JamMo: Developmentally designed software for children's mobile music-making

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ABSTRACT

Mobile learning is one of the most recent branches in educational research. In contrast to traditional classroom learning, mobile learning extends outside the classroom, allowing mobility and flexible interaction between formal and informal learning. Up to this date, only few music based mobile applications have been developed for educational purposes and especially for young children. In the present study, software JamMo will be designed for Nokia N810 Internet tablet. JamMo aims at child-centred, intelligent musical engineering and pedagogical design of stand-alone, ad hoc and networked creative music making. It is targeted to 3–12-year-old children including those with moderate learning difficulties, such as attention deficit disorders, and those who are newly immigrated. This paper describes the developmental and pedagogical framework of the design and, the features and functions of the stand-alone sequencer software. The requirements for cognitive development and learning are described. The design encompasses software features and functions, structured learning materials, decision-making structures, support of attention, feedback, game features supporting motivation and, musical materials. The end product will be an accessible mobile learning device to be used in classroom and informal creative music learning, and tested with user groups mentioned to promote social inclusion of children.

I. INTRODUCTION

In the present study, which is a part of EU FP7 UMSIC (www.umsic.org) research project 2008-2011, software JamMo ('Jamming Mobile') will be designed for Nokia N810 Internet tablet. JamMo aims at child-centred, intelligent musical engineering and pedagogical design of stand-alone, ad hoc and networked creative music making: singing and instrument playing, improvisation and composition. It is targeted to preschool (aged 3-6 years) and school-aged (7-12 years) children including those with moderate learning difficulties, such as attention disorders, and those who are immigrant and, tailored to children's different levels of cognitive and musical development.

A. Mobile Musical Applications

The first music based applications for Palm OS based PDAs were simple keyboard applications allowing simple sequencing. As the platform developed MIDI applications appeared. Similarly the Pocket PC/Windows Mobile platform allowed developers to explore a range of music making applications from drum machines to sequencers with plug-ins and mixing capabilities (Elsdon, 2007). Most of them had root functionality in desktop origins. However, these applications have been commercial and generally targeted to musicians. Some applications such as miniMusic Sight reading pad and Ear training pad (http://www.minimusic.com) were developed for educational use. Few applications have been developed for young children, such as Tratti, a noise maker (Beloff &

Pilchmair, 2007) with which children can record their voice and, by moving the device they get playback manipulated by the instrument. Malleable Mobile Music (Tanaka 2004) took social navigation and mobility as inputs to an audio re-composition engine enabling communities of listeners to experience familiar music in new ways. It extended music listening from a passive act to a proactive, participative activity. The system consisted of a network based interactive music engine and a mobile rendering player. Kayali, Kotik and Pilchmair (2008) presented a study of portable game-console (Nintendo DS) used as a tangible music-making interface. They developed three different musical instrument prototypes for the platform to find different approaches for gestural interaction with music.

Currently, as an example, there are over 1000 third party music applications for iPhone 3G mobile phone alone, ranging from different virtual instruments to social music sharing and mobile music information retrieval applications. PDA devices were generally inadequate for convenient musical data input, and many problems occurred when users tried to produce notation or sequences with a small screen and a PDA pen (Salavuo, 2006). New mobile devices have enabled versatile ways for musical data input with a larger screen and touch screen gesture controllability. Multi-touch mobile devices let one tap, drag, flick, glide and pinch, and ultimately 'touch' the music. Sensor technologies, such as built-in accelerometers, provide new opportunities for movement controlled virtual instruments. Mobile phones have indeed reached a point of including sufficient interesting sensory capabilities and computational power to serve as generic devices for musical expression, creation and collaboration.

We present a general categorization for music-based applications in mobile environment: 1) music creation; mobile sequencers, 2) stand-alone virtual instrument applications, 3) music listening and sharing applications, and 4) educational applications. The present project aims at combining all four purposes mentioned in an innovative way, continuing the pilot study MobiKid (Fredrikson & Paananen 2008).

B. Mobile Learning

In contrast with traditional classroom learning which is founded on an illusion of stability of context – a teacher, a fixed location, common resources and, a set curriculum – mobile learning is time and place independent, embracing learning outside the classroom and interactions between formal and informal learning (Sharples, 2000; Sharples, Taylor, & Vavoula 2005). Sharples (2000, 178-179) argues that the tools for lifelong learning should be highly portable and available anywhere, designed to support personal learning and retrieve knwledge without the technology obtruding on the situation, adaptable to the learner's evolving skills and knowledge, suited to everyday communication and learning

and, intuitive to use by people with no previous experience of technology. Situated, collaborative and ubiquitous learning get a special emphasis in mobile learning, as well as usability which relates to learner centredness (Sharples, Taylor, & Vavoula 2005). Learning is interwoven with activites as part of everyday life, and learners are constantly 'on the move', constructing their own learning context as a result of interaction (Sharples, Taylor, & Vavoula 2005). Mobility means learners' moving in physical space and portability of technology, however, it also means mobility in conceptual and social space, when learners' attention moves among competing topics, as learners interact within various social groups (Sharples, Sanchéz, Milrad, & Vavoula 2008). Following these ideas, constructive learning processes in time and place independent 'mobile music classrooms', in which children could be moving and interacting anywhere anytime, would then be based on sounds from the everyday physical environment, sounds symbolizing the physical environment, intentional human sounds, sounds of digital environment and sounds of online communities and websites, representing social belonging.

Moreover, mobile music learning is multimodal and based on double-layered communication. When composing music in collaboration, the learners communicate real time peer-to-peer and with the teacher, and simultaneously via the device. These features both support the learning process and simultaneously form a challenge for the design of the learning environment. For example, nonverbal communication during collaborative composition makes the process faster, but at the same time it might be a challenge for the learners' attention capacity. In mobile learning, the device itself can act as a teacher or mentor during learning. Problem-solving may be simulated in a virtual environment, and structured in a game form. Communication may also be extended to websites and online communities, in which materials, information and experiences can be shared via reflective dialogues and wiki, and musical materials can be stored. These features provide new possibilities for social inclusion, when a sound basis for positive social interaction is created for learners.

II. AIMS: DEVELOPMENTAL AND EDUCATIONAL BASIS OF JamMo

User characteristics define the design of a developmentally and educationally targeted mobile learning environment for creative music making. In this project, target users differ in age, attention capacity and/or other executive functions, as well as cultural background. *Age* forms loose boundaries within which developmental changes happen, and according to which children are grouped at school and music play school environments. In cognitive load theory (Sweller, 1988) related to learning as well as neo-Piagetian / information-processing theories of cognitive development (Case, 1985, 1992) the role of executive is central.

C. Executive Functions and Cognitive Load

Executive functions start to develop in the first year of human life and continue to develop until adolescence. With age children are better able to focus their attention, process information faster, hold information in working memory, and use multiple thinking strategies more fluently and flexibly. In the field of music, executive functions tap a wide variety of

everyday individual and social situations such as active listening of music, singing, learning to play musical instruments (informal or formal contexts), playing musical instruments and games and, improvising and composing music with sequencer-software etc.

In neuropsychology executive function is defined as neurocognitive processes that maintain an appropriate problem solving set to attain a future goal (Luria, 1973; Shallice, 1982; Welsh & Pennington 1988) and, involve multiple distributed neural networks that include the thalamus, basal ganglia and prefrontal cortex (Fuster, 1997; Middleton & Strick 2001, 2002; Pennington, 2002). These processes facilitate future-oriented behaviour and decision-making by maintaining information about possible choices in working memory and integrating this knowledge with information about the current context to identify the optimal action for the situation (Willcutt, Doyle, Nigg, Faraone, & Pennington 2005); allowing planning, flexible strategy employment and impulse control (Welsh, Pennington, & Groisser 1991; Weyandt & Willis 1994). Within the cortex the frontal lobe that controls higher-order thinking processes and executive functions, matures last; another factor that influences thinking and learning is myelination, which continues into adolescence (Welsh, Pennington, & Groisser 1991).

Children with ADHD exhibit impairments in executive functions such as inhibition, working memory, set-shifting, interference control, planning and sustained attention. Structural (brain volume) and functional neuroimaging studies (CT, MRI, rCBF, PET) have confirmed that ADHD is associated with alterations in the prefrontal cortex, usually limited to the right side, and its projections to subcortical structures (Faraone & Biederman, 1998, 2004; Gustafsson et al., 2007), which control the executive functions mentioned.

Cognitive load theory (Sweller, 1988) describes learning structures in terms of an information processing (IP) system involving long term memory, which stores all of our knowledge and skills and working memory, which performs the tasks and which is limited in both capacity and duration. These limitations will, under some conditions, impede learning. In parallel with IP theories of development, such as Case (1985, 1992), cognitive load theory is based on an IP model of cognition, and the limitations of working memory, which can be overcome by training and automation of acquired schemata.

In educational design of the present software JamMo, we specially aim at reducing cognitive load. *Intrinsic load* of JamMo is related to the difficulty of software functions and complexity of musical information in relation to children's age, knowledge and skills. Hierarchical decision-making including several subgoals is avoided in JamMo of young children. Every action should be a goal in itself and lead to the next goal in the decision-making chain (goal free effect). The more complex sequencer with multiple virtual instruments and functions is introduced by gradually extending the previous simple procedures within orientation games, which present game elements separately *(isolated interacting elements effect)*. The mentor is always present to guide the user. *Extraneous load,* which is due to the design of the instructional materials, is avoided by presenting visually only essential features and using simple but vivid graphics. Especially children with ADHD are very sensitive in this

respect. For this reason, combining text and visual materials is avoided, as well as abstract symbols. Whenever possible, auditory information is supported by visual feedback. Preset musical materials are used as worked examples in addition to instrumental and vocal improvisation (*worked example, problem completion and imagination effects*). *Germane load,* which relates to the degree of effort involved in the processing, construction and automation of schemas, is reduced by increasing motivation in multiple ways related to playfulness and game features, such as intrinsic and extrinsic rewards.

JamMo design includes a virtual mentor to provide *scaffolding.* Scaffolding aims to increase learners' Zone of Proximal Development — ZPD relating to the difference between what a learner can do independently versus tutored (Vygotsky, 1978). The following characteristics of effective tutoring are required of the mentor: recruitment, reduction in degrees of freedom, direction maintenance, marking critical features, frustration control and demonstration (Wood, Bruner, & Ross 1976). Moreover, the mentor provides contingent teaching by helping when needed, and the eventual fading out of support (Wood & Wood, 1996). Moreover, JamMo aims at scaffolding of cognitive strategies in several ways listed by Bereiter and Scardamalia (1987): by offering musical examples for imitation, limiting choices by regulating the number of sequencer tracks and sound banks at hand, making cognitive process visible by providing feedback of instrumental and vocal production, providing labels to categorize and organize tacit knowledge, an by being tailorable to the learner's level and needs.

D. Developmental Basis and Requirements

In a motivating learning environment learners' skills and task demands are in balance, and the learning context is fit to learners' age, stage of development and culture. In other words, cognitive load should be regarded in relation to cognitive structures, which get more comples and organized with age. In Case's (1985, 1992) theory, the form of hierarchical integration of executive control structures is common to the development of different cognitive domains, while the structures themselves are domain-specific, which explains why the degree of complexity of structures children are able to understand and produce is relatively similar across domains.

JamMo preschool and school aged users fall mainly into two stages of cognitive development: the (inter)relational stage (from 1,5 to 5 years of age) and the dimensional stage (from 5 to 11 years of age). The stage of development sets requirements to both decision-making – the structure and features of JamMo User Inteface – and the preset musical materials of the software. A model of musical development (Paananen, 1997a, 1997b, 2003) from birth to 11 years of age as constructed applying Case's developmental mechanism to musical development defines the development of musical production as follows: 1) in the sensorimotor stage (4–18 months), the relations between general parametrical changes of sound develop, 2) in the relational stage (1.5–5 yrs), the polar relations between and within musical patterns develop, and 3) in the dimensional stage (5–11 yrs), hierarchical relations of the musical event structure develop as a coordination of the melodic-rhythmic surface, metre and tonal hierarchy. Following Case (1985), each major stage includes

sub-stages of 1) unifocal coordination, when a new structure can be applied in isolation, 2) bifocal coordination, when two such units can be applied in succession, and 3) elaborated coordination, when two or more units can be applied simultaneously and integrated into a coherent system.

1) Preschool children. For preschool children music is often intrinsic of play, movement or daily life routines (Fredrikson, 1994). Therefore, preschoolers' user interface should be based on play. Musical materials of the software should be organized according to 'mental units' of young children. As a relational structure, a musical pattern can be apprehended as a musical unit. In the relational stage, as the model (Paananen, 1997a, 1997b, 2003) suggests, children control polar relations between patterns (repetition, change) and polar relations within patterns, such as the direction of melodic contour, relative duration (long-short), relative tempo (fast-slow), regular vs. irregular speed of release of events, the direction of a melodic interval, the relation of pitch to the reference pitch of the context, and the relative stability/instability. In the first sub-stage children focus on the relative durations of rhythmic patterns and on the melodic contour. Spontaneous songs consist of repetitive contour patterns, sometimes composed of fragments of familiar songs (Moog, 1976; Davidson, McKernon, & Gardner, 1981; Dowling, 1988). In the netxt sub-stage, key and pulse stability within a phrase is achieved (Davidson, 1994). At around 5.5 years of age, a moderate intervallic accuracy, key stability and pulse between phrases is achieved in the song. However, 5–6-year-old children attend to melodic contour and the global key context, with the adult level of responding to changes of both key and intervals developing around 8 years of age (Bartlett & Dowling, 1980; Trehub, Morrongiello, & Thorpe, 1985).

The user interface targeted to young children should be as simple as possible and in a form of play, which forms a working space. The mentor should be available whenever children need guidance, as well as encourage children after successful actions. The mentor should speak the mother tongue of the children, either being a familiar person or an animated character. The mentor should be ready to suggest suitable actions whenever children hesitate for a longer time, or try to perform an action without success, and do not know how to proceed.

In loop-based composition short musical patterns work as a mental units; children are not expected to modify musical pieces at the level of single pitch. At this age, musical working memory is restricted to relatively local levels, and the mental working space should be visually present on the JamMo touch screen. Each musical pattern should be visually represented as a play symbol. The number of visual symbols should not overload working memory. The procedure of dragging and dropping the icon to the sequencer timeline requires attention, too. For 5-6 year-olds a simple hierarchical icon menu may be used (a scrollable menu of loops).

The accompaniments and loop materials should be in suitable keys, support sense of key, steady pulse and cultural patterns of music. In spite that children begin to show some sensitivity to harmony in the age of 5 years in very simple tasks, they are not expected to be able to compose with multiple tracks. Music is represented as a horizontal tune-path, with each note having its place in the temporal sequence.

However, children are beginning to understand simultaneity, and would benefit of composing and making music in pairs; we think that an opportunity to use one to three tracks should be provided.

2) School age. In the dimensional stage, children are increasingly able to attend to hierarchical structures in different domains. According to the present model (Paananen, 1997a, 1997b, 2003), in music children attend to the melodic-rhythmic surface in a more differentiated manner, and become able to focus on the conflicting effects of different hierarchical levels of the musical event structure in production. Analogous development of surface and deep structures during the age of 6 to 10 years can be found, for example, in the narrative domain (story-telling) as a development from a script to a plot with sub-problems (McKeough, 1992); in the spatial domain (drawing) as a development from figures to a scene with fore-, middle- and background (Dennis, 1992). In the motor domain, sub-stages of uniaxial, biaxial and integrated biaxial control have been found (Reid, 1992). In the mathematical domain, children are able to solve problems first within a single dimension, then within two dimensions and, finally, mastering bi-dimensional problems requiring compensation of values (Griffin, Case, & Sandieson, 1992). As a consequence of the development, children are able to understand a more hierarchic structure of the user interface.

Empirical studies of children's structural knowledge of tonal music in instrumental composition and improvisation show developmental change in the melodic and rhythmic surface, metre and tonal organization between the ages of around 5 to 11 years of age. Children's understanding of musical structures get more differentiated as well as more integrated, as products get more complex, hierarchic and extended in time. In JamMo design, the development of musical cognition is directly related to the structure and complexity of musical tasks included in the orientation games of JamMo, as well as the musical materials, especially preset accompaniments.

Youngest school children tend compose shorter and simpler structures, which may (Swanwick & Tillman, 1986) or may not (Kratus, 1985) be metrically regular. A stronger sense of tonal centre, use of melodic motives, and a restricted pitch range emerge around age 8 or 9 years of age (Kratus, 1985). The compositions of 9–11-year-old children may even contain surprising elements, sometimes at the cost of the clarity of pulse and phrasal structure, representing the speculative stage of development (Swanwick & Tillmann, 1986). Brophy (2002) found that in alto xylophone melodic improvisations conjunct melodies, melodic motives and tonal closure increase between the years 6 and 12, as well as the sense of pulse, beat divisions and rhythmic motives, which emerge around the age of 9 years

When investigating keyboard melodic improvisations, non-pitch rhythmic improvisations, rhythmic tapping and harmonisations of 6–11-year-old children in MIDI environment Paananen (2003) found different types of rhythmic, melodic and harmonic production, and suggests that hierarchical features of tonal music develop sequentially, through three sub-stages: First children focused on either surface (melodic/rhythmic figures) or deep (metre, tonality) structures of the musical event, then surface and deep

structures began to get coordinated and finally, they were fully integrated. *Improvised rhythms* became more complex including out-of-phase groups and syncopations and their form became more hierarchical with age. Metre and synchronization to the given pulse developed earlier in metrically oriented children, while rhythmic complexity and motivic fluency developed earlier in figurally oriented children. In *melodic improvisation,* the 6–7-year-olds tended to focus on rhythmic of melodic surface *or* repeat tonally important tones, not forming clear motives. The 8–9 year-olds tended to seek for a 'common denominator' of tonal events in tonal and modal sections of the piece, at the cost of the tonal centre. The 10–11-year-olds emphasized the tones of the tonic triad in their improvisations in both tonal and modal sections, and integrated tonally important tones and event-hierarchical information (see Krumhansl & Keil, 1982; Lamont & Cross, 1994; Lamont, 1998). The tonal closure emerged, and metre was strongly present. In *harmonisation* of a tonal melody, typical features of the early levels of harmonic development were great amount of events, lack of metre and lack of the tonal centre. Melody and harmony were coordinated weakly or locally. At the next level chord production became periodic and were coordinated to the strong beats, and the coordination of melody and harmony increased. In the most advanced harmonisations, melody and harmony, metre and tonal functions got coordinated. The tonal centre was identified and tonal closure emerged.

In addition to different foci on musical syntax, compositional strategies are likely to vary across individuals. It is probable that some children will tend to compose horizontally, and add vertical texture after composing the main melodic line, while others will represent more vertical approach, composing a short sequence with several tracks, and moving to another section after completed the first one, as adolescents did in Folkestad's (1998) study in MIDI environment.

As a conclusion, the structure of UI targeted to 7–12-year-old children should be based on the idea of increasing hierarchy, starting from the simple horizontal one-track timeline, and adding gradually vertical dimensions as well as sequencer functions, which represent sub-goals in the musical decision making structure. Hierarchical icon menus can be used, however text menus should be avoided, and use iconic menus instead. It is necessary to provide immediate feedback when exploring musical materials, as well as feedback of the composed or improvised music.

Children need time to rehearse musical, sequencer-related skills in isolation, such as loop-based composing, instrumental and vocal performing and improvisation. In addition, there is a number of sequencer-functions to be learned. Children's working memory capacity is expected to be larger than in the age of 5-6. This means, that children can more flexibly explore musical materials (loops), without losing the general goal in composition. Exploration and combining different loops should be made as simple as possible, by using scrollable loop families, so that the loop view remains as a coherent working space. As a result of a more effective working memory, the form of composition gets more hierarchic and more extended in time. When 7-year old children still may produce chain-like compositions, including repeated or transformed patterns and phrases, children from 9

years of age tend to improvise and pieces including several sections, such as popular songs. Music enfolding in time should be visually represented by gradual activation of the sequencer timeline, or loops on that timeline.

For 7–9 year-old children, it is still easier to focus attention to one or two musical dimensions, e.g. rhythmic or melodic-rhythmic surface, metre, or tonal stability. The number of sequencer tracks should be growing gradually from one to three. 10–12-year children are able to focus attention to three or four musical dimensions. The number of tracks can be four to six: The number of tracks should be high enough to take account also those children that tend to compose vertically; however, the size of the device sets limits to the number of tracks. It is important that all tracks are visible simultaneously in the main working space, the sequencer view.

Children need several virtual instruments for playing the touch screen: percussion sets, keyboard and a slider instrument. Selected cultural percussions and scales should be included in the sound banks of these instruments. Because the touch screen of the device is remarkably small, the number of percussions and keys in one window is restricted, however instruments can be scrollable.

Melodic patterns should be composed so that they can work as ostinati, or be combined with each other to form longer melodies. Rhythmic loop bank should vary from short simple in-phase rhythms including two different durational classes to more complex and syncopated rhythms, which include several durational classes.

Harmonic materials can in principle be provided in various ways. Vertical chords, harmonic riffs and bordunas can be recorded as loops. A harmonic virtual instrument could also be programmed and played in real time with the melodic line.

3) Children with ADHD. Attention-deficit hyperactivity disorder (ADHD) is defined as an early-onset, clinically heterogeneous disorder of inattention, hyperactivity, and impulsivity, which affects 8-12% of children worldwide (Faraone & Biederman, 1998; Faraone, Sergeant, Gillberg, & Biederman 2003; Biederman & Faraone, 2005). There are three symptom-based subtypes of ADHD: mainly inattentive, mainly hyperactive-impulsive, and both combined (Bierderman & Faraone, 2005). Disorders of executive functioning, such as response inhibition, working memory deficits or a more general weakness in executive control, appear to be an important component of ADHD (Pennington & Ozonoff, 1996; Barkley, 1997; Schachar, Mota, Logan, Tannock, & Klim, 2000; Nigg, 2001; Castellanos & Tannock, 2002; Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Children and adolescents with ADHD display challenging, confrontational behaviours and often struggle with interpersonal relationships with peers and authorities. ADHD symptoms increase social problems and isolation, aggression, risk of accidents, poor school and academic functioning, risk for dropping out school and have negative effects on self-esteem (Barkley, Fischer, Edelbrock, & Smallish, 1990; Barkley, 1998; Frick, 1998). Low socioeconomic status, male sex and young age are associated with raised prevalence of ADHD (Scahill & Schwab-Stone, 2000; Doyle, 2004).

Laboratory studies have showed that increasing relevant intratask stimulation and novelty, repeating task instructions throughout the task, and reducing task complexity reduces ADHD symptoms (Douglas & Parry, 1983; Zentall, 1985). Tasks can be made more attractive through the use of different colours, shapes, and textures, allowing motor participation while learning, shifting the nature of the task frequently and presenting the task vibrantly and with enthusiasm by the teacher. Tasks can be made more simple through chunking tasks into smaller units to fit within the child's attention span, providing feedback and breaks, and using written rules and time-management (Zentall, 1985; Barkley, 2002). Many of these procedures can be adapted to the classroom. In the light of findings of Shaw, Grayson & Lewis (2005), who found that ADHD children were no more impulsive than typically developing participants when playing two commercial computer games, and showed a significant reduction in impulsive responding and error making and an increase in on-task activity in a more game-like version of a computerized task over a laboratory-based version of the same task, it seems plausible that ADHD children would also benefit of scaffolding in goal-pursuit: providing support in selecting appropriate strategies, providing direct feedback, and gradually increasing independence in problem-solving. Direct instruction has been used in special education to provide students with multiple opportunities to acquire and practice new academic skills (Slocum, 2004; Grossen, 2004, Jitendra, Edwards, Sacks, & Jacobson, 2004).

It is likely that computer games and game-like e-leaning environments stimulate effort, motivation and arousal in ADHD children. However, a special concern should be targeted to avoiding of any intrinsic or extraneous cognitive load. Too many visual features with no other purpose than decoration should be avoided. Building an effective, warm and enthusiastic mentor is essential. Isolated rehearsing of different skills, immediate feedback and a reward system in the orientation games is necessary especially for 7–12-year old children with ADHD.

Dual communication with JamMo (communicating with peers real-time and with JamMo) is great challenge for these children. Using head-set during composition process is very likely to diminish off-task behaviour caused by situation related distractors. Teacher should organize composition sessions so that all children have a peaceful moment for stand-alone activities, as well as controlling turn taking in an equal manner.

Simultaneous visual and textual communication should be avoided. The number of software function control icons should be minimized. Because it is possible, although not predictable, that children with ADHD might learn slower to use JamMo than their peers without ADHD, the lower levels of orientation games should contain play context targeted only for 7–9 year old children; too childish mentor or avatar features etc. should be avoided. Similarly, the musical materials of JamMo should be usable for the whole age range of 7–12 years.

Time and place independent production serves well especially this user group, for as soon as they have learned the very basics of JamMo games, they can use as much time as they want, and lower processing speed is not an obstacle for social music making.

4) Immigrated children. Newly immigrated children usually have language problems, which in turn may often cause a

negative circle of development, leading to poor academic achievement, problems with peers and lowered self-esteem. Children also differ in cultural backgrounds and often have socio-economic problems. In JamMo design, we aim at a multicultural musical repertoire for all children to support social inclusion. In addition, written language is avoided in the stand-alone software. The mentor will speak preset languages, but whenever is needed, the mentor 'package' should be translated in users' mother tongue.

III. PEDAGOGICAL DESIGN OF JamMo

Figure 1. JamMo hardware: Nokia N810 Internet tablet.

JamMo user interface has been designed for two main user age groups, 3–6 years and 7–12 years. We target the very same games to both children with and without ADHD. The musical material will be multicultural, representing European cultures, and the language mentor speaks can be tailored according to the mother tongue of the users. The user interface does not include written language, but icons. The user interface for 3–6-year-old children will include two games, composition game and singing game. The user interface for 7–12-year-olds will include multi-track sequencer, communal features (see Myllykoski & Paananen, 2009) and orientation games.

The sequencer has its origin in computer based loop-sequencer applications. Music is constructed from elements (loops), which can be melodic, harmonic or rhythmic, or combinations of those. In the composition game for the youngest age group (3-6 years) loops are presented as animals in three different play themes. Children should compose their songs by dragging and dropping animals to the sequencer's timeline. The sequencer interface for 7-12 year old children consists of a six-track- sequencer with looping features and virtual instruments. The main displays of the sequencer, editor and loop windows are easily accessed through touch screen sweeping gestures. The MIDI editor of the sequencer can also be accessed directly through the track view of the editor window. The editor with all usable tracks represents the working space for the main goal in composition, while other windows represent the most important sub-goals in composition.

The functionality of the sequencer has been designed for tangible and easy use through different touch screen gestures. Nokia N810's qwerty-keyboard and external buttons can be used as complementary input method for the sequencer. Furthermore, USB-MIDI-keyboards can be connected to the device and utilized as a virtual instrument controller. JamMo provides three different MIDI-based virtual instruments for playing, improvising and recording: traditional keyboard, drum machine and slider instrument.

JamMo will introduce multi-user sequencer functionality in mobile environment; songs can be created individually, in pairs or with small group. Generally, music production can be synchronous or asynchronous: users can make their songs in real-time with others or share a composition workshop, which gives access to the song any time. The communal features include user profile, threaded mobile discussion board, song and loop bank, and jukebox. The orientation games for 7–12-year-old children will be pedagocically designed instructional tasks for learning sequencer features and functions, fostering communication and social navigation, and learning music making.

E. Mentor

The mentor's role is to guide the user, provide feedback and encourage into social interaction and self-assessment. The mentor will be available whenever the user needs help, and sensitive to stay in the background when user is able to work independently.

Young children's mentor will represent play context, which is familiar to all children, such as a friendly animal character or a teddy bear, which are culturally universal and gender free play symbols of young children. School aged children's mentor will be a universal cartoon like character, which can be preferred from ages 7 to 12 years; not feeling too childish for the pre-teen users. The mentor of all user groups will be warm, sympathetic, and enthusiastic, and also dance with the music made by the users.

The mentor guides users to use JamMo software, to proceed into the next decision in a sequenced task, to find musical materials, to become aware of alternative ways of music-making, by anticipating problems in music-making, to become aware of the mood related to musical materials, and the mood related to the composition a hand and to retrieve information. Moreover, the mentor is provides positive feedback of proceeding and completing tasks, formative assessment to users, and encourages to self-assessment by asking whether users are content with their products.

F. Games for 3–6-year-old Children

The purpose of young children's JamMo is to provide usable, playful learning environment for musical creativity and music performing in individual and social contexts. Adapting the sequencer software to young children's needs develops digital literacy at early age, as well as positive cultural interaction via music and social sharing of music. We have constructed UI scenarios for different games, such as composition games, instrument and singing games, and a jamming game. All of these games are based on the same sequencer, however, providing different starting point to music making. Two of these UI scenarios were chosen to be technically completed and tested with children: singing game (which, unlike other games, will be designed in *University of Oulu*) for 3–6 year-old children and, composition game for 3–6 year-old children.

The composition game includes two versions, an easy version and an advanced version for 3–6-year-old children. The composition game aims at introducing young children to loop-based composing with sequencer software. Working space is based on a play scene, and the user can choose form three different themes: Jungle, Fantasyland and City. These themes also contain different sound families. Jungle contains natural, acoustic sounds, such as ethnic percussion loops, as well as acoustic melodic and harmonic patterns, and acoustic and synthetic sounds that fit well to this theme. Fantasyland contains imaginative musical patterns, concrete sounds as well as tonal music. City represents urban sound world, including electronic sounds and patterns related to popular music genres.

The structure of the game is a simple non-hierarchical path starting from view 1 and ending to view 5. In every view there is always the possibility to return back to the start. The mentor, a friendly teddy bear, is in the right upper corner. The mentor guides the user when the user enters the view, and the user can call the mentor by touching the bear. The mentor zooms larger before speaking and again smaller after speaking the line.

The main idea of the game is to explore musical materials and compose in play context consisting of a landscape and animal icons representing sound loops (simple version) or sound families (advanced version). Loops can be selected by dragging and dropping them on the 'tune-path', which is the sequencer timeline (track). They can be temporally reorganized by drag and drop, and deleted by dragging off the track. In the simple version there are six different loops per game to used; there are 3 different loop sets (with six loops in each set) per theme, and the set change automatically when the user starts a new game. In the advanced version there are 4 loop families per each theme, with 15 loops in each family; of these 15 loops five are visible simultaneously, and more can be seen when scrolling.

After composing a musical piece, the users can by choice sing along the music and record it on a video. After completing the task, the user is asked to send the composition to the music play school teacher, who will use composed materials in social situations with the music play school group.

As an example, we present here the user interface scenario of 3-6 yrs easy composition game (stand alone) including five successive views:

1) Select game. The user sees four icons representing composition game, singing game, songbank and mentor. The mentor starts the action by guiding the user, what to do, e.g. "If you like to compose, touch the jungle". The user touches the jungle icon and proceeds automatically to view 2.

2) Select sound bank (theme). The user sees three different theme icons: jungle, fantasyland and city. In the left upper corner there is a home icon for navigating back to the start. In the right upper corner there is the mentor, who guides the user to select between the themes, by touching the theme icon. The mentor tells the purpose of the home icon. The user selects one theme by touching it and proceeds automatically to view 3.

3) Compose. The user sees six animals representing six different loops. The animals are in a jungle scene, which contain some simple elements like the ground, some trees, a pond and he sky. The home icon is in the left upper corner and the mentor in the right one. Below the jungle view there two tracks. The upper track is for composing (drag and drop animals there) and the lower one can be activated for listening of the accompaniment simultaneously. The backing track also works as a scroll bar for the sequencer timeline. In the beginning of the composition track there is an ear icon: touch for playback. In the beginning of the backing track there is a lock icon for muting the accompaniment. The mentor encourages the user to touch different animals to listen to the loop sounds, and selecting sounds by drag & drop to the track. The mentor guides the users to organize the loops on the track by drag & drop, and to choose a similar loop as many times as they wish (repetition). At times the mentor gives positive feedback. If nothing happens for a relatively long time, the mentor asks, if the user wants to continue to make a video by entering the next view, or to explore more loops.

4) Record a video. The user sees a TV set, home icon and the mentor. The mentor encourages the user to sing along her/his own composition by touching the TV. The child touches the TV, hears the music and sings. The vocal track is automatically recorded and immediate played back. The mentor gives positive feedback and encourages to child to proceed to the songbank by scrolling the scene.

5) Songbank; select icon, store & send. The user sees a tree (or a train), which represents a songbank of self-composed music. The user also sees different song icons, and home icon and the mentor. The mentor asks the user to select an icon for the song drag it to the tree (or the train). After storage, the mentor asks the user to send this composition to the music play school teacher. In the end of the game the mentor says: "Great music! Now you can play a new game!"

G. Games for 7–12-year old children

The games for school age children are based on the same sequencer than the games for young children. However, along with more complex functions and with more tracks on JamMo screen, and because of the very limited size of the screen, the play themes (jungle, fantasyland, city) cannot be used. The structure of the orientation games is rule-based, according to children's thinking in this particular age and stage of development. The games include four different levels built on each other and including a reward system to support both intrinsic (earning of JamMo functions and materials) and extrinsic (earning points) motivation. Because of individual differences in learning speed, we do not define particular age groups to be working with particular levels. However, we expect that age groups 7-9 are likely to feel comfortable using levels 1-2, and the proceeding to levels 3-4 is likely to happen in the age of 10-12. All age groups will begin JamMo use at level 1, and there is no reason to prevent children to proceed to higher levels of the game in case their individual pace is faster than average, or expected.

JamMo orientation games include four levels. They provide a good opportunity to learn different instrumental and sequencer skills. These games include levels and a clear reward system to enhance both intrinsic and extrinsic motivation.

Level 1 games introduce the users with loop-based composition, instrument playing, singing, and 'jamming' skills in isolation. In addition, the users explore and get

acquainted with musical materials of JamMo and the very basic software functions such as play, stop, delete, select musical materials and drag & drop. The number of tracks is two, including accompaniment. As a reward of learning these skills, children may send their composition to Jukebox in the server, and move to level 2.

Level 2 games are no more related to isolated learning of skills. The number of tracks has increased to three. The main challenges at this level concern using skills learned at level 1, learning some more sequencer functions such as volume, tempo and reverberation control and, learning the basic communal functions of JamMo, such as adding the song in the communal song bank in the server, adding an audio comment on other children's music, learning how to find a workshop for collaborative music-making, and finally, to make music in a workshop with others. The rewards are related to musical identity of the user: selecting a character, style and musical instrument for avatar.

Level 3 games are related to more complex communal functions such as using help desk, learning to discuss music and make written comments on music. Moreover, a very motivating function to be learned is how to make a music video and share it in the community. Music video serves as a reward.

Level 4 includes the most detailed sequencer functions related to MIDI editor, and learning of recording, editing and importing new loops. As a reward workshop of users may publish a record online.

The sequencer includes four different categories of views: 1) Sequencer view, which is the main working space, 2) loop view, in which four different types of loops can be explored and fetched, 3) instrument view according to the chosen instrument: keyboard, percussion or slider, and 4) track view, which allows to user to transform musical events at a detailed level. Using these four views makes the decision-making structure hierarchic. The general goal is represented in the main working space, the sequencer view, in which all tracks and the length of the musical piece are visible. Finding new loops, playing individual tracks and transforming individual events represent important sub-goals in the decision-making structure. Each sub-goal has to be rehearsed in isolation in orientation games.

IV. CONCLUSION

In the present study, cognitive, social, and neuropsychological theories and studies of learning and development, as well as recent advancements in the field of mobile learning and mobile music technology and development have been applied in developing a novel mobile learning environment for children's musical creativity and collaboration. This paper described the main stand-alone features of JamMo software, and some examples of the future games to be technically demonstrated and tested with 3-12-year-old children. These studies will include both usability tests (*University of Central Lancashire, UK; University of Oulu, Finland*) and impact analysis of the effects of JamMo on social inclusion of children (*University of Jyväskylä, Finland; University of Oulu, Finland; Institute of Education, London, UK; University of Zürich, Switzerland).*

As a conclusion, we list the most essential features, which include aspects that make JamMo an innovative mobile music

pedagogic tool: *1) User sensitivity:* JamMo presents an easy to use mobile sequencer for target groups including children as young as 3 years of age, children with mild learning disabilities such as ADHD, as well as newly immigrated children. *2) Pedagogical structure:* the use of JamMo sequencer, virtual instruments and social sharing happens in a form of play and orientation games, based on developmental psychology and psychology of learning in the domain of music; *3) Social sharing, collaboration and inclusion:* By encouraging in social interactions in various ways, including pair games and communal features as an integrated part of the stand-alone sequencer, JamMo aims at enhancing communication and collaboration across different groups of children in a positive and inclusive way, as well as enhancing digital literacy of children via music; *4) Mobile music classrooms:* With their 'JamMos' children can move and interact almost anytime, collecting sound probes from the everyday physical environment, creating and sharing songs symbolizing their environment, as they move in digital environments of the device and participate JamMo online community, in and out of school; *5) Integration:* JamMo integrates all above mentioned features to a holistic learning environment; *6) Research tool:* By inluding log for social communication via the device and log for individual compositional decision-making, JamMo provides a new tool for cognitive and social developmental research tool in the domain of music.

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