Virtual Reality Games as an Intervention for Children: A Pilot Study

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ABSTRACT

Purpose: *This pilot study explored the use of virtual reality-based games as an enjoyable yet effective intervention to improve skills in children with developmental disabilities. Although the intervention was primarily targeted at the enhancement of motor skills, the children's communication, cognitive and social/emotional skills were also monitored and changes, if any, were tracked during this period.*

Methods: *Therapists guided 5 children (4 boys with Autism Spectrum Disorder and 1 girl with Learning Disability) while they played carefully chosen games on the Xbox-Kinect, in individual sessions. Each child attended between 4 and 6 sessions over a span of one month. Therapists used a 4-point rating scale to evaluate specific skills in each of the four domains (motor, communication, cognitive and social/emotional) at the beginning of the intervention, and again at the end.*

Results: *Pre-and post-intervention scores revealed that the children made significant progress, not only in certain motor skills but also in skills from the cognitive and social/emotional domains. None of the children regressed in any of the skills monitored from the different domains.*

Conclusions: *Initial findings indicate that virtual reality games provide a useful platform for building interventions for children with developmental disabilities. There is much scope for future research in this area. The results of the study provide insights into the skills which might require prolonged, consistent inputs during the intervention, and the ones which might be acquired quickly through leaps in learning. The different ways in which children with varied developmental profiles might benefit from virtual reality-based interventions were also highlighted.*

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INTRODUCTION

A large population of children with Autism and other developmental disorders learn better through visual inputs (Quill, 1995). This preference for visual cues is often utilised to counter challenges they face in sustaining attention, generalising skills and processing multiple sources of sensory input. It is therefore not surprising that many studies are beginning to document the benefits of using technology – such as videos, computer-aided learning programmes, virtual or augmented reality and robotics - to enhance children's attention, motivation, generalisation, communicative functions and play skills (Goldsmith and LeBlanc, 2004; Hetzroni and Tannous, 2004; Herrera et al, 2008; Ferrari et al, 2009; Herrera et al, 2012; Bartoli et al, 2013).

In particular, there has been growing interest in the use of virtual reality (VR) environments, for rehabilitation of people with disabilities (McComas et al, 1998; Lanyi et al, 2006) and, more recently, in interventions for children with Autism Spectrum Disorders (ASD). This technology allows users to manipulate a 3-D virtual environment with real-time, self-determined movements. Strickland et al (1996) were among the first to suggest that autistic children could accept and readily attend to virtual environments. Since then, virtual environments have been explored to train social skills and promote symbolic play in children with ASD (Parsons and Mitchell, 2002; Herrera et al, 2008). More recent research has demonstrated enhancement of attention skills using the Xbox and Kinect, a motion-sensing device for full-body interaction with a virtual environment (Bartoli et al, 2013). The results indicate that children learn through trial and error, and benefit from the visual feedback of their movements through the Xbox-Kinect. Moreover, this supports earlier findings that eliciting gestures from children can bring out implicit knowledge and prepare children for further learning (Broaders et al, 2007).

Other skills which could be targeted using motion-sensing devices and virtual environments are those in the motor domain, including functional movements for daily living activities. Preliminary studies with people suffering from stroke, acquired brain injuries and orthopaedic difficulties have shown that skills learnt through such activities transfer to real world situations (Holden, 2005). Holden (2005) further suggests that augmented feedback available through virtual environments could, in fact, make VR-based motor learning superior to practice in the real world. However, in spite of numerous studies documenting the prevalence of motor difficulties among these populations (Noterdaeme et al, 2002; Ming et al, 2007; Provost et al, 2007; Fournier et al, 2010), there is little literature on the use of this technology to improve motor skills in children with ASD and other developmental disabilities.

Objectives

This paper investigates the use of VR environments as 'fun' and effective interventions to enhance motor skills. It predicts gains in motor skills for children with developmental disabilities. In addition, it investigates the effects of the intervention on gaps in children's skills across other domains - communication, cognitive and social/emotional. Studying the global effects of an intervention is, firstly, important to gauge the holistic benefits to a child's development. Secondly, insight is gained into the underlying skills that need to be targeted before attending to skills of a higher level.

Ethical standards

The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed parental consent was obtained from all participants. All the children's names in this study are pseudonyms.

METHOD

Participants

All 5 children chosen for this pilot study were attending sessions at an early intervention centre in Bangalore, India. Selection was based on factors such as diagnosis, age and parental consent for their child's participation.

Inclusion criteria:

- Children below 8 years of age.
- Children with developmental delays, with preference given to those with gaps in skills or delays relating to motor coordination and execution, and pre-requisite learning skills.

The study participants were 4 boys (pseudonyms AT, SAM, AR, SAG) who had been clinically diagnosed with ASD, and a girl (pseudonym SH) with Learning Disability (LD). The children were between 4 and 8 years of age, and were first-time users of the Xbox–Kinect, though all of them had some exposure to gadgets such as mobile phones, laptops, desktop computers and tablets. All the children were enrolled in junior classes within regular schools with or without additional support. The profile of each child (motor skills, pre-requisite learning skills, communication skills, pre-academic [cognitive] skills, social and emotional skills) is briefly described below:

- Child 'AT' (4 years) had gaps in motor skills, with difficulty in balance and coordination, and limited pre-requisite learning skills. He was predominantly non-verbal, and had large gaps in his communication, pre-academic (cognitive), social and emotional skills. Sensory processing and modulation issues were also present.
- Child 'SAG' (5 years, 2 months) shared a similar profile, and had large sensory processing and modulation issues that hindered a lot of the pre-requisite learning skills. Additionally, he was short-sighted and wore spectacles.
- Child 'AR' (5 years, 9 months) had fairly good motor skills, but his inattention and varied compliance (pre-requisite learning skills) hindered participation in adult-directed motor tasks without prompts. The child was verbal, but had social communication gaps and a few gaps in language concepts.
- Child 'SAM' (5 years, 7 months) exhibited fair motor skills, with difficulties in balance and coordination. He also had poor sensory awareness of body (proprioceptive/ kinesthetic sense) but fair to good eye-hand coordination. Hypotonia was evident. The child was verbal but with poor social communication skills. Despite good pre-academic (cognitive), play and emotional skills, limited confidence and the presence of abnormal fears hindered his learning.
- Child 'SH' (7 years, 5 months) was the only girl in the study. She had issues with body coordination, awareness of self-image, visual motor and perceptual skills, which additionally impacted her pre-academic / academic readiness skills. Her pre-requisite learning skills and listening skills were not adequate for academic-based tasks. She was a verbal child but with communication delays in specific social communication contexts. Despite having good emotional skills, she had issues with perspective taking and motor processing.

Materials

Xbox360 and Kinect: The Xbox360, developed by Microsoft, consists of a console with a 240 GB hard drive and a controller. A user selects and inserts a video game in the CD/DVD drive of the console. The console connects to the TV and a power supply. The controller is used to navigate and select options in the gaming environment.

The Kinect is a motion-sensing device created by Microsoft for use with the Xbox 360. It appears as a moveable horizontal bar that is perched on a base. The sensor and camera capture a user's movements. Hence, it enables users to interact with the gaming environment through gestures, without using the controller.

TV: The Kinect was connected to a 40-inch flat screen TV. This size enabled comfortable viewing when playing different games.

Kinect games: Games from two DVDs were used in this study: (a) Carnival Games - Monkey see Monkey do (Carnival Games, 2011-2K Play, USA); and (b) Kinect Adventures (Kinect Adventures, 2010 - Microsoft Game Studios, Redmond, USA).

The games played from Carnival Games (Monkey see Monkey do) included Wheel of fortune, Strength test, Court king, Granny fling, Alley ball, Ring fling, Knockout punch, Pig race, Funnel game, Crash test dummies and Monkey see Monkey do. From Kinect Adventures, children played the games Space pop and River rush. Details about these games and a description of the movements they involved are given in Table 1.

Table 1: Description of Games used in the Study

Sl. No.	Name of game	Level of game	Player (self / avatar)	Speed /pace of game	Description of actions used in the game
1.	Wheel of fortune	Easy	Self	Slow	1. Movement of both arms together. 2. Action: Swing arm (to swing the large wheel). 3. The game does not require imitation. 4. This is a single player game.

2.	Strength test	Easy	Avatar	Slow to medium	1. Movement of both arms together. 2. Action: Swing arms (as if holding a hammer). 3. The game does not require imitation. 4. This is a single player game.
3.	Court king	Medium	Self	Slow	1. Movement of both arms. 2. Action: Sequenced actions required – (a) Grab the ball by stretching arms out (b) Swinging arms backwards, simultaneously (c) Throwing the ball overhead into a basket with both hands, simultaneously. 3. The game does not require imitation. 4. This is a single player game.
4.	Granny fling	Medium	Self	Slow	1. Movement of body and arms. 2. Action: Sequence of two actions is required-(a) Bending of knee (b) Moving both arms- lifting action (swinging them in front of the body) while standing up to throw the ball. 3. The game does not require imitation. 4. This is a single player game.
5.	Alley ball	Medium	Self	Slow	1. Movement of a single hand and arm. 2. Action: Sequenced actions required - (a) Catching ball by stretching out the hand (b) Throwing it overhead or sideways. 3. The game does not require imitation. 4. This is a single player game.

6.	Ring fling	Medium to hard	Self	Slow	1. One hand swinging. 2. Action: Sequenced actions required - (a) Grab / catch a ring by stretching out one hand. (b) Aim and swing it (to throw). 3. The game does not require imitation. 4. This is a single player game.
7.	Knockout punch	Medium	Self	Medium	1. Both arms and body movements. 2. Action: Swinging punches (right or left) and ducking on cue. 3. The game does not require imitation (unless the therapist models the actions to prompt the child). 4. This is a single player game.
8.	Pig race	Medium	Avatar	Medium	1. Whole body movement. 2. Action: Two combined actions are required– (a) Moving the whole body right and left to move the pig as it runs along a path with obstacles. (b) Movement of both arms to flap hands around the pelvis region or slapping hands on sides of thighs to make the pig go faster on the track. 3. The game does not require imitation. 4. This is a single player game.
9.	Funnel game	Medium	Self	Medium	1. Whole body coordination. 2. Actions: Combined actions required - (a) Holding hand upright as in holding a tray (b) Moving body right or left to catch pancakes falling from the top. 3. The game does not require imitation. 4. This is a single player game.

10.	Crash test	Difficult	Self	Fast	1. Whole body coordination. 2. Action: By adjusting the whole body, the child has to imitate the figure on the screen. It can include one leg balancing, standing akimbo etc. 3. The game requires imitation. 4. This is a single player game.
11.	Monkey see monkey do	Difficult	Avatar (imitation)	Fast	1. Whole body coordination. 2. Actions: The child has to imitate the different body movements and actions of a monkey avatar. The movement continuously changes with the music. 3. The game requires imitation skills. 4. This is a single player game.
12.	Space pop	Medium	Avatar	Medium	1. Whole body movement. 2. Actions: Combined actions required - (a) Swinging of both arms (flapping them) (b) Moving the whole body to the right and left to move the avatar and catch bubbles. 3. The game does not require imitation. 4. This can also be a two player game; hence the therapist may provide imitation as a means to prompt the child.
13.	River rush	Difficult	Avatar	Fast	1. Whole body movement. 2. Action: Sequenced or combined actions required-(a) Jumping (b) Moving whole body to right or left (c) Ducking- all actions are to move the avatar and avoid obstacles along a river path. 3. The game does not require imitation. 4. This can also be a two player game; hence the therapist may provide imitation as a means to prompt the child.

Space considerations: The room which was used had sufficient space for a child and an adult to move around freely and use the multi-player mode simultaneously. The lighting was adequate and there was place for the child to sit and rest, if needed.

Procedure

Kinect game sessions: The child was accompanied by a caregiver, typically the mother, for each session. A therapist (developmental therapist or speech language therapist) modelled the actions and helped the child learn the games. The caregiver's presence was tapered off over one or two sessions, depending on the child's comfort-level with the therapist, environment and the game, or whenever the therapist deemed the child to be ready.

Each child attended between 4 and 6 sessions over a span of one month. Each session lasted around 20 – 30 minutes. The therapist recorded a few of the sessions (with parental consent) for review and documentation.

The sessions were conducted as follows:

1. During the first session, therapists chose the games. Each child was started on an easy game or the beginner's level of a game. Subsequent games and difficulty levels were chosen on the basis of the child's interests and capabilities. By the second session, children were given the opportunity to make choices (verbally or non-verbally) of the game they wished to play from the therapist's selection of games.

2. Each game was played for around 5 minutes with repeated trials. Under the therapist's guidance, children could play at least 3 games during a session, and each game was repeated at least twice.

3. Short breaks were scheduled between games to allow the child to rest, and for the therapist to change from one game or DVD to another. The breaks were reduced with each session. Children were encouraged to indicate when they needed a break.

Skills: Skills from different domains were assessed in the course of the children's sessions with the Kinect. A description of the skills evaluated through the games is given in Table 2.

Table 2: Skills monitored during the Intervention

Sl. No.	Skill and its Domain	Description of the Skill
Motor related		
1.	Eye-hand coordination	Ability to control hand movements through visual feedback from coordinated eye movements. E.g., in selecting a game, grabbing a ball, throwing at a target, popping a bubble.
2.	Body coordination (in general)	Level of control over one's body when using it to achieve a target motor movement.
3.	Imitation	Skill of copying a motor movement modelled by the therapist/avatar in the game.
4.	Body balance	Maintaining an upright posture against gravity with different body positions.
5.	Swiftness in motor movements	Ability to perform actions fast or keep up with an increasing pace of game.
6.	Precision	Test of how well a movement is used to attain a goal. E.g., throwing a ball in a basket, dart on a board, popping a bubble, reaching for a coin.
7.	Sequencing motor actions as per the game.	Planning and executing 2 or 3 motor actions to attain a goal. E.g., to shoot a hoop- grab ball, lift arms, throw. Also imitating movements in a sequence as in 'monkey see' or 'knock-out punch'.
8.	Independence in motor skills	Whether dependent on physical prompts to guide movements in the game.
Communication related		
9.	Following instructions of game	Simple 1-2 step instructions given by the therapist / parent during the game. E.g., hand up, roll the ball, go left and pop bubble.
10.	Concepts	These relate to concepts learnt via the game and with therapists' inputs while playing the Kinect. E.g., right / left, fast / slow, action verbs.
11.	Choice making	Expressing preferences such as choosing between games, whether to play again or whether to stop playing a game.
12.	Relating one idea to another (understanding if, when, why)	Following instructions related to 'if, when, why' concepts learnt via the game with therapist's inputs. E.g., if you hit the hammer hard, you get more points. The pig moves when you move from side to side.

13.	Initiation of interactions (Requesting game/help, directing) –Verbally or non-verbally	To spontaneously request for a game, request for help or share joy and disappointment with the therapist/adult.
14.	Reporting –Verbally or non-verbally	Attempting to tell other adults about where s/he was or which games s/he played a short time after the session with the Kinect.
Cognitive related		
15.	Rate of learning the game	How quickly children are able to pick up aspects of the game- such as how to play, the goal, obstacles to avoid, correcting movements – through experience.
16.	Sustained attention	Attending to the game for a longer duration of time.
17.	Shift in attention	Being able to shift attention from one activity to another, as the game or the therapist requires.
18.	Selective attention	Selectively attending to the inputs of the game or the therapist, blocking out other distracters.
19.	Observational learning	Learning without being taught. Modifying behaviour/gaining a skill from watching the adult or watching the effect of an action on the game.
20.	Cause effect in game	Realising how action modifies output of the game. E.g., jump to make the avatar jump, move hand left to catch the pancakes falling on the left.
21.	Rules of the game	Understanding how to play and the goal. Rules of the games varied with complexity.
Social / Emotional related		
22.	Connect with therapist	Building a rapport/bond with the therapist through time spent playing the Xbox.
23.	Emotional connect with the game	Involvement in the game; judged by attention, effort made to play and a reaction to the game (happiness, disappointment, frustration).
24.	Using the Kinect as a tool for leisure	Does the child enjoy the experience? Would s/he choose/ talk of playing when bored as an option to keep self entertained?
25.	Sense of winning/ competitiveness	Attempts to achieve goal and feels happy/ disappointed accordingly. E.g., trying to throw a ball through the hoop. May watch for points scored or rank secured (1st, 2nd,etc).

Scoring: The therapist who conducted the sessions rated the child's skills on a 4-point scale. The scale used is described in Table 3. Skills for each of the 5 children were scored twice, once after their first sessions with the Kinect, and againat the end of the last session.

Table 3: Rating Scale

0	1	2	3
Poor (Less than 25 %)	Fair (between 25 – 50 %)	Moderate (between 50 – 75%)	Good (More than 75%)
Absence of skill or requires complete prompts.	Skill is emerging with intermittent prompts (verbal /non-verbal).	Skill is inconsistent. May need intermittent prompts (verbal /non-verbal).	Consistent skill. Requires minimal verbal or no prompts.

RESULTS

Pre-and post-intervention test scores in each of the domains – motor, communication, cognition and social/emotional – were analysed. The sign test was found most appropriate for analysis, considering the sample size and also that the data did not meet an assumption of the Wilcoxon signed rank test (symmetric distribution of paired differences).

Findings revealed a statistically significant median increase in the post-test scores for:

a) body coordination, precision in movements and independence in motor skills - from the motor domain;

b) rate of learning a game, for instance, understanding the goal and adapting movements to achieve them - from the cognitive domain; and, c) connecting with the therapist - from the social/emotional domain at p = .031 (Exactsig.1-tailed).

Although the children showed progress in the communication skills tested, the number of post-test scores which increased in comparison to pre-test scores were not found to be statistically significant. Moreover, it is noteworthy that in all the skills analysed, none of the children obtained a negative difference post- to pre-intervention. Thus, no regression in skills was observed throughout the course of the intervention.

Detailed Findings from each Domain

Motor: The results obtained from the sign test (Table 4) highlight a marked improvement in Skills 2, 6 and 8 (body coordination, precision and independence in movements) by all 5 children. Though the children appear to have made progress on the other skills as well, two things stand out. Firstly, all the children retain exactly the same scores on pre- and post-tests for Skill 3 (imitation). Secondly, while the progress made by each child on the different skills varies, certain skills record considerably lower improvement in scores. These may either be more challenging for the children or may require a longer duration to learn and stabilise. For instance, 3 out of the 5 children were rated ‘1’ on Skill 4 (body balance) post-intervention, which is relatively low compared to post-test scores of other skills.

Table 4: Children’s Scores on the eight skills tested in the Motor Domain, pre- and post-intervention

Skill / Child	1. Eye-hand coordination		2. Body coordination		3. Imitation		4. Body balance		5. Swiftness in motor movements		6. Precision		7. Sequencing motor actions		8. Independence in motor skills	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SH	2	3	2	3	3	3	2	3	2	3	2	3	3	3	2	3
SAG	0	1	0	1	1	1	1	1	1	2	1	2	1	2	1	2
AR	1	2	1	2	2	2	2	2	1	2	1	2	1	2	2	3
SAM	1	2	2	3	3	3	0	1	0	1	1	2	1	3	2	3
AT	1	1	0	1	1	1	0	1	0	0	0	1	1	2	1	2

Communication: It is evident from Table 5 that children made progress on these skills, although changes were statistically non-significant. On Skill 6 (reporting), there is considerably wider variation in the pre-to post-test changes compared to other skills. While 2 children continued to fare poorly (scored 0) in this skill, 2 others made marked progress from a score of 1 to 3. Overall there is a positive trend in the data, with the exception of one child, SAG, who improved only on Skill 1 (following instructions) but showed no change with respect to the other skills.

Table 5: Children's Scores on the six skills tested in the Communication Domain, pre- and post- intervention

Skill / Child	1. Following instructions of game		2. Concepts		3. Choice making		4. Relating one idea to another -understanding if, when, why		5. Initiation of interactions - Verbally or non- verbally		6. Reporting –Verbally or non-verbally	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SH	2	3	2	3	2	3	3	3	3	3	2	3
SAG	1	2	1	1	1	1	1	1	1	1	0	0
AR	2	2	1	2	2	3	1	2	1	3	1	3
SAM	2	3	2	3	3	3	2	2	2	3	1	3
AT	1	3	1	2	3	3	1	2	1	3	0	0

Cognitive: There were a statistically significant number of positive changes in the children's scores from pre- to post-test on Skill 1, rate of learning a new game. Furthermore, there were two interesting observations about the children's cognitive profiles. Firstly, they all started out with relatively low pre-test scores (Table 6), unlike the previous domains where they were at different levels. Secondly, they made marked progress to scores of 2 and 3 on the post-test, with the exception of SAG who improved only on Skill 1 (rate of learning the game). This may be indicative of skills which are acquired by a leap in learning.

Table 6: Children's Scores on the seven skills tested in the Cognitive Domain, pre- and post-intervention

Skill / Child	**1. Rate of learning the game**		**2. Sustained attention**		**3. Shift in attention**		**4. Selective attention**		**5. Observational learning**		**6. Cause effect in game**		**7. Rules of the game**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
SH	1	3	1	3	2	3	1	3	1	3	1	3	2	3
SAG	0	1	1	1	1	1	1	1	1	1	1	1	1	1
AR	0	3	1	2	1	1	1	2	1	3	1	3	1	2
SAM	1	2	1	3	2	3	1	2	2	3	1	2	1	3
AT	2	3	2	3	2	2	2	2	1	1	1	2	1	3

Social / Emotional: As in the case of the cognitive skills discussed above, most children made marked progress on the social skills (Table 7). Analysis revealed that the intervention significantly encouraged a better rapport with the therapist (Skill 1). Moreover, positive changes were seen in Skill 2 and Skill 3 (connect with the game, using the Kinect as a tool for leisure) with scores increasing from 0 and 1 to 3 in the post-test. In this context, Skill 4 (building a sense of competitiveness) appears to be relatively more challenging for the children, as indicated by the low scores which did not change during the intervention. Contrary to the profiles of the other children, SAG improved only on Skill 1 (connect with therapist) and showed no improvement on the other skills.

Table 7: Children's Scores on the four skills tested in the Social/Emotional Domain, pre-and post-intervention

Skill / Child	1. Connect with therapist		2. Emotional connect with the game		3. Using the Kinect as a tool for leisure		4. Sense of winning/ competitiveness	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SH	1	3	1	3	1	3	1	3
SAG	1	2	1	1	0	0	0	0
AR	2	3	1	3	0	1	1	1
SAM	2	3	1	3	1	3	3	3
AT	1	3	1	3	2	3	1	1

Overall, children made significant gains in certain skills from the motor, cognitive and social/emotional domains, and showed progress (though this did not achieve statistical significance) in communication skills. There were variations in the children's profiles and the progress they made through the intervention. For instance, while SH was better than the other children in motor and communication skills, SAM did comparatively better in social skills. Of the 5 participants, SAG made the slowest progress; slight improvement was seen in a few skills in the motor domain but hardly any change in the other domains.

DISCUSSION

This pilot study hypothesised a gain in children's motor skills through the proposed intervention with the Xbox–Kinect games. Furthermore, it sought to investigate the effects of this intervention on children's communication, cognitive and social/emotional skills.

The results obtained are in partial agreement with the hypothesis. Certain motor skills, in particular those related to body coordination, precision and independence in movements, recorded a significantly higher number of gains by the participants. A higher number of post-test improvements were also recorded for the rate of learning the game and for connect with the therapist, from the cognitive and social/emotional domains respectively. Thus, preliminary findings of this pilot study strongly suggest that intervention through the Kinect is an effective means to enhance children's developmental skills. Moreover, they confirm the viability of further research in this novel intervention technique.

To better understand the nature of the changes observed, some of the findings from the previous section will be considered in more detail.

Firstly, while none of the children regressed on any of the skills, they made comparatively less progress on skills such as maintaining body balance and acquiring a sense of competitiveness. Certain skills require consistent, prolonged inputs over a period of time compared to others. The comparatively fewer number of sessions conducted in this study may not have been sufficient to observe changes in higher-level skills.

Secondly, the children's scores remained constant on certain skills, for instance imitation, with no change between pre- and post-tests. Consistency in a learned skill is a positive sign and, in some cases, could even be indicative of implicit progress towards the next level. However, such patterns are also useful indicators to therapists of the skills for which a child may require additional adult support through modelling and scaffolding activities to facilitate progress. The therapist may need to reflect on skills pre-requisite to the one targeted, in the same or different domains, which the child may not yet have mastered. In some cases, the assessment procedure may need to be checked for sensitivity to smaller changes in performance.

Thirdly, the children sometimes displayed a varied level of mastery of certain skills with, in addition, each child maintaining a constant score from pre- to post-test. For example, in the skill of reporting experiences to others, the children were at very different levels, yet not making visible progress. In such situations, it could be beneficial to encourage socialisation and build skills through peer-modelling involving typically growing children in the intervention, whenever possible.

A fourth pattern observed in children's scores was a leap in learning, where all the children performed rather poorly on a skill in the pre-test but had almost mastered it by the post-test, as for instance, in sustaining attention and understanding rules of games. It could represent the children's state of readiness for that skill, or possibly, a lack of consistency or previous exposure.

Lastly, it must be remembered that the 5 children in the study sample had different profiles and made progress in a different manner through the intervention. Four of them had diagnoses of ASD and one of LD. In addition, they were not from the same age group. Even if they shared a single diagnosis and were of the same age, developmental disabilities present in a heterogeneous manner. Hence, this study which is an exploration of a novel intervention, benefitted from selecting children with different developmental profiles. This helps to understand in which sub-groups the intervention is most beneficial or where adaptations may be required for other sub-groups. It was pointed out earlier that compared to the other children, SAG made the least progress during the intervention. SAG presented with several associated challenges, including severe sensory issues, myopia and an inadequate attention span (despite good cognitive and receptive skills). These factors may have interfered with different aspects of relating and attending to the games and thus, learning from the sessions. However, it is important to recognise that while he did not progress as quickly as the others, there were minor improvements in certain skills in the short span of four sessions. The fact that his skills did not worsen is also relevant. It indicates subtler learning and further, motivation to use the skills he possessed and developed during the intervention. However his disengagement in the sessions, compared to the other children, is a reminder of the fact that no activity, however fun and engaging, will appeal to all children in the same way. It is often up to the therapist to be attuned to the needs and preferences of the child, and to modify activities appropriately to make them enjoyable as well as beneficial.

Limitations

Certain constraints on the study limit the claims that could be made from the data. Firstly, the small study sample, although necessary for a detailed analysis of each participant in a pilot study, means that the findings cannot be confidently generalised to a larger population. Ideally, for future work, a larger, heterogeneous, randomly selected sample would be better suited to support external validity. Secondly, the intervention was conducted over a very short duration of time. This needs to be followed up with longitudinal studies which employ control groups or match-paired designs in order to identify casual relationships. Lastly, it would be advantageous to adopt standardised assessments of developmental skills in extensions of this study, to enable replication of the study on a wider scale.

CONCLUSION

The results of this study highlight the potential benefits of using technology such as the Kinect to develop 'fun' yet effective interventions for children with developmental disabilities. Such sessions would keep children motivated while facilitating holistic development of skills. Preliminary evidence of success in enhancing children's developmental skills through the Kinect, within such a short span of time, is strongly suggestive of the need to extend this field of research further. With greater insight into its strengths and limitations, interventions can be suitably adapted for clinical practice and integrated with other training programmes to maximise enhancement of children's skills.

There is much scope for further research in this area, to confirm preliminary findings and extend understanding of the effects of interventions with the Kinect for children with autism and other developmental disabilities. It is important to investigate how such an intervention might be effectively integrated with others, and the extent to which skills learnt are maintained and generalised. Other means of using the Kinect for customised learning, apart from available gaming environments, also need to be explored.

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