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Object Control Skills Training for Children With Intellectual Disability: An Implementation Case Study

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Abstract

Children with intellectual disability (ID) tend to have difficulty with mastering fundamental movement skills, associated with cognitive deficits that impair skill acquisition. In this case study, motor learning evidence was transformed into an object control skills training program for children with ID in a school context. An implementation framework was used for program design, pilot, and evaluation. Research evidence on error-reduced motor learning was combined with practitioners' insights to inform the program design. Children with ID in the participant school were allocated to a training or control group for the pilot; object control skills proficiency was the measured outcome. The lead trainer was interviewed and their notes were reviewed for process evaluation. Significant improvements in participants' object control skills proficiency were found following training. The process evaluation confirmed fidelity and identified implementation factors. The systematically designed application was found beneficial for children with ID. Implementation criteria were identified for future iterations of an error-reduced approach to training movement skills of children with ID.

Keywords

object control skills, intellectual disability, error-reduced approach, motor learning, implementation

The ability to move proficiently enables a child to play and interact with others in a range of environments, thereby developing later social adaptation skills and behaviors (Bart et al., 2007; Ommundsen et al., 2010). In contrast, a child with poor motor skills will tend to engage in relatively less social play and demonstrate increased social reticence (Bar-Haim & Bart, 2006). Thus, it appears that the risks associated with poor motor skills during childhood have far-reaching negative consequences on future wellbeing.

Children with intellectual disability (ID) are known to have higher risks of poor wellbeing (Emerson, 2013; van Schroyen et al., 2005), and recent evidence has shown that their social and behavioral problems are associated with poor motor proficiency (Lee & Jeoung, 2016). Children with ID do tend to have impaired or delayed development of movement skills (Goodway et al., 2018; Vuijk et al., 2010). Difficulties in processing complex information and learning new skills appear to negatively affect motor, along with language and psychosocial, proficiencies (Schalock et al., 2021). Motor deficits often manifest as lack of mastery in fundamental movement skills (Eguia et al., 2015; Westendorp et al., 2011). Fundamental movement skills consist of locomotor skills that require overall movement of the body, object control skills that involve applying force to or receiving force from objects, and stability skills that allow rapid adjustment of the body when balance is altered (Donnelly

et al., 2017). According to skill acquisition theories, movement skills are initially learnt through processes that are dependent on verbal knowledge, and skills become automated through extensive practice (Magill & Anderson, 2017). Such learning mechanism is reliant on cognitive resources, which could explain the difficulty that children with ID experience in mastering fundamental movement skills.

Contemporary research, however, had shown that movement skill proficiency can be acquired with less reliance on cognitive resources to support skill performance (Masters, 1992) and relatively lower load on the working memory (Maxwell et al., 2003). It has been argued that children, in particular, are likely to acquire movement skills with little reliance on their cognitive resources (Masters et al., 2013). One validated approach to achieve such acquisition of movement skills is by ensuring that errors during practice are

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minimized—this has been referred to as errorless learning (Maxwell et al., 2001) or error-reduced approach (Capio, Poolton, Sit, Holmstrom et al., 2013). It was proposed that when learners experience success during practice (i.e., reduced errors), hypothesis testing and eventual load on the working memory are diminished.

It has been evident that the error-reduced approach could be effective in improving movement skills of young children, especially those with weak motor abilities (Capio et al., 2017; Maxwell et al., 2017). This approach was initially tested in training overhand throwing among 7- to 9-year-old typically developing children (Capio, Poolton, Sit, Holmstrom et al., 2013). In this approach, movement training began with an easy task such that few practice errors were experienced by the children during the initial stage of learning. Task difficulty was progressively increased as learners' skills improved. Experiences of success during early practice led to improved overhand throwing performance and also allowed the children to engage in a secondary task (i.e., counting backward) without it disrupting the primary throwing task. This suggested that with the error-reduced approach, motor skills improved without reliance on cognitive resources which remained available for engagement in non-motor tasks. For children with ID, the error-reduced approach was subsequently found to improve overhand throwing (Capio, Poolton, Sit, Eguia et al., 2013) and a range of object control skills (Capio et al., 2018). Moreover, children with ID who experienced fewer practice errors tended to perform their learnt movement skill during free play more frequently than those who committed more errors during practice (Capio, Poolton, Sit, Eguia et al., 2013). It was presumed that the children were influenced to continue performing the skill beyond the practice sessions because successful experiences have been associated with enhanced self-efficacy (Bandura, 1997). Based on the growing evidence base, we deemed that the next step to take is toward translating research into a program that would mitigate the limitations imposed by cognitive deficits on fundamental movement skill proficiency of children with ID.

Translating knowledge from research involves processes that enhance the usefulness of evidence, and systematic dissemination and implementation (Dixon-Woods, 2019). In the health service sector, implementations have facilitated the uptake of research knowledge into routine practice (Eccles & Mittman, 2006). Ultimately, when research knowledge was implemented, practice became more effective and outcomes were improved (Wensing & Grol, 2019). A well-established guide for implementations is the Consolidated Framework for Implementation Research (CFIR; Damschroder et al., 2009). The CFIR is a comprehensive framework that has been used widely to guide implementations in mostly health care service contexts. Viewed as a system of concepts, assumptions, expectations, beliefs, and theories, CFIR facilitates the examination of the key factors that influence implementation (Keith et al.,

2017). It was deemed a suitable guide for translating motor learning research into a training program for children with ID because the CFIR constructs are defined clearly and consistently such that they can be applied across a variety of settings (Damschroder et al., 2015).

Aim of Implementation

The premise of implementations is that programs are successful when they are tailored to suit local contexts (Chambers et al., 2013). As a systematic framework, the starting point of an implementation is an evidence-informed intervention (Alberts et al., 2014), which in this study is a program to train object control skills of children with ID that is drawn from evidence on the error-reduced approach.

Fundamental movement skill components are known to form the foundations of more complex skills that children use in different forms of physical activity (Donnelly et al., 2017). Children with ID tend to be less active than their peers, and those who have compromised movement proficiency tend to be less fit (Frey et al., 2008). Moreover, playing and participating in games are restricted by poor movement skill proficiency, which subsequently hinder the formation of lifetime patterns of physical activity (Hills et al., 2007). Of the components of fundamental movement skills, object control skills were found to significantly contribute to physical activity of children with and without ID (Crane et al., 2015; Eguia et al., 2015). This implementation, therefore, focused on object control skills because of their potential positive impact on physical activity participation of children with ID. The project aimed to systematically design, pilot, and evaluate an evidence-informed object control skills training program for children with ID.

Method and Procedures

The study design was guided by the CFIR (Damschroder et al., 2009), with the following domains representing the key influencing factors in an implementation: (a) intervention characteristics, (b) inner setting, (c) outer setting, (d) characteristics of involved individuals, and (e) process. These domains guided the program design and process evaluation (see Table 1 for domain descriptions). Reflecting the implementation process, the methods and procedures are presented here in three sections: (a) program design, (b) program pilot, and (c) process evaluation. All procedures were approved by the ethics review board of the university affiliation of the first author. Participants (or their parents) provided signed informed consent.

Program Design

As a case study, the implementation was situated in a school for children with ID and/or physical disabilities in the capital region of the Philippines. To tailor the program to the local

Table 1. Relevant Domains and Constructs Examined in the Implementation.

Domain	Description
Intervention (program) characteristics	Participants' knowledge of error-reduced motor learning and the degree to which the approach would suit the target participants; includes the characteristics of the intervention that would be advantageous to the participants and could be trialed in the school
Inner setting	The degree of tangible fit between the value accorded to the training program and the practitioners' dispositions; also refers to how the program fits with existing school programming
Outer setting	The extent to which client needs and the relevant external context are known and addressed by the school; also includes community expectations and government regulations
Individual characteristics	Trainers' familiarity and understanding of the underlying principles and evidence; also includes belief in their capability to execute the program
Process	The degree to which the program parameters were carried out according to plan, including quantitative and qualitative feedback about the implementation

Note. Modified based on constructs from the Consolidated Framework for Implementation Research (Damschroder et al., 2009).

context, three focus group discussions (FGDs) were conducted with mixed groups of teachers and therapists. The participants included teaching and rehabilitation staff ($N = 16$) comprising special education teachers ($n = 7$), physical therapists ($n = 3$), occupational therapists ($n = 3$), and speech therapists ($n = 3$). All participants were licensed/qualified practitioners and had at least 2 years' experience working with children with ID.

The FGDs were structured, a priori, to explore the CFIR constructs in the domains of (a) intervention characteristics, (b) inner setting, and (c) outer setting. Intervention characteristics are believed to form the criteria for success of the implementation (Greenhalgh et al., 2004). The inner setting explores the interacting factors in the implementation site and the outer setting accounts for the prevailing external context (Dopson & Fitzgerald, 2005). To determine relevant intervention (program) characteristics, contemporary motor learning evidence and its applications for children with ID were discussed, and the suitability of applying the error-reduced approach for the program design was explored. The relevant contexts outside and inside the school setting as they related to movement proficiencies of children with ID were also discussed. The FGDs were facilitated by the first author. Deductive coding was performed on the participants' responses, and the themes that were relevant to each of the three CFIR domains were identified. These themes were used to inform the program design and are reported in the "Results" section.

Program Implementation

The program implementation involved students with ID ($n = 20$), aged 6 to 10 years ($M = 8.30$, $SD = 0.84$; 12 males, 8 females). Inclusion criteria included the following: (a) enrolled in the study site; (b) diagnosed with ID by a developmental pediatrician; (c) has impaired cognitive, communication, and social behavioral functions based on selected components of the Vineland Adaptive Behavior Scales–Second

Edition (VABS-II; Sparrow et al., 2005) as administered in the study site; and (d) able to follow a minimum of two-step instructions. In the absence of a government policy that mandates IQ tests for children with ID, the school does not require IQ tests for their students. While the children could not be categorized into ID severity based on IQ cut-points, the school confirmed that the student participants were categorized as mild to moderate ID based on their administration of VABS-II. Exclusion criteria included the following: (a) medical conditions that prevented participation in moderate to vigorous physical activity (e.g., cardiovascular conditions) and (b) behavioral problems that limited instructional procedures (e.g., oppositional behavior). The participants were randomly allocated to either training or waiting-control group. There was no significant difference in the mean age of the two groups, and the distribution by sex was matched (i.e., six males and four females per group).

Procedures. The training group participated in an 8-week program (once weekly, 60 min; total dosage of 480 min) that was delivered as an extracurricular activity. In previous research, significant improvements were found after 450 min of object control skills training in children with disability (Capiro et al., 2018). The waiting-control group did not participate in any other extracurricular activity and received the same training only after completion of the pilot period. Sessions were conducted in groups of five children and implemented by two physical therapists, with one having special training in adapted physical activity (i.e., lead trainer). Typically, physical activities for children with disabilities are designed and implemented by physical therapists in the local context. It is noted that there are currently no adapted physical education programs in the Philippines, thus limiting the availability of such specialists in schools for children with disabilities. Prior to commencement of the training sessions, a summary of the evidence and theoretical underpinnings related to error-reduced motor learning (Capiro et al., 2018; Capiro, Poolton, Sit,

Table 2. Parameters to Manipulate Task Difficulty and Minimize Practice Errors.

Skill	Equipment/set-up parameter	Progression
Overhand throwing	Distance from target	Start at 200 cm Progression: increments of 50 cm
	Size of target Size of beanbag	Constant at 125 cm ² Constant at 9 × 5 cm
Underhand rolling	Distance from target	Start at 350 cm Progression: increments of 50 cm
	Width of target (bowling pins) Size of balls (light rubber)	Constant at 200 cm wide Constant at 15 cm diameter
Catching	Distance from trainer/pitcher	Start at 150 m Progression: increments of 50 cm
	Size of balls (beach ball to light rubber)	Start at 25 cm diameter Progression: 20 cm, 15 cm
Kicking	Distance from goal	Start at 300 cm Progression: increments of 50 cm
	Dimension of goal Size of balls (soccer)	Constant at 300 × 300 cm Start at size 5 (21.5 cm diameter) Progression: size 4, size 3
	Number of one-hand dribbles before catching the ball with two hands	Start at 1 dribble: 1 catch Progression: increments of +1 dribble
Dribbling	Size of balls (basketball)	Constant at size 5 (22 cm diameter)
	Size of balls (light rubber)	Start at 15 cm diameter Progression: 10 cm, 7.5 cm
Striking (two-hand)	Distance from the wall	Start at 350 cm Progression: increments of 100 cm
	Size of bats	Constant at 66.0, 68.6, or 71.1 cm depending on the height of the child

Note. Progression is considered after completion of one practice set (i.e., 10 trials). Three practice sets are completed for each skill during each training session.

Eguia et al., 2013; Masters et al., 2013) was provided to the trainers, followed by an orientation to the components of the training program (i.e., see Table 2).

The training program consisted of tasks that targeted practice of six object control skills: overhand throwing, underhand rolling, catching, kicking, dribbling, and two-handed striking. Each training session comprised an opening activity (i.e., 10 min of welcome and warm-up), object control skills practice (i.e., 40 min), and a closing activity (i.e., 10 min of cool down and closing). Task difficulty was manipulated by altering equipment-related constraints (e.g., size, distance) to minimize practice errors especially in the initial sessions (Capio et al., 2018; Capio, Poolton, Sit, Holmstrom et al., 2013). Table 2 summarizes the parameters for task difficulty manipulations for each skill that were determined following the practitioners' insights during program design.

To allow individualization, all participants started at the easiest level, and task difficulty was progressed individually, upon the participant displaying $\geq 70\%$ success (i.e., at least 7/10 successful trials) per bout. No verbal instructions were provided on how to perform each skill; instead, trainers performed demonstrations. To allow adaptability, some participants were provided with manual (e.g., hand-over-hand)

guidance or prompting to initiate movement. No feedback was given on how the children performed during practice, but prompts (e.g., "try again") were given to encourage completion of 10 practice trials per bout and three bouts per skill (i.e., total of 240 practice trials per skill across 8 weeks).

Measures. The outcome variable was object control skills proficiency. Because cognitive deficits may impact motor proficiency and skill learning, verbal and visuospatial short-term memory were considered covariates. All variables were measured 1 week prior to commencement of the program; object control skills proficiency was again measured 1 week after program completion. All tests were administered individually in the same venue as that of the training program, by a research assistant who was trained to administer standardized testing procedures.

Object control skills proficiency was measured using a subtest of the Test of Gross Motor Development, Third Edition (TGMD-3; Ulrich, 2019). TGMD has been shown to have high levels of validity, internal consistency, and reliability (Maeng et al., 2017) and has been widely used for research and practice involving children with ID (Eguia et al., 2015; Simons & Eytayo, 2016). The TGMD-3 object control skills subtest consists of two-hand striking, dribbling,

kicking, two-hand catching, overhand throwing, underhand throwing, and one-hand striking (Ulrich, 2019). It is noted that the training program involved six object control skills, whereas TGMD-3 tests seven skills. Because developmental progressions are typically found between skills within the construct of object control skills proficiency (Donnelly et al., 2017), we expected that TGMD-3 will suitably capture any apparent changes in proficiency following the pilot implementation. Following procedures used for testing children with ID, each skill was demonstrated once by the tester, followed by one practice trial by the participant, and finally by two test trials that were scored (Capio et al., 2016; Eguia et al., 2015). Tests were recorded on video, concurrently from the lateral and anterior views. A physical therapist (>10 years' research and clinical experience with using TGMD), who was not involved in the program implementation and blinded to participants' group allocation, performed post hoc scoring based on the videos. Scores were based on the presence ("1") or absence ("0") of each performance criterion in every trial; the criteria scores from two trials were summed to determine the score for each skill. The highest possible score based on the seven object control skills is 54.

Short-term memory was measured using the forward digit recall test (Alloway & Archibald, 2008) and the forward Corsi block tapping test (Farrell Pagulayan et al., 2006), both of which had been used for children with ID (Capio et al., 2018). For verbal short-term memory, the tester read a sequence of numbers and asked the participant to recite the numbers in identical sequence. The length of the sequence increased by one item until the participant failed to recite the sequence correctly on two consecutive attempts. The longest sequence (i.e., number of digits) that a participant was able to recite correctly represented the verbal short-term memory span. For visuospatial short-term memory, using the Corsi block tapping test, the tester tapped a sequence of cubes while the participant watched; the participant was subsequently asked to tap the same sequence of cubes. The length of the sequence increased by one until the participant failed to reproduce the sequence correctly on two consecutive attempts. The longest sequence (i.e., number blocks) that the participant was able to reproduce represented the visuospatial short-term memory span.

Data analysis. The relationship of pre-training object control skills proficiency with age was tested using Pearson's correlation and with short-term memory spans using Spearman's rank correlation. Shapiro–Wilk test confirmed that object control skills proficiency scores were normally distributed ($p = .927$, pre-training; $p = .550$, post-training). As such, a 2 (group: training, control) \times 2 (time: pre-training, post-training) analysis of covariance was performed to test the effect of training on object control skills; verbal short-term memory score was considered a covariate because it was significantly associated with pre-training object control skills proficiency. Greenhouse–Geisser correction was used

because the sphericity assumption was violated. Significant effects were followed up by paired-samples t tests. Statistical analyses were performed using SPSS 24.0; statistical significance was set at $p < .05$.

Minimal detectable change (MDC) was computed to determine whether the observed changes in skill proficiency were not due to uncontrolled error (Haley & Fragala-Pinkham, 2006). MDC was computed based on the standard error of measurement (SEM) and the confidence interval (95% CI) of the mean changes in scores. Change in object control skills proficiency scores of each participant was compared with the calculated MDC to verify whether the observed changes in object control skills proficiency may be reliably attributed to factors other than random error (Beaton, 2000).

Process Evaluation

Information were gathered from the lead trainer's notes from each training session, which recorded participants' attendance, task progression, and rates of task completion (i.e., successful practice trials per bout). The second and fourth sessions were recorded on video for post hoc examination. The trainer's notes and the video recordings were examined for fidelity, which refers to the extent to which the training program was implemented as intended (Backer, 2002; Pérez et al., 2015). The following specific components of fidelity (Carroll et al., 2007) were checked: (a) adherence to training program, which included the target skills and the principles of the error-reduced approach, and (b) dosage which included attendance, task progression, and number of practice trials and bouts. A post hoc interview was conducted with the lead trainer to describe the implementation process from the practitioner's perspective. The data from the interview were analyzed using deductive coding that was guided by the CFIR constructs in the domains of (a) individual characteristics of trainers and (b) implementation process.

Results

Program Design

Program characteristics. The practitioners reported varied levels of understanding of motor learning concepts and their application to movement skill proficiency of children. The concept of error-reduced approach was relatively novel, along with the evidence that errors during practice could increase cognitive requirements when learning a motor skill. The first theme that relate to the program characteristics was the use of *incremental progression of task difficulty*, which was reported as common practice—although not necessarily focusing on minimizing practice errors. In practice, manipulation of task difficulty is familiar to the practitioners and could be refocused toward reducing practice errors. Two further themes were identified from the practitioners' input:

Table 3. Student Participants' Object Control Skills Proficiency Scores and Short-Term Memory Span.

Variables Measured	Training group (n = 10)		Control group (n = 10)	
	Pre-training, M (SD)	Post-training, M (SD)	Pre-training, M (SD)	Post-training, M (SD)
Object control skills proficiency (TGMD-3)	22.40 (7.48)	43.40 (7.46)	19.00 (7.91)	20.60 (8.91)
Verbal short-term memory span	2.90 (1.19)	—	2.80 (1.14)	—
Visuospatial short-term memory span	3.10 (1.10)	—	3.00 (1.05)	—

Note. TGMD-3 = Test of Gross Motor Development, Third Edition.

The program needs to reflect a high level of *adaptability* and should be *individualized* for children with ID when possible. Across domains of learning, it was noted that students' varied abilities would have to be accommodated to achieve optimal outcomes. As such, the consensus was that the increments of task difficulty in this program needed to have a range of flexibility, and children with ID should progress through task difficulty levels at their own paces.

Inner setting. There was general agreement that children with ID need support in the motor domain, and there was a shared understanding in the school that movement proficiency has implications to the long-term health and development of students. However, the practitioners noted that in their current context, an object control skills training program should be trialed as an extracurricular activity to minimize disruption of scheduled curricular programs. The theme of *holistic child development* was also found in practitioners' comments that revealed an appreciation for the importance of motor skill proficiency, which the school administration supported.

Outer setting. The participating teachers and therapists reported that students' parents are increasingly wishing for their children to be prepared for wider community sports participation. Parents tended to expect the school to offer sport-specific activities (e.g., soccer, bowling). The theme of *bridging community sports participation with school preparation* through movement training was apparent. Practitioners reported not having the competence to deliver specialized sports programs, and they perceived a need to expose their students to movement skill training. Because object control skills are known to be foundation skills required in sports (Donnelly et al., 2017), targeting these skills was deemed to respond to the outer setting demands.

Program Pilot

There were no significant differences between the training and control groups in the participants' age, short-term memory spans, and pre-training object control skills proficiency scores (all p s < .05). Object control skills proficiency was found to have a significant positive association with verbal short-term memory span ($r = .64, p = .002$), but not with

visuospatial short-term memory span ($r = .12, p = .620$). There was also no significant association between proficiency and age ($r = .19, p = .407$). The participants' scores are summarized in Table 3.

A significant main effect of time was found, $F(1, 17) = 11.78, p = .003, \eta_p^2 = .41$, indicating change in object control skills proficiency scores from pre-training to post-training. Significant interaction was found between time and group, $F(1, 17) = 90.11, p < .001, \eta_p^2 = .84$. As illustrated in Figure 1, the difference in pre-training and post-training scores was significant for the training group, $t(9) = -12.63, p < .001$, but not for the control group, $t(9) = -2.23, p = .053$. The interaction between time and verbal short-term memory span was not significant, $F(1, 17) = 0.40, p = .537, \eta_p^2 = .02$.

MDC of object control skills proficiency score was determined to be 8.93. All training group participants displayed improvements that are greater than the MDC, which indicates that the changes in object control skills score from pre to post-training were not due to uncontrolled error. Figure 2 shows the changes in object control skills proficiency scores of each participant.

Process Evaluation

Individual characteristics of trainers. The trainers were experienced in movement training of children with disabilities, but the deliberate focus on minimizing practice errors was a relatively novel component of the program. It was reported that the orientation to the theoretical underpinning of the error-reduced approach prior to the program implementation was important in enabling fidelity. The lead trainer being specialized in adapted physical activity was a factor that contributed to decision-making in terms of individualization (i.e., task difficulty progression) and adaptability (i.e., prompting, demonstrations). It was therefore determined that *professional development*, such as the training and orientation that the trainers received, is a key component for future implementation of the program. The trainers' confidence with implementing an error-reduced approach increased substantially during the first half of the execution, further evidencing the role of professional development. It was noted that after the fourth session, the trainers were generally confident that their implementation was consistent with the program design (i.e., adherence).

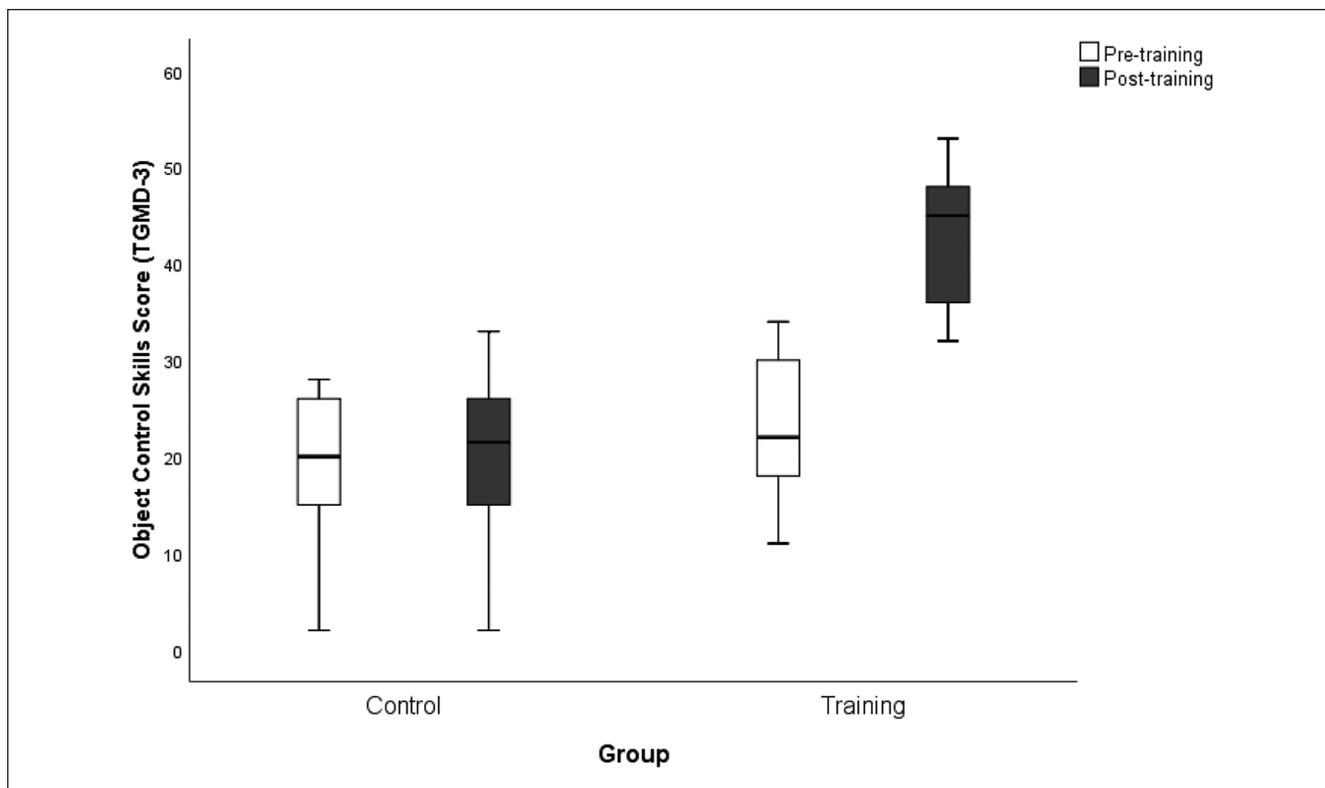


Figure 1. Object control skills proficiency scores of participants before and after the training period.

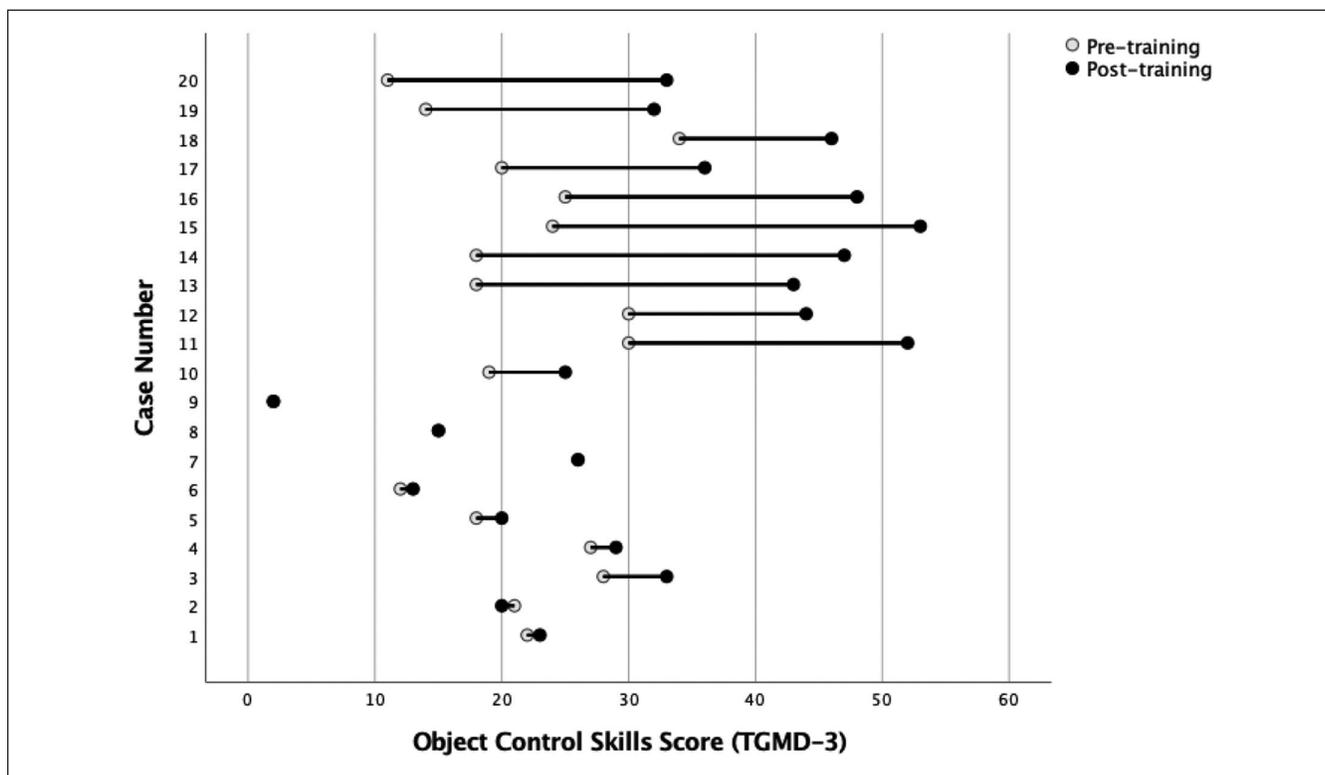


Figure 2. Change in object control skills proficiency scores for each participant. Note. Control group: Case Numbers 1–10. Training group: Case Numbers 11–20.

Process. Eight out of 10 children in the training group completed all training sessions; two out of 10 children missed one session each due to illness. Practice errors were successfully limited to no more than three in every bout of 10 practice trials across all skills. All participants began at the lowest level of task difficulty, but variations in progression were needed immediately after the first bout to accommodate individual differences. Fidelity check at the fourth session confirmed adherence to the following criteria for error-reduced approach: (a) no more than 30% practice errors, (b) no verbal instructions provided on how to perform the skills, and (c) no feedback provided on performance other than those that are visually available during task performance.

A theme was identified in relation to *challenges of individualization*. It was noted that the individualized task difficulty progression entailed changes in the set-up of equipment to accommodate each child, which was essentially time-consuming for the trainers (e.g., balls and targets had to be located at different distances for different children). In terms of planning, the lead teacher noted that the range of planned task manipulations enabled the individualization. While some of the materials (e.g., balls, bats) were varied in size and material to adjust task difficulty levels, it was noted that the range could have been wider, and other parameters could have been considered (e.g., variation in weight). Some of the parameters that were constant could also have been varied (e.g., size of target) to allow further manipulation of task difficulty. Nevertheless, the task difficulty progression plan was deemed a key structure of the program design that helped the trainers achieve an individualized approach.

Discussion

This case study explored the transformation of contemporary motor learning evidence to an object control skills training program for children with ID. Using an implementation framework, the program was designed to fit the local context by directly engaging practitioners. The program pilot showed that exposure to 480 min of error-reduced training was sufficient to cause significant and large improvements in object control skills proficiency of children with ID. The improvements were larger than the MDC, affording confidence that the observed changes were not due to uncontrolled error. We believe that these findings are important because movement skills contribute to child wellbeing (Bart et al., 2007), and object control skills proficiency in children with ID is associated with physical activity participation (Eguia et al., 2015).

The theoretical underpinning of the error-reduced approach suggests that it could circumvent the cognitive limitations of children with ID when acquiring movement skills. The findings of this case study lend support to this, as short-term memory did not influence the improvements in object control skills proficiency following training. It appears that the error-reduced training program could promote motor skill acquisition without being hampered by cognitive

deficits. This relative lack of reliance on cognitive resources has been evidenced in earlier experimental work on error-reduced approach by Capio and colleagues (e.g., Capio et al., 2018; Capio, Poolton, Sit, Holmstrom et al., 2013; Maxwell et al., 2017). This current case study expands the evidence base as findings are now drawn from an implementation context. While further work is needed to establish more robust evidence for the training gains in object control skills proficiency, the apparent benefits appear to be larger than those that might be attributed to random error. Moreover, the training parameters in this case study (see Table 2) could serve as a reference point for further implementation in comparable settings.

There are key learning conditions that characterize the error-reduced approach according to previous researches: (a) minimal practice errors especially in the early stages, (b) absence of verbal instructions and rules, and (c) absence of explicit feedback on movement performance (Capio et al., 2018; Capio, Poolton, Sit, Eguia et al., 2013; Poolton et al., 2005). The fidelity check determined adherence to these learning conditions in this implementation, reaffirming their importance for error-reduced training programs. Based on the process evaluation, a number of additional criteria are suggested for future implementations of error-reduced programs to train movement skills of children with ID.

Criteria for Error-Reduced Movement Skill Training

Individualized task progression is crucial to ensure that errors are minimized during practice, without the task becoming too easy such that the challenge point is no longer effective in facilitating improvements (Guadagnoli & Lee, 2004). Standardized task difficulty progression, typical of error-reduced motor learning studies (Maxwell et al., 2017; Poolton et al., 2005), would not work in a program for schools where children with ID have varied motor abilities. The transformation required from research evidence to practice and the balance needed between standardization and individualization are therefore underscored. The amount of allowable practice errors may be standardized (i.e., $\leq 30\%$ in this study), but progression through task difficulty levels would have to be individualized. We note that individualization was highlighted by the practitioners during program design, and this is a key contributor to the design of task difficulty progression.

A second criterion is the provision of a *variety of equipment and set-up parameters* (e.g., size of balls, weight of rackets, distance from the target, dimensions of the target/goal). This criterion is linked to individualized task progression, as these represent the parameters that practitioners could manipulate to increase task difficulty (Buszard et al., 2016). As noted in the process evaluation, the trainers perceived that a wide range of equipment and parameters would enable the creation of task difficulty levels through which

progression could be better individualized. The parameters described in this case study could be developed further such that they are more variable than constant.

A third criterion, which relates to the program delivery, is the provision of *professional development* for the practitioners. The trainers noted that their preparation prior to the program pilot facilitated understanding of the theoretical underpinning of the error-reduced approach, which subsequently was deemed crucial in implementation. This is expected, as previous research had identified that evidence-informed programs invariably require a professional development component (Veldman et al., 2016).

Translating Motor Learning Research

There has been relatively limited work in systematically transforming and evaluating motor learning evidence into practitioner-led programs. Translational work that had utilized motor learning evidence, thus far, had been in the area of coaching (e.g., Eather et al., 2020; Thomas et al., 2013). There continues to be limited attempts to use motor learning evidence in an implementation framework to support program development for children with ID.

Earlier on, it was proposed that children with movement difficulties could benefit from motor learning strategies that are less reliant on cognitive resources (Steenbergen et al., 2010). Supporting empirical evidence was generated by experimental studies that had involved children with disabilities (Capio, Poolton, Sit, Eguia et al., 2013; van Abswoude et al., 2019). However, translational work and systematic implementation remained largely unexplored. A generally inefficient uptake of research to practice in this area is perhaps reflected in other research that indicated a lack of consensus in therapists' understanding of motor learning approaches (Kleynen et al., 2015). The implementation process described in this case study could serve as a model for future work that would use motor learning evidence to inform practitioner-led programs for children. Future implementation could also consider exploring the potential for transforming motor learning research to programs such as those that the Special Olympics offer. Initiatives by the Special Olympics across the globe are known to promote motor skill development in children with ID (Tint et al., 2017); evidence from motor learning research could contribute toward practitioner-led programs.

Limitations

The findings from the program implementation must be interpreted in the local context for which the program was designed. While it is evident that the training parameters worked for children with ID in this study, future implementations should similarly employ a systematic engagement of practitioners at the design stage. The parameters for task difficulty manipulation that were used in this program could be a model for replication, but modifications are ultimately

necessary to suit other local contexts. Subsequent implementations could also consider engaging parents or caregivers of children with ID who could provide input from a wider perspective of the outside setting. A bigger group of practitioners and trainers could also be involved in any future process evaluation. As only the lead trainer was interviewed in the process evaluation of this implementation, it is possible that the reflections of the second trainer could have provided other relevant insights.

Previous research had suggested that experiences of success during practice of motor skills could be beneficial to children's self-efficacy (Capio, Poolton, Sit, Eguia et al., 2013). However, we did not assess self-efficacy as an outcome nor as a covariate in the program pilot and is a variable that still needs to be explored in future work. It also needs to be acknowledged that the waiting-control group did not participate in other training activities during the pilot period. As such, we are not able to rule out the possibility that the gains of the training group could be attributed, to some extent, to simply participating in an extracurricular activity. Future implementations could consider an active control (instead of a waiting-control) group to verify causal attribution to the training intervention.

Conclusion

This implementation case study demonstrated a systematic approach to transforming motor learning evidence into a training program that facilitated improvements in object control skills proficiency of children with ID. Training parameters that could be further developed and replicated in comparable contexts were designed, and implementation criteria for error-reduced movement skill training programs for children with ID were identified. Future work is recommended toward amplifying the impact of motor learning research through systematic implementations in different contexts.

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