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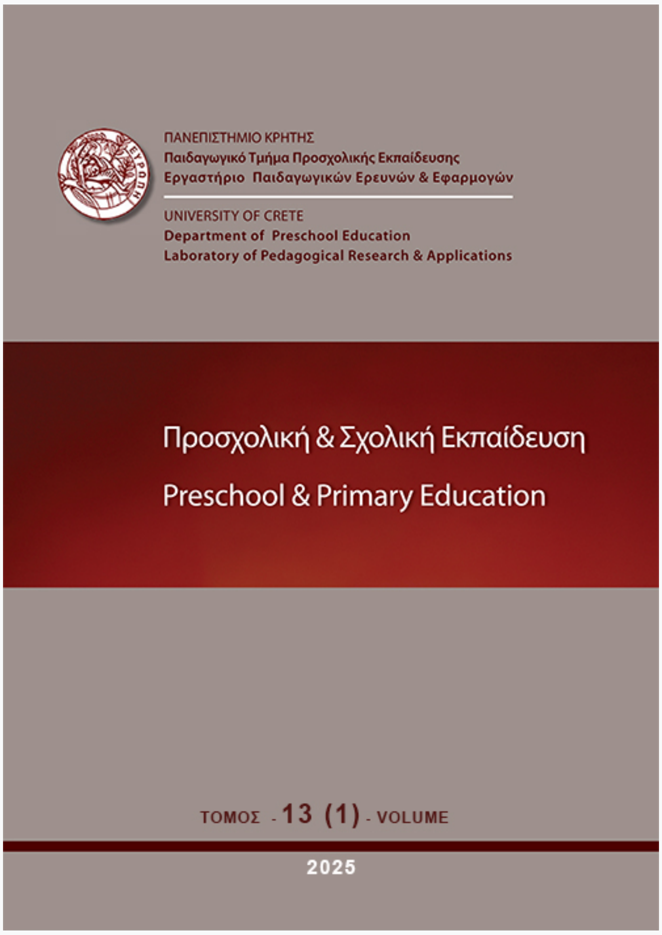

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Eleftheria Farsari, Chrisa Nitsiou

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Laboratory of Pedagogical Research & Applications
Department of Preschool Education, University of Crete
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The implementation of an interactive educational intervention programme using the Kinems learning games platform to improve gross motor skills in children with ASD

Eleftheria Farsari
Frederick University

Chrisa Nitsiou
Frederick University

Abstract. Autism spectrum disorder (ASD) is a developmental disorder that simultaneously affects several areas of development, such as communication, cognition, socialization, and movement, causing stereotyped behaviour to occur at the same time. The purpose of this study was to investigate the use of interactive educational games as part of an educational programme to enhance gross motor development of primary school students with ASD. An experimental cohort design was applied using a 3-month interactive educational platform-based intervention with 15 children with ASD, while a similar control group of 16 children with ASD followed their schools' typical teaching methods. The mean age of the children was 9.2 ± 1.4 years old, and the groups were matched for gender, age, body type and dominant foot or leg. Children's gross mobility skills were measured using the latest version of the Test of Gross Motor Development (TGMD-3-version 3.0), pre- and post-implementation of the intervention programme. The intervention was conducted using a selected list of games from the interactive educational platform named Kinems. The gross mobility skills TGMD-3 scores showed significant differences in children in the intervention group compared to the children in the control group, specifically regarding two of the thirteen skills, namely 'gallop' (Locomotor Skill) and '2-hand catch' (Ball Skill). In two of the thirteen skills studied, children in the intervention group showed higher mean differences compared to the children in the control group. Mean Success Scores (MSS) were calculated from all Kinems games played by each child during intervention, and they were correlated with equivalent ages based on Locomotor skills. The findings suggest that the interactive educational intervention programme applied with primary school children with ASD had a positive effect in their gross motor skills.

Keywords: Autism Spectrum Disorder; Kinems; Interactive educational platform; Gross motor skills; Equivalent age

Introduction

Autism spectrum disorder (ASD) is a developmental disorder that simultaneously affects several areas of development (Happé & Frith, 1996) such as communication, socialization, behaviour, and movement (American Psychiatric Association, 2013). The severity levels of autism differ among individuals with the diagnosis. This heterogeneity that

Correspondent Author: *Eleftheria Farsari*. Y. Frederickou Str., Pallouriotisa, 7, Nicosia 1036, Cyprus.
e-mail: st017022@stud.frederick.ac.cy

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characterizes the severity of autism difficulties (American Psychiatry Association, 2013; Martinez-Murcia et al., 2016; Mottron & Bzdok, 2020; Warrier et al., 2022; Waterhouse, 2022) creates challenges for researchers to prevent and treat the symptoms of individuals on the spectrum.

At the same time, the rate of ASD has been rising, with current estimates indicating that 1 in 54 children in the United States are affected (Maenner et al., 2020). Notably, 95% of individuals with autism reside in low or middle-income countries (Franz et al., 2017). Children with ASD in these countries often face significant disparities in the quality and type of education they receive compared to those in high-income countries. Addressing these educational disparities which stem from financial inequalities is crucial. One effective approach to mitigate these discrepancies is using digital technology. Digital learning, facilitated by new technologies, can provide equal learning opportunities at a low cost for all ASD communities (Naslund et al., 2017), and can enhance the daily routines of children (Abirami & Deepalakshmi, 2022).

In recent years, digital media in education have become quite widespread and they have sparked a scientific dialogue regarding the cultivation and development of digital skills, both in the typical student population, as well as among students with special educational needs. This fact creates new needs in education and school environments, and it mandates using such media in education to develop various skills, including cognitive, fine and gross motor, and social skills in children. This in turn mandates developing training programmes for educators and other professionals in new technologies. One of the main goals of digital learning in special education is the emotional and social development of students by providing equal opportunities that this form of teaching has to offer (Chaidi & Drigas, 2022).

Digital Technology for developing skills in students with autism spectrum disorder

There is a continuously developing interest in the field of digital technology as a means of assessment, intervention, and development of the learning process in individuals with ASD (deLeyer-Tiarks et al., 2023). Every technological advance is adapted to help develop skills of children with ASD. Computers, smartphones, smartwatches, and wearables could be included in the technological means, while media and technologies such as media tools, websites, virtual reality sensing technologies, artificial intelligence (AI) are included in this growing list (Kientz et al., 2020; Sandgreen et al., 2021; Shahamiri et al., 2022). Also, several researchers have reported the effectiveness of these technological media, such as the studies performed (Grynszpan et al., 2014; Wilkes-Gillan & Joosten, 2016).

The importance of using technological media has been explored in several studies. There are researchers who created an application to develop empathy skills of children with autism, based on the relative deficit they have according to the ″theory of mind“ (Munoz et al., 2019), while others implemented a four-week intervention programme using three tablet applications to develop cognitive and social skills (Esposito et al., 2017).

In the past two decades, the main intervention programmes for developing skills in children with ASD applied the use of multimedia and web technology. Researchers have shown interest in the development of communication skills (Ploog et al., 2013; Ramdoss et al., 2011), as well as social and emotional skills (Ramdoss et al., 2012). The use pf technology has shown improvements in social response (Fage et al., 2018), in mathematical skills and in expressive language (Vyshedskiy et al., 2020). In another study, researchers evaluated data from one-hundred fifty-five free web-based mobile applications and concluded that they related to the domains of executive functions, entertainment, and language and most of them improved those domains (Gallardo-Montes et al., 2022). In another review, authors investigated fifteen applications which are used to teach social skills to children with autism, in order to change their behaviour, whereas in an another study, authors mentioned that video modelling can improve social skills of children and adolescents with autism, such as reciprocity and social initiative (Hanna et al., 2022; Mason et al., 2012). Similar findings were supported by another literature review which showed that educational mobile applications are helpful for the development of communication and language skills (Hussain et al., 2021)

Additionally, Augmented Reality (AR) and Virtual Reality are two relatively new technologies that have been implemented in educational programmes for children with and without disabilities. Augmented Reality is a technology that overlays objects or places digital information in the real world, while Virtual Reality (VR) is a technology that creates a totally digital environment (Berryman, 2012). In a recent systematic review (Lian & Sunar, 2021), the authors concluded that there was an increasing interest in AR for children with ASD, as showed by the increasing number of publications in the decade between 2010-2019. Amongst ten different research questions found in the literature regarding children's skills, the most often targeted skill was "social communication" and "behaviour", while there was a limited number of publications focusing on motor skills Another systematic review about the use of VR for children and adolescents concluded that there was moderate evidence for the effectiveness of VR in children with ASD (Mesa-Gresa et al., 2018). AR and/or VR were used to expand the social response of children with ASD through various software platforms like VOISS, Floreo and others, which were used mainly to navigate social interaction through interpreting facial expressions, body language, and emotions (Carreon et al., 2023; Lee, 2020; Ravindran et al., 2019).

Sensory assisted and interactive software

In the past decade there has been a tendency to move from multimedia and web-based software to sensory assisted and interactive software. Based on such platforms, children with ASD could improve various skills such as academic, cognitive and motor skills. In previous studies, Kinems (http://www.kinems.com), an interactive software and educational platform that includes multisensory learning games was used with preschool and primary school age children to develop cognitive and executive skills (Retalis et al., 2014), as well as gross motor skills and visual motor coordination. Kinems games may be played by both typically developing children and children with special educational needs, to improve a variety of skills, combined with an interdisciplinary approach through the software. The platform keeps detailed data about the rate of success, time of completion, etc. that could be used by researchers, educators, parents and children for research, educational and informational purposes.

Previous research studies have applied the Kinems educational games with children with special educational needs (Kourakli et al., 2017), as well as with children with Autism Spectrum Disorder (Aloizou et al., 2021) and Attention Deficit Hyperactivity Disorder (ADHD) (Retalis et al., 2014). Moreover, in a recent pilot study, an attempt was made to examine the school readiness of six typically developing preschool children using the Kinems software, as well as the Movement Assessment Battery for Children-2 (MABC-2). The results showed that there was consistency between the two instruments in terms of the 'balance' skill, therefore it was concluded that Kinems was a reliable instrument to assess this skill in pre-school children (Karahotzitis et al., 2022).

Although interactive games have not been scientifically proven to have a negative effect on children's behaviour, previous research has shown that digital technology may cause negative consequences in their behaviour. In a survey with parents of typically developing children and children with autism, researchers found that boys used video games more than girls, and that using electronic technology had a negative impact on individuals with autism

(MacMullin et al., 2016). Similar comparative data between ASD and children with typical development was found (Mazurek & Engelhardt, 2013). This finding deserves serious consideration by the specialist professionals in the field, so that they can target the use of digital technology for a specific period of time, for educational and research purposes among people with autism.

Kinetic skills and interventions

Although the focus of interventions was until recently mainly related to the improvement of social and communication skills of children of ASD, there is a long list of publications regarding the improvement of motor skills. A study about the prevalence of motor deficit in ASD showed that among one-hundred fifty-four children, hypotonia (38%) and apraxia (27%) were the most common deficits in children between 7-18 years old (Ming et al., 2007). There is a wide spectrum of these deficits, and the abovementioned percentages could be different in different research cohorts.

In another study, the use of sports exergames was tested in groups of typically developing and ASD children to see if they improve motor skills of children with ASD. Findings showed a better perceived 'object control' skill in ASD children, although the scoring in the TGMD-3 scales was not significantly different in pre- and post- measurements (Edwards et al., 2017). Better results in locomotor and object control skills, measured with the TGMD-2 inventory, were found after applying different interventions (including a computer training programme) in children aged from 6 to 12 years (Arabi et al., 2019). Another study on fundamental motor skills showed better but not significant outcomes in TGMD-3 skills between workshop and home-based groups of children with ASD, aged from 4 to 11 years (Columna et al., 2021). In another study, the imitation of the gross movements of a robot was tested in children aged from 4 to 7 years old, in both typically developing and ASD children. Results indicated fewer errors in imitating robot movements after intervention (Srinivasan et al., 2013).

In general, the effect of digital interventions in gross motor skills among children with ASD is still under investigation within the field. According to our literature review, there have been limited studies that have examined the impact of multimedia applications or software on the development of gross motor skills in children with ASD, as most studies focus on enhancing communication and social skills. The present research study aims to fill this gap, as we attempted to investigate the effect of an online educational games platform on the development of gross motor skills in children with ASD.

Purpose of the study

The purpose of this research study was to determine whether an intervention programme applying the interactive Kinems software would contribute positively to the development of gross motor skills of children with autism. Additionally, to the general purpose of the study, the following research questions were also addressed: Is there any significant effect in pre- and post- intervention measurements in children with ASD who played the Kinems games, that is the intervention group of children? Also, is there any significant effect when comparing the gross mobility skills scores changes to the scores of a group of children with ASD who follow a conventional education programme, that is the control group of children? And finally, is success in these games associated with the mobility skills of the students with ASD?

In this study, the measurement of gross motor skills was performed using the Test of Gross Motor Development (TGMD-3), pre- and post- intervention, in both the experimental and the control groups of children with ASD.

Overall, with this study, we aim to add to the existing knowledge regarding the beneficial usage of the Kinems platform, this time within the Greek special educational system, where in fact the use of educational software is not so common. Occasionally though, specialists may use educational software mainly to enhance children's cognitive skills, but not their mobility skills. Thus, in the future, research results of the use of the Kinems educational platform may be useful to determine the success rate of the skills under consideration, as well as the corresponding appropriate games depending on the capabilities and needs of children with ASD.

Method

Participants

The sample of the present study consists of thirty-one ASD students (ten girls and twenty-one boys) aged between 7 and 10.11 years old, who were selected from four special education primary schools in the prefecture of Heraklion, in Crete, Greece. To be included in the study, children had to have an ASD diagnosis confirmed by official multidisciplinary team assessments, they had to be capable of participating in motor assessments, they had to be able to understand and follow instructions, and they should not present any other neurological (visual or hearing) or movement disorders. The clinical diagnoses of ASD in children were provided by child psychiatrists and developmental paediatricians, working in either private child psychiatric assessment services or public hospitals and mental health centres. These diagnoses were based on clinical assessments using the International Classification of Diseases 10th Revision (ICD-10) and the Autism Diagnostic Observation Schedule (ADOS) tools.

All participating children were assigned to two groups applying the convenience sampling method: a Control Group (CG) of sixteen children who followed typical teaching methods applied at their schools, and the Intervention Group (IG) of fifteen children who received the intervention and participated in the interactive video games using the Kinems software. The comparison of the demographic characteristics of the students with ASD showed that the participating children did not differ significantly in terms of age (p=.411), gender (p=.901), body type (p=.583) and dominant hand (p=.318) and foot (p=.570) (**Table 1**).

Research Tools

Kinems Software

Kinems is an interactive learning games platform, with an easy and attractive software that was first mentioned in a research publication used with children with Attention Deficit Hyperactivity Disorder (Retalis et al., 2014). Games were played using a built-in camera and an extra motion sensory device like the Xbox 360 kinect motion sensory in previous software releases. In its latest update the software can work only with a built-in camera and without the extra motion device. The selection of the Kinems games used in the intervention was based on their utility in terms of the study objectives.

A short description of the selected games' effectiveness or enhancement of students' skills is provided below. Additionally, the contribution of video games to fine and gross motor skills is shown in Table 2.

Table 1 Demographic (age, gender) and somatometric characteristics (body type, dominant hand/foot) for each group of students with ASD

		Group		
		CG (16)	**IG (15)**	
		n (%)	n (%)	**p**
Gender	**Boy**	11 (68.8)	10 (66.7)	.901*
	Girl	5 (31.3)	5 (33.3)	
Hand	**Left**	2 (12.5)	4 (26.7)	.318*
	Right	14 (87.5)	11 (73.3)	
Foot	**Left**	2 (12.5)	3 (20.0)	.570*
	Right	14 (87.5)	12 (80.0)	.583*
Body	**Normal/Slim**	14 (87.5)	14 (93.3)	
Type	**Overweighted**	2 (12.5)	1 (6.7)	
		Mean (SD)	Mean (SD)	
Age	**Chronological**	9.8 (1.6)	9.5 (1.2)	.411**

CG: Control group IG: Intervention group using Kinems
* Pearson's chi-square test ** Mann-Whitney

Test of Gross Motor Development (TGMD-3)

The TGMD-3 is the latest version of the TGMD inventory, a well-known tool that was first developed by Ulrich in 2019. The TGMD-3 has been translated and validated in different languages, such as Farsi (Al-Hajjaj et al., 2021), Italian (Magistro et al., 2020), Spanish (Estevan et al., 2017) and other languages. According to our literature review, a master's degree thesis examined the TGMD-3 for internal consistency and construct validity in the Greek language (Pliatsika, 2021).

Regarding the content of the TGMD-3, the thirteen skills that are included in the inventory are divided into two main subset inventories: the Locomotor Skills inventory and the Ball Skills inventory. The Locomotor Skills inventory includes the skills "Run", "Gallop", "Slide", "Horizontal Jump", "Skip", "Hop", while the Ball Skills inventory includes the following skills: "Two-hand strike of a stationary ball", "Kick a stationary ball", "Underhand throw", "Two-hand Catch, "Overhand throw", "One-hand forehand strike of self-bounced ball", "One-hand stationary dribble". All skills are described in detail in the examiner's manual (Ulrich, 2019).

Each skill was examined based on three to five criteria of performance. There are fifty criteria in total, and each skill was performed twice (2 trials) by the participating children. Each child's performance on these criteria had a binary response (0-not achieved, 1-achieved). Each skill was summed to two final subtests scores from all skills: a Locomotor skills score and a Ball Skills score. As an example, the "Run" skill score ranges from 0 to 8, based on the 4 performance criteria multiplied by the 2 trials. Based on the estimated Locomotor and Balls Skills scores, a total equivalent age score can be produced, based on population data presented in the TGMD-3 Examiners Manual, as well as in former editions, such as the TGMD-2, and were previously used by other researchers (Carvalho et al., 2021; Hodge et al., 2019; Ulrich, 2019). A description of the Locomotor and Ball TGMD-3 skills are presented in Table 3.

Table 2 Kinems games used during the intervention phase, their description and their relation to motor skills

Kinems game*	Description**	Motor Skills***
Do Like	Gross motor activities improving postural control and balance	Repetitive movements, Hop
Over the Galaxy	Learning to count and practising math vocabulary	Sidewalk
Paleo	Related to math problems and cognitive tasks	Sidewalk
Ponder Up	Practising comparisons of number and quantities	Jumps, Gallops
Runi Roon	Following visual and/or oral instructions and improving motor coordination	Sidewalk
Shape in Place	Puzzle for expanding their vocabulary, recognition of shapes	Visual-Motor coordination, Catch and Release, 1-hand catch
The Melody Tree	Executive Skills, Increasing concentration and audio-visual memory	-
U-Paint	Executive Skills, Sensory processing and creativity	Overhand-Underhand Throw
UnBoxit	Improving visual recognition, language development, and motor planning skills	-
Word Splosh	Learning and practice identifying words with similar sounds	Kick
Yeti Jump	Improving students' critical thinking and mathematical vocabulary development	Jumps, Gallops

*the name of the game ** Description on the game focus *** motor skills affected

Table 3 A short description of the TGMD-3 inventory (skills, performance criteria and score range).

	Skills	Performance Criteria	Score Range
Locomotor	Run	4	0-8
	Gallop	4	0-8
	Hop	4	0-8
	Skip	3	0-6
	Horizontal Jump	4	0-8
	Slide	4	0-8
	Total Locomotor Skills	23	0-46
Ball Skills	Two hand strike *(stationary ball)*	5	0-10
	One hand forehand strike *(Self bounced ball)*	4	0-8
	One hand stationary dribble	3	0-6
	Two-hand catch	3	0-6
	Kick *(stationary ball)*	4	0-8
	Overhand Throw	4	0-8
	Underhand Throw	4	0-8
	Total Ball Skills	27	0-54

Procedure

In this study, both groups of children followed their schools' educational programme, based on the detailed guidelines for Special Primary Education of the Ministry of Education, Religion and Sport of Greece. The intervention group children participated once a week, for twelve weeks, in the Kinems intervention programme during school hours. The study may be categorized into three phases. The pre-intervention phase, which refers to children's motor skills assessment before the start of the intervention, the intervention phase, when the intervention took place with the intervention group (IG group) on the one hand, and the application of conventional teaching method to the control group (CG group), on the other hand. And finally, the post intervention phase which refers to the time after the end of the intervention, when post-intervention scores were calculated.

The TGMD-3 scores of the pre-intervention phase started in the end of November of the school year and finished in the middle of December. Each of the children was assessed once in that period during the physical education lesson. During the TGMD-3 scoring, the primary school teacher or the physical educator of the school was present. The duration of gross motor skill scoring ranged from 20 to 30 minutes which was less than the 45 minutes school period. Data were kept in a hard-copy record before the onset of the statistical analysis. All students followed their school educational programme, except for the intervention group children, who were offered the Kinems intervention programme.

During the intervention phase, the CG group of children followed their educational programme, while the IG group of children participated in the Kinems learning games intervention. Before the intervention began, a schedule had been drawn up to visit children with ASD at their participating schools. The main researcher visited the different special primary educational units, where the Kinems games platform was used by the children in the intervention group, following a specific process. The participating children were scheduled to play four or five Kinems games per session, each, during their school period. Overall, the intervention group sessions lasted three months, and each session duration was 30 to 40 minutes. At the end of this time interval, the children returned to their classrooms. After finishing playing the list of the selected Kinems games for each child, a second, third and possibly a fourth round of the Kinems games were re-played. Finally, during the post-intervention phase, all students' gross mobility skills were re-assessed, so as to have pre and post scores.

Ethics

The research was licensed by the Directorate of Primary Education of Heraklion Prefecture (19555/18-11-2022) in Crete, Greece. Additionally, the four principals of the special primary schools were informed regarding the details and aims of the study, as were the teachers who were responsible for the participating children. Moreover, an explanatory document was sent to all the parents along with a declaration of consent. This document included information about the purposes of the study, as well as the procedure, and assured parents of the confidentiality of their children's personal data and informed them that participation was optional. All parents had the same information regarding the experimental process, and nothing was given in return to the participating children.

Data Analysis

Means and standard deviations were used for the TGMD-3 scores description, while percentage frequencies were used to describe the percentages of success in the Kinems learning games. Pearson's r coefficient was used for bivariate association between results from the Kinems platform and the TGMD-3 scores. A chi-square test was applied to compare two discrete or categorical variables. The comparison of the TGMD-3 scores between phases, as well as the intervention effect was examined using repeated measures ANOVA. Bar charts were used for visual representation of the data, while analyses were made using Microsoft's EXCEL 365 and IBM SPSS Statistics 24.0. An a=0.05 was set as a level of significance.

Results

The results of repeated measures ANOVA between the IG and CG groups in the two phases of the intervention (pre and post) are presented in Table 3. The "Gallop" TGMD-3 skill was the only Locomotor TGMD-3 Skill that was significantly different between phases, as well as in the intervention group performances. In more detail, the IG group showed a mean of 4.6 ± 2.5 in post-intervention phase, vs 3.7 ± 2.6 in pre-intervention phase. The corresponding means in the "Gallop" TGMD-3 skill in the CG group showed a slight decrease from 4.1 ± 2.4 in post intervention, vs 4.3 ± 2.1 in pre-intervention phase ($F(1, 29) = 5.427$, $p = .027$).

The comparison of the Ball Skills (TGMD-3) scores between the CG and IG groups during the two phases of the experiment, is shown in **Table 5**. Only the "2-hand catch" showed a significant effect between the two phases of the experiment and between groups (CG vs IG), $F(1, 29) = 7.553$, $p = .010$). Also, there was a decrease in the CG group in "2-hand catch" score from pre-intervention phase (3.8 ±1.1) to post intervention phase (3.2 ± 1.2) while an increase was observed in the IG group from pre-intervention phase (3.5 ±1.2) to post intervention phase (3.9 ± 1.3).

Each child who participated in the IG group was assessed by the Kinems software with a total mean success score in each game played (MSS). A mean success per game (MSG) and a mean success score (MSS) from all games were also calculated from these data. In **Figure 1** the MSS of each game played per student is shown. 'U-paint' was used as a practice skill for overhand and underhand throw.

Table 4 Locomotor skills (TGMD-3) measures (mean ± SD) of the control and the intervention group in pre-post intervention

Skills	CG (n=16)				IG (n=15)			
	Pre intervention		Post intervention		Pre intervention		Post intervention	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Run	5.8	1.5	5.8	1.4	5.7	1.7	6.3	1.6
Gallop	4.3*	2.1	4.1*	2.4	3.7*	2.6	4.6*	2.5
Hop	1.6	1.9	1.4	1.4	2.4	2.5	2.5	2.3
Skip	1.8	1.7	1.7	1.9	2.6	1.4	2.5	1.6
Horizontal Jump	3.3	1.9	3.2	1.8	3.8	1.5	4	1.3
Slide	3.3	3.1	3.9	3.4	4	1.9	4.5	1.8
Locomotor skills	20.1	10	19.9	10.1	22.2	8.6	24.5	8.9

CG: Control group IG: Intervention group using Kinems
p: p-value derived from repeated measures ANOVA (phase x group interaction)
* asterisk indicates a p-value less than .05

Table 5 Ball skills (TGMD-3) measures (mean ± SD) of the control and the intervention group in pre-post intervention

Skills	CG (n=16)				IG (n=15)				
	Pre intervention		Post intervention		Pre-intervention		Post-intervention		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p
2-hand strike	3.9	2	4.2	1.9	5.4	2.2	5.3	2.3	.398
1-hand forehand	1.3	1.8	1.1	1.5	1.9	1.8	2.3	1.7	.324
1-hand stationary dribble	1.2	2.1	1.0	1.6	1.2	1.5	1.8	1.7	.186
2-hand catch	3.8*	1.1	3.2*	1.2	3.5*	1.2	3.9*	1.3	**.010**
Kick a stationary ball	3.8	1.4	3.7	1.3	4.5	1.6	4.7	1.2	.482
Overhand Throw	2.1	1.5	2.5	1.6	2.7	1.0	3.7	1.6	.250
Underhand Throw	3.5	2.3	3.5	2.1	4.3	1.6	4.4	1.7	.717
Ball Skills	19.6	9.1	19.2	8.6	23.5	6.6	26.1	8.2	.199

CG: Control group IG: Intervention group using Kinems
p: p-value derived from repeated measures ANOVA (phase x group interaction)
* asterisk indicates a p-value less than .05

More than 70% of mean success was estimated for the following list of games: Shape in Place (89.6%), Unboxit (78.2%), Ponder Up (75.6%) and Yeti Jump (73.9%). The rest of the games ranged in descending order: 61.1% (Paleo), 58.9% (The Melody Tree), 52.5% (Over the Galaxy and RuniRoon), 45.6% (Word Splosh) and minimum success was 12.3% (Do Like).

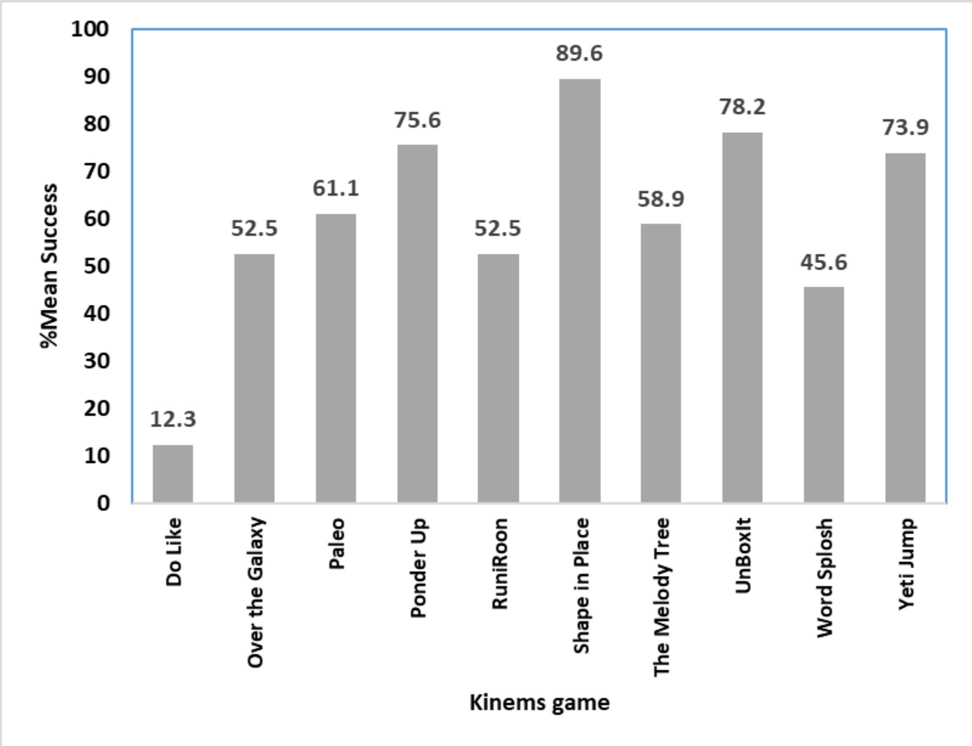

Figure 1 Bar chart of the %Mean Success per Game (MSG) of the students in IG group

Table 6 Differences in TGMD-3 scores and equivalent ages between research phases (pre-post intervention)

	IG group intervention (n=15)		
	Pre-Intervention Mean ± SD	**Post-Intervention Mean ±SD**	**P Wilcoxon**
Locomotor	21.8± 9.0	24.2± 9.3	.022
Ball Skills	23.7 ± 6.5	26.9 ± 7.8	.063
Locomotor Age	4.6 ± 2.1	5.1 ± 2.1	**.012**
Ball Skills Age	4.6 ± 1.0	5.0 ± 1.7	.647
Run	5.7 ±1.7	6.3 ± 1.6	**.011**
Gallop	3.7 ± 2.6	4.7 ± 2.4	**.012**
Hop	2.4 ± 2.6	2.5 ± 2.3	.852
Skip	2.5 ± 1.5	2.5 ± 1.6	.705
Horizontal Jump	3.8 ± 1.5	4.0 ± 1.3	.726
Slide	4.0 ± 1.9	4.5 ± 1.8	.109
2-hand strike	5.2 ± 2.2	5.3 ± 2.3	.942
1-hand forehand	2.1 ± 1.7	2.5 ± 1.7	.366
1-hand stationary dribble	1.2 ± 1.5	1.9 ± 1.6	.096
2-hand catch	3.5 ± 1.2	4.0 ± 1.2	.190
Kick	4.6 ± 1.6	4.8 ± 1.0	.739
Overhand throw	2.7 ± 1.0	3.8 ± 1.7	**.018**
Underhand throw	4.4 ± 1.5	4.6 ± 1.4	.564

p*= p-values for Wilcoxon signed rank test

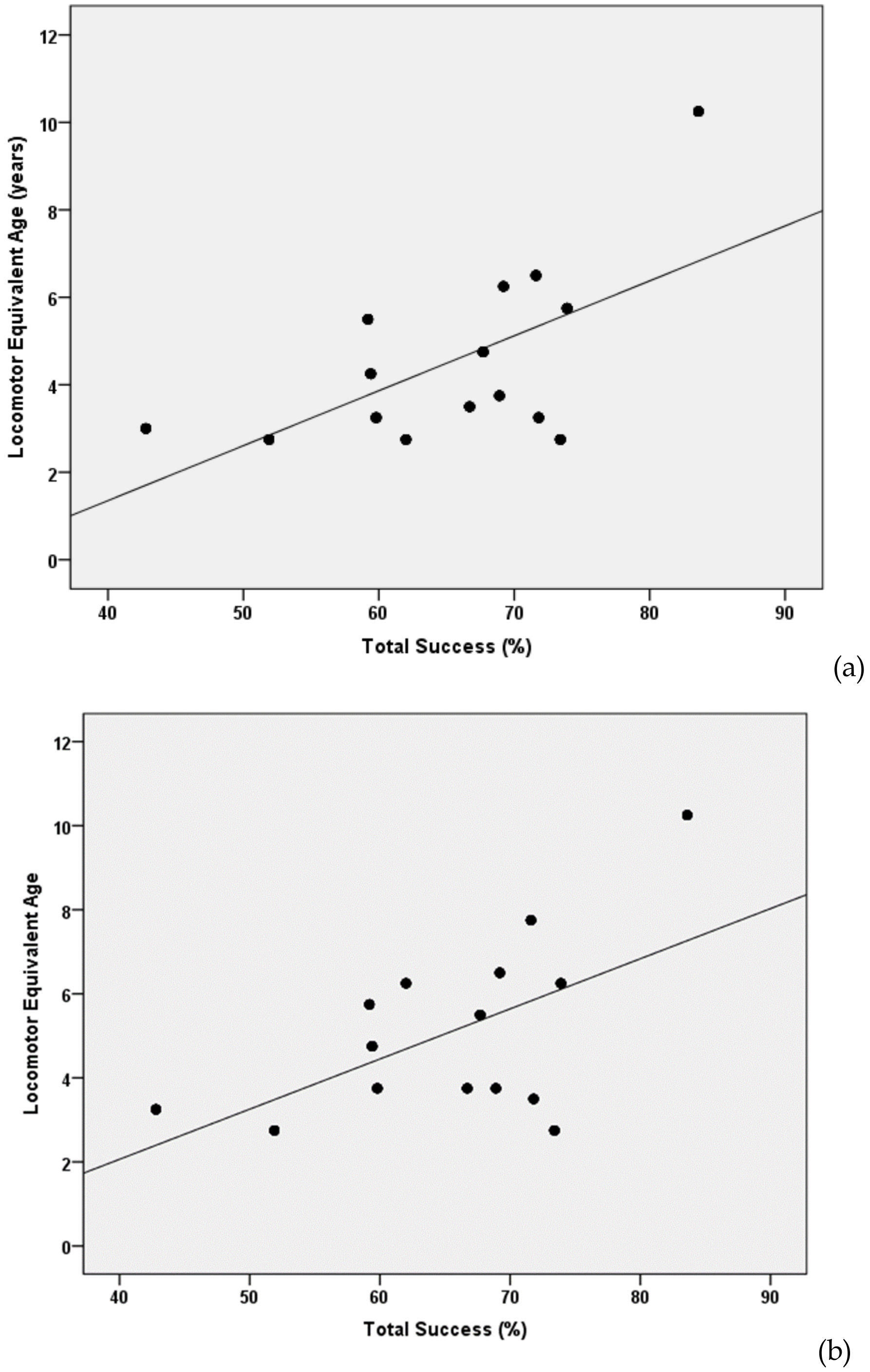

Figure 2 Association of Locomotor equivalent age with %total success in Kinems games in pre-intervention (a) and in post-intervention (b)

In another analysis, the TGMD-3 Locomotor and Ball Skills scores and their corresponding equivalent ages were tested for differences between pre- and post- intervention using the Wilcoxon test. All the comparisons showed higher scores or equivalent ages in post-intervention in comparison to pre-intervention measurements, but not all of the differences were significantly important. Significant differences were found between "Locomotor Age" scores (p=0.012) with mean age 5.1 ± 2.1 in post-intervention and 4.6 ± 2.1 in pre-intervention. Also, a significant difference was found in the scores of "Run" (p=.011), "Gallop" (p=.012) and

"Overhand Throw" (p=.018), after the Kinems learning games intervention. Results are presented in Table 6 below.

Figures 2a and 2b below presents the correlation of equivalent age based on the TGMD-3 Locomotor Skills in pre- intervention and post- intervention with MSS of the students in the Kinems. This correlation was performed to investigate whether there was an association between the performance in Kinems games and the Locomotor equivalent age of children with ASD at baseline and after the intervention. Based on those correlations and their difference in pre-intervention and post-intervention diagrams the correlation coefficients were: Locomotor equivalent age (TGMD-3) and MSS was r=.610, p=.016 and, r=.568, p=.027 respectively. The Locomotor Skills score showed a significant correlation pre-intervention (r=.518, p=.048). The Ball Skills score and the equivalent ages showed no significant correlation, neither pre-intervention (Age: r=0.064, p=0.821, score: r=0.093, p=0.742) nor post-intervention (Age r=0.141, p=0.617, score=0.205, p=0.463).

Discussion

The present experimental study focused on the effect of an interactive game platform used by children with ASD in special primary schools to enhance their gross motor abilities. One of the main conclusions of the study is that there was an increase in specific gross motor skills scores, as measured using the TGMD-3 in the intervention group compared to the control group. Specifically, the Kinems software intervention effect was found to be significantly higher in the performance of the intervention group children than that of the control group children in the "gallop", and the "2 hand catch" skills, a TGMD-3 Locomotor Skill and a TGMD-3 Ball Skill respectively. Additionally, the performance changes with significant differences within the intervention group children (pre- vs post-intervention) where found for "run", "gallop" (a TGMD-3 Locomotor skill) and "overhand throw" (a TGMD-3 Ball skill), while Locomotor equivalent age was also significantly higher after the intervention took place. Another conclusion of the study is that there was no consistent pattern of success in the Kinems games within the same student, and this is related to the different abilities that each child seems to have in terms of learning and performance skills. The effect of the Kinems learning games expressed as a percentage of success was found to be associated with the Locomotor Skills equivalent age, but not with the Ball Skills equivalent age. Similar findings were found in specific skills of gross mobility such as "run", ''gallop" and "overhand throw".

Until recently, children's gross mobility skills were not so widely studied probably due to the fact that gross motor dysfunctions in ASD were considered as "associated symptoms" and not as core characteristics of autism (Ming et al., 2007). Children's social behaviour has certainly been the main focus of research in the area of autism and it has been studied extensively by many researchers in the past (Radley et al., 2017; Yun et al., 2017). Nevertheless, recent research study results have shown that gross mobility is associated with social skills (Ohara et al., 2019; Wang et al., 2022), although it is still under investigation if the improvement of social or gross motor skills could affect one another directly or indirectly.

In general, there are many approaches to enhance or to improve the mobility or the motor impairments in children with autism. In a recent systematic review, which included metanalysis data, the authors examined interventions for improving mobility issues and they concluded that there is a positive effect in children aged from 6 to 12 years old (Kangarani-Farahani et al., 2023). Other approaches, using a special programme with physical activities, like table tennis, for twelve weeks with children with mean age 9.1 ± 1.8 years old (Pan et al., 2017), playing games through a physical intervention programme (Hassani et al., 2022), and the effect of rhythmic cueing in ASD children aged from 8 to 10 years old, showed improvement in mobility (El Shemy & El-Sayed, 2018). Another study, using the TGMD-3, showed that the comparison of locomotor skills showed an improvement after a one week programme (3 days/week sessions lasting for 80 min/session) (Dong et al., 2021). All these interventions do not include any specific educational software, exergames or interactive games platforms.

A remark must be made here regarding the fact that most of the studies previously conducted, and included in the research literature review, focused mostly on the intervention group, and thus the software intervention, and did not incorporate a corresponding control group, without applying any intervention. Another remark is that we were not able to find any previous methodologically identical research approaches using the TGMD and the Kinems learning games platform for the investigation of a possible improvement of gross mobility in children with ASD. In our study design, a comparison was made between the performance of children with ASD following a traditional educational programme and the performance of children using the interactive educational software Kinems. Our results indicated that there was a statistically significant improvement in gross motor skills such as the "Gallop" and the "Two hand catch" skills in the IG group, compared to the CG group after the intervention, and at the same time, there were many improvements in children's performance that were not statistically significant in most of the skills and in the overall scores.

Comparing with the literature review in this area, our opinion is in agreement with the mainstream belief that there is a positive "software" effect, although in the literature there is a blurry pattern (e.g. increased but not significantly increased differences). Specific research study examples could highlight our findings. Significant differences were found in the mobility of children with ASD based on a list of locomotor inventories -including the TGMD-2- but these findings were found in children aged 4 to 6 years old, whereas the study's control group did not receive any other type of intervention (Ketcheson et al., 2017). A comparison between using a structured programme of physical activity and exergaming resulted in improvement in "aiming" and "catching" skills vs the control group in children aged from 6 to 10 with autism. It is worth mentioning that there was no clear description of whether there was an intervention applied with the control group (Rafiei Milajerdi et al., 2021). A better static or dynamic balance was observed in a cohort of sixteen children aged from 6-10 years old after an Wii® intervention (Ghobadi et al., 2019). No significant changes in gross motor skills were found after an intervention was applied with ten children with ASD aged from 10 and 17 years old, using VR software (Hocking et al., 2022).

In the present study, success in Kinems games was found in most of the games to range over 50% (%total mean success). This rate of mean success in most of the games is related to the game selection which was appropriate for equivalent ages of pre-school children, showing that these games were appropriate for the ASD primary school children who presented motor deficits. Similar motor deficits in TGMD categories were found in children with ASD aged 6-8 years old (Berkeley et al., 2001). The overall mean rate of success in Kinems is proportional to the equivalent ages derived from TGMD-3 Locomotor ages, but not with the equivalent Ball Skills ages. One possible explanation is that the Kinems games played by the ASD children affected their locomotor skills positively but did not particularly enhance their ability in ball skills.

Such a finding could be seen under two different views: The Kinems scoring (rate of success) can be a valid measure of gross mobility, since it is at least moderately correlated with equivalent ages of a well-known instrument, the TGMD-3. Also, there was an improvement in equivalent age of 0.5 years (6 months) for Locomotor age and 0.4 years (4.8 months) in Ball skills age after the intervention took place.

Strengths and limitations

Overall, the strengths of the present study can be summarized as following: a) the pre-post- research design, using a control group as a comparative sample, was an appropriate design for revealing differences in the skills being studied due to the software's (Kinems) effect, b) all students were following their schools' educational programme and the studied software effects were more sound when compared with the typical education programme which also aimed to improve their motor skills, c) all children were in the same type of educational environment (special education primary schools). In other words, the children who participated in this study comprised a homogenous sample of children with ASD severity who followed similar educational programmes.

At the same time, certain limitations may be considered: a) the relatively short time interval of the educational intervention which lasted three months, and although sample size estimations were performed, there would still be a need for a more extended sample in future studies, b) the fact that the participating children were from different school units, which might have brought upon possible differences in regards with a potential variability in teaching in their schools, c) specific success percent per Kinems game was not tested in relation to locomotor and ball skills scores and equivalent ages and, finally, d) a more detailed explanation regarding the mechanism that potentially associates gross mobility skills with the use of Kinems games should be sought after in the future.

Educational implications

The results of this study may well lead to certain educational implications. Children with special needs, including those with ASD, can greatly benefit from interactive educational technologies. Although the Greek educational system tends to be conservative regarding changes in school methodologies, we have noticed some evidence suggesting slight to moderate benefits exist in special education school units where the impact of interactive educational software is being studied. Educational software like Kinems, offers tailored learning experiences that cater to individual needs, enhancing gross motor skills and cognitive development through interactive games and activities. Considering the study results, as well as the need for improved mobility in children with ASD, there is a clear need for more such intervention programmes to be implemented with the use of such interactive software.

As a conclusion, and in the context of our study, the Kinems interactive learning games played by primary school children with ASD brought positive results in the children's gross mobility. This is an important finding, and it may well pave the way for the introduction and implementation of this educational interactive software in special education classrooms for intervention purposes, in order for children with ASD to improve their motor skills, and subsequently their overall performance and development.

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