Smart Toys Design Opportunities for Measuring Children's Fine Motor Skills Development

Svetlana Mironcika
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
s.mironcika@hva.nl

Antoine de Schipper
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
a.w.de.schipper@hva.nl

Annette Brons
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
a.e.brons@hva.nl

Huub Toussaint
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
h.toussaint@hva.nl

Ben Kröse
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
b.j.a.krose@hva.nl

Ben Schouten
Amsterdam University of Applied Sciences
Amsterdam, The Netherlands
b.a.m.schouten@hva.nl

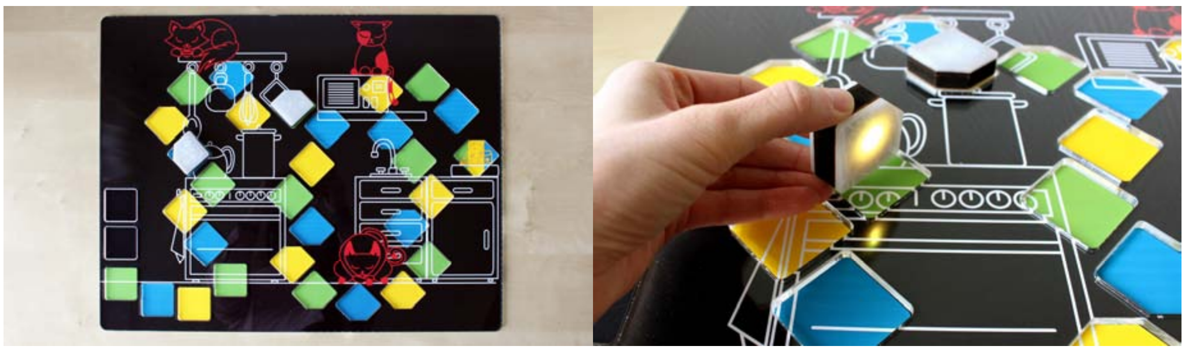

Figure 1a: The design of the interactive board game. The board depicts a kitchen, several sleeping cats and slots for the token-mouse placements that are deepened in the board and guide the player's actions in the game.
Figure 1b: Interaction with the token.

ABSTRACT
Smart tangible toys, designed for hand manipulation, can transform fine motor skills assessment into enjoyable activities which are engaging for children to play (partially) unsupervised. Such toys can support school teachers and parents for early detection of deficiencies in motor skills development of children, as well as objectively monitor the progress of skills development over time. To make a game enjoyable for children with different skills level, these smart toys could offer an adaptive game play. In this paper we describe the design and deployment of a digital board game, equipped with sensors, which we use to explore the potential of using smart toys for fine motor skills assessment in children.

TEI '18, March 18–21, 2018, Stockholm, Sweden

ACM ISBN 978-1-4503-5568-1/18/03…$15.00
https://doi.org/10.1145/3173225.3173256

Author Keywords
Tangibles for play, serious games, fine motor skills, adaptive games, toy design.

INTRODUCTION
Children's performance at school depends on a number of skills where fine motor skills are one of the strong predictors of their later achievement in math, reading, and science scores [5]. Fine motor skills require small muscles of the hand to work together in order to perform precise and refined movements [4]. Each child develops fine motor skills at his own pace and, arguably, an individualized attention in skills training could be beneficial to a child's development. Teachers at schools and parents at home may help children in their fine motor skills development by providing appropriately difficult tasks. Moreover, it is important to early detect development delays and address them timely with the help of a child physiotherapist. However, parents may not have expertise in assessing and training motor skills and teachers at schools may lack time for highly personalized training.

Various non-digital assessment tools are used to assess children motor skills (for example Movement ABC-2 [2]).

These tools require a trained specialist to guide the assessment process, equipment kits and assessment time may take from 15 up to 60 minutes [2]. To save time and effort required for assisted fine motor skills assessment, the use of smart technologies may be considered. Digital technologies, together with the analysis of acquired sensor data, may allow (partially) unsupervised fine motor skills assessment. To make the process of (partially) unsupervised skills assessment appealing and enjoyable for children we investigate the idea of turning this process into a game play. Moreover, to ensure that a child is playing at a level that matches his fine motor skills abilities, the game will dynamically adjust its levels based on the movement data collected while a child plays the game.

In this paper we describe the design and deployment of the tangible interactive board game, called *Get that cheese*. While children play and manipulate sensor-augmented token in their hands, the token collects children's fine motor skills data and adjusts game difficulty level according to the skills of each child. Here, we report on a first user study with 30 children where we evaluated whether children interact with toys as expected, whether the game has the potential for use in fine motor skills assessment, and whether children enjoy the game. We show that, *Get that cheese* has a promising potential in this field. Children enjoy using it, and the collected data correlates with standard fine motor skills proficiency test. Whereas more work is needed to improve its sensitivity and selectivity, *Get that cheese* inspires us to further work on smart toys for fine motor skills assessment.

RELATED WORK

Sensor-augmented toys for children have been proposed in several previous works. Vonach et al. [15] present a toy for measuring physiological parameters such as pulse, temperature, blood oxygen saturation and others. Sensor information is gathered while the child listens to a fairy tale and interacts with cubes following audio prompts. Westeyn et al. [16] have developed toys with integrated wireless sensors to monitor children's development progress based on object play interactions. These two works demonstrate that a child will participate in the monitoring of his health and development progress, through interactions with toys. These toys are designed in a way that a child easily understands how to use them and finds them engaging. Data, generated while the child interacts with these toys, allows assessing health parameters and development progress of the child. A similar approach can be adopted for fine motor skills assessment.

We see three categories of works that describe sensor-augmented toys and tools for fine motor skills training and assessment. The first category describes tangible toys or tools that aim to train fine motor skills while playing the game during the therapy setting. For instance, van Delden et al. [3] and Li et al. [9] describe tangible interactive toys for the repetitive training of fine motor skills for children with Cerebral Palsy.

The second category of works describes toys for automated fine motor skills assessment with the aim of conducting studies for fine motor proficiency. Rivera et al. [12] describe a smart toy system, that consists of cubes with wireless sensors and a mobile computing platform to collect the information sent from the cubes, allowing later analysis by development professionals to verify normal behavior or to detect a potential disorder. Jeong et al. [7] presente a play-based assessment tool, called *TaG-Games*, for measuring cognitive problem-solving skills and fine motor proficiency. Sensors (accelerometer and optical sensor) integrated into cubes and a host computer allow observing behavior and manipulation patterns during assembly type of play. *DataSpoon* by Zuckerman et al. [17] is an instrumented spoon that monitors movement kinematics of children with motor disorder during self-feeding. Sander et al. [13] propose to use a commercially available motion controlled gaming cube, called Futurecube, for studies on movement feature selection and they found that several data features can be used for distinguishing between children with normal and delayed motor skill development.

The last category of works describes tools that not only assess motor skills with the help of digital technologies but also adapt the task to the appropriate level based on the assessment result. Kim et al. [8] proposed a sketch-based interface, called *EasySketch2*, that can be used for both fine motor skills assessment and training. The interface classifies children's fine motor skills and teaches children how to draw, practice and improve their drawing skills as well as provides teachers and parents with information on the maturity of children's fine motor skills. This work is very interesting for us since it integrates both fine motor skills assessment and training, although it does not provide opportunities for play.

From the described research work we found that some toys and tools measure fine motor skills proficiency, others aim at skill training and some of the tools do both. Little work has been done in integrating fine motor skills assessment process and game play.

Tangible toys for motor skills should be enjoyable for children with a wide range of differences in motor skills. Based on the significant skill differences in the target group, it is important to make games more adaptive [14] so that a game or play environment can automatically change [11] within the limits of a specific user. In our vision game adaptability to player's skills, especially in assessing motor skills, is essential and we specifically defined this aspect as a requirement for our game design.

In the last year we have conducted research in the assessment of motor skills of children between 7-9 years old, in a research project called Smart Play Sets. The research is supported by Dutch game industry and intended to spin off in a company, designing health related games. In this paper we describe an interactive board game that we use to explore the design space for games and toys for computerized fine motor skills assessment.

GAME DESIGN PROCESS

Prior to the game design, we would like to present in this paper, we will describe requirements that informed the tangible toy and the game design. Two contextual interviews with child physiotherapists were conducted to find out what tasks therapists give children when assessing their fine motor skills. During fine motor skills assessment child physiotherapists often use small objects (for example coins, pegs, cubes) to evaluate how well a child can manipulate them by using one hand only. For example, therapists give a child a task (for example, hold the coin horizontally and rotate the coin with finger tips 180°) and evaluate how a child manipulates the object during this task [2]. Among other movements, therapists are looking at how children can perform picking the object with one hand, rotating it in the hand, flipping the object around while holding it in the hand, placing it precisely into the slot. One of the parameters that therapists assess is the overall smoothness of movements.

Smooth movements are characteristic for healthy and well-trained motor behavior and it shows how well a child is in control of his or her hand movements [1]. Such movements are characterized by little changes in accelerations and decelerations. In their work Sander et al. [13] used accelerometers to collect hand movement data of children and they concluded that smooth movements can be used to distinguish between children fine motor skills.

Based on before mentioned findings, the smoothness of hand movement and small object manipulations were selected to become core elements of the toy and the game design.

Requirements

For the design of our smart toy, the following three requirements were defined:

Requirements on Affordances

Based on the tasks that child physiotherapists give the children for fine motor skills assessment, our tangible toy should afford several types of manipulations: picking up the token with one hand, flipping it around while holding it in one hand, and precisely placing it in a designated place, e.g. into a slot. The size and the form of the tangible should afford the aforementioned interactions.

Sensor Data Feature Requirements

To assess smoothness of movement the toy should contain sensors such as an accelerometer sensor. Next to that, the game should encourage a player to make smooth hand movements. Therefore this smoothness of hand movement should become an essential parameter of the game.

Game Adaptability Requirements

The toy and the game should be enjoyable for children with different levels of fine motor skills, thus the game should have an adaptation mechanism to the current fine motor skills level of a player.

To sum up, the mechanics of the game should encourage players to make smooth movements while manipulating the toy with one hand. During the game the toy should capture child's movement data and adapt the game level according to the skill level of the child.

Board Game Design

Taking the above mentioned requirements into account, we have developed a game for one-hand manipulations where players move small tokens that represent mice. The children have to compete to bring their mouse to the cheese first. Each child should move his token-mouse as smoothly as possible, otherwise he will wake up cats and the token-mouse should be returned to its previous position on the board.

We will first describe the design of the game elements, such as interactive tokens and the board and then how these elements are used within the game play.

Game Elements

The board game consists of two small tokens and a board that depicts a kitchen, sleeping cats and a plate with a cheese. The tokens have the shape a quadrat with a cut off corner (to stimulate in-hand rotation before placing the token precisely into the designated slot). Each of the tokens carries a Light Blue Bean microcontroller with built-in accelerometer and two RGB LEDs. LEDs are placed behind two semi-transparent facets with engraved images of mice and they provide visual feedback to players during the game. Given the size of the sensor, tokens were made as small as possible. Dimensions of each token are 38 mm by 38 mm by 18mm (Figure 2). The tokens were shown to two child physiotherapists to assess their dimensions for interaction suitability for 7-9 year old children. Therapists expected that dimensions of tokens will be suitable for children to pick tokens up and precisely place them on the board. And that some children may have difficulties with flipping the token in one hand, although they suggested that the user study is necessary to confirm that.

The board, where the tokens should be placed on, consists of a 5 millimeter thick transparent acrylic plate with cut out slots and a printed illustration of the kitchen and sleeping cats (Figure 1a).

Game Play

The game is turn based and is played by two players. Each player moves the token which represents a mouse in a kitchen that is walking near sleeping cats and tries to get to the cheese. The goal of the game is to take the mouse to the cheese faster than another player. Each player cautiously moves the interactive token (mouse) from the start of the board to the finish by placing the token on colorful

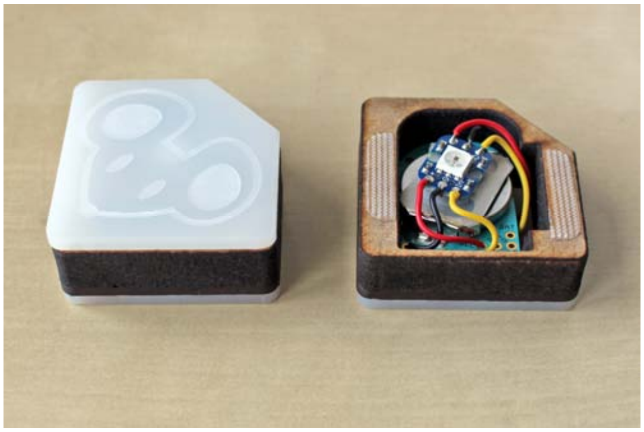

Figure 2. Design of the tokens. The top and back facets of the token are made from a semi-transparent plastic that allows players to see light feedback from the token.

segments printed on the board. Every time that a player picks up the token and flips it around the token randomly lights up in one of three colors (green, yellow or blue) that corresponds to the colorful segments printed on the board (Figure 1b). If the player makes rapid movements while moving the token it will light up in red color (cats woke up) and this means that the token should be returned to its previous location on the board.

In this game scenario the players are stimulated to pick up the token, flip it around (to see the color which appears on the opposite side of a token), and precisely place the token to the corresponding slot. The context of the game (mice walking near sleeping cats) encourages the players to move the tokens as smoothly as possible**.**

Adaptability of the described game was designed in the following way: during the game tokens constantly generate data from the accelerometer sensor that is used to calculate smoothness of hand movement. We assess smoothness of movement by calculating the mean squared jerk feature that is a common measure of smooth and coordinated movements [13]. We set a threshold for the mean squared jerk, so that when the threshold is exceeded the rapid movement is detected and a player gets immediate feedback (the token will light up in red color, which means that the mouse woke up the cats).

After each move performed by the player the threshold for that token is recalculated. If a player succeeds his turn without making rapid movements, in his next turn he will need to move the token even more carefully (threshold for this token will be lowered). If a player makes a rapid movement during the turn and "wakes up cats" in his next turn it will be easier for a player to succeed (the threshold for this token will be increased).

The board game was reviewed by two child therapists and the received feedback was generally positive. Therapists said that interactions with tokens in the game are relevant for children age 7-9 years old and that they expected that children will enjoy playing the game.

USER STUDY

A user test was set up with the following three goals to be evaluated: 1) whether the children interacted with the tokens as it was expected, 2) whether sensor data collected during the game would correlate with a standard movement proficiency test scores, 3) whether the children would enjoy the game.

Study Design

The board game was deployed in a primary school in Amsterdam, the Netherlands. 30 children between seven and nine years old took part in the study. This age group was selected over younger children for their ability to articulate their opinions about game. The school was chosen where a high prevalence of deficiencies was expected. 30 children were selected from four classes. Teachers were asked to select children that in their opinion are likely to have motor issues. This was done to ensure that in the user study there are children with a spectrum of fine motor skills level. Both qualitative and quantitative observations were performed by the interdisciplinary team consisting from an experienced child physiotherapist, a game expert, two movement scientists and a game designer. Before and during the game play children were interacting with a test administer, who first explained children the rules of the game and then in the course of the game was available to answer children's questions.

To gather children opinions about the game we have used Five Degrees of Happiness Likert scale by Hall et al. [6]. It is a pictorial 5-point Smiley Face Likert scale consisting of a variation of five happy faces. This tool aims to increase the variance in children answers comparing to the often used scales (e.g. 'Smileyometer' [10]) where smiley faces range from negative to neutral to positive. A game expert was observing children playing and made notes related to children play experiences.

Both the game expert and the child physiotherapist were observing children interacting with tokens during the game play and after the study they gave their feedback in a semi-structured interview.

The children's fine motor skills proficiency level was collected by two trained movement scientists using the standard motor skills proficiency test called Movement ABC-2 test. Movement ABC-2 test is used to identify and describe impairments in motor performance of children and adolescents and consists from three parts Manual Dexterity, Aiming and Catching, and Balance. For the user study children took Manual Dexterity part of the test that consists of three tasks such as placing pegs, threading lace, and drawing trail. All tasks were timed, scored and compared with the standard percentile rank.

All sensor data from each token was transmitted over Bluetooth.

Study Procedure

All children were divided by their teacher into couples taking into account their friendship tendencies. Each couple of children was invited into a test room one by one. Children were seated at a table where the test administer showed them the game and explained the rules. Then children were given tokens to try out interactions. Once children understood how to interact with tokens, the game session started. During the game eight couples of children were allowed to interact with tokens as they liked (e.g. they were allowed to use both hands regardless the initial instruction to use one hand only) and the other seven couples of children were allowed to use only one hand when playing. This separation was done to find whether children on their own initiative would use one hand during the play, and if they use both hands, whether we can still differentiate children skill levels in the collected data. Each game session lasted for approximately 10 minutes. After the game was finished, children proceeded to separate tables where they rated the game with the help of the Smiley Face Likert scale and then took Movement ABC-2 test which lasted around 10 minutes. After approximately 20 minutes children returned to their class.

RESULTS

In this section we will present the results of our user test with respect to 1) the observed interactions with the tokens, 2) the correlation between collected sensor data and the Movement ABC-2 motor skills proficiency test and 3) the level of enjoyment of the children.

According to the Movement ABC-2 test, children who participated in the study had the following distribution in fine motor skills proficiency: 53% ($n = 16$) had age appropriate skill development, 20% of children ($n = 6$) were at risk of having movement difficulties, and 27% of children ($n = 8$) had significant movement difficulties.

Interactions with the Tokens

According to observations of child physiotherapist children quickly understood how to play the game and did not experience considerable issues when interacting with tokens. All children were able to easily perform such interactions as picking the token up with one hand and placing it in the designated slot. Flipping the token around by holding it in one hand was more difficult for most of the children. Some children who experienced difficulties in flipping the token while holding it in one hand (and who were allowed to use both hands during the game) applied coping strategies such as helping themselves with another hand. Although interactions were not difficult it was more challenging for children to perform these interactions smoothly.

Based on the observations done by child physiotherapist the size of the tokens should be a bit smaller to allow more comfortable manipulation in one hand.

According to the game expert observations, for six children the game was too difficult and they were struggling to accomplish their turns successfully (they were shaking tokens too much while manipulating it and they quickly exceeded set threshold) and this caused their decrease of interest in the game. As soon as the game became too challenging these children started adopting coping strategies in order to succeed. Therefore the scaffolding range for game difficulties should be increased to accommodate children with big variance in fine motor skills.

The physiotherapist and the game expert admitted that several pairs of children were showing very competitive behavior and this distracted their attention from the tasks that needed to be performed with the token (children looked agitated during the game and experts observed them making less smooth movements). According to the experts, more cooperative behavior during the game play could help children to better focus on the tasks in the game (especially when tasks require concentration). We see that the category of playful experiences that the game elicits (in our case it is a victory-oriented competition) may have an influence on how children interacted with tokens and may have an effect on collected movement data and potentially on predictiveness of the collected data. In this way game experiences should be taken into account when designing games for fine motor skills assessment.

We found that all children were able to perform interactions with tokens, although many of them were trying to use compensatory movements. Experts recommended making tokens a bit smaller and transforming the game into cooperative game, however it is unknown yet whether such changes will result in more predictive data set.

Sensor Data and Movement Proficiency Test Correlation

According to the requirements the smoothness of movement was the essential parameter of the game and the game encouraged children to make smooth hand movements. During the game the common measure of smoothness (mean squared jerk feature) was collected.

For the user study all children were divided into two groups where the first group was allowed to move the tokens as they liked and the second group was allowed to use only one hand to move the token.

For children who were asked to play only with one hand ($n = 14$) a correlation was found between sensor data (the average of all collected mean squared jerk values over the whole game) and Movement ABC-2 test (correlation coefficient = -0.563; p-value = 0.045) (Figure 3). This result shows that the smoother the children move the token while holding it in one hand the better their fine motor skills are.

For children who were not told to manipulate the token with one hand only, in other words, it was up to them to decide how to interact with the token, ($n = 16$) there was no significant correlation between sensor data (the average of all collected mean squared jerk values over the whole game) and Movement ABC-2 test results (correlation coefficient = -0.191; p-value = 0.494) (Figure 4).

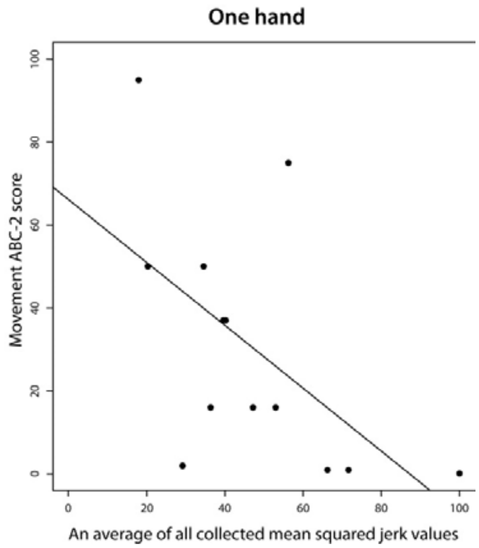

Figure 3. Scatter plot for children who manipulated the token in one hand only.

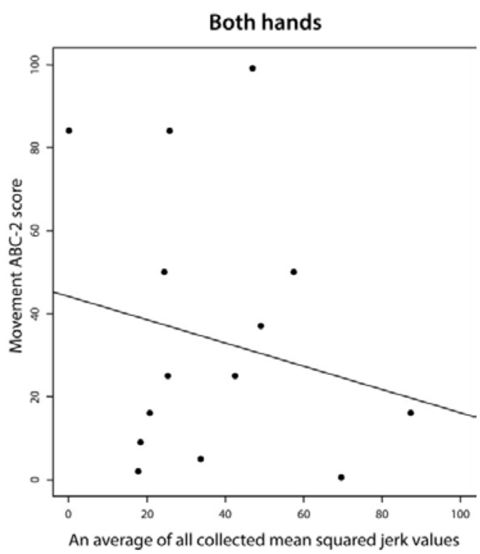

Figure 4. Scatter plot for children who manipulated the token as they preferred.

Enjoyment of the Game

Children gave the game a high evaluation despite the level of their motor skills. Figure 5 shows the overall enjoyment of the game, for which 63% (n = 19) of all children who participated in the study including 75% (n = 6) children with significant movement difficulties choose the most positive smiley. The mean rating from the Smiley Likert Scale is 4.33 (SD: 1.14). Correlation between the smiley rating and Movement ABC-2 measurements is not significant (correlation coefficient = 0.301; p-value = 0.105) and that shows that children liked to play the game regardless of their fine motor skill proficiency level. The fact that 75% children who had significant difficulties highly rated the game is an interesting result to us. We might hypothesize that we succeeded to challenge especially those children to play our game and that is

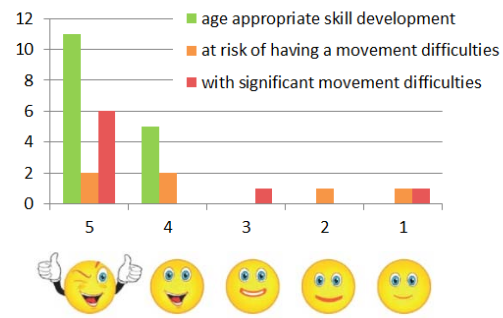

Figure 5. Smiley Face Likert scale rating for the enjoyment of the game.

exactly what we hoped for.

When asked why they have chosen smileys 4 and 5 children commented *"I liked the game"*, *"The game is exciting and you had to be careful"*, *"You must be careful as ninja"*, *"A bit difficult but nice"*, *"I felt that I was a mouse"*, *"I like the game, where to buy it?"*. Several children based their positive rating on the fact that they won the game *"I like that it was challenging and I won"*. Two children, being at risk or having significant (fine motor skill) difficulties gave the lowest score to the game admitted and that they have lost the game and it was difficult for them: *"The game is not so nice and I had to be very careful"*, *"I lost and I do not like the game"*.

According to the observations carried out by the game expert most of the children looked genuinely excited while playing the game. There seem to be a natural gameplay, the children were concentrated on the tasks and most of them did not pay attention to the experts (the physiotherapist and the game expert). The story and visual elements such as images of the kitchen, the sleeping cats, and the cheese helped children to understand the context of the game.

Children felt that the game was getting progressively more difficult expressing that *"Game becomes more difficult!"* and that *"I think it will become harder later"*. Apparently the designed adaptive scaffolding in relation to the skill proficiency of the individual child worked well. Only a few children looked frustrated and their interest in the game decreased. The system adaptation was not coping well enough with the behavior of these children. The issues were mainly related to the speed of token manipulation as well as the precision of the placement of the tokens. According to the physiotherapist, for a small fraction of children, these tasks will always be hard to perform well.

We found that children performed interactions with the tokens as it was initially expected, although several children were compensating movements by using the second hand to help themselves. Children gave high evaluation to the game and looked genuinely excited while playing the game. The correlation between collected sensor data and standard motor skills proficiency test Movement ABC-2 was found for children who were using only one hand during the game play.

LIMITATIONS AND FUTURE WORK

This is a preliminary work where we explored the possibility to assess children fine motor skills with the help of a tangible game. In the future more games and tangibles will be designed and tested with children to generate more evidence that fine motor skills can be reliably assessed with the help of smart tangible toys.

Get that cheese is, as we have shown, a promising step in the direction of creating automatic and fun tests for assessing children fine motor skills. Nevertheless, more research has to be done. As it is now, standard tests like Movement ABC-2 require the presence of a skilled observer, and *Get that cheese* is not yet sensitive enough to work unattended. Furthermore, to be fully reliable when played while unsupervised, *Get that cheese* should be able to detect whether a child is manipulating a token with one or two hands, as interactions in one hand showed correlation with the standard fine motor skills proficiency test.

Therapists admitted that they would have wanted smaller tokens, but this wasn't really feasible due to the sensor size. Following the advice of the therapists, the future version of the tokens will be smaller in size.

As we duly acknowledge these limitations, we take them as an encouragement to iterate further on our system. A combination a slightly different physical shape of the token, and some improved game rules will likely increase the accuracy of our system, which will need further testing before being able to function in a clinical and therapeutic setting.

DISCUSSION AND CONCLUSIONS

While this study is exploratory and preliminary, nevertheless we successfully gathered qualitative and quantitative insights supporting our work on tangible board games for partially unsupervised fine motor skills assessment. We still don't have a way to test children without any intervention from a movement scientist, but these exciting initial results encourage us to proceed in our research and design on tangibles and games, with the objective of developing smart toys to assess motor skills and detect early development delays.

For the design of the board game we have defined requirements such as requirements on affordances, sensor data feature requirement and game adaptability requirement. All children were able to perform such interactions as picking the token up with one hand and placing it in the designated slot. Flipping the token around by holding it in one hand was more difficult for most of the children. According to observations during the user study the tokens should have been slightly smaller to afford more comfortable flipping. Requirement for sensor data feature was met as smoothness of movement became an essential part of the game. The game encouraged players to make smooth hand movements while interacting with the tokens. The requirement of game adaptability was met in the game design so that the game was adapting its difficulty levels according to a child's motor skills level. Observations during the user study showed that the range of adaptability should be adjusted to accommodate children with big variance in fine motor skills.

A range of toys and games can be developed for fine motor skills assessment. In our case, such movement feature as smoothness informed the design of the tangibles (tokens), the board and game theme and it was the only movement feature that was assessed during the game. There are various other movement features that may be considered when designing toys and games for fine motor skills assessment. It is not clear yet what movement features may have a stronger predictive power for fine motor skills and it opens opportunities for future research. Moreover, it is also interesting to research whether other game concepts for evaluation of smooth movements would generate more predictive data for fine motor skills of children.

In this work the age appropriateness of the game concept was not fully addressed in the design process since our priority was to find whether selected interactions with tokens would generate necessary data that will have some predictive power about children fine motor skills. Therefore we have based the choice of the game theme on experts' views. In the future we will involve children in the design process to ensure that games are fun for children of different ages. It may be an interesting research opportunity to explore what kind of game themes may result in most predictive data.

When children were allowed they were playing the games with two hands although that interaction did not result in useful data set. When the game was getting to difficult for children, they were trying their best to succeed their turn and accomplish the move without waking up cats. We observed that children were using both hands to help themselves shake the token less and to move it more smoothly. Such coping strategies allowed children to perform better than they would have done using only one hand. Thus compensatory strategies that children used to succeed their turn had an influence on the collected data. It is an interesting design challenge to design games that are fun to play and on the other side children would not use compensatory movements. We will address this in our future work.

Clearly, the shape, the size and, and most likely also the weight of the token have an effect on the way a child manipulates it and therefore on the data that is being generated during the play. In our study we have seen that the size of the token could have been a bit smaller to allow more comfortable manipulation. Although it is not clear whether manipulation of a smaller size token would result in more predictive data. It is interesting to investigate further whether the shape, the size and the weight of the token have an influence on the collected data and in what way. Therefore we see opportunities for new studies addressing mentioned points.

ACKNOWLEDGMENTS
This research/publication was supported by COMMIT/.

REFERENCIES
1. Sivakumar Balasubramanian, Alejandro Melendez-Calderon, Agnes Roby-Brami, and Etienne Burdet. 2015. On the analysis of movement smoothness. *Journal of neuroengineering and rehabilitation*, 12(1),112.
2. Wouter Cools, Kristine De Martelaer, Christiane Samaey and Caroline Andries, 2009. Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. *Journal of sports science and medicine*, 8(2), 154-168.
3. Robby van Delden, Pauline Aarts, and Betsy van Dijk. 2012. Design of tangible games for children undergoing occupational and physical therapy. *In Proceedings of the 11th international conference on Entertainment Computing* (ICEC'12), Marc Herrlich, Rainer Malaka, and Maic Masuch (Eds.). Springer-Verlag, Berlin, Heidelberg, 221-234.
4. Fingergym Fine Motor Skills. Fingergym Fine Motor Skills School readiness program. 2011. Available from: www.fingergym.info/downloads/Finemotordevpp1-4.pdf
5. David Grissmer, Kevin J. Grimm, Sophie M. Aiyer, William M. Murrah, and Joel S. Steele. 2010. Fine motor skills and early comprehension of the world: two new school readiness indicators. *Developmental psychology*, 46(5), 1008.
6. Lynne Hall, Colette Hume, and Sarah Tazzyman. 2016. Five Degrees of Happiness: Effective Smiley Face Likert Scales for Evaluating with Children. In *Proceedings of the The 15th International Conference on Interaction Design and Children* (IDC '16). ACM, New York, NY, USA, 311-321.
7. Donghwa Jeong, Kerci Endri, and Kiju Lee, K. 2010. TaG-Games: tangible geometric games for assessing cognitive problem-solving skills and fine motor proficiency. IEEE International Conference on *Multisensor Fusion and Integration for Intelligence Systems*, 32-37.
8. H. Kim, P. Taele, J. Seo, J. Liew, T. Hammond. EasySketch2: a novel sketch-based interface for improving children's fine motor skills and school readiness. Proceeding Expresive '16 Proceedings of the *Joint Symposium on Computational Aesthetics and Sketch Based Interfaces and Modeling and Non-Photorealistic Animation and Rendering*, 2016, pp. 69-78.
9. Ying Li, Willem Fontijn, and Panos Markopoulos. 2008. A Tangible Tabletop Game Supporting Therapy of Children with Cerebral Palsy. In *Proceedings of the 2nd International Conference on Fun and Games*, Panos Markopoulos, Boris Ruyter, Wijnand Ijsselsteijn, and Duncan Rowland (Eds.). Springer-Verlag, Berlin, Heidelberg, 182-193.
10. Janet C. Read. 2008. Validating the Fun Toolkit: an instrument for measuring children's opinions of technology. *Cogn. Technol. Work* 10, 2 (March 2008), 119-128.
11. Pepijn Rijnbout, Mark de Graaf, Tilde Bekker, Ben Schouten. 2016. The Introduction of IMO, an integrated model for designing open-ended play. In: *Journal of Entertainment Computing* (2016).
12. Diego Rivera, Antonio García, Bernardo Alarcos, Juan R. Velasco, José Eugenio Ortega, and Isaías Martínez-Yelmo. 2016. Smart Toys Designed for Detecting Developmental Delays. *Sensors*, 16(11), 1953.
13. Jörg Sander, Antoine de Schipper, Svetlana Mironcika, Annette Brons, Huub Toussaint, Ben Schouten, and Ben Kröse. Detecting delays in motor skill development of children through data analysis of a smart play device. In *Proceedings of the 10th EAI International Conference on Pervasive Computing Technologies for Healthcare*(PervasiveHealth '16).
14. Ben Schouten, Menno Deen, Tilde Bekker (2014). Playful Identity in Game Design and Open-ended Play. *In Playful Identities, The Ludification of Digital Media Cultures*, V. Frissen et al. (Editors), Amsterdam University Press.
15. Emanuel Vonach, Marianne Ternek, Georg Gerstweiler, and Hannes Kaufmann. 2016. Design of a Health Monitoring Toy for Children. In *Proceedings of the The 15th International Conference on Interaction Design and Children* (IDC '16). ACM, New York, NY, USA, 58-67
16. Tracy L. Westeyn, Gregory D. Abowd, Thad E. Starner, Jeremy M. Johnson, Peter W. Presti, and Kimberly A. Weaver. 2012. Monitoring children's developmental progress using augmented toys and activity recognition. *Personal Ubiquitous Comput.* 16, 2 (February 2012), 169-191.
17. Oren Zuckerman, Tamar Gal, Tal Keren-Capelovitch, Tal Karsovsky, Ayelet Gal-Oz, and Patrice L. Tamar Weiss. 2016. DataSpoon: Overcoming Design Challenges in Tangible and Embedded Assistive Technologies. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '16). ACM, New York, NY, USA, 30-37.