Motivating Adults with Developmental Disabilities to Perform Motor Coordination Exercises using Exergames

Karina Caro
Autonomous University of Baja California
karina.caro.co@gmail.com

Lourdes M. Morales-Villaverde
University of California, Santa Cruz
lommoral@ucsc.edu

Taylor Gotfrid
Rochester Institute of Technology
tg3200@rit.edu

Ana I. Martinez-Garcia
CICESE
martinea@cicese.mx

Sri Kurniawan
University of California, Santa Cruz
skurnia@ucsc.edu

ABSTRACT

Adults with developmental disabilities (DD) might have visual-motor coordination problems, which may affect their independence. Exergames, videogames that involve physical exertion, can support visual-motor coordination of adults with DD, as they can offer an interactive technological experience to engage them in different motor tasks. In this paper, we explore the use of exergames at helping and motivating adults with DD to perform visual-motor coordination exercises. We conducted a user study evaluation with ten adults with DD. The participants played an exergame designed to support visual-motor coordination on three sessions over the course of one week. Our results show that all participants performed the visual-motor coordination exercises successfully using the exergame, decreasing the required verbal or physical assistance from the first to the third last session. We conclude that exergames designed to support visual-motor coordination have the potential to help and motivate adults with DD to perform visual-motor coordination exercises.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in HCI*;

KEYWORDS

Developmental disabilities, exergame, kinect-based game.

Goodtechs '18, November 28–30, 2018, Bologna, Italy

ACM ISBN 978-1-4503-6581-9/18/11…$15.00
https://doi.org/10.1145/3284869.3284914

ACM Reference Format:
Karina Caro, Lourdes M. Morales-Villaverde, Taylor Gotfrid, Ana I. Martinez-Garcia, and Sri Kurniawan. 2018. Motivating Adults with Developmental Disabilities to Perform Motor Coordination Exercises using Exergames. In *International Conference on Smart Objects and Technologies for Social Good (Goodtechs '18), November 28–30, 2018, Bologna, Italy.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3284869.3284914

1 INTRODUCTION

Several developmental disabilities (DD), such as Autism Spectrum Disorder (ASD), cerebral palsy, and Down syndrome; are characterized by deficits in motor coordination, including visual-motor coordination (*i.e.*, coordinating limb movements with visual stimuli). Deficits in visual-motor coordination can hinder an individual's ability to perform activities of daily living (*e.g.*, getting dressed) and physical or leisure activities (*e.g.*, playing ball sports) which in turn can affect their physical and mental health as well as hinder their independence and overall life satisfaction [2, 6, 20].

Motor rehabilitation therapy (MRT) designed to support visual-motor coordination of people with DD through exercises and repetition can help them improve their aimed-limb movements (*i.e.*, limb movements required to reach a visual target), as well as their daily-living, social, and communication skills [11, 13]. The literature shows that exergames, which combine game technology with exercise [16], make exercise more fun and enjoyable and thus, more likely to be continued over time [14].

Several works have demonstrated that exergames are an effective therapeutic tool to support visual-motor coordination of children with DD such as autism [3] or cerebral palsy [10]. However, studies that explore the use of exergames in supporting visual-motor coordination of adults with DD are scarce. Adults with DD might benefit from using exergames to help and motivate them to perform exercises designed to improve their visual-motor coordination. According to

[14], improving visual-motor coordination of adults with DD might strengthen their mental and physical health as well as their independence and overall life satisfaction [14]. In this paper, we present a three-sessions user study evaluation of an exergame designed to support visual-motor coordination with ten adults with DD. Some considerations for designing and evaluating exergames with adults with DD are discussed.

2 RELATED WORK

Several studies have explored the development of exergames specifically designed to support motor rehabilitation therapy (MRT) for children with motor coordination deficits, such as children with cerebral palsy [10] and autism [3]. There are also studies exploring the use of existing exergames with children and adolescents with Down Syndrome [15, 21]. Their results suggest that exergames are appropriate for supporting visual-motor coordination skills of children with motor coordination deficits in therapeutic environments, and that exergames might have the potential to support visual-motor coordination of children and adolescents with motor coordination deficits in non-therapeutic environments. However, little has been said if these results can also extends to adults with DD. That is, if this technology also has the potential to support visual-motor coordination of adults with DD, such as adults with autism, cerebral palsy or Down syndrome .

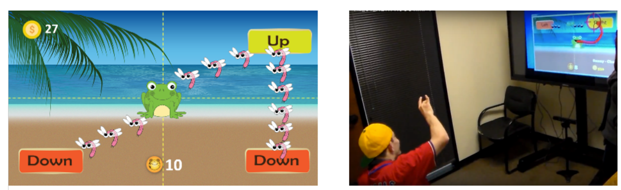
On the other hand, there are studies on exergames designed to support MRT for adults with motor coordination deficits, such as stroke survivors [17], adults who use wheelchairs [9], and older adults in general [8]. For example, Plow *et al.,* [17] present a review on exergaming for adults with disabling conditions[1]. It presents 25 studies that reported on 346 adults with disabling conditions (most were stroke survivors). Most of the studies used commercial exergame technology such as Nintendo Wii. In the same way, Staino and colleagues [18] present a systematic review of the therapeutic uses of exergames. The discussed studies were focused on balance improvement of older adults, youth with cerebral palsy, cancer survivors and people with stroke. Additionally, the systematic review of [4] comprises 31 studies of motor rehabilitation using Kinect games. These studies focused on patients with Multiple Sclerosis, older adults, and general rehabilitation. Their results suggest that exergames might be appropriate for adults who face difficulties with motor coordination; however, their results also suggest that research on exergaming to support adults with disabling conditions such as stroke survivors it is still in infancy.

According to the literature, studies on using exergames specifically designed to support motor coordination for adults with DD are scarce. Most of the studies involved children with DD or adults with chronic systemic disabling conditions such as stroke survivors. Hence, more research is needed on exploring the optimal design of such games as adults with DD would have different needs and abilities than children with DD or adults with chronic systemic disabling conditions (*e.g.*, stroke survivors). This work presents a first step on exploring whether exergames can help and motivate adults with DD to perform visual-motor coordination exercises.

[1]Long-term conditions affecting multiple organ systems and limits participation in life roles (*e.g.*, neurological conditions).

3 THE EXERGAME

Building on the work of [3], we extended the FroggyBobby exergame[2] to investigate if exergames designed to improve visual-motor coordination of children with motor problems, can also support these skills of adults with DD. To do that, we conducted two design sessions with three HCI researchers and two specialists of Hope Services[3], a local center that offers developmental and job skill training services to adults with DD, such as adults with autism, Down syndrome, and cerebral palsy. FroggyBobby, a Kinect-based exergame, requires players to perform upper-limb movements; players must guide the tongue of an animal avatar (in this version, a frog) by moving the specified arm (left or right) from an initial point to an end point along a path marked by animated bugs (Figure 1-(a)). Next, we describe the modifications/adjustments of the new version of FroggyBobby, emerged from the design sessions with the specialists of adults with DD.



(a) (b)

Figure 1: (a) The exergame; (b) A participant (P1) playing the exergame.

Game Dynamics

FroggyBobby has six levels; each level has a unique movement path (vertical or diagonal) with a specific arm to play. Level one presents a vertical path requiring to use the right arm, level two presents the same vertical path, but the required arm to play is the left one. Finally, level three has the same vertical path, but it requires a combination of both arms, alternating.

[2]See [3] for more information about the FroggyBobby design process.
[3]https://www.hopeservices.org/

For the exergame version for adults with DD, the specialists from Hope Services suggested not including levels defined by the type of path. Instead, they proposed creating a new version of the exergame, where levels are defined only by the specific arm to use, having the movement paths appear randomly. In this way, from one level, we can observe if there are movement paths that are challenging for adults with DD, with no need to go through the six levels and make the playtime boring. Thus, the new version of the exergame has three types of paths that indicate the upper-limb movements players must follow with a specified arm (Figure 1):

- Horizontal: left to right, right to left,
- Vertical: up and down,
- Diagonal: up and down, diagonally.

Players can select the level according to the arm they want to use to play: (a) right, (b) left, or (c) both arms, alternating. In each level, players perform ten repetitions[4] of visual-motor coordination exercises guided by the bugs' path which is chosen at random.

Interface Design

The exergame provides visual indicators of the initial and end points as flashing buttons (Figure 1-(a)), and it gives verbal instructions to indicate where the path starts and ends, the path to follow, and which arm to use (*e.g.*, "Right arm up, then cross down to the left."). To ensure players perform the exercises correctly (*i.e.*, follow the path from a starting to an end point), it requires players to: 1) move a target cursor (on screen) to the starting point by moving the specified arm accordingly so that the avatar's tongue is released (at this point the target cursor becomes the tip of the avatar's tongue); 2) guide the avatar's tongue along the bugs' path to catch them by moving the specified arm accordingly; and 3) reach the end point so that the avatar eats the bugs it caught, otherwise it releases them, and they reform the path. At the beginning of the design sessions, our research team had concerns regarding the *"childish"* design of FroggyBobby, so the proposal to change the avatars or the exergame design for a more realistic environment arose. However, the specialists based on their experience suggested testing the current design first. Hope Services uses commercial tablet-based games designed for children to support different developmental skills (e.g., cognitive) of adults with DD, and they have found that adults enjoy the interface design, even if the games are aimed at children.

[4]The number of repetitions was decided together with a physical therapist, who recommended that ten repetitions are a good standard to perform physical exercises.

Table 1: Participants' demographics.

P#	Developmental Disability	Age	Gender
P1	Cerebral palsy (CP)	23	M
P2	Autism Spectrum Disorder (ASD)	31	M
P3	Inverted X Syndrome (IXS)	25	F
P4	Down Syndrome (DS)	36	F
P5	Mild intellectual disability (MID)	27	F
P6	Mild intellectual disability (MID)	35	F
P7	Mild intellectual disability (MID)	27	F
P8	Autism Spectrum Disorder (ASD)	24	M
P9	Mild intellectual disability (MID)	26	M
P10	Down Syndrome (DS)	30	F
AVG		28.4	
SD		4.4	

4 USER STUDY

We conducted a user study to investigate the potential of the new version of the FroggyBobby exergame in motivating adults with DD to perform visual-motor coordination exercises.

The user study was informed by the following research questions:

- What is the game experience of adults with DD while playing the exergame?
- How do individual differences (*e.g.*, cognitive and motor abilities) of the adults with DD can influence the interaction, motivation, and experience with the exergame?

Participants

After getting the approval of our University's Institutional Review Board (IRB), we conducted a user study of the exergame in collaboration with Hope Services, with ten of their clients (Table 1), 6 females and 4 males, between the ages of 23 and 36 (AVG = 28.4 years, SD = 4.4 years). Two participants had experience playing Kinect games.

Procedure

At the beginning of the study, the researchers explained the study and its goals and went over the consent forms with all participants. After participants signed the consent forms (permitting to be video and audio recorded), each participant played the exergame for approximately 6 minutes on three sessions over the course of a week. After each session, participants answered a semi-structured interview about their experience with the exergame. Finally, at the end of the third session, participants answered a questionnaire to measure their game experience.

Data collection and analysis

The semi-structured interview included themes around participants' experience with the exergame such as: whether they understood the instructions and the goal of the exergame, felt the exergame was fun and motivating and felt the exercises were easy or hard. To measure participants' game experience, participants were asked to complete the In-Game Module of Game Experience Questionnaire (GEQ) [12] during the final session. GEQ measures game experience as scores (using a 5-point Likert scale) on seven-game dimensions: Immersion, Flow, Competence, Positive and Negative Affect, Tension, and Challenge. We selected the In-Game module since it is a concise version of the Core module of GEQ (14 items), and people with DD might not have the attention and tolerance to deal with long questionnaires and too many answer options [5]. Thus, we used a 3-point scale (no, maybe, yes) to clarify and simplify the options for the participants. All game sessions were video recorded for later analysis.

For data analysis, we used a mixed method approach. To analyze the qualitative data, we used content analysis using techniques to derive grounded theory (*e.g.*, open and axial coding) [19]. Quotes obtained from interviews and recorded videos were grouped to uncover emerging themes related to the player experience.

We used sequential analysis [1] to quantify different behaviors that the participants exhibited while they were playing with the exergame, using the following coding scheme:

- **Positive Reactions.** Physical or verbal indications that imply that the participant is enjoying the exergame (*e.g.*, smile, laugh, jump with excitement).
- **Negative Reactions.** Physical or verbal indications (*e.g.*, facial or verbal expressions) that imply that the participant is not enjoying the exergame (*e.g.*, frustrated, disinterested).
- **Assistance**[5].
  - *Physical*: Participants required physical assistance (*e.g.*, a researcher helps to move participant's arm to the visual target, physically) to perform the exercises and without which the participant would not have been able to continue playing.
  - *Verbal*: Participants required verbal instructions to perform the exercises and without which the participant would not have been able to continue playing (*e.g.*, a researcher verbally indicates which arm to use).

Three researchers, two with expertise in HCI and accessibility, and another with expertise in HCI and cognitive science coded the videos of each participant, using our coding scheme. In the beginning, the researchers independently coded the same 8 videos (*i.e.*, quantified the occurrences of the themes in the coding scheme) and obtained an acceptable inter-observer agreement (90.5%). Then, all the videos (n =30) were divided among the three researchers and coded independently using the Behavioral Observation Research Interactive Software (BORIS) [7], a free event logging software for video/audio coding. We used a Wilcoxon Signed-rank Test to determine if there were a significant difference between the behaviors the participants exhibited from the first to the third session regarding the percentage or frequency.

[5]The process to provide assistance was as follows: First, researchers would provide verbal assistance. Then, if the participant continued to experience difficulties, researchers would provide physical assistance.

5 RESULTS

Use and Adoption

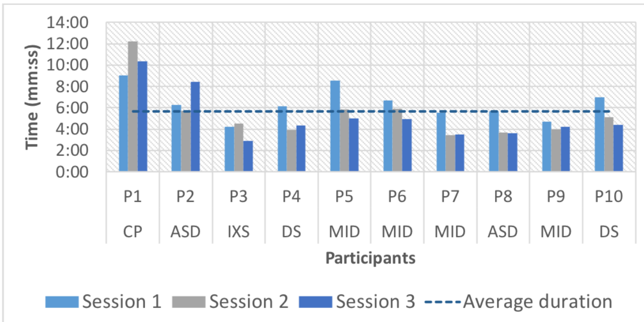
On average, each participant played the exergame for approximately 5:40 minutes (SD = 2:08 minutes) (Figure 2-(a)). Eight of the ten participants decreased the play time from the first to the third session. This result could indicate that the participants learned how to play the exergame, as they successfully finished all the visual-motor coordination exercises required by the exergame. In contrast, two participants increased their play time from the first to the third game session (P1 and P2). P1 is a participant with cerebral palsy and hemiplegia (*i.e.*, paralysis of the left side of his body) who uses a wheelchair. It took P1 more time to complete the game, as P1 had to move the wheelchair to obtain a better Kinect detection. P2 is an individual with severe ASD and cognitive disability. P2 did not completely understand the goal of each motor exercise; P2 seemed to be only interested in following the bugs, instead of going from the initial to the end point to complete the exercises.

Game Experience

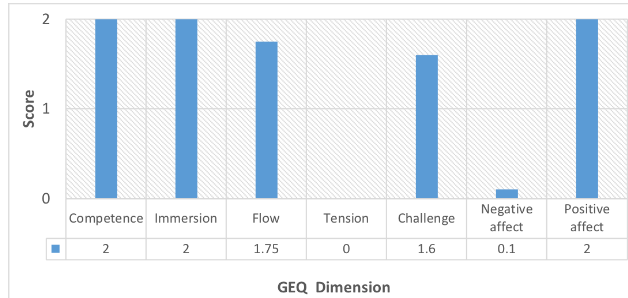
The qualitative analysis suggests that all participants stated that they felt motivated to play the exergame and that the exergame was fun. Also, all the participants expressed that they would like to play it again and that they liked the exergame's pictures, animations, and music. All participants commented that they enjoyed the idea of using their arms to make the animal avatar catch bugs:

> *"Getting all the bugs and having my own avatar that's so cool, that's awesome"* –P6, session 1.

During the interviews, all the participants expressed that they felt the exergame could help them follow verbal instructions, support visual-motor coordination and motivate and train their brain to learn about "left" and "right" concepts. Most of the participants (seven out of ten) expressions suggest that they felt like the exergame could help them with exercising and moving their arms in a coordinated way:



(a) Session duration by participant



(b) Average scores by GEQ dimensions

Figure 2: Sessions duration and GEQ dimensions scores.

> *"...the exergame can help me in exercising, with my hand-eye coordination and [with] getting a good workout and exercising the arms.'* –P7, session 3.

The results of the GEQ show that participants' game experience was positive as the dimensions of competence (if participants felt successful and skillful when played the exergame), immersion (if participants perceived the game immersive and interesting) and positive affect (if participants felt content and good when playing the game) had an average score of 2 (max value) (Figure 2-(b)). On the other hand, the dimensions of tension and negative affect, regarding if participants felt frustrated or bored when playing the game, was 0. These results indicate that the exergame caused an enjoyable and positive game experience to the participants with DD.

Positive Reactions

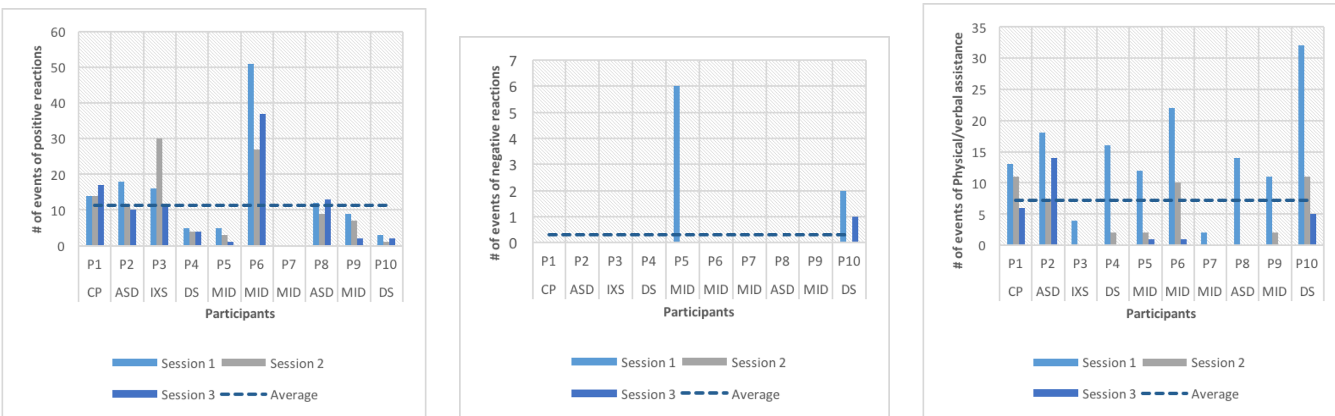
The most common types of positive reactions were smiling, laughing and positive verbal comments about the game. On average, participants exhibited 11.2 times of positive reactions while they were playing the exergame in each session (Figure 3-(a)). No significant difference was found between the numbers of positive reactions across the different sessions (p >0.05), indicating that participants maintained their positive reactions while they were playing through the three sessions.

Although all the participants expressed that the enjoyed playing the exergame, differences were observed regarding the number of positive reactions participants exhibited. P1, who uses a wheelchair and he has left hemiplegia (Figure 1-(b)), had to make a bigger effort when using his left arm. The researchers gave him the option to play only with his right arm but, P1 chose to use both arms. Even so, P1 was very excited about playing with the exergame during the three sessions (Figure 3-(a)). The two participants with Down syndrome (P4 and P10) expressed positive reactions during the three sessions (although the frequencies of incidences are below the average). In particular, P10 was affected by a number of external issues (*e.g.*, the weather condition). During session 2 and session 3, she expressed that she felt sad and tired (before she started to play the exergame) due to personal issues. However, during the interviews, she expressed that the exergame was fun, and she would like to play it again. The participants with MID (P5, P6, P9) and the participant with IXS (P3) showed positive reactions during the game sessions but with some individual differences. For example, P6 was very expressive and often commented that she was having fun and that she liked the exergame. In contrast, P7, who also has a MID, did not show any reaction. However, during the interviews and the three sessions, P7 expressed that the exergame was fun. On the other hand, the two participants with ASD (P2 and P8) displayed positive reactions in every session. Most of these were in the form of smiles and laughter. During the interviews, both enthusiastically expressed that they enjoyed playing the exergame, and that it was fun.

In summary, our results show that there is a large individual difference among people with DD, some of them exhibited positive reactions very often (as P1 and P6), some hardly expressed positive emotions (as P7) without meaning that they dislike the exergame. The use of different data collection methods when evaluating technology for people with DD can enhance the understanding about their user experience of the technology. By combining questionnaires, interviews, and video analysis, we received richer information regarding the user experience, and we can also use one technique to verify the other one.

Negative Reactions

Only two participants (P5, P10) displayed negative reactions while playing the game (Figure 3-(b)). P5's negative reactions were due to problems with the Kinect tracking her left arm



(a) Positive reactions **(b) Negative reactions** **(c) Assistance**

Figure 3: The frequency of positive and negative reactions, and assistance events exhibited by each participant on each session.

(which is undeveloped). In session 1, P5 commented that she felt that the system was not tracking her left arm properly.

> *"I felt that [the exergame] wasn't detecting my arm, maybe because I was moving faster than the avatar and I should slow down a little"* –P5, session 1.

However, during session 2 and 3, P5 did not experience any problems with the Kinect's tracking nor display any negative reactions. In contrast, P10's negative reactions were due to the game freezing (in session 1 and 3 for nearly 30 seconds) and thus, not responding to her arm movements. Nevertheless, during the interviews, P10 expressed that she did not feel frustrated when the exergame froze.

Assistance

The type of assistance needed by participants was a combination of physical and verbal assistance. On various occasions, researchers gave participants verbal instructions on how to play the exergame while pointing to the area on the screen that they had to reach to complete an exercise.

On average, participants needed physical and verbal assistance 7.2 times (Figure 3-(c)). The number of times participants needed assistance decreased significantly from 14.4 to 2.7 from session 1 to session 3 ($p=0.002$). Furthermore, most participants (except P2) expressed that it was easy for them to understand and follow the instructions of the exergame. P2, an adult with severe ASD and cognitive disability, had difficulty in understanding the goal of the exergame since he seemed more focused on catching bugs rather than completing the exercises by going from initial point to end point while following the path. As a result, although he was able to play the exergame, he needed physical/verbal assistance constantly to direct his arm movements.

Implications of the Results

In summary, all participants performed the visual-motor coordination exercises in the exergame. Most participants (nine out of ten) understood the goal of each exercise and performed the exercises without feeling tired and with less assistance in session 3 than in session 1. Hence, the ten repetitions of each motor exercise with each arm were appropriate for the participants. Plus, repeating the exercises helped the participants mastered the exercises. All participants expressed that the exergame was fun and motivating to perform visual-motor coordination exercises.

Although the visual and auditory prompts were found helpful by most participants, this was not the case for one participant (P2) who needed constant assistance to complete the exercises. This result suggests the addition of other kinds of prompts (*e.g.*, for indicating the direction of the movement) and the customization of the number of prompts provided so that people with varying abilities can play the exergame. Similarly, even though P1 (who is in a wheelchair) and P5 (whose left arm is undeveloped) were able to play the exergame, it required them to make adjustments (*e.g.*, move around or slower until the Kinect's detection improved). Thus, the exergame's tracking techniques should be improved to enable people with DD and different abilities (*e.g.*, people in wheelchairs) to play the exergame more easily.

6 CONCLUSION

In this paper, we presented a user study of an exergame, to help and motivate adults with DD to perform visual-motor coordination exercises. Despite the room for improvements and although the sample was small considering that adults with DD have varying abilities, our results suggest that exergames have the potential to help and motivate adults with

DD in general to perform visual-motor coordination exercises. More research is needed to lessen the novelty effect of the game and the technology and to test whether these results hold in long-term. Nevertheless, this study was exploratory, and we believe that it is a necessary first step to understanding the design characteristics of exergames that would support the motor coordination of adults with DD.

ACKNOWLEDGMENTS

We thank all the user study participants and Hope Services for their support. Authors also thank Zak Rubin for recording the verbal instructions of the exergame. This work was funded by the UC MEXUS - CICESE Graduate Student Short-Term Research fellowship.

REFERENCES

[1] Roger Bakeman and John M Gottman. 1997. Observing interaction: An introduction to sequential analysis. Cambridge university press.

[2] Eli Carmeli, Tamar Bar-Yossef, Claudette Ariav, Ran Levy, and Dario G Liebermann. 2008. Perceptual-motor coordination in persons with mild intellectual disability. Disability and Rehabilitation 30, 5 (2008), 323–329.

[3] Karina Caro, Mónica Tentori, Ana I Martinez-Garcia, and Ivan Zavala-Ibarra. 2015. FroggyBobby: An exergame to support children with motor problems practicing motor coordination exercises during therapeutic interventions. Computers in Human Behavior (2015).

[4] Alana Da Gama, Pascal Fallavollita, Veronica Teichrieb, and Nassir Navab. 2015. Motor Rehabilitation Using Kinect: A Systematic Review. Games for Health Journal 4, 2 (2015), 123–135. https://doi.org/10.1089/g4h.2014.0047

[5] Deborah Dewey, Bonnie J Kaplan, Susan G Crawford, and Brenda N Wilson. 2002. Developmental coordination disorder: associated problems in attention, learning, and psychosocial adjustment. Human movement science 21, 5 (2002), 905–918.

[6] Kimberly A Fournier, Chris J Hass, Sagar K Naik, Neha Lodha, and James H Cauraugh. 2010. Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. Journal of autism and developmental disorders 40, 10 (2010), 1227–1240.

[7] Olivier Friard and Marco Gamba. 2016. BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. Methods in Ecology and Evolution 7, 11 (2016), 1325–1330.

[8] Kathrin Gerling, Ian Livingston, Lennart Nacke, and Regan Mandryk. 2012. Full-body motion-based game interaction for older adults. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, 1873–1882.

[9] Kathrin M Gerling, Conor Linehan, Ben Kirman, Michael R Kalyn, Adam B Evans, and Kieran C Hicks. 2016. Creating wheelchair-controlled video games: Challenges and opportunities when involving young people with mobility impairments and game design experts. International Journal of Human-Computer Studies 94 (2016), 64–73.

[10] Hamilton A Hernandez, TC Graham, Darcy Fehlings, Lauren Switzer, Zi Ye, Quentin Bellay, Md Ameer Hamza, Cheryl Savery, and Tadeusz Stach. 2012. Design of an exergaming station for children with cerebral palsy. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, 2619–2628.

[11] Thessa IM Hilgenkamp, Ruud van Wijck, and Heleen M Evenhuis. 2010. Physical fitness in older people with IDâĂŤConcept and measuring instruments: A review. Research in developmental disabilities 31, 5 (2010), 1027–1038.

[12] Wijnand IJsselsteijn, Karolien Poels, and Yvonne AW de Kort. 2008. The Game Experience Questionnaire: Development of a self-report measure to assess player experiences of digital games. TU Eindhoven, Eindhoven, The Netherlands (2008).

[13] Connie C Johnson. 2009. The benefits of physical activity for youth with developmental disabilities: a systematic review. American Journal of Health Promotion 23, 3 (2009), 157–167.

[14] Elizabeth J Lyons. 2015. Cultivating engagement and enjoyment in exergames using feedback, challenge, and rewards. Games for health journal 4, 1 (2015), 12–18.

[15] Adrian Macias, Karina Caro, Luis A Castro, Veronica Sierra, Edgar A Ahumada, and Iván A Encinas. 2017. Exergames in Individuals with Down Syndrome: A Performance Comparison Between Children and Adolescents. In International Conference on Smart Objects and Technologies for Social Good. Springer, 92–101.

[16] Florian Mueller, Rohit Ashok Khot, Kathrin Gerling, Regan Mandryk, et al. 2016. Exertion Games. Foundations and Trends® in Human–Computer Interaction 10, 1 (2016), 1–86.

[17] MA Plow, C McDaniel, S Linder, and JL Alberts. 2011. A scoping review of exergaming for adults with systemic disabling conditions. J Bioeng Biomed Sci 1 (2011), 002.

[18] Amanda E Staiano and Rachel Flynn. 2014. Therapeutic Uses of Active Videogames: A Systematic Review. Games for Health Journal 3, 6 (2014). https://doi.org/10.1089/g4h.2013.0100

[19] Anselm Straus and Juliet Corbin. 1998. Basics of qualitative research: Techniques and procedures for developing grounded theory. (1998).

[20] Stefano Vicari. 2006. Motor development and neuropsychological patterns in persons with Down syndrome. Behavior genetics 36, 3 (2006), 355–364.

[21] Yee-Pay Wuang, Ching-Sui Chiang, Chwen-Yng Su, and Chih-Chung Wang. 2011. Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome. Research in developmental disabilities 32, 1 (2011), 312–321.