along'). These songs were chosen because they include a break in which Panze stands still, which is a timing moment.

All three activities have a similar structure. The first version of the songs (A) is about the clapping of the hands or stepping with the feet. The movements that Panze makes to this version are clapping the hands or tapping the feet to the beat of the music. The next versions have variations in lyrics and movement. The second version (B) is about stepping with the feet (when version A was about clapping) or clapping with the hands (when version A was about stepping). The third (C) has a high volume and is about jumping or banging with the fists. Finally, the fourth version (D) has a low volume and is about ticking with the fingers. The different activities with their variations are given in Appendix 1.

Rewards

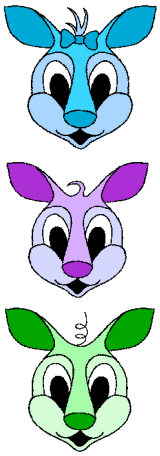


Figure 8.6. Baby kangaroos

When a participant joins in an activity, it is rewarded. The following rewards were chosen for this prototype. When the child imitates the movements of Panze, it is rewarded by a baby kangaroo that pops out of Panze's pouch. This baby kangaroo has the color of the inserted CD and a tuft of hair like the shape pictured on the CD (see Figure 8.6). When the child imitates the movements of Panze in time to the music, also a funny sound is audible when the baby kangaroo appears. When the child has shown some action (singing or moving) for 3 repetitions of the song, Panze starts to sing version B. This version is repeated until the child again has shown some action for 3 repetitions of the song. Panze then starts to sing version C, then to version D. After the last version, Panze returns to the original song and starts all over. When the child sings along, one of Panze's ears, that is normally down, raises (see Figures 8.7 and 8.8).

Figure 8.7. Ear is down

Figure 8.8. Ear is raised

8.2 Set up for the WoZ test

The application of the prototype ran on a laptop with an extra wireless keyboard and an extra screen attached. The input kangaroo, the extra screen and the tangibles were placed on a low table, so the participants could see and reach it well. The input kangaroo was placed next to the screen, and the tangible CDs and instruments were laid down in front of the screen and the input kangaroo. In front of the table there was a space large enough for the child to move freely.

At all tests the same experimenter was present. She sat next to the space for the child, at a place where she could observe the child well. She had no previous experience with testing with children or WoZ testing.

During the tests one or two observers looked at what the children did with the input kangaroo and the tangibles, how they reacted to Panze and the visual and audio rewards and what movements they made to the music. They used observation schemes to guide their observing. These schemes are given in Appendices 3 and 4. They include questions

about the child's reactions, and a time line for the child's actions with the tangible interface. The list of questions was divided into sections according to the different states of the WoZ program. For the *Standby* and *Welcome* states was evaluated whether the child wanted to stroke the input kangaroo, and how the child reacted when Panze appeared and sang the welcome song. For the *Wait* state was evaluated whether the child grabbed the tangibles in response to Panze's directions, and what the child did with the tangibles. For the *Activity* state, it was evaluated how the child responded to the activity that Panze offered and to the rewards. It was observed whether the participant just watched, sang, moved, experimented with the tangibles or did something else. When the child sang, it was evaluated what it sang and how it reacted to the reward. When the child moved to the music, it was evaluated whether it imitated Panze's movements or other movements, whether it moved in time to the music or not, and how it reacted to the rewards. Furthermore it was evaluated whether the participants seemed to have fun and enjoy the system.

8.3 Pilot Test

Before a larger scale WoZ test was conducted, a pilot test was done to see whether the prototype worked well and whether the observation schemes were appropriate.

Participants

The participants of the pilot test were two sisters. One was aged three and one was aged six. Although the six-year-old was not in the target age group, she participated because she wanted to herself.

Set Up

The test was conducted in the living room of the children's home and their mother was present. The other people present were the experimenter and one observer. The observer was one of the programmers of the prototype and had no professional experience in observing. He filled in the observation lists and took notes. The mother took pictures of the children. The other child was in the room, just behind the playing child.

Procedure

During the building up of the test setting, the participants were already present. They talked with the researchers and played with the tangibles. Before the test started, the participants were only told: “This is Panze. Do you want to play with Panze? Go stroke Panze, and see what happens...” The participants watched each other playing, but they were

told not to speak while the other child was playing.

Results

From the pilot test no video was made. Only field notes and observations from the mother were used for the results. The detailed results for each child are given in Appendices 5 and 7.

Both children discovered the functionality of the tangibles by themselves. However, for the three-year-old it took nearly three minutes before she put the tangibles in the pouch. During these three minutes she stroke and kissed the input kangaroo and played with the tangibles: pretending to whistle on the whistle and to play fiddle with the guitar and the whistle. While the three-year-old was playing, the six-year-old was watching. She immediately understood that her sister was supposed to put the tangibles in the pouch. However, she was told not to say anything to her sister, which was hard for her. Both children put the tangibles in and out of the pouch very rapidly.

Both children moved to the music as was intended and were having fun. The three-year-old child appeared to be what Eerola, Luck and Toiviainen (2006) called a 'hopper' (see Chapter 3): she jumped and clapped to all activities, however she was so busy with moving around that she did not watch the screen (see Figure 8.9). The six-year-old child imitated all Panze's movements in time to the music and sang along with one of the songs. After the test was over, the six-year-old child asked what a pouch was.

Figure 8.9. Three-year-old child jumping and clapping to the music

Conclusion of the Pilot Test

The WoZ application crashed several times. Part of this was solved before the next test. The prototype input kangaroo and tangibles appeared to be appropriate. The tangible instruments appeared to evoke play and exploration, as the children played whistle on the tangible whistle, and played fiddle with the tangible guitar and whistle together. The three-year-old kept stroking and kissing the input kangaroo, which may indicate that she found it

adorable.

The observation schemes as given in Appendices 3 and 4 initially formed one observation scheme together. From the pilot test became clear that the scheme was appropriate, but as the children were very fast with handling the tangibles, it was impossible to fill in the time line and the questions at the same time. Therefore it was decided to split up the scheme into the time line and the questions, to be filled in by different observers.

The concept of the game appeared to be a success, because both children discovered the functionality of the tangibles, moved to the music as was intended, and were very enthusiastic.

8.4 Test at Preschool

The WoZ test was conducted in a preschool setting. Two preschools in the same building were involved.

Participants

The tests were done with children from one group of each preschool. At one of the preschools the computer was used regularly with the children for educational games, at the other preschool not. In total, 11 children (7 boys, 4 girls) participated in the test. The participants were aged 2 and 3 and one just turned 4 in the previous week. One participant had ADHD, and one could not speak. The parents of the children had previously given their written consent for the children's participation.

The participants were chosen by the main teachers of the preschools. The teacher of the first preschool selected the children that she thought would react best (4 participants). The teacher of the second preschool asked for volunteers (7 participants).

Set up

The system was set up in a shared playing room between the two preschools. In this playing room, there were the experimenter and two observers. One of the observers is an expert observer of preschoolers in a PME setting, the other observer is one of the programmers of the prototype and had no professional experience in observing.

Figure 8.10 shows pictures of the test setup. The screen, the loudspeakers, the input kangaroo and the tangibles were placed on a low table. The input kangaroo was placed left to the screen, the tangibles were placed in front of the screen and the loudspeakers were

placed on both sides of the screen.

Two video cameras were used to record the children's responses. One camera was placed behind the table, it was directed to the child's face. The other camera stood near the observers and was directed to the child, the screen and the input kangaroo.

Figure 8.10. Test setup

Procedure

The experimenter welcomed the children, gave explanation, operated the program and encouraged the children when necessary. The two observers filled in observation lists and took notes. With most of the tests, the main teacher of the children was present. She took pictures of the child and of the experimenter and observers. With some of the tests some other children were in the room or stood in the doorway and looked quietly.

The tests were conducted with one child at a time. When the child entered the room, it was welcomed by the experimenter. Initially, little explanation was given, for it was hoped that the child would experiment and discover how the game worked itself. The child was only told: “This is Panze. Do you want to play with Panze? Go stroke Panze, and see what happens...” Each test took ten minutes from the moment the program was started, except when the participant wanted to leave earlier. Each participant did the test once. Some participants had the opportunity to look while others were playing with the system.

After three tests the amount of explanation they were given was increased, for the children did very little experimenting and gave hardly reactions to what Panze told them. They seemed not to understand it. In addition to what the previous children were told, the other children were told that Panze is a kangaroo and that she has a pouch. The CDs and instruments were shown and named. The children were asked to put the instruments and CDs in the pouch. If they seemed to understand all this, they were asked to stroke Panze, and the program was started.

Many participants showed nervous tics during the test. Some already seemed to feel uncomfortable before the test started, some later on during the test. For this reason, from

the sixth test on, the tests were conducted with two children collaborating. This helped the children to feel more at ease and made them more focused on the system and less on the experimenter and observers. However, as the system was designed for use at home with only one child at a time, collaboration was not provided for and is not representative for the envisioned use.

Results

For the results, the field notes from the observers and the video recordings were used. In appendices 6 and 7 the results for all individual participants from the test at the preschool are given.

All participants but one directly stroked Panze when the experimenter told them to do so. One child needed a little more encouragement. The stroking varied between the children from just touching, stroking, stroking for a long time, kissing or pushing on the feet.

When Panze appeared on the screen, the reactions of the children varied. Eight children watched the screen. Two children were more interested in other things. During the welcome song, the participants did different things: four children just watched Panze, two of them laughed. Two children were busy with the input kangaroo. Three looked at Panze and the input kangaroo (some of them also to the teacher and through the window). One child kept looking at the experimenter and the observers.

None of the children grabbed the tangibles at the moment Panze first indicated this. Only one child started to experiment before Panze said so. All other children only started to experiment after extra encouragement or instruction from one of the present adults. The different amount of explanations the children got before the tests made no difference. Five children did look to and fro to the screen, the tangibles and the input kangaroo. Some children showed clear nonverbal signs that they did not understand what to do. Eventually, with or without help, all children inserted CDs and instruments in the pouch of the input kangaroo. After this, all but one started to experiment with the tangibles.

Figure 8.11. Boy inserting tangibles into the pouch

Some searched for approval and confirmation from the experimenter or teacher. Many participants had a high tempo of putting the tangibles in and out of the pouch. Three participants laughed when the first activity started. During the test, some children played with the tangibles themselves.

During the different activities, a total of five children moved to the music. Two of them occasionally made the same movements as Panze did. They all (also) made their own movements to the music.

The activity “Klap klap” (1A) was played in seven tests, involving nine participants. Five children moved to the music. One of them made the same movements as Panze did. All of them moved to the music with (also) other movements: swaying with the hips or the whole body, ticking with the tangibles and stamping a foot. One of the children did not move to the music, but only put her hands together, she did not really clap. None of the children sang, and none of the children reached a next variation of the activity.

The activity “Wie niet stappen wil” (2A) was played in five tests, involving six participants. Three children moved to the music. One of them made the same movements as Panze did. The other two made small movements with the hips. One of the children made silent mouth movements, partly matching the lyrics. None of the children reached a next variation of the activity.

The activity “Wil je klappen” (3A) was played in five tests, involving seven participants. Five children moved to the music. One of them once made the same movements as Panze did. The other movements they made to the music were one moving with the hips, moving with the hips and the knees, and moving a foot. None of the children sang. None of the children reached a next variation of the activity.

Not many rewards appeared during the tests. In two tests a baby kangaroo popped out of Panze's pouch without a sound effect. The children did not react to it. During one activity, one child made the same movements as Panze in time to the music. Which caused a baby kangaroo to pop out of the pouch with an accompanying sound effect. She looked at the screen and to the teacher. In some cases she kept moving in time to the music, in some cases she stopped moving. As none of the children sang aloud during the tests, Panze's ears did not raise. Therefore it could not be observed how the children reacted to the raised ear.

Only two children left before the end of the test time. All other participants stayed for the full ten minutes.

8.5 Reflection

Reflection on the Method and Procedures

The results from the two different tests show large differences. This is probably because of the setting. The children in the home setting were far more enthusiastic than the children in the preschool setting. The children in the preschool setting seemed uncomfortable, the children in the home setting were not. This was unexpected, because it was assumed that the children were used to their preschool environment and their teacher, and would in both places want to play with new toys. Possible explanations for the children's behaviour are the following.

- The children may have felt not as comfortable at the preschool with their teacher as in their own home with their mother.
- The area and the distance between the participants and the other people were much larger in the preschool setting than in the home setting. This might have caused the children to feel uncomfortable.
- The children may have felt uncomfortable because there were many unfamiliar people looking. In the home setting there were two unfamiliar researchers and two family members, in the preschool setting there were three unfamiliar researchers and one familiar teacher. The effect that experimenters and observers influence the behaviour of the children is called the 'observer influence' (Berk, 2006).

To make the children in the preschool setting feel more comfortable, six children were allowed to collaborate in pairs. Although the game was designed for one child at a time, collaboration was a good choice for the test. It seemed to make the children feel more comfortable and react more spontaneously, which resulted in more movement responses to the music and longer experimentation with the tangibles. In total, 5 children were seen moving to the music, 1 of them played alone, 4 of them played together. However, the Panze system cannot be considered suitable for collaboration, because for example some children argued about what to put in the pouch.

There were two problems with the WoZ application that influenced the results. A major problem was the application's long response time when a CD was inserted. Many children took out the CD immediately, apparently because they thought nothing happened. Another problem was the stability of the application. After the pilot test this was improved, but during the tests at the preschool the application crashed twice. Fortunately the time before the crashes gave enough information.

The prototype input kangaroo proved to be strong enough for the test. Pushing on the

feet, trying to insert tangibles in slots where they did not fit and rapid experimentation with the tangibles did not harm the input kangaroo and most foam tangibles. Only the tangible guitar did not survive, due to a weak construction. Fortunately this could be repaired during the test.

Despite the fact that the children in the preschool setting did not feel comfortable, the WoZ tests gave a lot of valuable information. The WoZ method was appropriate for testing how the children reacted to Panze and the input kangaroo and how they handled the tangibles. However, more simpler tests earlier in the design process, like the one that was done for the appearance of Panze, could also have revealed a number of the problems. For example, a test with only the tangibles and the input kangaroo, prior to the WoZ test, could have revealed that the children did not know kangaroos and did not recognize all of the instruments.

Even more information could have been obtained from the WoZ test if the participants got more opportunities to play with the prototype. This will give them the opportunity to learn, they may get used to the tangibles and become more focused to the activities. Two children indicated they wanted to play with the prototype again. One child from the pilot test (aged 3) asked her mother, after the researchers left, when she could play with it again. One child from the preschool (aged 2½) started crying when she could not play a second time, even though she left earlier than ten minutes. However, due to time constraints, more testing was not possible within this research project.

Reflection on the Results

During the explanations by the experimenter, it appeared that the children had problems with recognizing what the tangibles represented. They did recognize the guitar, but most children did not recognize the xylophone. Also the whistle was not clear to all of them. Further research has to be done why they did not recognize the tangible instruments. Two possible reasons are the following.

- They knew the instruments, but did not recognize them in the tangibles. In this case the appearance of the tangibles need to be improved.
- They did not know the instruments. Then there is no problem and the system might provide a good way to teach the children the vision and sound of instruments that they do not yet know.

Because of children's exploring nature, it was expected that most participants of the WoZ test would start to experiment with the system by themselves. It was assumed that the

participants were familiar with a box of blocks and therefore would soon discover by themselves that they could put the tangibles in the pouch of the input kangaroo. This assumption appeared to be wrong. Most participants did not insert the tangibles in the pouch, not even when Panze gave instructions. Many children looked puzzled. They looked to and fro between the input kangaroo, the screen and the tangibles, but seemed not to understand what to do. Even the children who received instructions from the experimenter and did 'dry practice' with the tangibles and the pouch before the game started, needed extra encouragement before they started playing with them during the game. Possible explanations for this behaviour are the following.

- The children did not dare to experiment because there were so many strangers watching them.
- The children were used to computer games in which they were given explicit assignments. They might not be used to systems that allow them to experiment. Although Panze explained them "*if* you put a CD / musical instrument in my pouch, ...", she did not explicitly tell them to do something.
- The children did not understand Panze's encouragements. Maybe the language of the encouragements was too difficult for the children. It appeared that many of the children did not now what a kangaroo and a pouch was.
- In some cases it could have been that the children were so busy watching Panze, that they forgot the tangibles, or they were too busy with playing with the input kangaroo and the tangibles themselves that they did not pay attention to Panze.

As the children initially did not do anything with the system, they got more guidance than was previously planned. This was helpful, for now the children started to experiment with the tangibles. Without the extra explanations it would not have been possible to observe what the children did with the tangibles.

When the children did insert a tangible in the pouch of the input kangaroo, it seemed that most of them understood that there was a connection between the input kangaroo and Panze on the screen, because they looked to and fro between the input kangaroo, the screen and the tangibles. The children had some difficulties with inserting the tangibles in the pouch of the input kangaroo.

All children that were actively experimenting with the tangibles, both in the pilot test (also the six-year-old) and in the preschool setting, wanted to take the CD out of the pouch as soon as a song had ended. Sometimes the song started again before the CD was really out of the pouch, then they left it in sometimes. So for the children it seemed to be natural to take the CD out when the song had ended.

Some children just played with the tangibles or the input kangaroo. This is positive,

because this indicates that their appearance attracts the children.

When Panze appeared on the screen, most participants watched with interest. Some children laughed, which indicates that they enjoyed it.

About half of the participants (of both the pilot test and the test at the preschool) spontaneously moved to the music. It was expected that almost all children would do so. Maybe some children did not move to the music because they felt uncomfortable or focussed on the tangibles.

Some of the children who did move to the music made the same movements as Panze did: they clapped or tapped a foot. the clapping and tapping movements that Panze offers are appropriate at least for a part of the children in the target age group. However, according to the PME-expert observer, the movements that the prototype Panze makes are too small.

Three children within the target age group made movements in time to the music. This shows that the chosen tempo of 136 beats per minute allows at least a part of the children in the target age group to move in time to the music.

Only two children sang along with Panze. However, one of them was not within the target age group (six year old), and the other one made only mouth movements without sound. So, from the target age group no one really sang along. As was said in Section 3.2, children usually start observing, then moving along, and only after many repetitions they start singing along. Regarding this, it is not surprising that the children did not sing along during their first session with the WoZ prototype.

It was expected that the children would find the rewards funny. But in the few occasions that a visual effect without a sound effect was shown, the children did not react to it. In the pilot test the three-year-old was so enthusiastically jumping around the room that she did not watch the screen. In the test at the preschool either the children did not notice or were not impressed. The rewards that included a sound effect appeared by only two participants (one of them was outside the target age group). They both noticed the reward, their reaction differed.

Reflection on the User Experience Goals and the Usability Goals

In Chapter 5, the user experience goals and the usability goals for the system were formulated. In the WoZ tests was evaluated whether the user experience goals and the utility and learnability goals were met.

The user experience goals of the system are fun and enjoyment. In the tests it was examined how the participants responded, to see whether they enjoyed the system. The two participants in the pilot test clearly viewed the system as fun and enjoyable. The participants in the test at the preschool varied in their reactions. Some laughed when Panze appeared or when they discovered the functionality of the tangibles, one participant seemed not to understand the meaning of the game nor to enjoy it. However, with most children in the preschool setting, discomfort was more obvious than fun and enjoyment. Therefore no clear conclusion can be given.

The Panze system was considered to have good utility when it provides an appropriate set of functions that enables children to have musical interaction in the way they want. With the prototype, the users had the opportunity to play with the system and explore the system's reactions and they eventually did. In turn the system did respond to the users actions, although for inserting the CDs, the response was very slow. The users could also have multimodal interaction with the system. But in the tests it was not seen that they were aware of this. Not much musical interaction was seen. The users need probably more guidance to join in the activities. Therefore it cannot yet be concluded that the participants had musical interaction in the way they wanted.

The learnability of the Panze system is about how fast and easy a child can learn to play with the system. The interaction was tried to be made very intuitive by basing the system on play, exploration and responding to music, thereby taking care of the familiarity of the system. However, the assumption that the children would start experimenting with the tangibles by themselves appeared to be wrong. They needed help to start. The encouragements by Panze were not enough. Therefore, from the WoZ tests it can be concluded that the learnability of the tangible user interface needs to be improved.

Natural movement responses to music were seen by about half of the children. This probably is a good score, regarding that many children felt uncomfortable and their focus on the tangibles. More testing is needed to see what the children do when they feel more comfortable and are less focussed on the tangibles.

9 Project Conclusions

The objective of this research project was to design an interactive music system for two and three-year-old children, with the intent to stimulate the child's inherent musical abilities through the interaction with the system. To preserve and develop the inborn musical abilities of children, it was conceived that they need to be stimulated in the early years. For this, it is important that the child is an active participant in musical interactions. The system was made suitable for the target age group by conforming to their needs for learning and their abilities, and by consulting some guidelines for interaction design for children. Practical experience from Dutch Preschool Music Education was used to reach the aim of helping to develop children's musical abilities. Furthermore, user experience goals and usability goals were formulated. The musical interaction between the child and the Panze system was chosen to take place by using natural interaction. The interaction styles that were considered appropriate are movement, singing and playing with tangible objects.

Based on the information gathered, the Panze system was designed. It consists of an input device that contains several input modalities (the input kangaroo), connected to a television set. On the television screen, the embodied pedagogical agent Panze is visible. Panze acts like a kind of role model for the child; she gives examples and motivates the child by singing, dancing and speaking to the child.

The Panze system has the aim to make the child an active participant in musical interactions between the child and the system. The aim is that the child will give musical responses, like moving to the music, singing or making body sounds like clapping with the hands or on the body. The musical responses of the child evoke a reaction in the system. By using tangibles, the child can choose songs and musical instruments that accompany the songs.

The design of the Panze system was evaluated with a Wizard of Oz test with children in the target age group. Although the aim of the Panze system is to stimulate the child's inherent musical abilities, it was not tested whether the children indeed learned from the Panze system.

In the following Sections the three research questions are answered.

9.1 RQ1: What Are the Requirements for an Interactive Music Educational System for Two and Three-Year-Old Children?

In the literature, five main issues were found for children's needs in educational interactive technology: play and exploration, fun and enjoyment, control, multiple forms of interaction and interaction with adults (see Chapter 2). For each of these main issues, a requirement was derived. A little word can be said about these requirements based on the results of the WoZ test

In the literature it was found that it is children's nature to explore and play, and that this aids their learning. The requirement related to the issue of exploration was that the system should provide the user with an interactive environment in which the user will learn about music by exploring and playing in this environment. To provide for this need, the Panze system is discovery-oriented. This means that by playing with the system, the users can discover it's functionality. In the WoZ test, children's need to explore and play was seen with some children, but not with most of them. But as eventually almost all participants started playing and experimenting with the tangibles, an interactive environment in which the user can explore and play, seems to be appropriate for the target age group.

The requirement related to the issue of fun and enjoyment was that to accomplish motivation to interact with the system and better learning, it is important to incorporate fun and enjoyment in the system. To make the Panze system fun and enjoyable, the system was given the form of a toy or game: something to play with. It is hoped that the users like the music, the singing and dancing with a virtual character and the rewards. The WoZ test showed that fun and enjoyment indeed appeared to be related to motivation to interact with the Panze system. Children that laughed, experimented a lot with the tangibles, while children who did not seem to enjoy themselves did only little experimenting.

The requirement related to the issue of control was that to let children enjoy the system and to promote effective learning, it is important that the user quickly understands the basics of the interaction and feels in control of the system. To accomplish this, natural interaction was used and the users are given control. They can choose themselves what they want to hear and what form of interaction they want to use, and their actions evoke responses in the system. In the WoZ test the participants were not in control soon, apparently due to learnability problems. Instead of freely experimenting with the system and taking control, they searched for approval and confirmation. Even after more explanation and encouragement, they may have felt that they were not in control, because of the slow

responses of the application. However, it was not seen that this made the participants impatient, as Druin et al. (1999) supposed, for most of the children stayed with the system for the full ten minutes. The children liked to get direct feedback when they inserted tangibles.

It appeared to be true that the users need to quickly understand the basics of the game and to feel in control of the system, for the children became more uncomfortable when they did not know what to do. When they understood that they could influence the system, they enjoyed experimenting.

Active exploration of the system can be promoted by offering the users different forms of interaction. The users should have a choice in the way they interact with the system. The forms of interaction that were conceived appropriate for an interactive music educational system for two and three-year-old children are: responding to the music by movement and singing, and playing with tangible objects. These are the three possible ways of interaction that the users of the Panze system can use.

The musical activities that are offered by the Panze system should be tailored to the children's abilities. As the motor and vocal abilities of the target user group vary, the system has to be adapted to the minimal abilities of the youngest children in this age group. Yet it has to be challenging enough for older children with more developed abilities. To make the musical interaction appropriate for even the youngest children, there are two requirements for the offered music.

- Songs that are offered with the aim to let the child sing along, should exist of small intervals between the tones.
- Music that is offered to evoke movement responses from the users should have a tempo between 132 and 141 beats per minute, in order to give the child the opportunity to move in time to the music.

The phases in which young children join in musical activities led by others are first observing, then imitating the movements and finally singing along. The users should also be given the option to observe the Panze system and it's music without joining in the interaction.

In the WoZ test, eventually almost all children played and experimented with the tangibles. Therefore the tangible user interface can be considered an appropriate form of interaction for the target age group.

According to Chen-Hafteck (2004) children move to music without encouragement. Some participants of the WoZ test moved to the music deliberately, some seemed to do so unconsciously, but most did not move to the music. It is not clear why. A possible reason may have been that the children felt uncomfortable because of the visible presence of the

experimenter and observers.

In the WoZ test, the children did not discover the possibilities of interacting with the system by responding to the music by moving or singing. Therefore these forms of interaction, and the offered activities could not be assessed.

Adults can play an important role in the development of children's musical abilities, by setting the examples and by taking children's music making seriously. The requirement for the system was that it has to provide an alternative role model for the user, that has a similar effect as a supportive adult. The pedagogical agent Panze was developed to try to resemble the role models that the adults are in the MoL lessons. For support, encouragement and motivation, the users are given rewards when they imitate Panze. In the WoZ test, the participants' reactions to Panze were positive. This is important because, according to the literature (see Section 6.1), a positive attitude towards Panze enhances motivation and engagement of the users. However, the participants did not imitate Panze, act according to her encouragements or react to the rewards as intended. This can have different reasons. Maybe the participants did not feel comfortable enough to act according to Panze, maybe they where overwhelmed by this new kind of computer system, or maybe Panze's examples, encouragements and rewards are not good enough.

9.2 RQ2: What Musical Interactions Between Child and Adult that Stimulate the Child's Musical Abilities can be Used as an Example for the System?

As an example for the system, the Dutch Preschool Music Education method called Music on the Lap (MoL) was used. From the many goals the MoL method has, three goals were chosen for the Panze system:

1. sense of beat and timing,
2. sense of dynamics, and
3. learning to associate timbre with the corresponding musical instrument.

Adults play an important role in the MoL lessons. The parents and the teacher set the example for the children by singing and moving in the activities. By doing so, they function as a role model for the children. Furthermore, the parents actively involve the children in the movements and guide them in making the movements themselves.

To imitate the interactions between child and adult in the MoL lessons in the Panze system, the pedagogical agent Panze was created. She provides the users of the system with a role model like in the MoL lessons. Panze offers the users activities that resemble the activities in the MoL lessons. As is the case in the MoL lessons, the aim is that the child will

imitate the musical behaviour of the role model and will eventually internalize this behaviour.

In the evaluation, most children did not imitate Panze. As children start with observing before joining in the activity, this does not necessarily prove that Panze is not an appropriate role model. However, from the evaluation, some suggestions could be done to improve Panze. These are given in Section 10.1.

The activities offered in the MoL lessons have some properties to meet the musical developmental goals of 'sense of beat and timing' and 'sense of dynamics'. The activities are repeated many times, so that the user can slowly adapt to the beat. Short songs are used to make it easier for the user to remember the course of the activity. Furthermore, direct as well as delayed musical responses are valued. For a sense of dynamics, songs are offered that have different variations on a normal, low and high volume, with lyrics and movements that properly support the volume of the song. These properties were used for the activities that Panze offers to the users. In the WoZ test the activities could not be evaluated, as most children did not imitate Panze.

The MoL teacher gives the children the opportunity to listen to the instrument she plays. In this way they can learn to associate timbre with the corresponding musical instrument. For the Panze system, instrumentalists were designed that play instruments to give the children the opportunity to listen to different musical instruments.

The multiple forms of interaction that are used in the activities of the MoL lessons are: observing, moving, singing and playing with tangibles. Therefore these forms of interaction were used in the design of the system. As is the case in the activities in the MoL lessons, the Panze system provides for all three phases in every activity: there are no different activities for observing, moving or singing. The user can choose to do any of these during the same activity: the user has the opportunity to observe and listen to Panze without actively participating, to imitate Panze's movements to the music, and to sing along with Panze.

9.3 RQ3: What Interaction Styles are Eligible for Natural Musical Interaction Between the Child and the System?

Embodied agents are often used to make human-computer interaction more natural. For children aged two and three this was also considered a good solution. Therefore the embodied pedagogical agent Panze was designed. In the WoZ test the children reacted positive to Panze, but they did not imitate her, or act according to her encouragements. This suggests that the concept might be good, but Panze needs to be improved to be an

appropriate role model.

From the literature and observations of MoL lessons, movement, singing and playing with tangibles were considered suitable interaction styles for natural musical interaction between the child and the system. For these interaction styles, the input modalities motion tracking, sound detection and tangibles are necessary. A small review was done to different options.

An appropriate method for motion tracking was not yet found, because different methods all have their drawbacks. The solution will probably lie in a combination of computer vision, and wearables or a dancing mat.

For the detection of children's singing, one or more microphones and intensity detecting software are needed. These may, in combination with motion tracking also detect sound-producing movements of the user.

To let the children play with tangibles, the input kangaroo is equipped with a large pouch in which tangible CDs and instruments can be inserted. To make the system able to detect the CDs and tangibles that are in the pouch, RFID technology can be used. The input kangaroo is also provided with a touch sensor to detect that the child touches the input kangaroo.

In the WoZ test, the participants were mostly focused on the tangibles. Although the TUI needs some improvements, the tangibles appeared to be an appropriate form of interaction for the target age group. The participants were willing to stroke the input kangaroo, which suggests that the touch sensor is also appropriate. The children did not discover the other forms of interaction. So the interaction by movement and singing could not be evaluated.

10 Suggested Improvements and Further Research

10.1 Suggested Improvements for Interaction

As expected, the evaluation revealed several problems with the design. To overcome these problems, several improvements are suggested in this Section. Preferably, children from the target user group should be involved in the design process.

The Input Kangaroo

The slots in the pouch of the input kangaroo have to be larger, for the children appeared to have some difficulties inserting the tangibles in the pouch of the input kangaroo. Also it needs to be more clear that only one CD can be inserted at a time, for some children tried to put several CDs in the pouch together.

The input kangaroo should better be placed in front of the screen. The first reason for this is that the children can then see the input kangaroo and the screen at the same time and can see the changes at the screen when they look to the input kangaroo. In the WoZ test, one of the children did not notice that something happened on the screen when she put the tangibles in and out of the pouch. The second reason is that it is beneficial for the ergonomics of the system. During the WoZ tests at the preschool setting, the input kangaroo was placed at the left of the screen. Most of the children were right-handed. This caused them to look over their shoulder to the screen when they were working with the input kangaroo.

The responsiveness of the WoZ prototype was not sufficient. It appeared that the response time of the system needs to be very fast to catch up with children that put the tangibles in and out the pouch very fast. Many participants of the WoZ test were also very fast with taking out the CD when a song had ended. Probably they did not realise that the song would be repeated when they left the CD in the pouch. To solve this problem, the pauses between the repetitions of the song have to be shorter.

Feedback

All feedback needs to be directly audible. Only direct visual effect is not enough, because the participants did not always look at Panze. It appeared that the children cannot insert tangibles and watch the screen at the same time. Therefore, when a tangible is inserted, a sound should be audible immediately, not delayed, to make the effect of inserting

the tangibles more clear. Furthermore, none of the children reacted to an only-visual reward. One of the participants did not notice the visual rewards, because she was so busy jumping and clapping around in the room that she did not pay much attention to the screen. There are too little results to properly evaluate the rewards, but in the events when a reward was given that included a sound, the children did react to it. Therefore it is suggested that all rewards need to be audible.

Additional rewards or encouragements need to be designed for other behavior that deserves a reward. For example for children that move in time to the music while making their own movements, and for children that make a gesture like Panze's movements, like the child that put her hands together but did not clap.

Panze

The character of Panze should be elaborated and her encouragements needs to improve. As the focus of this research was on musical interaction, and spoken instructions of Panze were kept to a minimum, no special attention was given to the style of the instructions. However, in the evaluation became apparent that most participants needed more guidance to start experimenting with the tangibles and that they did not react to Panze's encouragements. Therefore, in further research attention does need to be given to the style of Panze's instructions. Also additional encouragements might be required. For example, to make the children move along consciously with the activities, Panze could say something like “Join me”. As the evaluation showed that many children did not know a kangaroo, maybe another character should be used, or a new welcome song could be written in which Panze introduces herself. In this song she should tell that she is a kangaroo and show and name her pouch.

Much literature is available about the personality of animated agents (see Chapter 6), mostly targeted to adults. To make Panze a believable role model, this literature should be consulted. To extend this to the age group of two and three-year-olds, child development literature should be consulted. A more thorough observation of adults in a MoL course may also be valuable. Children's preferences for cartoons could be reviewed, and testing with children should be done in order to develop a believable virtual role model.

Detection

It appeared that also mouth movements need to be detected, for one child made mouth movements as if she was singing, but she produced no sound. This also deserves a reward. A video camera is probably the only way to detect these mouth movements.

10.2 Suggested Methodology

For the design of the Panze system, the next thing to be done is to revise the prototype according to the suggested improvements in the previous Section. After this, more WoZ tests can be done. It is important to evaluate each little development step, for it can prevent proceeding in the wrong way.

Because of the big differences between the home setting and the preschool setting, future testing should be done only in home environments, for eventually, this is were the system is supposed to be used. Hopefully, other children in home settings will be as comfortable as the children in the pilot test.

When the desired interaction between the child and the Panze system has been achieved, longitudinal tests consisting of multiple sessions with the Panze system should be conducted to assess how the interaction between the user and the system changes over multiple opportunities to play with the system. When the participants are given more opportunities to play with the system, it will be possible to see the learning effect. The participants might discover more when they play with the system for the second, third, fourth, etc., time.

The user experience goals and some of the usability goals have been evaluated in the WoZ test. But not all usability goals could be evaluated. For evaluation of the effectiveness and memorability goals, more sessions with the same children are necessary. For the evaluation of safety, a fully functional prototype is necessary.

When the desired musical interaction between the child and the system is brought about, and the detection methods have been decided, a design of the input kangaroo needs to be made that includes all necessary hardware and software. Then a fully functional prototype of the Panze system should be built. This prototype needs to be placed in a home to see how a child uses it without people watching and when it's there all the time.

Finally, it should be tested whether the Panze system meets the aim of helping children to develop their musical abilities. A study could be done to see whether the musical abilities of users of the system increase after a specified period of opportunities to play with the system at home.

If it appears that the goal was met, a study can be done to compare the development of musical abilities of children using the Panze system and children following a MoL course. In such a study, the differences in musical abilities between children that have played with

the system for a specified period and children that have attended a MoL course during the same period can be assessed.

10.3 Further Development of Technology

In this research project the focus was on the interaction styles that would enable the users to develop their musical abilities. The concept of the Panze system was developed, but it needs to be elaborated. In particular, the technology needed for the system has to be further considered.

To implement Panze, the techniques used for the Virtual Rap Dancer (Reidsma et al., 2006), the Virtual Conductor (Bos et al., 2006) and the Reactive Virtual Trainer (Ruttkay et al., 2006) can be used. The instrumentalists could be implemented based on the techniques used for the animated drummer (Kragtwijk, Nijholt and Zwiers, 2001). For the first prototype this was considered unnecessary.

Only little literature research and no practical research was done to the input modalities of the Panze system. For further development of the Panze system, the chosen input modalities have to be worked out and a functional prototype should be made and evaluated. For this, the tangibles need to be embedded with RFID, appropriate software for sound and singing detection needs to be found or developed, and further research needs to be done to find an attractive and appropriate way to detect two and three-year-old's movements to music. In the future, video based motion capture may improve and more advanced dancing mats may become available. Or else, an effort can be made to design attractive non-distracting wearables. Maybe several options need to be combined for a sufficient detection of children's movements to the music.

10.4 Extending the Panze system

When the Panze system is operational, it can be extended. This Section gives some suggestions to extend the Panze system.

Activities

In the prototype only three activities were used. In the final product, the Panze system should provide more activities. According to several researchers, it is advisable to let children hear a broad range of music styles (Pound and Harrison, 2002; Chen-Hafteck, 2004). Further research should be done to obtain an appropriate, more complete set of

activities to offer the child. This research will be entirely on the field of early childhood music education.

Voice Formation

In the Panze system, three musical developmental goals were incorporated, the goal of learning to sing was not one of them. However, singing is one of the input modalities, and the user is rewarded when it sings along. In a future version of the Panze system, the goal of voice formation could also be incorporated. For the memory of pitch, it is important that the child sings a song always on the same pitch. The vocal chords can then always experience the same tense of the muscles, which will aid the ability to sing in tune (Langelaar, 1980, p103). The Panze system is perfect for this purpose, for the songs are always offered on the same pitch.

Flexibility

The Panze system could be provided with a wireless connection to update the system via the Internet. In this way parents or caregivers can choose and add new activities and instruments by buying loose tangibles and downloading the corresponding activities and instrumentalists from the Internet.

Embodiment

In this project was chosen to display the embodied agent Panze on a screen, because that is the most easy and low cost way to make a dancing character. But this may be not the best way to embody Panze to provide the most effective role model. It may be possible and desirable to make Panze a robot, like the dancing robots by Sony (Sony, 2006). In this way the pouch and the kangaroo can be the same thing, e.g. with a web cam in the nose like in the Philips iCat, and with some pictures lighting op for the visual rewards. However, some screen needs to remain, to display the instrumentalists. A disadvantage of a robot-Panze is that it will greatly increase the costs of the system. This probably makes parents less willing to buy it for their children, which results in a smaller amount of children that will be able to benefit from the system.

11 Reflection

11.1 Panze's Future in Education

Very little research is done on computer use of children under age five. However, commercial desktop computer programs are available to help young children with learning for example mathematics or to recognize colours. The children have to control these programs with the mouse and sometimes the keyboard. These programs often only tell children whether they have done a task right or wrong and give them no insight in the material. Probably better results can be gained with computer systems that are designed based on an understanding of how children learn about specific topics and how they can effectively interact with computer systems, resulting in systems like the Panze system. In the future, hopefully the development of learning systems like the Panze system will lead to a new kind of games that contribute to children's education at home and use interaction styles that are more natural for children.

The Panze system can be a valuable addition to every child's education. But in particular, systems like the Panze system can be beneficial in a society where parents have little spare time, or in situations where the parents do not have the skills to educate their children. For example when the parents have difficulties with the language that is spoken in the country they live in. In the Netherlands there are many children that do not master the Dutch language before they enter primary school, which causes problems in their learning at school. Nowadays, to resolve this problem these children are provided with special classes where they learn to speak Dutch. In the future, systems like the Panze system may also contribute to these children's language abilities.

The Panze system fits in with two current trends. The last few years, more and more computer games appear that let the users move with their whole body. Dancing mats, Sony's EyeToy® (Eyetoy, 2007) and Nintendo's Wii™ (Wii, 2007), are examples of such systems. Playing with a computer system by full-body movement discourages sedentary behavior and obesity, in contrary to the traditional desktop and game computer use (Siraj-Blatchford and Whitebread, 2003). Therefore it might be beneficial for children's health if this trend in gaming would also become a trend in the development of educational systems.

Another trend are animated agents. For people under about age 19, agents are becoming common, as they appear for example on mobile phones, in games and in internet applications (Baylor, 2007). Also pedagogical agents are getting more attention, as was illustrated by the recently published special issue about pedagogical agents from the

Educational Technology magazine (Educational Technology, 2007).

These two trends may predict a growing interest in systems like the Panze system. This may give good opportunities for further development of the Panze system. Ideally, within a few years the Panze system will be sold in all toy stores.

11.2 Reflection on the Development Process: Two Research Areas Combined

In this research project knowledge was brought together from two totally distinct research areas. On one hand is a research area with a technological background: 'human-computer interaction' (HCI) and in particular it's sub-area 'interaction design and children'. The latter is a relatively new and small research area. On the other hand is 'early childhood music education', with a background in developmental psychology. This research area is older and much larger, and has more research history. The field of interaction design and children has no own theories. Therefore the designs of interactive technologies for children have to be based on knowledge from the general HCI (which focusses most on adult users) and theories about child development from disciplines like psychology or pedagogy. Sciences with a technological background and sciences with a social background have a totally different approach to research. This made this research project interesting, but also caused some difficulties when combining these disciplines.

In general, an effort should be made to bring together the two totally distinct research area's of interaction design for children and child development. The field of interaction design and children could profit much more from all the research that has been done in the field of child development, resulting in designs that are better tailored to the needs and preferences of the target age groups.

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Appendix 1 - Songs and Activities

W – Welcome song		
Music	track 1: voice	singing “Hallo hallo hallo. Ik ban Panze. Hallo hallo hallo. Wie ben jij?”
Sound effect		none
Volume		default
Movements Panze		– singing (mouth movements) – waggling tail
Visual effects		none
Instrumentalists		none
Background		standard

Explain CD		
Music	track 1: voice	speaking “Als je een CD in mijn buidel doet, kunnen we gaan zingen en dansen” (If you put a CD in my pouch, we can sing and dance)
Sound effect		none
Volume		default
Movements Panze		– speaking (mouth movements) – waggling tail
Visual effects		none
Instrumentalists		inserted instrument(s) still
Background		standard

Explain instrument		
Music	track 1: voice	speaking “Als je een muziekinstrument in mijn buidel doet, dan hoor je hoe die klinkt” (if you put a musical instrument in my pouch, you will hear its sound)
Sound effect		none
Volume		default
Movements Panze		– speaking (mouth movements) – waggling tail
Visual effects		none
Instrumentalists		none
Background		standard

Demonstrate instruments		
Music	track 3: guitar	chord (only if the guitar is in the pouch)
	track 4: flute	one tone (only if the flute is in the pouch)
	track 5: xylophone	one tone (only if the xylophone is in the pouch)
Sound effect		none
Volume		default
Movements Panze		waggling tail
Visual effects		none
Instrumentalists		inserted instrument(s) play(s)
Background		standard

Activity 1: Klap Klap

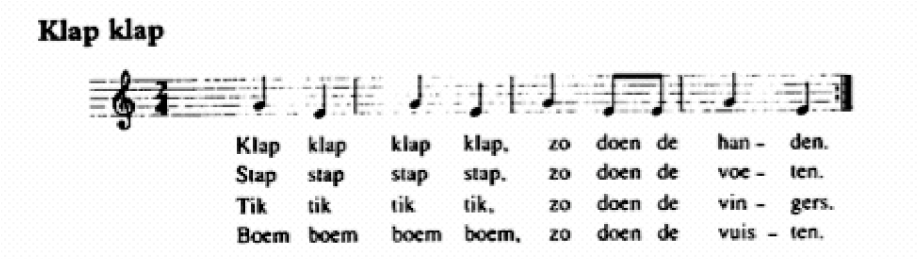

Figure App1.1. Score of the song 'Klap klap'

1A - Original song: Klap klap		
Music	track 1: voice	singing “Klap klap, klap klap, zo doen de handen”
	track 2: body sounds	clapping the hands on every beat
	track 3: guitar	chord on every beat (only if the guitar is in the pouch)
	track 4: flute	play melody (only if the flute is in the pouch)
	track 5: xylophone	play melody (only if the xylophone is in the pouch)
Sound effect		funny sound when detecting well timed movement imitation
Volume		default
Movements Panze		– clapping in the hands on every beat – singing (mouth movements)
Visual effects		– ears down, raise ears when singing is detected – baby kangaroo pops out of Panze's pouch when movement imitation is detected
Instrumentalists		inserted instrument(s) play(s)
Background		picture of inserted CD

1B – Changes of the original song for variation B: Stap stap		
Music	track 1: voice	singing “Stap stap, stap stap, zo doen de voeten”
	track 2: body sounds	stepping with the feet on every beat
Volume		default
Movements Panze		– stepping with the feet alternating left and right on every beat – singing (mouth movements)

1C - Changes of the original song for variation C: Boem Boem		
Music	track 1: voice	singing “Boem boem, boem boem, zo doen de vuisten”
	track 2: body sounds	bang with the fists on the knees alternating left and right on every beat.
Volume		high
Movements Panze		– bang with the fists on the knees alternating left and right on every beat. Large movements. – singing (mouth movements)

1D - Changes of the original song for variation D: Tik tik		
Music	track 1: voice	singing “Tik tik, tik tik, zo doen de vingers”
	track 2: body sounds	none
Volume		low
Movements Panze		– 'tick' the fingers (fingers, hands and forearm in one line) on every beat. Small movements. – singing (mouth movements)

Activity 2: Wie Niet Stappen Wil

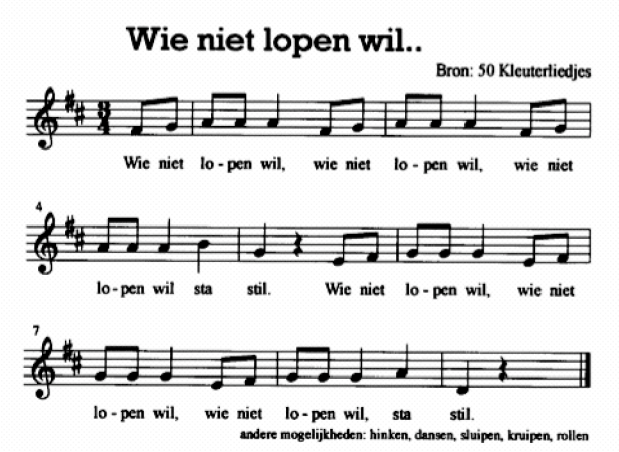

Figure App1.2. Score of the song 'Wie niet lopen wil'

2A - Original song: Wie niet stappen wil		
Music	track 1: voice	singing “Wie niet stappen wil, wie niet stappen wil sta stil. Wie niet stappen wil, wie niet stappen wil sta stil.”
	track 2: body sounds	stepping with the feet on every beat
	track 3: guitar	chord on every beat (only if the guitar is in the pouch)
	track 4: flute	melody (only if the flute is in the pouch)
	track 5: xylophone	melody (only if the xylophone is in the pouch)
Sound effect		funny sound when detecting well timed movement imitation
Volume		default
Movements Panze		– stepping with the feet alternating left and right on every beat – singing (mouth movements)
Visual effects		– ears down, raise ears when singing is detected – baby kangaroo pops out of Panze's pouch when movement imitation is detected
Instrumentalists		inserted instrument(s) play(s)
Background		picture of inserted CD

2B - Changes of the original song for variation B: Wie niet klappen wil		
Music	track 1: voice	singing “Wie niet klappen wil, wie niet klappen wil sta stil. Wie niet klappen wil, wie niet klappen wil sta stil.”
	track 2: body sounds	clapping in the hands on every beat
Volume		default
Movements Panze		– clapping in the hands on every beat – singing (mouth movements)

2C - Changes of the original song for variation C: Wie niet springen wil		
Music	track 1: voice	singing “Wie niet springen wil, wie niet springen wil sta stil. Wie niet springen wil, wie niet springen wil sta stil.”
	track 2: body sounds	jumping on every beat
Volume		high
Movements Panze		– jumping on every beat – singing (mouth movements)

2D - Changes of the original song for variation D: Wie niet tikken wil		
Music	track 1: voice	singing “Wie niet tikken wil, wie niet tikken wil sta stil. Wie niet tikken wil, wie niet tikken wil sta stil.”
	track 2: body sounds	none
Volume		low
Movements Panze		– 'tick' the fingers (fingers, hands and forearm in one line) on every beat. Small movements. – singing (mouth movements)

Activity 3: Klap Maar Mee

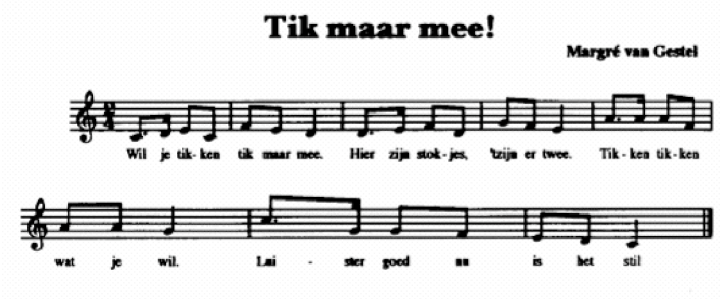

Figure App1.3. Score of the original song 'Tik maar mee'

3A - Original song: Klap maar mee		
Music	track 1: voice	singing “Wil je klappen, klap maar mee. Met je handen alletwee. Klappen klappen wat je wil. Luister goed, nu is het stil”
	track 2: body sounds	clapping in the hands on every beat
	track 3: guitar	chord on every beat (only if the guitar is in the pouch)
	track 4: flute	melody (only if the flute is in the pouch)
	track 5: xylophone	melody (only if the xylophone is in the pouch)
Sound effect		funny sound when detecting well timed movement imitation
Volume		default
Movements Panze		– clapping in the hands on every beat – singing (mouth movements)
Visual effects		– ears down, raise ears when singing is detected – baby kangaroo pops out of Panze's pouch when movement imitation is detected
Instrumentalists		inserted instrument(s) play(s)
Background		picture of inserted CD

3B - Changes of the original song for variation B: Stap maar mee		
Music	track 1: voice	singing “Wil je stappen, stap maar mee. Met je voeten alle twee. Stappen stappen wat je wil. Luister goed, nu is het stil”
	track 2: body sounds	stepping with the feet on every beat
Volume		default
Movements Panze		– stepping with the feet alternating left and right on every beat – singing (mouth movements)

3C - Changes of the original song for variation B: Spring maar mee		
Music	track 1: voice	singing “Wil je springen, spring maar mee. Met je voeten alletwee. Springen, springen wat je wil. Luister goed, nu is het stil”
	track 2: body sounds	jumping on every beat
Volume		high
Movements Panze		– jumping on every beat – singing (mouth movements)

3D - Changes of the original song for variation B: Tik maar mee		
Music	track 1: voice	singing “Wil je tikken, tik maar mee. Met je vingers, tik tak tee. Tikken, tikken wat je wil. Luister goed, nu is het stil”
	track 2: body sounds	none
Volume		low
Movements Panze		– 'tick' the fingers (fingers, hands and forearm in one line) on every beat. – singing (mouth movements)

Appendix 2 - Wizard Keys

The keys that the experimenter used to operate the program, are described in the following table.

Wizard keys	Key	Action
Start	Enter	Start welcome song
Stop	k	Show black screen
Inserted CD 1	1	play activity 1A
Inserted CD 2	2	play activity 2A
Inserted CD 3	3	play activity 3A
Ejected CD	0	stop current song, go to state “Wait”
Inserted guitar	q	Show 'guitarman' and sound guitar
Ejected guitar	a	'Guitarman' disappears and silence guitar
Inserted whistle	w	show and sound instrument 2
Ejected whistle	s	instrument 2 disappears and silences
Inserted xylophone	e	show and sound instrument 3
Ejected xylophone	d	instrument 3 disappears and silences
Detect movement imitation not in time	space bar	Show visual effect at the next beat
Detect movement in time	`	Show visual effect and sound audio effect at the next beat
Detect singing	z	Raise ears for 3 seconds
Play next variation	.	Play next variation when the current has finished
Play previous variation	,	Play variation A when the current has finished

Appendix 3 - Observation Scheme 1

Standby / Welcome

Wil het kind de input kangoeroe aaien?

❒ ja

❒ aarzelend

❒ nee

❒ anders, nl _____

Hoe reageert het kind als Panze verschijnt?

❒ geïnteresseerd

❒ geschrokken

❒ anders, nl _____

Wat doet het kind tijdens het welkomsliedje?

❒ alleen kijken

❒ anders, nl _____

Wait

Pakt het kind de tangibles als Panze dit aangeeft?

❒ ja, direct

❒ ja, al vòòr Panze dit aangeeft

❒ ja, na een tijdje

❒ nee

Wat doet het kind met de tangibles?

❒ doet ze in de buidel van de input kangoeroe

❒ probeert ze in de buidel op het scherm te doen

❒ anders, nl _____

Activity

Wat doet het kind tijdens de activities?

	alleen kijken	bewegen	zingen	experimenteren met de tangibles	anders, nl:
1A – Klap klap	❒	❒	❒	❒	_____
1B – Stap stap	❒	❒	❒	❒	_____
1C – Boem boem	❒	❒	❒	❒	_____
1D – Tik tik	❒	❒	❒	❒	_____
2A – Wie niet stappen wil	❒	❒	❒	❒	_____
2B – Wie niet klappen wil	❒	❒	❒	❒	_____
2C – Wie niet springen wil	❒	❒	❒	❒	_____
2D – Wie niet tikken wil	❒	❒	❒	❒	_____
3A – Wil je klappen	❒	❒	❒	❒	_____
3B – Wil je stappen	❒	❒	❒	❒	_____
3C – Wil je springen	❒	❒	❒	❒	_____
3D – Wil je tikken	❒	❒	❒	❒	_____

Als het kind zingt, wat zingt het dan?

❒ één of een paar woorden uit de tekst

❒ de hele tekst

❒ anders, nl _____

Als de oren van Panze omhoog gaan:

Hoe reageert het kind?

❒ reageert niet

❒ lacht

❒ schrikt

❒ anders, nl _____

Gaat het kind door met zingen?

❒ ja

❒ nee

❒ soms

Als het kind beweegt op de muziek:

Welke bewegingen maakt het kind?

❒ de bewegingen van Panze

❒ eigen bewegingen

❒ anders, nl _____

Beweegt het kind (ongeveer) op de maat van de muziek?

❒ ja

❒ nee

❒ soms

❒ eerst niet, later wel

Als een baby kangoeroe uit de buidel komt (zonder audio effect):

Hoe reageert het kind?

❒ reageert niet

❒ lacht

❒ schrikt

❒ anders, nl _____

Gaat het kind door met bewegen?

❒ ja

❒ nee

❒ soms

Als een baby kangoeroe uit de buidel komt en er klinkt een audio effect tijdens lied 1 – “Klap klap”:

Hoe reageert het kind?

❒ reageert niet

❒ lacht

❒ schrikt

❒ anders, nl _____

Gaat het kind door met bewegen?

❒ ja, nog steeds in de maat

❒ ja, maar niet meer in de maat

❒ nee

❒ soms

Als een baby kangoeroe uit de buidel komt en er klinkt een audio effect tijdens lied 2 – “Wie

niet stappen wil”:

Hoe reageert het kind?	Gaat het kind door met bewegen?
❒ reageert niet	❒ ja, nog steeds in de maat
❒ lacht	❒ ja, maar niet meer in de maat
❒ schrikt	❒ nee
❒ anders, nl _____	❒ soms

Als een baby kangoeroe uit de buidel komt en er klinkt een audio effect tijdens lied 3 – “Wil je klappen”:

Hoe reageert het kind?	Gaat het kind door met bewegen?
❒ reageert niet	❒ ja, nog steeds in de maat
❒ lacht	❒ ja, maar niet meer in de maat
❒ schrikt	❒ nee
❒ anders, nl _____	❒ soms

Bijzonderheden

Appendix 4 - Observation Scheme 2

Timeline

Wat doet het kind wanneer?

Input kangoeroe aanraken	P
CD1 (blauw) in de buidel (Klap klap)	1
CD2 (groen) in de buidel (Wie niet stappen wil)	2
CD3 (paars) in de buidel (Wil je klappen)	3
CD uit de buidel	0
gitaar in de buidel	+g
gitaar uit de buidel	-g
fluit in de buidel	+f
fluit uit de buidel	-f
xylofoon in de buidel	+x
xylofoon uit de buidel	-x
lachen	☺
raakt gefrustreerd/ anders negatief	☹
stopt spelen met Panze (einde test)	|

Appendix 5 - Observations WoZ Pilot Test

- **Participant 1**

  A girl aged 3.

Explanation Before the Test

Experimenter: “That is Panze. Go stroke Panze. See what happens then.”

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told her to do so. She kept stroking it for a long time and then started kissing it. The child did not react when Panze appeared, she was still busy with the input kangaroo. Later on, the child looked at the screen during the welcome song.

Wait

During the wait state the child was at first playing with the tangibles: she whistled on the whistle, and played fiddle with the guitar and the whistle. She did not react to Panze's explanations to put the tangibles in the pouch. Only after nearly three minutes she put the tangibles in the pouch of the input kangaroo and discovered their functionality.

Activity

The child did the activities 1A 'Klap klap', 2A 'Wie niet stappen wil' and 3A 'Wil je klappen'. During all of these activities she jumped and clapped, independent of the activity and the movements Panze made. Her movements were not in time to the music. She was so busy jumping and clapping around in the room that she did not pay much attention to the screen. Therefore she did not notice the visual rewards. The child did not sing.

Notes

At first the child did not react to Panze's explanations to put the tangibles in the pouch. Maybe she did not understand the instructions, or it was just because she was still busy playing with the tangibles.

Reflection

The child was very enthusiastic. She moved to the music as was intended. She did

not pay much attention to the screen.

- **Participant 2**

  A girl aged 6.

Explanation Before the Test

The child watched her younger sister play with the system. When participant 2 was allowed to play, the experimenter only told her: “Go stroke Panze.”

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told her to do so. She reacted interested when Panze appeared. During the welcome song she just looked.

Wait

The child directly grabbed the tangibles when Panze indicated this and put them in the pouch of the input kangaroo.

Activity

The child did the activities 1A 'Klap klap', 2A 'Wie niet stappen wil' and 3A 'Wil je klappen'. During all these activities she experimented with the tangibles and imitated Panze's movements in time to the music. When a baby kangaroo popped out of Panze's pouch, accompanied by an audio effect, she laughed and continued moving in time to the music.

During activity 2A 'Wie niet stappen wil' the child also sang most of the lyrics. She did not react when Panze's ears raised, she continued singing.

Notes

The child played with the tangibles: she played whistle on the tangible whistle and placed the input kangaroo on her head.

Reflection

She understood the instructions and did everything well, but never reached the next variations of an activity, for she was too quick with changing the CDs.

Appendix 6 - Observations WoZ Test Preschool

- **Participant 1**

  A boy aged 3½, from group 1.

Explanation Before the Test

The experimenter said: “That is Panze. Go stroke Panze. See what happens then.”

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told him to do so. He reacted interested when Panze appeared. During the welcome song he laughed a bit. He looked to and fro between the input kangaroo and the screen. He also looked at the teacher a few times.

Wait

The child did not grab the tangibles when Panze indicated this. He looked at the screen, looked at the input kangaroo, looked at the pouch, and then raised his eyebrows very high. He looked to the experimenter and the observers, looked to the input kangaroo, looked to the screen, looked to the tangibles, looked to the teacher, and looked puzzled more and more. When the experimenter asked him what he could do with a CD, the child shrugged its shoulders. Only after explanation from the experimenter he put a CD in the pouch of the input kangaroo.

Activity

The child tried all three CDs. Two of these were taken out again within a few seconds, before the song sounded. Only the CD corresponding to activity 3A 'Wil je klappen' stayed in a little longer. Only when the song started, he looked at the screen, for the rest of the time he looked to the experimenter and the observer. He did not sing or move to the music. He did explore the tangibles. Once he understood that something happened when he put the tangibles in and out the pouch, he started experimenting. If there was not directly a change in sound when he inserted a tangible, he removed it right away. If he heard a change in the sound, he looked to the screen. He inserted the instruments subsequently in different slots. He never put more than one tangible in the pouch at the same time. After something over 3 minutes he had had enough of it, and stopped experimenting. He looked at the

screen, looked around, talked a bit with the teacher and showed some nervous tics.

Reflection

This child did not seem nervous before the test, but showed some nervous tics later on. During the *Wait* state he really did not understand what to do. After the explanation that he could put a CD in the pouch, he started to understand. But because he did not immediately hear something when he put a tangible in the pouch, he did not completely understand. He was mainly concerned with the effects of the tangibles, not so much with the music.

- **Participant 2**

  A boy aged 3½, from group 1.

Explanation Before the Test

The experimenter said: “This is Panze. Panze is a kangaroo and Panze has a pouch. And these are CDs and these are musical instruments. Do you want to play with this?” The child answered “no”. When the experimenter asked “do want to look?”, the child answered “yes”.

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told him to do so. He pushed on a foot of the input kangaroo. When Panze appeared, the child looked at the screen just for a moment and then returned his focus to the input kangaroo. During the welcome song he kept pushing on the feet of the input kangaroo.

Wait

The child did not grab the tangibles when Panze indicated this. He first looked at the tangibles, than at the screen for a moment, and then returned to the input kangaroo. After a while he looked again at the screen and the tangibles for a moment. After a hint of the teacher the child inserted a CD and two instruments in the pouch of the input kangaroo.

Activity

The child did only activity 1A 'Klap klap'. During this activity the child looked at the screen only for short periods, especially during the pause between the repetitions of the song. Only for a very short time the child experimented with the tangibles, he put the guitar

and the whistle in the pouch. For the rest of the time he kept pushing on the feet of the input kangaroo. After a while he started pushing harder. Sometimes he looked at the experimenter and the observers or at the teacher. He started scratching his head after a while.

After a short explanation by the experimenter about putting things in and out of the pouch, he looked more at the screen and the tangibles, stopped pushing the feet of the input kangaroo, stopped looking at the input kangaroo and started to scratch himself almost continuously. But after a while he started pushing the feet again. He did not experiment with the tangibles anymore.

The child did not sing and did not move to the music.

Reflection

This child pushed on the feet of the input kangaroo. It was not clear why he did so. Did he expect something to happen if he pushed on the feet of the input kangaroo? Did he try to turn it off? Or was he doing this because he was nervous? He looked a bit frustrated now and then while pushing the feet. This child was already nervous before the test started.

- **Participant 3**

  A boy with ADHD, aged 3½, from group 1.

Explanation Before the Test

The experimenter said: “This is Panze. Panze is a kangaroo.” The child answered: “Those are in the zoo.” The experimenter acknowledged this, and showed and named the pouch, the CDs and the musical instruments. She asked the child whether he wanted to play with it, he answered “yes”.

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told him to do so. He reacted interested when Panze appeared. During the welcome song the child already tried to put a CD in the pouch. He had difficulties with this and looked at the experimenter. Because he already experimented with the tangibles, the application directly entered the *Activity* state.

Activity

The child started experimenting with the tangibles right away as soon as the program was started, and continued to do so. When the song 2A 'Wie niet stappen wil' sounded, the

child smiled. He put the tangibles in and out the pouch very fast, with his left hand, while looking at the screen. Because he did this so fast, there were at first hardly any sound reactions from the system. The child broke the tangible guitar. He had difficulties with inserting the CDs in the pouch, trying to put them in the slots for the instruments. He tried to insert all three CDs, but only managed to insert CD 2 a number of times. The first few minutes he put only one tangible in the pouch at a time, after more than three minutes he had a CD and all three tangibles in the pouch. He smiled and paused his experimenting. Once he explored the back of the input kangaroo. He smiled a lot. Sometimes he looked to the teacher and experimenter. The child stopped playing after almost seven minutes and walked away. He did not sing and did not move to the music.

Reflection

This child did not seem nervous. It looked like he understood the working of the tangibles and enjoyed playing with them. He seemed not to understand that there was a special slot for the CDs.

- **Participant 4**

  A girl aged 3 (almost 4), from group 1.

Explanation Before the Test

The experimenter told the child that the input kangaroo is a kangaroo called Panze. She told her that a kangaroo has a pouch, and showed her the pouch of the input kangaroo. She also showed the tangible CDs and instruments. When the experimenter asked whether the child knew what the tangible whistle was, the child answered “little whistle”. The experimenter acknowledged this and asked the child if she wanted to play with it. The child answered “yes”. The experimenter told her that that's OK and said: “Go stroke Panze, and look what happens.” The child answered “yes”.

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told her to do so. She reacted calm when Panze appeared. During the welcome song the child looked in different directions: at the screen, at the teacher, at the input kangaroo, and through the window.

Wait

The child did not grab the tangibles when Panze indicated this. Only after clear instructions from her teacher and the experimenter the child put the tangibles in the pouch of the input kangaroo.

Activity

The child did the activities 1A 'Klap klap' and 2A 'Wie niet stappen wil'. During these activities the child only looked at the screen. The child did not sing and did not move to the music. She looked to teacher and the experimenter and put tangibles in and out of the pouch when they told her to, but she did not experiment herself. Sometimes she looked at the screen when she put something in or out the pouch, but not always. She looked to the screen when she heard instruments, but not when she heard Panze speaking.

Notes

The child came to look herself and said she wanted to play, but she looked nervous from the first moment on. She showed no emotions.

Reflection

She seemed to understand the link between the tangibles in the pouch and the screen, because sometimes she looked at the screen when she had put something in the pouch. But she did not seem to understand the meaning of the game nor to enjoy it.

- **Participant 5**

A girl aged two or three (exact age unknown), from group 2.

Explanation Before the Test

This child was present at a group introduction for 5 children from group 2 at the same time (participants 5, 6, 7 and two other children). The teacher from group 2 introduced the system and the experimenter. After this, the experimenter took over. The experimenter told them: “This is Panze. Panze is a kangaroo. Do you know what a kangaroo has on its belly? a pouch. This is Panze's pouch.” The children were asked whether they knew the instruments. They did recognize the guitar, but not the whistle and the xylophone. They were told that the tangible CDs were fake CDs. The children were given the tangibles to hold. One child walked away with one of the tangibles. It was demonstrated once that a CD fits in the pouch. The children spontaneously put the tangibles they had in their hands in the pouch.

Participant 5 participated well during the group explanation. She was the second child that put a tangible in the pouch, without encouragement. After the group explanation, she volunteered to play with the system first.

Standby / Welcome

The child wanted to stroke the input kangaroo when the experimenter told her to do so, and kept stroking it. From the corner of her eyes she watched the experimenter. She reacted calm and interested when Panze appeared. During the welcome song the child looked to and fro at the screen and the input kangaroo and kept stroking Panze.

Wait

The child did not grab the tangibles when Panze indicated this, she did look to and fro at the screen, the input kangaroo, the pouch and the tangibles. When the experimenter told her to try something, she immediately took a tangible and put it in the pouch of the input kangaroo.

Activity

The child did the activities 1A 'Klap klap', 2A 'Wie niet stappen wil' and 3A 'Wil je klappen'.

During activity 1A 'Klap klap' the child first looked to and fro at the screen and the input kangaroo, then through the window and to the teacher. The child tapped her foot in time to the music. She was experimenting with the tangibles: she took the CD out when the first repetition of the song stopped. She put it in again when the song started again. After a while, when the experimenter told her to try something, she put instruments in the pouch and watched the screen.

During activity 2A 'Wie niet stappen wil' the child looked at the screen and moved a foot. She was also experimenting with the tangibles and played with the tangible CDs themselves: she traced the lines of the picture on the CDs with her finger and played with two CDs. The child was also kind of singing: she made mouth movements as if she was singing, but produced no sound. Her mouth movements partly matched the lyrics, but not all correct. While 'singing' she looked towards the camera once, and looked only occasionally to the screen. When the system became unstable (songs were mixing up), the child stopped 'singing' and sighed, but she kept playing with the tangible CDs.

During activity 3A 'Wil je klappen' the child looked at the screen and moved a foot.

During all three activities, the child tapped or waggled with the foot or legs, independent of the song. These movements were approximately in time to the music. No reaction from the child was seen when a baby kangaroo popped out of Panze's pouch without an audio effect. When a baby kangaroo popped out of Panze's pouch and an audio effect sounded during song 2 “Wie niet stappen wil”, the child looked at the screen and to the teacher. On these occasions, sometimes the child continued moving, still in time to the music. However, when the experimenter told her that it's good to dance, she stopped moving. When the test was finished she took all tangibles out of the pouch.

Notes

This child did not seem nervous before the test. During the test she made grimaces now and then.

Reflection

During the welcome song, the child started to look puzzled about the relation between the input kangaroo and the screen. That is a good reaction, for that may promote exploration. She looked puzzled during the whole test. She understood the working of the instruments, as well as the CDs. The foot tapping may be unconscious.

- **Participant 6**

A girl aged 2½, from group 2. She could not talk yet and was referred to the audiology center.

Explanation Before the Test

This child was present at the group introduction before participant 5. She got instructions of putting tangibles in and out of the pouch and tried this. The child was told that she was allowed to try everything she wanted, to dance, to clap, and that she could put everything into the pouch that she wanted.

Standby / Welcome

The child hesitated to stroke the input kangaroo when the experimenter told her to do so, but eventually did. When Panze appeared, the child looked at the screen only for a short moment, and then looked to the experimenter and observers. During the welcome song the child looked at the experimenter and observers most of the time.

Wait

The child did not grab the tangibles when Panze indicated this. After one minute, another child (participant 7) was asked to join participant 6 to help her. Immediately, participant 6 pointed to Panze on the screen to draw the attention of participant 7 to it. Participant 7 did not actively participate. Only after help from the experimenter, participant 6 put tangibles in the pouch of the input kangaroo.

Activity

The child did the activities 1A 'Klap klap', 2A 'Wie niet stappen wil' and 3A 'Wil je klappen'.

After the child put the CD for activity 1A 'Klap klap' in the pouch, she looked at the screen. She wanted to take out the CD when the second repetition of the song stopped, but first looked to experimenter. During this activity she experimented with the tangibles.

After the child put the CD for activity 2A 'Wie niet stappen wil' in the pouch, she looked at the screen and pointed to the picture of the CD at the screen to direct the attention of participant 7 to it.

During activity 3A 'Wil je klappen' the child looked at the screen and experimented with the tangibles.

The child did not sing and did not move to the music. Sometimes she shrugged her shoulders. She looked to the experimenter each time she wanted to put something into or out of the pouch. When she had put something into the pouch, she turned to the screen.

Notes

This child did not wait for an invitation to come. She came of her own accord when all adults were still discussing.

After a few songs, she experimented with the tangibles during the *Wait* state. Sometimes when the instrument had sounded, she took the tangible out again. She left after about 6½ minutes.

Reflection

She understood the working of the tangibles. She seemed more focused on the experimenter and observers than on the game.

- **Participant 7**

  A girl aged 2 or 3 (exact age unknown), from group 2.

Explanation Before the Test

This child was present at the group introduction before participant 5. When participant 6 played with the system, participant 7 joined her after one minute, during the 'Wait' state. However she did not participate in the game. Participant 6 directed her attention to Panze and to the picture of the CD on the screen. When participant 6 played with the system, participant 7 played with the tangibles. Participant 7 took over when participant 6 left, she was now alone with the system. Because she stood next to participant 6 for a few minutes, she had already seen what she could do with the system.

Wait

The child started playing with the system when participant 6 had left. At that moment the system was in the *Wait* state. She directly started to insert tangibles in the pouch of the input kangaroo.

Activity

The child inserted the CD for the activity 1A 'Klap klap' very soon when she started playing and never took it out again. During this activity the child put her hands together, but without clapping. It was hard to see, but it seemed like she imitated Panze's clapping. She experimented with the tangibles, but only with the instruments. When she did so, she looked to the experimenter and the observers, not to the screen. She had difficulties with putting the tangibles in the pouch. The child did not sing.

Reflection

The child did not seem to notice that something happened on the screen when she put the tangibles in and out of the pouch.

- **Participants 8 and 9**

Participant 8 was a boy aged 3½, participant 9 was a boy just turned 3, both were from group 2.

Explanation Before the Test

Before the test they did some 'dry practice' with putting tangibles into and out of the pouch together with the experimenter. The experimenter explained what happens when someone puts a CD in a CD player. The children thought that the input kangaroo was a rabbit. The experimenter told them that it is a kangaroo and that it has a pouch. Participant 8

knew that a kangaroo has a baby on its belly, but did not know the name of the pouch. He expected to see a baby in the pouch. They were told that they might see a baby if they would move along to the music. Participant 8 wanted to have a chair to sit in front of the screen. The experimenter told that they didn't need a chair, for they could stand and were allowed to dance, and when they sit on a chair they cannot dance.

Standby / Welcome

The children wanted to stroke the input kangaroo when the experimenter told them to do so. They reacted interested when Panze appeared. During the welcome song they just watched the screen.

Wait

The children did not grab the tangibles when Panze indicates this. But later on they put the tangibles in the pouch of the input kangaroo.

Activity

The children tried all three CDs. During all activities, they watched the screen, moved to the music and experimented with the tangibles. When they put something into the pouch, they looked to the screen. When they saw that something happened, they tried something else. They both did not await the end of the song to take the CD out of the pouch. They were arguing about what they put in the pouch. Participant 9 looked behind the input kangaroo and in the pouch. Participant 8 was playing mostly with the CDs, participant 9 mostly with the instruments and disagreed when participant 8 put a CD in the pouch. They did not notice that the program ended, for they were busy with the tangibles.

Both children made small movements with the hips for a very short time. Participant 9 ticked with a tangible in his hands, also only for a very short time. Their movements continued sometimes when the music had already stopped. The children did move approximately in time to the music, but it was hard to see. Both children did not sing

Notes

They did not seem nervous. Participant 8 tried to push the buttons of the screen. During the explanation before the test, they understood how to put things in the pouch before the game started, but during the *Wait* state they did nothing with the tangibles or the pouch.

Reflection

These children understood the effect of the tangibles. The children were rather focused on discovering how the tangibles worked, than on the music. When participant 9 looked behind the kangaroo and in the pouch, he was probably trying to discover how it worked.

Playing together made the children feel more comfortable, but the system is not suited for playing together, for the children were arguing about what to put in the pouch. When participant 8 indicated that it was getting late, he probably wanted to quit playing.

The movements that these participants made to the music, seemed to be unconscious. As their movements sometimes continued when the music had stopped, they had a delayed musical response.

- **Participants 10 and 11**

  Two boys, aged 3 and 4 (just one week), both from group 2.

Explanation Before the Test

The children got an introduction by their own teacher: “It is a computer, you can do nice things with it”. Then the experimenter took over, she told them: “This is Panze, Panze is a kangaroo. Participant 11 knew that a kangaroo has something on the belly, but could not tell the name of it. The CDs and instruments were explained by the experimenter. It turned out that it was not clear what the tangibles represent: they did not recognize the CDs, they thought the xylophone represented stairs and that the flute represented a clock. They did recognize the guitar. After the explanation they understood that they could put the tangibles in the pouch. Participant 11 did not see that there is a special hole for the CDs, participant 10 did see it. Participant 11 tried all possible ways to get all CDs in the pouch: he placed them before each other and on top of each other.

Standby / Welcome

The children wanted to stroke the input kangaroo when the experimenter told them to do so. They laughed when Panze appeared and kept laughing during the welcome song.

Wait

When Panze indicated to put the tangibles in the pouch, the children did not do this. Both looked to the screen, the tangibles and the input kangaroo. Participant 11 shrugged his shoulders and later on touches the tangibles. The children look to each other and to the

experimenter. Only after the experimenter said “try it”, the children put the tangibles in the pouch of the input kangaroo. After more explanation and some experimentation, participant 11 listened to the instructions from Panze during *Wait*: when Panze said “If you put an instrument in my pouch...” he said “oh” and placed an instrument into the pouch.

Activity

The first song that sounded was 1A 'Klap klap'. When the activity started, the children laughed and then looked to each other. Participant 11 looked nervous and sighed. They did not understand what do do next. Only after experimenter said: “Try what you can do with the instruments, put something in”, they experimented with the tangibles. Later on they moved to the music. During activity 3A “Wil je klappen” the children moved and experimented with the tangibles. They did also insert CD 2, but due to a system crash, this activity did not start.

During the activities the children moved. Participant 11 clearly moved to the music. He imitated Panze's movements: he clapped with a CD in his hands, but not in time to the music. He also made own movements: first he made small movements with the hips, later he swayed with the hips, and still later he swayed his whole body. Later on he started dancing after inserting a CD, but the song did not sound yet. Participant 11 moved in time to the music when he made movements with his hips or his whole body, but not when he clapped. Participant 10 moved with his foot and once with his hips, but it was hard to see whether this was a reaction to the music. It was not in time to the music. No reaction from the children was seen when a baby kangaroo popped out of Panze's pouch (without audio effect). The children did not sing.

Notes

Before the explanation, participant 11 looked nervous, participant 10 not. These children did collaborate.

Reflection

After some starting problems, these participants understood the game. They seemed to enjoy it.

Appendix 7 - Timelines

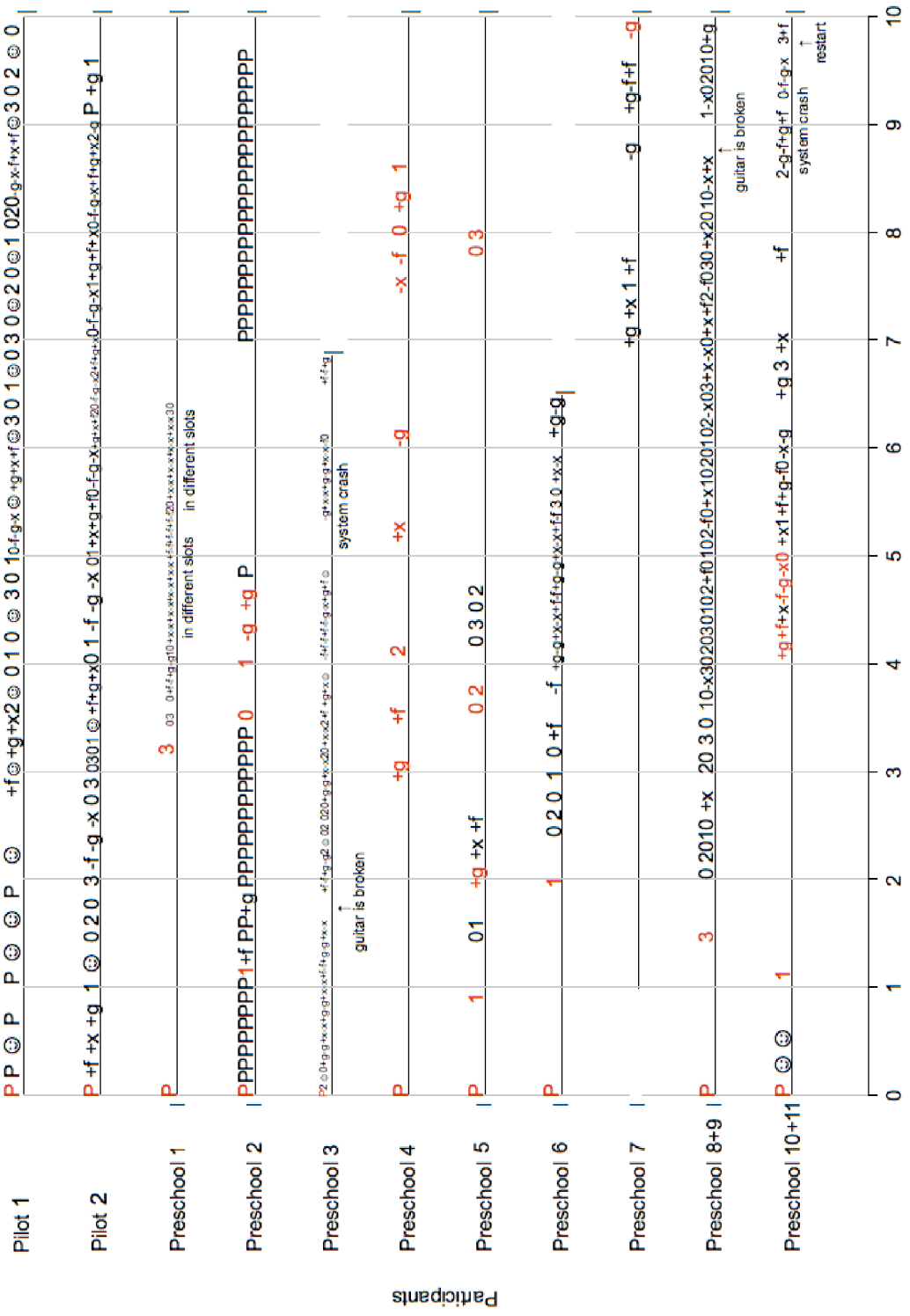

Figure App7.1. Timelines of all participants

Legend

P	participant touches the input kangaroo
1	CD 1 in the pouch (Klap klap)
2	CD 2 in the pouch (Wie niet stappen wil)
3	CD3 in the pouch (Wil je klappen)
0	CD out of the pouch
+g	guitar in the pouch
-g	guitar out of the pouch
+f	whistle in the pouch
-f	whistle out of the pouch
+x	xylophone in the pouch
-x	xylophone out of the pouch
☺	participant laughs
☹	participant cries or is frustrated
|	participant stops playing / end of test

The symbols in red are actions by the child on directions or encouragements from one of the present adults.

Appendix 8 - Paper IDC 2006 Conference

Jansen, L., van Dijk, B., & Retra, J. (2006). Musical Multimodal Child Computer Interaction. *Proceedings of 5th international conference for Interaction Design and Children (IDC 2006),* Tampere, Finland, 163-164.

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Summary

This Master's thesis describes a design research project, in which an interactive computer system was designed that envisions to contribute to the musical education of children aged two and three years old. The intent was to stimulate the child's inherent musical abilities through active musical interaction with the system. Three research questions guided the research.

RQ1: What are the requirements for an interactive music educational system for two and three-year-old children?

RQ2: What musical interactions between child and adult that stimulate the child's musical abilities can be used as an example for the system?

RQ3: What interaction styles are eligible for natural musical interaction between the child and the system?

For this project, first the product concepts and goals were specified, then the system was designed, and finally the design was evaluated with a Wizard of Oz test.

In the first phase of the project, the product concepts and goals were specified. In a literature review to children's needs for learning with interactive technology and for learning music, five main issues were found to be important: play and exploration, fun and enjoyment, control, multiple forms of interaction, and interaction with adults.

Movement and singing were found to be children's natural responses to music. They like music and often respond to music without encouragement. Responding to music by movement and singing, and the use of tangible objects are appropriate forms of interaction for a music educational system for two and three-year-old children.

Interaction between children and adults in the Dutch Preschool Music Education method called 'Music on the Lap' (MoL) has been the example for the Panze system. Three musical developmental goals from this method have been chosen for the Panze system: 'sense of beat and timing', 'sense of dynamics' and 'listening skills'. The goal 'listening skills' is refined to the skill to associate timbre with the corresponding musical instrument.

Design principles from the field of Human-Computer Interaction and guidelines for interaction design for children were consulted. User experience goals and usability goals were formulated.

In the second phase of the project, the system was designed based on the results of the first phase. For the interaction between the child and the Panze system, natural interaction was used. The system is connected to a television set. The pedagogical agent

Panze was invented that acts like a kind of role model for the child: she gives examples and motivates the child by singing, dancing and speaking to the child. The aim is that the child will give musical responses, like moving to the music, singing or making body sounds like clapping with the hands or on the body. The musical responses of the child evoke a reaction in the system. By using tangibles, the child can choose songs and musical instruments that accompany the songs. A short inventory was made of the technology that can be used for the interaction styles movement, singing and playing with tangible objects. A tangible input device called the 'input kangaroo' was designed, that contains the technology necessary for these interaction styles.

In the third phase of the project, the appropriateness of the interaction design of the Panze system was evaluated with a Wizard of Oz test with children in the target age group. The tangible user interface appeared to be an appropriate form of interaction for the target age group. Eventually all participants played and experimented with the tangibles. Therefore, an interactive environment in which the user can explore and play, seems to be appropriate for the target age group. The children that enjoyed themselves, experimented more with the tangibles. This indicates that fun and enjoyment is indeed related to motivation to interact with the Panze system. When the children did not know what to do with the system, they children felt uncomfortable. When they understood that they could influence the system, they enjoyed experimenting. This shows that children indeed need to be in control of the technology they use. The children's reactions to Panze were positive. However, in the test not much movement to the music was seen. Further research is necessary to see whether responding to the music by movement and singing are appropriate forms of interaction. Based on the evaluation, suggestions for improvements of the system and further research are given.

In a reflection on the research, it was conceived that to be able to design systems that are better tailored to the needs and preferences of children, an effort should be made to bring together the two totally distinct research area's of interaction design for children and child development.