Exploring Personalization Factors of Exergames to Support Visual-Motor Coordination of Children with Autism

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Abstract
Children with visual-motor coordination problems, such as children with autism, might have "clumsiness" in general, that impacts their independence. Exergames are good in supporting motor therapeutic interventions as children find them engaging. However, little has been said concerning factors for personalization of exergames for supporting visual motor coordination of children with autism. Nevertheless, they are important due to the specific characteristics of this population, for example attention issues. This work presents the personalization factors found in a formative and a summative evaluation of an exergame to support visual-motor coordination of children with autism.

Author Keywords
Exergames; visual-motor coordination; autism; personalization factors.

ACM Classification Keywords
K.4.2 [Computers and Society]: Social Issues – Assistive technologies for persons with disabilities; K.8.0 [Personal Computing]: General – Games.

Introduction

Children with autism commonly exhibit impairments in visual-motor coordination [7, 9]. The lack of motor coordination may limit the development and performance of other motor skills. In particular, visual motor coordination problems, that includes gross motor eye-body coordination and fine motor eye-hand coordination, may constrain the ability of an individual with motor problems to develop age-appropriate motor coordination skills, particularly in individuals with autism [7]. One therapeutic approach to support visual-motor coordination problems involves physical therapy, where a therapist encourages children[1] to practice different motor exercises to help them to develop age-appropriate motor skills [4]. Therapists use different stimuli (e.g., visual stimuli such as images or colored markers) to indicate children where to aim their limbs' movements. Conducting a successful physical therapy is challenging as it involves task-repetition and demands full attention from children. As a consequence, children find therapies boring, and tend to disengage from the therapy's tasks before the therapeutic goals can be met.

Exergames are appropriate to help children practicing motor skills [10] because they find them engaging. However, little has been said about how to personalize exergames to support visual-motor coordination of children with autism, in order to contribute in the performance of a successful motor therapeutic intervention. Personalization factors are important because they could balance both, stimuli (e.g., to maintain children´s attention) and physical exercises (e.g., to not over exercise children) to prevent children stop playing the exergame before they meet their motor therapeutic goals.

This work presents preliminary results, in terms of personalization factors, of formative and summative evaluation studies of FroggyBobby –an exergame to support visual-motor coordination of children with autism during therapeutic interventions. FroggyBobby was designed through an iterative user-centered design. First, we evaluated FroggyBobby with seven children with autism through a formative study [3]. Next, we incorporated the results of the formative study into a new version of FroggyBobby, and we proceeded to conduct a summative study of this new version with fourteen children with autism. In both cases, we found relevant personalization factors which contributed to conduct an appropriate and engaging therapeutic intervention with this population. This paper discusses the personalization factors of both evaluation studies, and how these help children[2] to maintain their attention, and perform and enjoy the practice of the motor coordination exercises.

Related work

Research in exergames for children with motor problems is mainly focused on children with cerebral palsy [5, 8]. However, it leaves aside questions to understand to what extent these works could support visual-motor coordination of children with autism, taking into account the specific needs of this population (e.g., attention issues). Projects in exergames for children with autism and other related disorders are scarce [1, 2, 6]. For example, [1] presents an

[1] For simplicity of reading, we will now refer to children with autism as children.

[2] Children participating in the evaluation studies.

exergame designed to support children with motor problems (such as autism) when practicing hand movements' exercises. This exergame has an interface that shows the expected path of the hand movement and the optimum one, enabling to have a comparison of the motor therapeutic goal. This exergame is based in four principles of therapeutic-educational intervention (e.g., repetitive exercises, personalized flow of learning activities, stimuli, feedback and reinforcement). On the side of personalization, the therapist can customize for each child the type of path (e.g., horizontal, vertical or diagonal), time limit, and width and length of the path. This work presents an evaluation with two children with motor problems, one with severe left hemiplegia and the other with cerebral palsy. Although their findings are promising (*e.g.*, children managed to perform the exercises within the exergame, with less attempts than doing the same exercises in a typical therapeutic way), and the personalization factors proposed worked for children who participated in the evaluation, further research is needed to explore if these personalization factors are also appropriate for children with autism, in order to perform a succesful motor therapeutic intervention to support visual-motor coordination.

Personalization factors of FroggyBobby

FroggyBobby is an exergame to support visual-motor coordination of children with autism [3]. It demands children to move their arms from side to side in a lateral or cross-lateral way controlling the tongue of a frog avatar to catch flies. We used Kinect technology to track children´s arm movements. FroggyBobby was designed through an iterative user-centered design methodology involving semi-structured interviews, passive observation and participatory design sessions. Our design team was multidisciplinary involving stakeholders of all kinds including clinical-specialists (e.g., physical therapists, occupational therapists, psychologists, neuropsychologists and physical rehabilitation clinicians), children with motor problems, parents of children with motor problems, interaction designers, and HCI and Ubicomp research experts. The last version of FroggyBobby incorporates the personalization factors that resulted from a formative evaluation from a previous version of the exergame [3], such as movement patterns. In the next sections, we refer to the version evaluated during our formative study as *FroggyBobby*, and we refer to the last version of the exergame evaluated during our summative study as *FroggyBobby Patterns*.

Personalization factors: formative study

During the formative study, seven children with autism (between ages of 7 and 10 years old) played FroggyBobby for about six weeks, twice a week, under the supervision of three psychotherapists[3]. All game sessions were video recorded[4] and we conducted weekly interviews with therapists to know children´s progress during that particular week. We used affinity diagramming to group quotes obtained from interviews and observation *(i.e.,* game sessions videos), and uncover potential personalization factors to conduct an appropriate and engaging therapeutic intervention with this population. The main personalization factor found during this study was the *Movement Pattern.*

a) Movement pattern

[3] We will now refer to psychotherapists participating in our evaluation studies as therapists.

[4] With consent from parents and therapists.

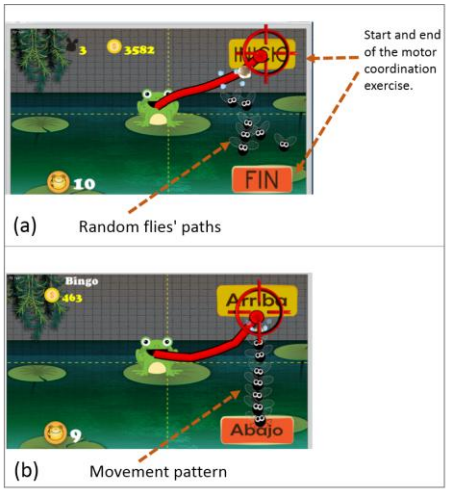

Figure 1. Exergame´s screenshots. (a) FroggyBobby, version used in the formative study; (b) FroggyBobby Patterns, version used in the summative study.

In FroggyBobby, the flying paths of the flies were defined at random in a limited area (Figure 1a), marking the start and end of the limb movement. However, we found out that more personalization was needed. We detected that children needed a visual pattern to follow better the movement demanded for the motor coordination exercise. For this reason, the flying paths of the flies in FroggyBobby Patterns are defined following the movement pattern in order to complete de motor coordination exercise[5] (Figure 1b).

Personalization factors: summative study

We introduced the personalization factor found in the formative study to FroggyBobby Patterns. For about 6 months, FroggyBobby Patterns was evaluated with fourteen children[6] with autism (between ages of 5 and 14 years old) and four therapists in a clinical center specialized in the care of children with autism. The design of the summative study was a multiple probe design in which visual-motor skills of the participants were tested or probed at the beginning of the study. Then, the motor coordination exercises were taught (both, in a typical therapeutic way and using the exergame) followed by probes of all visual-motor skills. All sessions were video recorded, including sessions with traditional therapy and sessions using FroggyBobby Patterns. In addition, therapists were interviewed once a week to find out children´s progress in that week. As in the formative study, we used affinity diagramming to uncover the personalization factors. Next, we explain the factors for personalization that emerged during our summative study, that we consider relevant to discuss in this forum.

a) Scale factor

In FroggyBobby, the extent of the arm movements to aim a specific area on the screen, depends of the player´s height, and it is defined by a scale factor. For example, a small scale factor (*i.e.,* for children with a height of 1 meter or less) in a child with a height over 1.5 meters will make a short extent of the arm movements. That is, the child will not have to extend his/her arms completely to perform the motor coordination exercise.

During the formative study, the scale factor worked well, with no problems for all children. However, in the summative study, we had problems with the scale. During a calibration day with two children (an adolescent and a young child, they were not part of the participants), we found out that the scale factor should be personalized for each child as children had different heights, and we realized that in the formative study it was nearly the same. For that reason, we added an option to FroggyBobby Patterns that enables therapists to select different children´s heights (*e.g.,* small – less than a meter, medium – between 1 and 1.5 meters, and large – more than 1.5 meters) according to the height of each child.

During the summative study, therapists used the scale factor to personalize the difficulty of the motor coordination exercises. For the case of children with severe frustration problems[7], at the beginning of the summative study, therapists selected the scale factor according to the children´s height. However, children

[5] The motor coordination exercises included in FroggyBobby (or in FroggyBobby Patterns) were defined with the support of a physical therapist.

[6] Participants in the summative study were different than participants in the formative study.

[7] Three of the fourteen participants of the summative study.

got frustrated because they had not only to coordinate their arm's movements with the visual stimuli on the screen, but also they had to extend their arm completely to perform the motor-coordination exercise. Thus, in the following game sessions, therapists decided to start first using a smaller scale factor to introduce children to the gameplay of the exergame (*e.g.,* the dynamic of the motor coordination exercise), and then, as children progressed in the exergame, to change the scale factor to work with the proper execution of the motor coordination exercise (*e.g.,* changing the scale factor, in order to work with the extension of children´s arms.) During the last week of the summative study, children were able to perform the motor coordination exercises using the scale factor according to their height. Thus, it is important to personalize the level of difficulty of the physical activity available in the gameplay of the exergame, adjusting the scale factor according the children's progress.

b) *Sound and background music.*
In the formative study, none of the participants had problems with the feedback sounds of the events on the screen (e.g., eat a fly or reach a button), or with the background music of FroggyBobby. However, in the summative study, two children were hypersensitive to sounds [4]. At the beginning of the summative study, they did not tolerate the sounds available in FroggyBobby Patterns. During the next game sessions, therapists adjusted the volume of FroggyBobby Patterns down, and children had no problem in performing the therapy with the exergame. Thus, like physical exercise, the sounds and background music of the exergame should be personalize, change and regulate, according to the characteristics of each child at the beginning of the therapeutic intervention.

c) Verbal rewards.
In the formative study, although FroggyBobby provided verbal rewards when a level was finished (e.g., Congratulations!), we found that therapists needed to provide verbal rewards constantly to children. Children responded to these reinforcements, showing motivated to continue performing the motor coordination exercises. Thus, we considered to add more verbal rewards to FroggyBobby Patterns (e.g., *Congratulations, the level is finished successfully, you did a great work!*) to reinforce the activity, as therapists did in the formative study. During the summative study, there were cases[8] where therapists did not need to give verbal rewards constantly to some children, and there were others where children still needed them repetitively. Therefore, it is important to have an option to select when a verbal reward is launched, because a child may need a verbal reward when he/she finished a level (perform 10 repetitions of a motor coordination exercise), while others may need a verbal reward every time they perform a single repetition of the motor coordination exercise. In order to accomplish a successful motor therapeutic intervention using exergames, the exergame should enable therapists to have control in deciding when to launch verbal rewards, and to decide the moment to fade them out. Our experience indicates that verbal rewards from therapists are important in all cases, but the amount of these verbal rewards can vary from child to child.

Conclusions

In this paper, we present three personalization factors that are relevant to design and develop exergames to

[8] Four of the fourteen children approximately.

support motor therapeutic interventions for children with autism. Although, the exergame evaluated in the summative study was personalized for children with autism (in a global way), we found factors that are important to personalize the exergame in a more individual way. These personalization factors could contribute to obtain not only a successful player experience, but an effective use of exergames as a therapeutic tool. We consider that this workshop is a great opportunity to disseminate our work with experts in the field of serious and pervasive games. We think that it is important for us to know how our work can be enriched by experts, as well as, how our work can support others in future research in this field.

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