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Developmental Coordination Disorder and the role of new technologies as intervention tool

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Abstract

Due to the advancement of modern technology and the impact of the Industry 4.0 using ICTs, IOT, smart systems and products and many others are now a significant and essential component of the daily lives of many people with disabilities. Developmental Coordination Disorder (DCD) is a highly comorbid and frequently underestimated by health professionals, disorder that affects 5-6% worldwide of children, occurring disturbances in their daily living and participation. The purpose of this study is to investigate recent studies and advancements in the use of 3 promising intervention technologies including tablets, virtual reality (VR) and active video games and consoles and the role they have in developing skill deficits that are presented in DCD. In the introduction main definitions of DCD and these technologies will be discussed and in the main part these 3 categories of tech will be introduced and the results of the studies will be examined.

Keywords: DCD; Dyspraxia; Tablet-based; VR; AVGs

1. Introduction

Developmental Coordination Disorder (DCD) is a common and highly co-occurent and persistent with a wide range of severity, neurodevelopmental disorder (Zwicker et al., 2018; Blank et al, 2019; Pergantis & Drigas, 2023). The main difficulties experienced by the person is motor learning-associated, presenting a series of fine and gross motor skills deficiencies that negatively impacts the person's autonomy and functionality in their daily living activities (Harris et al., 2015; Blank et al., 2019; Pergantis & Drigas, 2023). Many researchers investigated the correlation between DCD and neural basis. Through numerous neuroimaging techniques researchers found many correlations linked with basic brain structures and regions like the mesencephalon, basal ganglia, cerebellum, parietal lobe, and thalamus, as well as their connections (Reynolds et al., 2017; Wilson et al., 2017; Hyde et al., 2018; Brown-Lum et al, 2020; Lê et al., 2021). Regarding the functions of the frontal cortex as well as the synthesis and maturation of the white and gray matter of the brain, additional abnormal images have been discovered leading to a series of skill problems identified according to fine motor skills, writing, construction, obstacle avoidance, dynamic and static balance, divided attention, ball skills, response time and movement time. Additional data includes voluntary gaze control, cognitive-motor integration, practice- and context-dependent motor learning, internal modeling and more variable kinematics and kinetics (Cousins & Smith, 2003; Wilson et al., 2017; Subara-Zukic et al., 2022). All these symptoms can possibly lead to secondary problems associated with social interactions, low self-esteem, depressive disorders, and emotional/behavioral disorders (Kirby et al., 2013; Harris et al., 2021). DCD is also one of the most comorbid disorders including ASD, specific learning disorders and ADHD with the last one to be considered as the most prevalent, sharing many common characteristics related to executive functions (Goulardins et al., 2017; Villa & Barriopedro, 2019; Lachambre et al., 2021).

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Tablet-based interventions using apps has been used a lot in research as a tool to develop motor performance, visual motor skills and cognition in many different populations and conditions including dystonia (Bertucco & Sanger, 2014), stroke (Rand et al, 2013; Wijesundera et al, 2022) and ASD (Dessoye et al, 2017; Perochon et al, 2023). It is possible to apply a number of motor learning principles based on the tablet as an intervention tool. Application (app) is a term used to refer to a class of software that enables the performance of particular tasks. Even though iPad and tablet technology is increasingly being used for therapeutic purposes and that the most recent research supports top-down, performance-based opportunities for children with neurodevelopmental disorders, specific iPad applications and their effects on learning are still unknown and need further study (Coutinho et al., 2016).

VR technologies offer digital settings that foster virtual immersion through computerized visual simulations, submerging users in an engaging three-dimensional world full of sensory and affective cues. As VR gains popularity as a training tool in educational settings, expectations for its efficacy with regard to people with disabilities rise. Because VR provides a ludic, safe, controlled, and motivating training environment, it can be an interesting avenue of intervention for people with several types of disabilities. VR educational applications have already demonstrated promising results in this regard (Mitsea et al., 2023).

Active video games (AVGs) have been used as a novel strategy to enhance movement outcomes of motor skill development and physical activity by several researchers. Exergaming and active-input video games are examples of electronic games that require significant physical movement to play, as opposed to traditional sedentary electronic games that only require small finger movements. Common examples include the Nintendo Wii Remote, PlayStation Move, and Microsoft Kinect, which detect player movement using a hand-held wand, dance mat, or camera (Howie et al., 2017). Active video games are one type of intervention that could raise physical activity levels through direct and/or indirect pathways. In lab settings, it has been demonstrated that AVGs cause children to expend more energy (Howie et al., 2015).

The objective of this research is to highlight the advantages and advancements of recent technologies as a part of the intervention process for combating many symptoms of DCD through the scope of analysis and review of the data provided by several experimental and systematic and meta-analysis studies.

2. Methods and materials

The research for this review was conducted using the following databases: Google Scholar, PubMed, PsycINFO, and ResearchGate. The majority of the articles that were gathered and presented for this review were from international scientific journals. The terms "DCD," "Dyspraxia," "VR,"AVGs," "Tablet-based" and their combinations were used as keywords. This review of the literature is a synthesis based on recent articles about AT and DCD interventions. Articles were grouped according to their content and then further divided into subgroups within each group to create chapters. Subchapters were then created from these subgroups. The last act involved writing the paper and evaluating the findings.

3. Developmental Coordination Disorder and educational difficulties

DCD according to several studies is a highly comorbid disorder that affects the overall functioning of the person leading in a multitude level disturbance of several functions and skills that a person typically develops. Most of them refer to motor learning difficulties associated with problems that arise in motor coordination, balance, gait control and visual motor deficiencies. Many children with DCD due to the severity of their symptoms also experiences many problems regarding their school participation and successful integration in school environment. According to the 24-study systematic review by Dione et al. (2022) with the purpose to gather all the knowledge regarding the extension and prevalence of these difficulties among DCD children they found that for the mathematics and handwriting difficulties the pooled prevalence was 89,5% and 84,4% accordingly, however no pooled prevalence of other difficulties could be determined. More specifically it was reported that reading, math, writing and handwriting legibility was areas that all children with DCD underperformed. In relation to new technology and devices used for this purpose there are limited studies that are found to be effective in this population. To target these problems several researchers performed different series of experimental studies using multiple devices trying to examine their effectiveness.

4. Tablet-based interventions and apps

Coutinho et al. (2016) in their research tried to investigate the effectiveness of using of iPad apps in children with disabilities, 4-7,11 years old. 20 participants included in the sample who experienced poor visual motor integration skills. The participants shared in to two groups randomly. The experimental group received interventions using iPad while the control group received standard occupational therapy in order to improve VMI skills. Two sessions were used lasting 40 minutes for 10 weeks. In order to measure the results Beery VMI and M-FUN's visual-m were used. The M-FUN total raw score, as well as the subscales Amazing Mazes, Hidden Forks, Go Fishing, and VM Behavior, showed significant results for the main effect of time. Gains between intervention types did not, however, fluctuate over time. For the Beery-VMI, there were no noteworthy findings. From this study several limitations were found including small samples, the representativity of the population observed and the duration of the intervention phase.

In the pilot study conducted by John & Renumol (2018) in a group of 9 children aged 5-10 years old with Dysgraphia, a common disorder that is comorbid with DCD, the researchers explored the dexterity performance in a technologically enhanced learning environment. With the use of the iOS app Dexteria the researchers determined their current performance performing, a pretest using paper. After that, they were shown how to use the Dexteria tablet computer software. In this particular touch-based training program was offered three sessions of exercises called "Tap it," "Pinch it," and "Write it.". The tap, pinch, and "Write it" activities were designed to help them develop their fine motor skills. For the training, each activity was allotted 15 minutes per child per day, making a total of 45 minutes spent by each participant per day. For a total of 27 hours, each participant received iPad training to improve handwriting readiness. A post-training test was administered. The children's legibility and speed of handwriting were improved, according to the results. The study's findings suggested that children with dysgraphia appeared to benefit more from an iPad-based training program that focuses on developing their visual motor skills and their readiness for writing.

Cargot et al. (2021) in their study combined the Co-writer scenario in which a young person was asked to demonstrate writing to a robot using a tablet with a number of games that the researchers created to train the pressure, tilt, speed, and letter liaison controls. This configuration was suggested to a 10-year-old boy who had a complex neurodevelopmental disorder that included dysgraphia with sever DCD, dyslexia, attention deficit/hyperactivity disorder, phonological disorder, and dyslexia. The subject was attending 2 years of specialized support in school and professional speech and motor therapy, while the problems were persistent. The duration of the program was 20 consecutive weekly sessions. The results showed that using child-robot interaction to treat dysgraphia was possible and improved writing. Although for this setup to be beneficial for children with dysgraphia, larger clinical studies are needed.

From the systematic review by Zainol et al. (2022) that investigated the effectiveness of occupational therapy handwriting interventions in children with motor coordination issues results showed that the method of the intervention had a big impact on how well handwriting skills were improved. The use of modern technology devices and application however did not improve handwriting performance (Coutinho et al. 2016; Mcglashan et al., 2017). The results implied that this could be as a result of the strong correlation between intervention strategy and handwriting ability.

John & Renumol (2022) created, developed, and assessed a hand therapeutic application (HanDex) for kids who experienced trouble writing in order to improve their hand dexterity.6 main exercises used in it that focus on strengthening the tripod grip, hand-eye coordination, spatial organization, letter formation, and fine motor skills. 10 participants evaluated the prototype for users, and their feedback was used to develop the final product. In order to evaluate the program's effectiveness, the researchers ran case studies on two primary school children with subpar handwriting and then the effectiveness of the HanDex application was observed and evaluated in this study using a single-subject pretest-posttest design. The posttest results revealed improvements in these children's letter formation, letter size, spacing between letters and words, placement, speed, and legibility.

5. Virtual Reality

Ashkenazi et al. (2013) through their study revealed the beneficial aspect of VR games in improving DCD children's motor function. The purpose of this study was to investigate whether it is possible to treat young children with DCD using a low-cost, off-the-shelf virtual reality VR game and to ascertain the impact of this intervention on motor function. During the ten game-based intervention sessions, nine children, ages 4 to 6, who had been suspected of having DCD and were referred to physical therapy, took part. Results revealed statistically significant changes in the M-ABC-2's overall standard score ($P = .024$), balance subscore ($P = .012$), and DCD-Q ($P < .05$).

Through their systematic review, Neto et al. (2019) evaluated the effectiveness of VR in improving the performance of DCD children. 12 RCTs were eventually included after 2160 publications that had been found in total and had been narrowed down. 7 of these twelve were deemed to be of high methodological quality. The methodological quality of the studies included in the search was assessed through the PEDro scale. PRISMA guidelines and Cochrane recommendations for systematic reviews were followed. The effect size of each intervention was calculated to allow for the interpretation of clinical effects, and the body of evidence was synthesised through the GRADE approach. The results showed that there was little evidence that suggested the use of VR in improving the motor performance of children with DCD, as only three studies met the homogeneity requirements to be evaluated using the GRADE system.

However, Ebrahimi Sani et al. (2020) in their RCT study examined the effects of VR training on predictive motor control of children with DCD. The VR and control groups were randomly assigned to the forty female DCD children (aged 7 to 10 years). Predictive motor control functions were assessed prior to, following, and two months after the VR intervention in this study. Using the hand rotation task, the action planning task, the sword placement task, and the rapid and online control task, predictive motor control was assessed. The VR intervention involved playing sixteen 30-minute sessions of various Xbox 360 Kinect games over the course of eight weeks. The VR group significantly outperformed the control group in comparison on measures of Motor Imagery (MI), motor planning, rapid and online control scores, and they kept up their performance to follow-up. The results showed that the VR group outperformed the control group in both the hand rotation task and the sword task. By the posttest, the VR group's performance actually improved significantly more than that of the control group, and these positive effects persisted during the subsequent follow-up phase. These results suggested that using a VR training program as a suitable intervention strategy for improving DCD children's MI and predictive motor control functions was possible. The limitations of these study consisted by several issues regarding the use of measures, the lack of complexity during tasks and the lack of research on this topic.

Marshal et al (2020) also studied the predictive motor control in DCD children. For the purpose of this research the researchers looked at the advantages of a combined action observation (AO) and MI intervention intended to address internal modeling deficits and enhance eye-hand coordination during a visuomotor rotation task. Twenty DCD children were divided into two groups at random: AO and MI (which watched videos of performers performing the task while also imagining the kinaesthetic sensations associated with action execution) and control (which watched unrelated videos with no motor content). Then, while measurements of completion time, eye-movement behavior, and movement kinematics were being taken, each group attempted to learn a 90° visuomotor rotation. The AO and MI group, as expected, demonstrated quicker completion times, more target-focused eye-movement behavior, and smoother movement kinematics than the control group after training. There were no obvious aftereffects. The results implied that AO and MI treatments could help children with DCD by reducing such deficits and enhancing motor function. Some of the limitations of this study was the relatively small sample, the inclusion of participants according to the measures of previous studies and that the study did not have a delayed retention.

6. Game consoles and active video games

Ferguson et al. (2013) performed a quasi-expiremental study design to compare the effectiveness of two interventions (Neuromotor Task Training and Wii training) and the impact they had on strength, cardiorespiratory fitness and motor performance in DCD children aged 6-10 years old who were then divided in to two groups the NTT(n=37) and Wii training (n=19). Performance was evaluated before and after the intervention using the hand-held dynamometer MABC-2, the Functional Strength Measure, the Muscle Power Sprint Test, and the 20m Shuttle Run Test. The results showed that both groups mean motor performance scores increased during the course of the study. The NTT group, however, demonstrated greater improvement in motor performance, functional strength, and cardiorespiratory fitness, with significant differences in improvement between groups. In neither group were there any increases in isometric strength. Significantly better anaerobic performance was seen in the Wii training group. This study offered proof in favor of the Wii Training and NTT for children with DCD. But when compared to Wii training, the NTT method performed better on tests of motor competence, cardiorespiratory fitness, and functional strength.

In the study by Jelma et al. (2014) demonstrated the efficacy of the Wii Fit intervention as a treatment option for children with (dynamic) balance control issues. The purpose of this research was to compare the performance of children with probable developmental coordination disorder (p-DCD) and balance issues (BP) to typically developing children (TD) on a Wii Fit task and to assess the impact of a Wii Fit intervention on balance skills. Participants in the study included 20 TD children and 28 BP children. The Bruininks Oseretsky Test (BOT2)'s three subtests—Bilateral Coordination, Balance, and Running Speed and Agility—as well as the Wii Fit ski slalom test—were used to measure motor performance. A 6-week non-intervention period was followed by tests on the TD children and half of the BP group of kids. With the exception of the ski game, all BP children received a 6-week Wii Fit intervention, and both before and after tests were conducted. Children with BP performed worse than TD kids at the Wii Fit ski slalom game. Their motor skills were enhanced by Wii Fit training. After the intervention, the improvement was noticeably greater than it had been during the non-intervention period. Because of this, the modification cannot be solely attributed to natural development or the test-retest effect.

Starker et al., 2015 in their study compared changes in motor coordination between a 16-week period of AVG use and a 16-week period of normal activities game (NAG). A secondary goal was to contrast how children and parents perceived their physical performance under the AVG and NAG conditions. The Movement Assessment Battery for Children, Second Edition (MABC-2) and the Developmental Coordination Disorder Questionnaire (DCDQ), both at the 15th percentile, were used to determine the eligibility of the 21 9–12 year olds who were confirmed to be at risk of DCD. The results concluded that despite the fact that children with DCD felt their physical skills had significantly improved, a 16-week home-based AVG intervention did not improve motor skills in them.

Neto et al. (2020) also examined and found encouraging evidence that wii training resulted in gains on motor performance in DCD children aged 7-10 years old. More specifically the purpose of this study was through a RCT to examine the effects of Wii training with the task-specific matched training (TST). The Children were allocated at random to either task-specific training or Wii. Each intervention took place over an eight-week period in 16 sessions of 60 minutes each. The Movement Assessment Battery for Children-2 (MABC-2), administered by blinded assessors, served as the main outcome measure of movement skill. The metrics were manual dexterity, aiming/catching, balance component score, and total standard scores (TSS). After intervention, both groups significantly improved on TSS and balance from the pre- to post-test. Additionally, the manual dexterity of the Wii intervention group improved. In terms of aim and catch, neither group made significant progress. The results of the researchers suggested caution when recommending Wii-based training as a viable alternative to more task-specific matched training for children with developmental coordination disorder. The chosen Wii tasks were able to improve the motor performance in children with developmental coordination disorder, but they should not be used as an exclusive strategy for these children.

Another domain that Wii fit training have been used was to develop the executive functions (EF) and visual perception (VP) in boys with DCD. More specifically Hashemi et al. (2022) in their conducted RCT included 50 boys (M. A= 9,55) that were randomly divided in to two groups, n=25 (Wii fit training) and n=25 (usual program). To measure EF and VP they used CAS, TVPS-R before and after the experimental process (8 weeks, 3 sessions/week for 30 minutes). The results yielded positive effects in both visual perception and executive functions implying that when an intervention is being developed on improving VP and EF in children with DCD Wii Fit training should be seriously considered.

Jelsma et al. (2022) in another RCT, they examined balance and agility in DCD children using active video-games training. More specifically this study compared the effects of the Nintendo Wii-Fit and Xbox Kinect on motor performance and evaluated differences in effects between children with DCD and children whose development is typical (TD). A randomized comparator-controlled design was used in the methodology, and 68 participants (34 DCD and 34 TD) between the ages of 7 and 10 were randomly assigned to train on either the Wii-Fit or the Xbox Kinect. The results of a repeated measure ANOVA showed that time had a significant main effect on variables related to balance and agility (MABC-2, Wii Yoga stance, PERF-FIT side-hop, and PERF-FIT ladder-stepping; all p 0.02), but not on variables related to running (BOT2-sprint, 10 5 m sprint, and PERF-FIT ladder running; $p > 0.05$). No significant interactions were found, indicating similar changes on both devices. Overall, one or more outcomes were improved on by more than the smallest detectable difference for 35% of TD children and 76% of DCD kids. However, at the individual level, the Kinect group showed greater differences in improvement between the TD and DCD groups than the Wii group did.

7. Conclusion

In conclusion, we emphasize the importance of all digital technologies in the field of education and in DCD training. These technologies are highly effective and productive and facilitate and improve assessment, intervention, and educational procedures through mobile devices that bring educational activities anywhere [44-46], various ICTs applications that are the main supporters of education [47-53], and AI, STEM, and ROBOTICS [54-55] that raise educational procedures to new performance levels, and friendly games [56-58]. In addition, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the development of emotional intelligence [59-80], accelerates and improves educational practices and results more than those, particularly in minority children with DCD.

More specifically DCD is a persistent disorder that affects in multiple ways the daily living of many children and people across the globe. New technologies are now more than ever, a vital component of many health professionals/specialists that try to incorporate them in the lives of their patients/clients. The results of the study provided in a narrative way the recent advancements of the use of the aforementioned categories of technologies in the population of DCD. More specifically a lot of studies examined in the 3 main categories, resulted in positive effects through the use of these tech targeting many of the problems associated with DCD such as motor competence, visual motor integration and academic performance. The majority of them yielded positive effects on improving these skills and improving the overall performance of the participants but many of these studies were identified with several limitations that impacts the generalizability of them. Most of the limitations were related to small sample sizes, duration of the intervention phase and study design flaws. To conclude with, due to the promising results of many of the studies investigated, is raised more and more the need to further explore potential benefits of these technology for this population in order for the specialists and health professionals to be able to incorporate them in treatment as a modality and also in the daily living of the people.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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