Upper-Limb Rehabilitation With Adaptive Video Games for Preschool Children With Developmental Disabilities

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MeSH TERMS
- developmental disabilities
- motor activity
- motor skills
- psychomotor performance
- video games

OBJECTIVE. This study used a novel device to make video games accessible to children with developmental disabilities (DD) by modifying the training software and interfaces to enhance motor training.

METHOD. In the pretest–posttest design, 20 children (13 boys, 7 girls; mean age = 5.2 yr) with DD received adaptive upper-limb motor rehabilitation consisting of fifteen 30-min individual sessions 3 times per week for 5 wk.


CONCLUSION. The rehabilitation device modified for the needs of children with DD is effective in improving visual–motor performance of children with DD.


Children with developmental disabilities (DD) often have motor problems that impede their action control when playing games (Sveistrup, 2004). They generally must repeat the same movements many times to improve the motor control of their upper limbs, especially shoulder stability and mobility (Laufer & Weiss, 2011). Motor learning theory has asserted that repetition of motor patterns is a key factor in improving motor skills, and some researchers have found that adaptation of toys or training modalities in motor rehabilitation is related to improvements in motor performance (Hsieh, 2008; Regenbrecht et al., 2012).

Playing video games is an age-appropriate occupation for children, and interactive games, such as Nintendo® Wii™ Sports and Nintendo Wii Fit™ (Nintendo Co., Ltd., Kyoto, Japan), may offer a fun and effective way to provide repetitive practice for children with DD (Galvin, McDonald, Catroppa, & Anderson, 2011; Salem, Gropack, Coffin, & Godwin, 2012). However, standard interfaces may be difficult for young children with motor problems to use. We tested a rehabilitation device designed to meet the needs of children with DD for motor training in upper-limb control and eye–hand coordination. The primary research question of this study was, Is motor function and visual–motor integration of children with DD enhanced after rehabilitation with a modified video game?

Method

Procedure

The study used a pretest–posttest design. Children with DD participated in fifteen 30-min individual sessions 3 times per week and did not receive other
therapeutic intervention during the 5-wk intervention period. The experimental procedures were approved by the local institutional review board for human research.

**Participants**

In total, 20 children with DD (13 boys, 7 girls) were recruited from six elementary schools and three preschools in Taiwan. The age range of participants was 4.2–5.8 yr (mean $\mu = 5.2$ yr, standard deviation $\sigma = 3.6$ mo). The inclusion criterion was a Beery–Buktenica Developmental Test of Visual Motor Integration (VMI) score <80 (Beery & Buktenica, 1997). VMI scores of 85–115 are considered to be within normal limits. The participants' visual–motor skills were outside the normal range ($M$ VMI score = 72), which was the inclusive standard for recruiting participants. Both parents signed informed consent forms and acknowledged that they understood that their child would be assessed for research purposes.

**Assessment Tool**

A research assistant trained by an occupational therapist conducted pretesting after participant recruitment and posttesting after participants finished the intervention. Two assessments were used, the VMI and the Peabody Developmental Motor Scales, Second Edition (PDMS–2; Folio & Fewell, 2000).

The rationale for using the VMI was that it could measure eye–hand coordination directly. The VMI evaluates various visual–motor integration skills in preschool children through adults. Participants are presented with drawings of 24 geometric shapes, arranged in a developmental sequence from simple to complex. Participants simply copy these shapes into their test booklet. The standard scores used in this study were equal units of measurement with a mean of 100 and a standard deviation of 15. The VMI’s interrater reliability is .94, and its test–retest reliability is .87 (Beery & Buktenica, 1997). The occupational therapist also reviewed the videotapes and test booklets to score 7 children to assess interrater reliability.

The PDMS–2 is a standardized test for evaluating the motor skills of children from birth to age 71 mo. A previous study showed that the PDMS–2 has excellent test–retest and interrater reliability ($r_s = .84–.99$; Folio & Fewell, 2000), convergent validity, and discriminant validity (van Hartingsveldt, Cup, & Oostendorp 2005). The Total Motor Quotient, Gross Motor Quotient, and Fine Motor Quotient are derived by adding the subtest standard scores and converting the sum to a quotient (with a standard score having a mean of 100 and a standard deviation of 15).

**Training Instrumentation**

The training device consisted of an optical sensor platform, joystick with adjustable loading, notebook computer, and game software (Figure 1). Each participant sat comfortably in a chair with his or her arms stretched forward. The training instrument included a modified interface and an adaptive video game. The modified interface consisted of an optical sensor platform. The user interacted with the video game by operating the joystick on the platform (Figure 1). Compared with a standard joystick, the training device’s joystick increased the amplitude of upper-limb movement without causing compensatory movements. When a player moved the joystick on the platform, the light signal was interrupted, and the joystick’s position was read and transmitted to the computer.

The adaptive Scratch games were designed to increase functional movement of the upper extremities by increasing range of motion and endurance in upper-limb movements. For example, players can extend their elbow and abduct the shoulder to catch the fish in the aquarium games. The Scratch games for this study were designed to increase functional movement of the upper extremities; the Scratch website (http://scratch.mit.edu) offers free downloads of Scratch software. The programs trained participants in horizontal, vertical, and multiaxial upper-limb movements. As shown in Figure 2, horizontal movement comprised adduction or abduction of the arm to touch the target; vertical movement comprised flexion of the arm or extension of the elbow to touch the target; and multiaxial movement comprised arm movements to touch the target in all possible directions, combining both horizontal and vertical movements.

**Data Analysis**

To investigate the pretest–posttest relationship, we used SPSS Version 18.0 (SPSS Inc., Chicago) to conduct a repeated-measures multivariate analysis of variance (MANOVA). In MANOVAs, Wilks’ $\Lambda$ was applied as the multivariate statistic. Partial $\eta^2$ values were used as the effect size of a significant finding.

**Results**

Interscorer reliability using mean point-by-point reliability from a random sample of 7 children was as follows: VMI scores, 97% (range = 95–100); PDMS–2 scores, 98% (range = 96–100). The repeated-measures MANOVA examined the differences between participants’ pretest and posttest VMI and PDMS–2 scores (Table 1). Participants’
posttest scores improved significantly, $R(4, 16) = 7.66$, $p = .001, \Lambda = .719$. Simple main effects results (Table 1) indicated that video gaming rehabilitation had a positive effect on participants’ visual–motor coordination and motor skills development, $R(1, 19) = 15.31, p = .001$, for the VMI, and $R(1, 19) = 7.62, p = .012$, for the Total Motor Quotient of the PDMS–2.

### Discussion

This study investigated video gaming rehabilitation for children with motor disabilities using adaptive video games and a modified joystick. The target movement of the adaptive games is functional and easy; reaction time is longer and response time is slower than in commercial video games. In contrast to commercial video games, the player can repeatedly move his or her arms forward and backward to play the games. Moreover, the participants with DD could also work at their own ability level and pace. The analytical results show that video gaming rehabilitation for children with DD may increase their visual–motor coordination and further improve their motor skill development. One potential explanation is that children with DD could easily exert effort in functional actions with the newly adapted video games. This adaptation improved their upper-limb motor control,

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**Figure 1.** Participant manipulating the device and schematic diagram of the device.

**Figure 2.** Examples of Scratch games. (A) UE moves horizontally to touch the target by shoulder adduction and abduction. (B) UE moves vertically to touch the target by elbow flexion and extension. (C) UE moves in multiaxial direction to touch the target by combining shoulder adduction–abduction and elbow flexion–extension.

*Note: UE = upper extremity.*
influencing their experiences and performance in motor manipulation, which is in accordance with the results of previous studies (Lange et al., 2012; Thin, 2012).

We adapted video games and desktop interfaces to clients’ physical characteristics by controlling sensory features and simplifying manipulated processes in accordance with previous studies (Chuang et al., 2002; Grabowski & Mason, 2014). The adaptive video game created a playful environment in which children with DD could actively pursue achievable challenges and improve their motor abilities. This result agrees with findings in the literature (Linehan, Kirman, & Roce, 2010; Schaaf & Miller, 2005).

Grading activity levels is important to the motor performance of children with DD (Bryanton et al., 2006). Using Scratch software, reaction time can be adjusted to enhance motor performance. The results are in accordance with those obtained by previous studies (Brien & Sveistrup, 2011; dos Santos Mendes et al., 2012). Our experimental results also showed that appropriate task challenges contributed to improvements in motor performance of children with DD, which is also in agreement with previous findings (Linehan et al., 2010).

### Study Limitations

Purposive sampling was used because we had only one adaptive device and limited research staff. There was no randomization of children with DD and no control group of children with DD. The lack of a control group and the use of a purposive sample limit the conclusions and generalizability of the findings.

### Implications for Occupational Therapy Practice

Occupational therapists have developed effective tools for enhancing upper-limb function in clients with a variety of diagnoses using principles from motor-based theories (Amini, 2011; van Delden, Peper, Kwakkel, & Beek, 2012). This study’s results validate the inclusion of video gaming devices within the domain of occupational therapy for children with motor delay and may be generalized to populations with other disabilities, such as stroke.

- An adaptive video gaming rehabilitation device was developed as an effective treatment modality for enhancing motor coordination in children with DD.
- The device shows potential to effectively address symptoms of motor delay.
- The device provides a modifiable interface and games that can be graded according to therapists’ treatment plans.

### Conclusion

This study used an adaptive device to make video games accessible by modifying the training software and interface according to clients’ abilities. The adaptive video games for rehabilitation improved motor performance in settings that were safe and ecologically valid. This novel rehabilitation device can be used with a standardized protocol and tailored to each client’s functional level through the precise gradation of activities. Future study regarding video games may establish a grading system for motor rehabilitation and identify training parameters that are associated with optimal transfer to real-world functions. To build on existing knowledge of video gaming rehabilitation, further research involving video games may require different modifications.

The adaptive procedures involving interface design and video games will, we hope, assist occupational therapy practitioners in becoming aware of the relationship among motor control, modification, and related video gaming technology. Although several commercial video games have focused on improving motor abilities of typically developing children, the design of this device was based on children with DD.

### References


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### Table 1. Participants’ Pretest and Posttest Scores on the VMI and PDMS–2

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Univariate</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>VMI&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>72.55</td>
<td>6.60</td>
<td>77.45</td>
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<tr>
<td>PDMS–2</td>
<td></td>
<td></td>
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<tr>
<td>TMQ&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>69.65</td>
<td>8.07</td>
<td>73.37</td>
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<tr>
<td>FMO&lt;sup&gt;c&lt;/sup&gt;</td>
<td>67.25</td>
<td>8.33</td>
<td>73.42</td>
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</table>

<sup>a</sup>Standard scores. <sup>b</sup>VMI standard score interpretation: average, 90–109; below average, 80–89; low, 70–79; very low, <70. <sup>c</sup>Quotient scores. <sup>d</sup>TMQ score interpretation: average, 80–89; below average, 70–79; low, 60–69; very low, <60.

Note. FMQ = Fine Motor Quotient; GMQ = Gross Motor Quotient; PDMS–2 = Peabody Developmental Motor Scales, Second Edition; SD = standard deviation; TMQ = Total Motor Quotient; VMI = Beery–Buktenica Developmental Test of Visual Motor Integration.


