Using embodied learning technology to advance motor performance of children with special educational needs and motor impairments

Panagiotis Kosmas[1][0000-0003-3079-5556], Andri Ioannou[1], and Symeon Retalis[2]

[1] Cyprus Interaction Lab, Cyprus University of Technology, 3075, Limassol, Cyprus
pk.kosmas@edu.cut.ac.cy
[2] University of Piraeus, Athens, Greece

Abstract. Embodied learning, under the lens of Embodied Cognition theory, emphasizes on the inseparable link between brain, body and the world; it considers that the active human body can alter the function of the brain and therefore the cognitive process. From this perspective, the exploration of learning environments that promote bodily activity in relation to cognitive tasks are gaining the attention of the research community in the resent days. One such case is the use of multimodal, motion-based games mediated by sensors like a Kinect camera to enable learning through active and embodied interaction with learning content. This paper presents findings from an empirical investigation of using embodied touchless interactive games to enhance motor performance for children with learning disabilities and motor impairments. A total of ten children, mainly attending special units within mainstream elementary schools, participated in a five-month intervention. Kinetic analytics, together with teachers' self-reported observations and interviews, revealed improvements in children's motor performance, particularly psychomotor ability and psychomotor speed. The paper contributes to the technology-enhanced learning community by providing insights into the use of embodied learning technology in special education.

Keywords: Embodied Cognition, Embodied Learning, Motion-based Games, Kinect, Natural Interaction, Learning Disabilities, Special Education, Technology-enhanced Learning

1 Introduction

In the age of technological imperative, massive efforts are underway to transform traditional teaching and learning to something that is enriched and mediated by technology with the prospect of advancing learning. In this spirit, motion-based interactive environments are gaining the attention of interaction designers and learning scientists who have considered the role of the active body in the functioning of the brain. In this direction, the emerging field of embodied learning, offers new ways of understanding learning which builds upon the inseparable link between brain, body, and the world.

Embodied learning takes into consideration that the human body can play a significant role in the cognitive process, in thinking and in acting in the world [1, 2]. Advocates of embodied learning believe that the involvement of the physical body and activity in the learning process has the capacity to change the cognitive process [3]. Although a good deal of research in the field of education has investigated how the integration of bodily movements and senses can influence learning [4], there is still insufficient evidence about this link based on which firmed conclusions can be drawn [4, 5].

The present study investigates how the use of embodied touchless interactive games can advance the motor performance of children with learning disabilities and motor impairments. The study is part of a larger investigation of embodied learning addressing a range of skills, yet the present manuscript focuses on motor performance, particularly:

1. Gains in (a) Psychomotor Abilities (Gp) - the ability to perform physical body motor movements with precision, coordination, or strength, and (b) Psychomotor Speed (Gps) - the speed and fluidity with which physical body movements can be made, based on the Cattell-Horn-Carroll Integrated Model classification of skills, which is widely accepted as the most comprehensive and empirically supported model of cognitive abilities [6].
2. Perceived experiences of the special education teachers and therapists regarding the development of the abovementioned skills, through embodied learning.

In the sections below, we first provide an overview of the relevant literature and previous empirical work related to embodied learning using technology. Subsequently, the method of the present investigation is detailed, followed by major findings and implications for research and practice in the intersection of technology-enhanced learning, special education and multimodal, motion-based technologies.

2 Background

2.1 Embodied Cognition Theory and Technology Enhanced Learning

Embodied cognition has become a significant learning paradigm in contemporary theory of cognitive sciences. The fascinating insight of this theory is that behavior is not simply the output of someone's isolated brain [7]. Rather, embodied cognition holds that cognitive processes are deeply rooted in the body's interactions with the world [1]. Consequently, the body plays a central role in shaping the mind and therefore, learning scientists should consider ways of engaging the body in the learning activity [8], known as embodied learning. As Nguyen, and Larson [9] noted, in embodied learning environments where learners use their bodies "learners are simultaneously sensorimotor bodies, reflective minds, and social beings".

Theories such as embodied cognition serve as an interesting foundational approach to technology-enhanced learning research. Indeed, the progress of multimodal, interactive spaces and motion-based technologies in the field of education has brought to light a lot of interesting considerations, pointing to the need to reconsider teaching practices and educational settings. Embodied cognition also became prominent in the fields of human computer interaction and interaction design with the work of Dourish [10] who first suggested the term "embodied interaction". Since then, lots of research aims to explore the role of the body in learning to create appropriate design strategies and environments in the service of learning. For example, tangible computing and Tangible User Interfaces (TUIs) [5] [11], as well as the use of multi-sensor artifacts, gesture technologies, and whole-body interaction [12] aim to create innovative and interactive learning experiences.

Overall, embodied cognition theory and embodied learning practices have brought to light essential considerations on how to develop appropriate learning environments for interactions between people and learning content [13]. Yet, little prior work has focused on the integration and evaluation of technologies that mediate embodied learning with specific learning goals in mind [14], such as the advancement of Psychomotor Abilities (Gp) and Psychomotor Speed (Gps) for children with special educational needs. That said, this work aims to push the boundaries of new learning technologies, teaching methods and evaluation techniques for the investigation and exploitation of the embodied learning field.

2.2 Related Empirical Work

In the last few years, innovative embodied interaction technologies are replacing the traditional human-computer interface modalities like mouse and keyboard [15]. Motion-based, interactive games such as Wii, Wii Fit or Wii Balance Board, Kinect-based games and exergames have received the researchers' attention investigating their potential for learning. These types of interactive games require active participation and physical engagement by the participants. In doing so, players can practice their motor skills in addition to others (e.g., cognitive skills depending on the goals of the game). Without a doubt, education is a research area in which the theory of embodied cognition has strong implications [15]. However, there is limited empirical research that studies the use of embodied games in general education as well as special education [16].

Within the limited empirical evidence in special education, motion-based interactive games appear to enhance the motor skills of children with disabilities [17, 18]. For example, in a relevant study [19] a total of 15 children with cerebral palsy with limited motor control of arms, experienced increased physical activity during the interventions with motion-based interactive games, compared to children in the control group. In another study conducted with 40 children diagnosed with cerebral palsy spastic diplegia, the practice with Nintendo Wii Fit games showed significant improvement in children's motor performance, when the control group exhibited no significant changes in the respective measures [20]. Moreover, a study conducted with 10 children with motor impairments using Nintendo Wii (Wii), showed significant improvement in upper limb functions for children in the intervention group [21]. It should be noted that all abovementioned studies used motion-based interactive games in home settings (rather than in school environments or therapy centers) with children with motor impairments.

Along the same lines, a series of studies has been conducted to support both children and adults with attention problems and motor impairments [22, 23, 24, 25, 26]. In one study [27] children with gross motor skills problems were actively engaged in learning and, as a result of playing, improved their motor performance. In another recent study [28], a total of 20 children with special educational needs used a suite of Kinect-based learning games for a number of weeks; results showed significant improvement in children's motor, cognitive and academic skills. Moreover, previous findings from research on exergames suggest that their use in rehabilitation interventions is pleasant in addition to being effective in helping people to improve their motor skills [29]. Yet, other studies have shown limited effects of exergames in participants' performance [23].

Outside the field of special education, Lee et al. [30] used Kinect-based games to facilitate conversational language learning with 39 non-English speaking college students. Their findings suggested that gestures grasped the attention of the learners and stimulated their thinking about language. The study of VanDam et al. [31], showed that word meaning was linked to sensorimotor experience and therefore, the embodied approach resulted in language comprehension. The study of Chang et al. [32] claimed that the embodied learning experience facilitated students' cognitive learning outcomes and gave opportunities for more active learning engagement.

All things considered, a few empirical studies in the last decade, have shown that bodily movement can enhance learning and motor performance, whilst it appears to help with attention levels during the task. In all studies, researchers have emphasized the need for conducting more work to provide compelling evidence for the effectiveness of motion-based, multimodal interactive technologies for embodied learning.

3 Method

3.1 Participants

This present piece of investigation involved 10 elementary students (seven boys and three girls) with special education needs and motor impairments. Most of them (n=7) attended mainstream elementary schools with special education units. The remaining children (n=3) attended a special school. The participants had comorbid learning disabilities and disorders which influenced their motor performance, such as dyspraxia, brain paralysis, Down syndrome and ADHD. Five children were diagnosed with brain paralysis, spastic diplegia or quadriplegia which are subsets of spastic cerebral palsy that affects arms and legs. One child was diagnosed with dyspraxia which is a disorder that makes it hard to plan and coordinate physical movement. The rest four children had motor impairments combined with other disorders such as Down Syndrome, autism and ADHD (see Table 1). Inclusion criteria were age (6 -14 years old) and ability to use Kinect-based, multimodal interactive games, even from a seated position. Exclusion criteria included severe motor or mental disorders to the extent that no engagement with the activities would be possible, according to the participating educators/therapist. Nine special educators and one occupational therapist were involved in the study, who were responsible for implementing the interventions during five-month period.

Table 1. Children participating in the study

Child	Age	Diagnosis
1	8	Motor impairments (seated on a wheelchair)
2	8	Down Syndrome and motor impairments
3	11	Brain paralysis
4	8	Motor impairments and ADHD
5	9	Dyspraxia and motor impairments
6	8	Autism and motor impairments
7	10	Brain paralysis - Spastic diplegia
8	12	Brain paralysis - Spastic quadriplegia (seated on a wheelchair)
9	14	Brain paralysis - Spastic diplegia (seated on a wheelchair)
10	14	Brain paralysis and motor impairments

3.2 Kinect Movement-based Multimodal Interactive Games

Building on the idea of embodied learning, we used the commercial suite of Kinect movement-based interactive educational games, known as Kinems [33]. Kinems games engage students in learning related to verbal, math, and motor skills among others, through natural interaction, using only hands and body, via the Microsoft Kinect camera. Previous research has found evidence of many positive effects Kinems games have on children to develop a variety of skills [28, 34]. A unique aspect of Kinems is that children's interaction, performance and movements during the intervention sessions are recorded on a cloud server, therefore the researcher or practitioner can extract conclusions about the participant's progress. As of 2017, the Kinems suite includes 18 interactive games. In the present study, we focused on games which can enhance Psychomotor Abilities (Gp) and Psychomotor Speed (Gps), based on Cattell-Horn-Carroll Integrated Model classification of skills [6]. These are the "Walks" and "River Crossing". The study is part of a larger investigation addressing a range of skills through embodied learning using the complete Kinems suite.

To provide a better picture of the embodied learning games, "Walks" is a game that takes place in an imaginary farm. A farmer should walk along a path and collect carrots, without straying off the path into the mud or colliding with moving critters. The game can be made more/less challenging by selecting various path directions (horizontal, vertical, diagonal or zigzag) or by adding/removing obstacles to be avoided (see Fig. 1, left). On the other hand, in "River Crossing" (see Fig. 1, right), the child undertakes the task to lead a boat in a river and transfers animals and items of the food chain from one shore to the other. The child should be very careful so as not to crash the boat on rocks that exist. Sometimes the passage for the boat becomes narrower or wider, depending on the difficulty level of the game, that the teacher/therapist can adjust [33].

Fig. 1. "Walks" game (left) and "River Crossing" game (right)

3.3 Procedures and Data Collection

Special education teachers/therapists with their students were invited to participate in the study, upon ethical review of the proposed work. Once all parental permissions were obtained, a training workshop was conducted for teachers/therapists to practice the use of Kinems games and understand how to implement the method effectively with their special education children.

The intervention was conducted in a five-month period. In mainstream elementary schools with a special education unit (n=7 students) the interventions took place in the unit. In this case, the teacher prepared personalized intervention based on the needs of their students. Children in the special school (n=3) also received personalized instruction. On average, students received two sessions of 40-minutes Kinems interaction per week and completed between 12 and 40 sessions in the duration of the study (see Fig. 2). Children did not play the games in the same order, duration, or configuration settings; the personalized programme of each participating child involved different game settings as decided by the child's special teacher/therapist.

Fig. 2. Children using Kinect-based games by Kinems

In terms of data collection, system log-file data of children's interaction were automatically recorded in the Kinems platform. For example, depending on the game, the system recorded hand movements and stability, number of times the child completed the game, number of obstacles avoided (e.g., snakes and worms in "Walks" and rocks in "River Crossing" game) and speed of completing the game. In other words, the Kinect sensor recorded tracking data as the game progressed to enable the teachers' and researchers' understanding of children's progress on the variables of interest, in this case Psychomotor ability (Gp) and Psychomotor speed (Gps).

The dataset also included teachers' typed observations regarding children's performance, behavior and participation in the learning process; per researchers' instructions, these observations was noted by teachers at the end of each session in a specific notes-area for typing within the Kinems software. Furthermore, at the end of the programme, semi-structured interviews were conducted with all participating teachers. As shown in Table 2, questions focused on teachers' perceptions of students' improvement through their participation in the programme and the value of the Kinems games for embodied learning for students with motor impairments and educational needs.

Table 2. List of some questions asked in semi-structured interviews

Question	
1	How was the mood and motivation of the children during the sessions?
2	How children increase or not their participation during the intervention?
3	In what ways did the games support children's motor needs and learning needs?
4	Were the games hard, easy, and usable for the children and the teacher/therapist?
5	Please describe the general performance of children across sessions (motivation, completion time, body and hand movement etc.).
6	How do you see embodied games helping children to improve their skills?

4 Findings

4.1 Gains in Psychomotor Abilities (Gp) and Speed (Gps)

Initially, the analysis focused on understanding how the use of embodied touchless interactive games can enhance children's Psychomotor Abilities (Gp) and Psychomotor Speed (Gps). Based on the Cattell-Horn-Carroll Integrated Model classification of skills [6], Psychomotor Ability (Gp) is the ability to perform physical body motor movements with precision, coordination, or strength, operationalized in this study as the motor stability of the hand. Psychomotor Speed (Gps) is the speed and fluidity with which physical body movements can be made, operationalized in this work as the time for successful completion of the task.

With regards to Gps, we examined the speed-related analytics recorded in "Walks" which was used by all 10 participants for a different number of sessions, using configuration settings within the personalized programme of each child. Table 3 presents sequences of "Walks" usage by each child with the same configuration settings. As shown in Table 3, the overall completion time of the game improved across intervention sessions. In fact, there was a statistically significant difference on children's speed ($t(9) = 4.35$, $p = .002$), with children completing the task in shorter time in their last session ($M = 1.67$, $SD = .78$) compared to their first session ($M = 3.57$, $SD = 1.85$), with a large effect size (Cohen's $d = 1.37$) suggesting the practical significance of this finding.

With regards to Gp, we present the case of two children, while similar gains were evident across the majority children of Table 3. Child 2 played “Walks” for four consecutive sessions with the same configuration settings. As Fig. 3 shows, this child progressively improved his hand stability along a combination of horizontal and vertical movement, in only four sessions. Also, as the child was increasingly more capable of performing more accurate hand movement, success in completing the task was achieved in progressively shorter time (see Table 3). This child did not play other consecutive sessions of Walks with more advanced configuration settings.

Table 3. Completion time from the first to the last session in “Walks”

	Time in Walks Session 1	Time in Walks Last Session	Number of Sessions with same settings
Child 1	2.37	1.4	4
Child 2	5.1	2.12	4
Child 3	7.33	2.39	6
Child 4	5.8	3.34	8
Child 5	1.58	1.3	4
Child 6	2.19	1.51	7
Child 7	3.19	1.29	4
Child 8	2.42	1.7	4
Child 9	3.34	1.18	9
Child 10	2.4	0.49	7

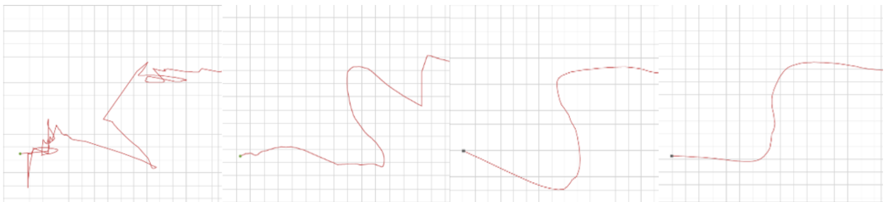

Fig. 3. The progressive improvement of the child’s hand movement in 4 sessions of Walks

In “River Crossing”, we present the case of Child 9 who played the game for twelve consecutive sessions with the same configuration settings. Fig. 4 shows progressive improvement of the horizontal movement of his hand for four different routes from left to right during the game. The charts of the first session (left side), show that child faces kinetic instability during the execution of the right to drive left. Instead, looking at the figures of the last session (right side) one can see the child's improvement in comparison with the hand movement of the respective first session. Overall, the child’s Gp ability for hand movements from left to right improved over time. Meanwhile, the game completion time of the child (Gps ability) was improved across sessions. In the first session, the child finished the “River Crossing” game in ten seconds; in the fourth session, he finished the game in four seconds and maintained this speed for the remaining sessions in “River Crossing”.

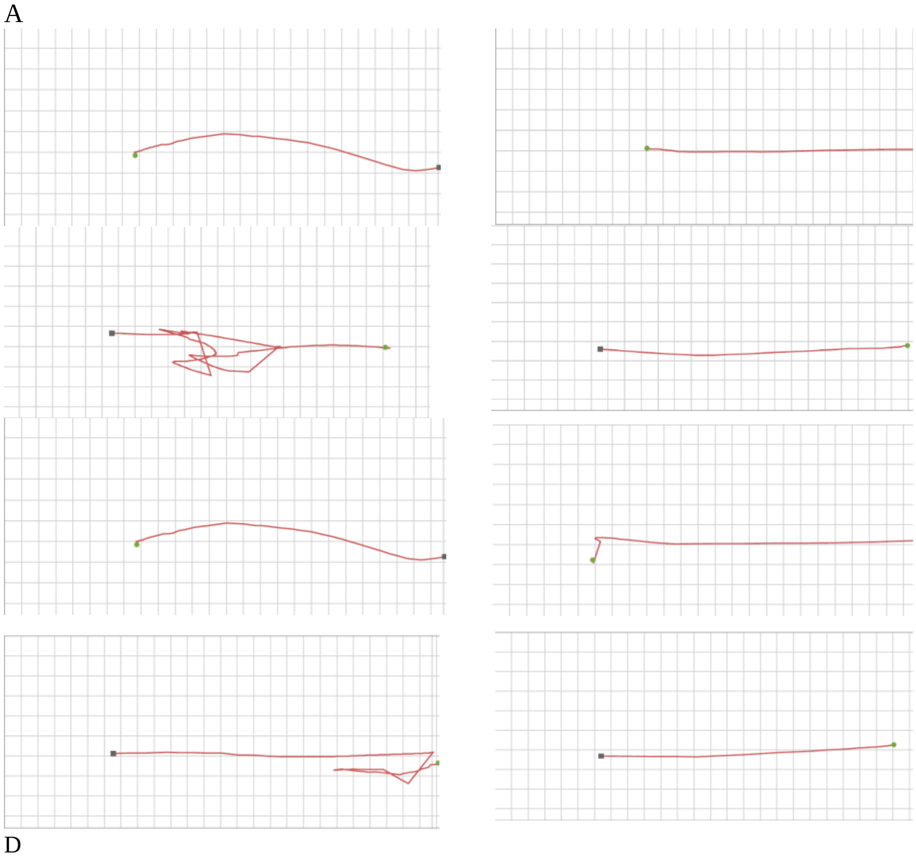

Fig. 4. A: Hand movement from 1st session to 12th session - route 1; B: Hand movement from 1st session to 12th session - route 2; C: Hand movement from 1st session to 12th session - route 3; D: Hand movement from 1st session to 12th session - route 4.

4.2 Teachers' Perceived Experiences of Embodied Learning

Teachers' observation notes taken upon each intervention session were analyzed in conjunction with the semi-structured interviews conducted at the end of five-month period. The interview data was transcribed and coded as described in Saldana [35]. Coding was done by two researchers (authors) who worked closely together on coding the interview transcripts, while considering the observation notes of the respective teachers. Following an iterative coding approach [35], a total of 18 thematic codes were identified until saturation was reached. These were then classified into four larger themes associated with the embodied learning experience from the teachers' perspective. Next, we report on one theme --"Improvement of motor skills" -- which is directly linked to variables of interest in the present study-- Gp and Gps. A detailed analysis of all four themes is beyond the scope of this manuscript.

According to the teachers, the method of touchless interaction enabled children to engage in physical activity and improve their body and hand movement. The clear majority of teachers discussed progress in vision-motor coordination, hand stability and speed improvement, as illustrated in Table 4.

Table 4. Teachers talk about visual-motor coordination, hand stability and speed

Participant	Visual-Motor Coordination	Hand Stability	Speed Improvement in task completion
p1	√	√	√
p2	√	√	√
p3	√		√
p4	√	√	√
p5	√	√	√
p6	√		√
p7	√	√	√
p8		√	√
p9	√	√	
p10	√	√	√

A few teachers went on to discuss that the embodied interaction with the games helped the children improve their gross motor and fine motor skills, body position in the space and ability coordinate thought and movement. Some indicative quotes on the matter are presented below to express the depth of the experience:

(p1) "*With the interactive games I saw that [child's name] was more concentrated and improved her movement. I think that this interactivity is very helpful especially for these children who have a lot of disabilities which affect their movement*."

(p2) "*In the beginning, it was very difficult for my students to play the interactive games, but after a few sessions, they became much more confident in their movements*."

(p4) "*I saw a significant improvement in the gross motor skills of my students. I saw that during the intervention my children could coordinate their hands better as well as their body position in front of the game*."

(p9) "*I believe that this learning experience helped the children to coordinate their thinking and how to materialize it; thought - movement coordination for these children is very important.*"

(p5) "*One of my students has issues with his balance and hand-movement coordination. He has also a lot of difficulties in physical activities and for this reason he cannot participate in the gym class. However, this student managed to complete all the interventions. I saw significant improvement in his balance, hand stability and hand-movement coordination. I think that the games helped him a lot*."

(p7) "*I saw improvement even with children who do not have severe mobility problems. Children with severe motor impairments had stress at the beginning, but during the programme they became capable of controlling their movement and their balance.*"

(p10) "*My children were seated on a wheelchair while playing. I saw an improvement especially in hand movement. I saw, for example, improvement in their hand stability and in their visual-motor coordination in the game. Playing these games, which require physical effort, I helped my students practice and learn to control their movements improving the fluidity of their hand and fingers movements*".

Some yet more promising feedback was related to the transfer of motor skills. One of teachers reported improvement in his student's writing, although the study did not have the data to triangulate this finding. In the teacher's own words:

(p9) "*During the programme, I noticed that one of my students improved the way of his writing; his grapho-kinetic skill improved significantly. Before the intervention, his movements were more steel and often without control; I noticed that after these sessions his movements are more limited around the body and are more controlled*".

Overall, the teachers' perceptions were fully consistent with the findings from the Kinetic analytics reported earlier. All the participating teachers felt that the embodied learning games can have an impact on children with motor impairments and special educational needs.

5 Discussion and Implications

A few studies in the field of educational technology have recently focused on exploring the potential of engaging the body in the learning process. This paper presents findings from an empirical investigation of using embodied touchless interactive games to enhance motor performance for children with learning disabilities and motor impairments. In sum, analysis of system analytics data from the Kinems embodied learning sessions revealed that children experienced significant gains in (i) psychomotor abilities (Gp) operationalized as stability of hand movement and (ii) psychomotor speed (Gps) operationalized as the time needed to successfully complete the task. These findings were consistent with the experiences and impressions of the teachers-participants.

In general, the results of the study are encouraging as they not only support our initial expectations driven by the theory of embodied cognition but also, confirm results of previous works making use of motion-based technologies to achieve learning goals including motor performance for children with special needs and learning disabilities [15, 16, 19, 20, 21, 27, 28]. Moreover, although many previous works make use of embodied learning technology in (isolated) home settings, the present study suggests that such methods can be used in traditional educational settings, including special schools, mainstream schools with special units and personalized education programmes, enriching the way of teaching and learning and enhancing the motor performance of children.

Nonetheless, empirical research in the field of embodied interactive games in special education for children with developmental coordination disorders are still limited [27, 28], not allowing for firm conclusions to be drawn. More investigation is needed to demonstrate how learning content and methods of embodied learning are best integrated in different domains [36]. Furthermore, theoretical frameworks need to be elaborated to explain the idea of body being active in the cognitive process [37] and to establish the limitations of the relationship between the body and the mind.

One limitation of this study is the use of a large suite of games. Because of the many options to choose from, the teachers did not make extensive use of each single game. For example, most of them used “Walks” with the default settings, while after several sessions when the child mastered the game (within 4 to 9 sessions as in Table 3), the teachers chose to switch to a different game, rather than continue with “Walks” configured with more difficult settings. Therefore, from the perspective of the researchers, the study lacked data from consecutive sessions in a single game with increasing levels of difficulty. Future work in this area, should aim to track progressive improvement of skills across time and increasing difficulty. Therefore, although encouraging, the results of the present investigation require replication and extension to inform scientists about the value of embodied experiences linked to specific (learning) goals.

Future efforts could also involve clusters of participants with very similar needs so that gains in specific skills can also be clustered. To elaborate, in this work we studied the complete pool of participants as one unit of analysis. Yet, it is our next aim to explore the different impact of Kinect-based games on different clusters of participants such as participants with mild brain paralysis, as well as in different intervention settings such as, receiving personalized intervention in special units in mainstream classrooms vs. special schools vs. being part of class-wide embodied learning interventions. Furthermore, given the initial teacher-reported evidence of skills transfer, future studies would do well to investigate whether any competence developed during the programme will last beyond its duration and even transfer to other domains. In other words, it would be essential to examine if good scores in the embodied games are linked to good skills in real life.

Overall the study contributes to the technology-enhanced learning community by providing a better understanding of the potential of using embodied learning technology in special education. The study suggests that the use of touchless, multimodal interactive games can help enact embodied learning and result to the advancement of motor performance for children with special learning needs and motor impairments. The findings from the study can inform and further encourage the integration of embodied learning experiences mediated by motion-based technology in different learning environments.

Acknowledgments. We would like to thank all who voluntary participated in this study, especially the teachers, for their active involvement and collaboration, and the children for their hard work and engagement. We also thank Kinems and Microsoft Cyprus for providing the learning games and Kinect cameras respectively, free of charge.

References

1. Wilson, M.: Six Views of Embodied Cognition. Psychonomic Bulletin & Review, 9(4), 625--636 (2002)
2. Price, S., Roussos, G., Falcão, T. P., Sheridan, J. G.: Technology and embodiment: Relationships and implications for knowledge, creativity and communication. Beyond Current Horizons, 29, 1--22 (2009)

3. Foglia, L., Wilson, R. A.: Embodied cognition. Wiley Interdisciplinary Reviews: Cognitive Science, 4 (3), 319–325 (2013)
4. Antle, A. N.: Exploring how children use their hands to think: an embodied interactional analysis. Behaviour & Information Technology, 32(9), 938–954 (2013)
5. Antle, A. N., Wise, A. F. Getting down to details: Using theories of cognition and learning to inform tangible user interface design. Interacting with Computers, 25(1), 1–20 (2013)
6. Schneider, W. J., McGrew, K. S.: The Cattell-Horn-Carroll model of intelligence. Contemporary intellectual assessment: Theories and tests, 3, 99--144 (2012)
7. Clark, A.: An embodied cognitive science? Trends in Cognitive Sciences, 3(9), 345–351 (1999)
8. Abrahamson, D.: Building educational activities for understanding: An elaboration on the embodied-design framework and its epistemic grounds. International Journal of Child-Computer Interaction, 2(1), 1–16 (2013)
9. Nguyen, D. J., Larson, J. B.: Don't Forget About the Body: Exploring the Curricular Possibilities of Embodied Pedagogy. Innovative Higher Education, 331–344 (2015)
10. Dourish, P.: Where the Action Is: The Foundations of Embodied Interaction (Vol. 36). The MIT Press, London (2001)
11. Shaer, O., Hornecker, E.: Tangible User Interfaces: Past, Present, and Future Directions. Foundations and Trends in Human–Computer Interaction, 3(1-2), 1–137 (2009)
12. Birchfield, D., Thornburg, H., Megowan-Romanowicz, M. C., Hatton, S., Mechtley, B., Dolgov, I., Burleson, W.: Embodiment, Multimodality, and Composition: Convergent Themes across HCI and Education for Mixed-Reality Learning Environments. Advances in Human-Computer Interaction, 1–19 (2008)
13. Hornecker, E., Buur, J.: Getting a grip on tangible interaction: a framework on physical space and social interaction. In: Proceedings of the SIGCHI conference on Human Factors in computing systems, pp. 437-446. ACM, New York (2006)
14. Li K.H., Lou S.J., Tsai H.Y., Shih R.C.: The Effects of Applying Game-Based Learning to Webcam Motion Sensor Games for Autistic Students' Sensory Integration Training. Turkish Online Journal of Educational Technology - TOJET, 11(4), 451--459 (2012)
15. Leitan, N. D., Chaffey, L.: Embodied cognition and its applications: A brief review. Sensoria: A Journal of Mind, Brain & Culture, 10(1), 3-10 (2014)
16. Bartoli L., Corradi C., Garzotto F., Valoriani M.: Exploring motion-based touchless games for Autistic children's learning, In: Proceedings of Interaction Design and Children (IDC) conference, New York, NY, USA, (2013)
17. Barnhart R. C., Davenport, M. J., Epps, S. B., Nordquist V. M..: Developmental Coordination Disorder, Physical Therapy. Journal of the American Physical Therapy Association, vol. 83, 8, 722--731 (2003)
18. Chang Y.-J., Chen S.-F., Huang J.-D.: A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities, Research in Developmental Disabilities, 32(6), 2566--2570 (2011)
19. Sandlund, M., Lindh Waterworth, E., Häger, C.: Using motion interactive games to promote physical activity and enhance motor performance in children with cerebral palsy. Developmental Neurorehabilitation, 14(1), 15--21 (2011)
20. AlSaif, A. A., Alsenany, S.: Effects of interactive games on motor performance in children with spastic cerebral palsy. Journal of physical therapy science, 27(6), 2001-2003 (2015)
21. Sajan, J. E., John, J. A., Grace, P., Sabu, S. S., Tharion, G.: Wii-based interactive video games as a supplement to conventional therapy for rehabilitation of children with cerebral palsy: A pilot, randomized controlled trial. Developmental Neurorehabilitation, 1-7, (2016)
22. Deutsch J. E., Borbely M., Filler J., Huhn K., Guarrera-Bowlby, P.: Use of a lowcost,

commercially available gaming console (wii) for rehabilitation of an adolescent with cerebral palsy. Physical Therapy, 88(10), 1196--1207 (2008)

23. Hsu, J. K., Thibodeau, R., Wong, S. J., Zukiwsky, D., Cecile, S., Walton, D. M.: A "Wii" bit of fun: The effects of adding Nintendo Wii Bowling to a standard exercise regimen for residents of long-term care with upper extremity dysfunction. Physiotherapy Theory and Practice, 27 (3), 1-9 (2010)
24. Joo L. Y., Yin T. S., Xu D., Thia E., Chia P. F., Kuah C. W. K., He K. K.: Feasibility study using interactive commercial off-the-shelf computer gaming in upper limb rehabilitation in patients after stroke. Journal of Rehabilitation Medicine, 42, 437--441 (2010)
25. Loureiro R. C. V., Valentine D., Lamperd B., Collin C., Harwin W. S.: Gaming and social interactions in the rehabilitation of brain injuries: A pilot study with the Nintendo Wii console. Designing Inclusive Interactions, Part V, 219--228 (2010)
26. Saposnik G., Teasell R., Mamdani M., Hall J., McIlroy W., Cheung D., Bayley M.: Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: A pilot randomized clinical trial and proof of principle. Stroke, 41, 1477--1484 (2010)
27. Altanis, G., Boloudakis, M., Retalis, S., & Nikou, N.: Children with motor impairments play a kinect learning game: first findings from a pilot case in an authentic classroom environment. J Interact Design Architect, 19, 91-104 (2013)
28. Kourakli, M., Altanis, I., Retalis, S., Boloudakis, M., Zbainos, D., Antonopoulou, K.: Towards the improvement of the cognitive, motoric and academic skills of students with special educational needs using Kinect learning games. International Journal of Child-Computer Interaction (2016)
29. Vernadakis, N., Papastergiou, M., Zetou, E., Antoniou, P.: The impact of an exergame-based intervention on children's fundamental motor skills. Computers & Education, 83, 90-102 (2015)
30. Lee, W., Huang, C., Wu, C., Huang, S., Chen, G.: The effects of using embodied interactions to improve learning performance. In: 12th IEEE International Conference on Advanced Learning Technologies (ICALT), pp.557–559. IEEE, New York (2012)
31. Van Dam, W. O., Van Dijk, M., Bekkering, H., Rueschemeyer, S. A.: Flexibility in embodied lexical-semantic representations. Human Brain Mapping, 33(10), 2322–2333 (2012)
32. Chang, C. Y., Chien, Y. T., Chiang, C. Y., Lin, M. C., Lai, H. C.: Embodying gesture-based multimedia to improve learning. British Journal of Ed. Technology, 44(1), E5-E9 (2013)
33. Kinems Learning Games, http://www.kinems.com/
34. Retalis, S., Korpa, T., Skaloumpakas, C., Boloudakis, M., Kourakli, M. Altanis, I., Siameti, F., Papadopoulou, P., Lytra, F., Pervanidou, P.: Empowering children with ADHD 21 learning disabilities with the Kinems kinect learning games. In: 8th European Conference on Games Based Learning, 1, pp. 469-477 (2014)
35. Saldaña, J.: The coding manual for qualitative researchers. Sage, London (2009)
36. Dijkstra, K., Eerland, A., Zijlmans, J., Post, L. S.: Embodied cognition, abstract concepts, and the benefits of new technology for implicit body manipulation. Frontiers in Psychology, 5(757), 2014
37. Dijkstra, K., Eerland, A., Zijlmans, J., Post, L. S.: Embodied cognition, abstract concepts, and the benefits of new technology for implicit body manipulation. Frontiers in Psychology, 5(757), 2014