The Application Of Remodeled Glove Puppetry For Children With Developmental Disabilities

Chia Ching Lai
Ling Tung University
Hsieh-Chun Hsieh (hchsieh@mx.nthu.edu.tw)
National Tsing Hua University
Hsin-Yung Chen
Chang Gung University
Chien-Heng Lin
National Taiwan University Hospital, Chu-Tung Branch

Research Article

Keywords: EV3® robot, hand control, puppetry, developmental disabilities, play

Posted Date: March 1st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1355269/v1

Abstract

Objective: To study the improvement of hand performance and play behavior in children with developmental disabilities using remodeled glove puppetry.

Method: A pretest-posttest design was used in this randomized controlled trial to evaluate the intervention. Sixty-two children with developmental disabilities were randomly divided into experimental and control groups (n=31 each). Both groups underwent puppet play sessions once daily in playrooms. The children in the experimental group underwent rehabilitation by playing with the remodeled glove puppetry for 12 weeks, while the children in the control group played with non-remodeled glove puppetry. The Chinese puppet was remodeled using the Lego EV3® robot. We analyzed the motion kinematics of the hand using Siliconcoach® Pro 7 software and measured the force produced by the Baseline® hydraulic pinch gauge. The revised Knox Preschool Play Scale was used to score the play behavior.

Results: Improvement in hand kinematics and play scales in the experimental group indicated that glove puppetry remodeled with EV3® robots had a good training effect.

Discussion: Remodeled glove puppetry improved the range of motion and the qualities of play behavior, such as material management and participation of play quality. Further studies using remodeled glove puppetry with different disability populations are needed.

What This Paper Adds

- Children with developmental disabilities have weaker hand function
- The useful application of glove puppetry remodeled with Lego EV3® robots
- Remodeled glove puppetry improved the range of motion and the qualities of play behavior

Introduction

Children with developmental disabilities (DD) often have impaired motor function. In previous studies, nearly one-fifth of the total sample (3608 children with DD) had mild to moderate gross motor and fine motor dysfunction in living, play, and leisure activities [1, 2]. For children with DD, intrinsic muscle contracture of the hand is a common deformity associated with flexion of the metacarpophalangeal (MP) joint. The degree of MP flexion provides information about the functional hand position for essential daily skills.[3] However, a poor degree of MP flexion and contraction of the finger extensors may impede functional hand participation [2, 3].

Puppet play is beneficial as it encourages the child's imagination, emotional development, and motor skills [4]. However, it is difficult for children with DD to enjoy conventional puppet playing. Studies have been conducted on adapted pretend play, such as using substituted toys, remodeled switches, or scripts for children with DD, allowing them to take part in symbolic play [4]. Research shows increased playfulness in children with DD through physical activity and assistive devices, such as robotic toys and gaming platforms [5-9]. Few studies used robotic therapy to improve postural control and facilitate children's general functional development [5-6]. In contrast, adaptive toys have been developed to increase fine motor control in children with DD [8, 9]. The use of remodeled puppets also boosts confidence in speaking and increases group participation.

Li-Tsang's study on 120 preschool children indicated that children with DD have weaker precision grip ($p = 0.00$) and dexterity ($p = 0.01$) than children without DD [10]. Early interventions for hand motor control have been carried out in a few previous studies. These studies found that the interventions, for example, opposing the thumb and stimulating the index finger in the finger-pressing position to tap the surface with an assistive device, can improve hand motor control in children with DD [11]. The results of clinical rehabilitation programs have shown that intense structured practice improves motor skills, quality, and timing of hand movements, but these programs did not focus on the relationship between motor skills and play behavior [12]. The present study used the revised Knox Preschool Play Scale (PPS) to monitor each child rehearsing, experiencing, and experimenting, and to observe whether the child orients itself to the actual world [13].

In a previous study, Chinese puppets were used in the application of EV3® robots to children with cerebral palsy, which showed improvements in hand kinematics [14]. We believe that the modified strategy of puppetry, adaptive switch interface, and interactive game mechanics need to be explored in depth; thus, the effectiveness of modified Chinese puppets should be studied not only in hand kinematics, but also in play performance. Therefore, the research question in this study was as follows: For children with DD, do play performance and finger movements facilitate greater improvement in the remodeled Chinese puppetry with EV3® robots or on the Chinese puppetry alone?

Method

Design

We used randomized controlled trials to assess the interventions. Participants were equally allocated into either the remodeled Chinese puppetry with the EV3® robot group or the standard puppet group. The research procedure for this trial followed the CONSORT 2010 guidelines and did not cause any harm to participants in the experimental group.

Participants

A total of 85 eligible participants aged 4-6 years were recruited from 16 preschools in Taiwan via school bulletins announcing recruitment information. The inclusion criteria were children diagnosed with developmental disabilities and a neuromuscular development index of ≤ 85 in the McCarron Assessment of Neuromuscular Development (MAND) test, indicating mild motor disability [15]. Children with severe cognitive impairment and visual disabilities, according to their disability cards in Taiwan, were excluded.

All participants were screened by a research assistant; among them, 23 children with DD were excluded (19 children did not meet the inclusion criteria, one had severe medical problems, and four were rejected due to COVID-19 infection). A previous study showed that motor training can improve range of motion (ROM) (5-45°) from baseline to week 12, with a standard deviation (maximum degree) of 24°, as determined by sample size estimation in a clinical trial [6]. A clinically important difference of 0.5 and Cohen's d of 0.2 is considered acceptable. In this study, 31 children were recruited for each group according to the formula for calculating sample size [16]:

$$\text{Number of samples per group (n)} = \frac{2 \times (Z_{(1-\alpha/2)} + Z_\beta)^2 \times \sigma^2}{\Delta^2} \qquad (1)$$

Where Δ=size of difference, minimal effect of interest

α=significance level

β=power, probability of detecting a significant result

σ=SD of data

Z_p=points of normal distribution to give required power and significance

$$n = \frac{2 \times (1.96 + 1.28)^2 \times 24^2}{20^2} = 30.23$$

Sixty-two children with DD were randomly and equally assigned to either the experimental (n=31) or control group (n=31). The background information of the participants is presented in Table 1. The participants' motor function was assessed using the McCarron Assessment of Neuromuscular Development (MAND) test [16]. The MAND test is used for children aged 3.5-16 years with motor problems, and comprises 10 items, namely, five for fine motor and five for gross motor.

Procedures

According to the experimental research design, pretests and posttests were conducted to determine the improvement in fine motor performance by operating the two kinds of glove puppetry over 12 weeks. We conducted the pretests on the 1st day of the 1st week of research, and the posttests on the last day of the

12th week of research. The experimental and control groups operated glove puppetry with and without remodeling by EV3® robots, separately. All subjects participated in 40-minute sessions of puppet play in the study hall twice a week for 12 weeks, totaling 24 sessions. The experimental process and experimental tools are shown in Fig. 1. A specified set of remodeled glove pupae was adopted in the experimental group, and traditional glove puppetry was used in the control group.

Remodeled glove puppets were prepared by a special education preschool teacher with 3 years of working experience. Two occupational therapists performed the tests and evaluations. A research assistant took care of the randomization and recruitment process to ensure that the evaluators were blinded to the process. The group number was chosen under one block, and block randomization was completed by MAND scores.

To increase the motivation of puppets playing in two groups, the well-known Chinese historical drama "Romance of the Three Kingdoms" was played. After children watched a period of drama, they operated puppets for role-playing. While the experimental group used switches to move the puppets, the control group put their hands in their puppets to move them. The study procedures were approved for human research by the Research Ethics Review Committee of the National Tsing Hua University University (REC number: 107011HT075). All participants' parents signed an informed consent form before testing.

TRAINING INSTRUMENTATION

We modeled the Chinese puppet using the robotic platform the Lego® Mindstorms® Education EV3 Core Set (45544). The EV3 Brick in the base set provided programming and data logging functions. It also includes interactive servomotors, sensors, and connection cables. The remodeled glove puppetry included three EV3® sensors attached to the robot puppets. The robot puppets' arms and leg can be moved or rotated using one (touch sensor) and one (light sensor) servo motors, respectively, as shown in Fig. 1. The lion's head and leg also can be controlled by the touch switch and light sensor. If the participants have problems with the EV3 switch, the modified switches also can be used in the experimental sessions, as shown in Fig. 1.

Outcome measures

We collected kinematic data, finger functional performance, and revised Knox Preschool Play Scale (PPS) scores. Kinematic analysis on the hand motion, including the angle and direction, was performed using Siliconcoach® Pro 7 software (Siliconcoach Ltd., Dunedin, New Zealand). A smartphone (OPPO-A55, BBK Electronics Ltd., Dongguan, China) was positioned 2 m away from the participants at a height of 100 cm for kinematic analysis. The piston finger device for restoring the motor function [17] was 172°– 140° at the metacarpophalangeal (MP) joint, and 155°– 86° at the proximal interphalangeal (PIP). The locations of kinematic markers for the MP, PIP, and DIP are shown in Fig. 1.

The Baseline® hydraulic pinch gauge (120226, LiTE™) is a reliable instrument to accurately measure tip, key and palmar pinch strength in both pounds and kilograms [18].

The revised Knox Preschool Play Scale (PPS) is based on developmental theories and assesses preschool children aged 0–6 years on their play performance [13]. The scale measures four aspects of play performance: play space management, material management, pretense symbolism, and participation (see Appendix A for details). The observer took the mean behavioral score as the dimension score. The inter-rater reliability of PPS for children with DD ranged from 0.984 to 0.986, and the test-retest reliability ranged from 0.861 to 0.961 [19]. Cameras were set up to record the first intervention for pretest, and the last intervention for posttest, and the play scores were generated from the recorded videos. Each behavior was scored at the upper age limit of the age group (for example, the 48- to 54-month level was scored at 54 months), according to the literature [20]. Assessment took approximately 40 minutes each on both the pretest and posttest, and two graduate assistants watched the videos to code behaviors.

Data analysis

Hand kinematics and preschool play scores were collected in both the pretest and posttest phases. Univariate analysis of variance (ANOVA) and analysis of covariance (ANCOVA) tests were used to measure the test results (Table 2). ANOVA can determine whether the intervention effect has a significant influence on these datasets (hand kinematics and PPS), and ANCOVA compares the adjusted means of two independent (experimental and control) groups, while using the *pretest* results as *covariates (*Table 3). These tests provide the benefit of statistically controlling a confounding variable (pretest score). The pretest score comparison between the two groups is also listed in Table 3.

Statistical analyses were performed using SPSS software (SPSS Inc., Chicago, USA) to analyze the results as follows: the effect size (partial eta squared, η^2) as values for significant findings and the power analysis for the probability of rejecting the null hypothesis when incorrect. Using the effect size to support the null hypothesis could be due to the inadequate sample size, as listed in Table 3.

Results

Table 1 shows the demographics of the participants, including age, sex, and motor performance. A total of 62 children in both groups completed the activities and tests. Inter-rater reliability of PPS scoring between two assistants was calculated for 20% of the videos, and an inter-observer correlation was found, ranging from 0.97–0.99.

The results of the ANOVA are shown in Table 2. The experimental group showed improvements in hand kinematics, including ROM of the wrist, MP, PIP, and DIP (wrist, $F = 17.7$, $p = 0.000$; MP, $F = 4.94$, $p = 0.034$; PIP, $F = 18.23$, $p = 0.000$; DIP, $F = 8.95$, $p = 0.005$). Their PPS scores also showed significant improvements in space management, material management, pretense symbolism, and participation. Most children in the experimental group thought that the remodeled Chinese puppet was interesting, and the operation was fun. Playing with glove puppetry remodeled with the EV3® robot induced positive feelings, including emotional stability and optimism, and positive actions, including engagement, positive interaction, competence, and achievement. This intervention also induced more aggressive engagement and control of the puppet. In contrast, the control group showed no significant improvements in hand kinematics and PPS performance. During the intervention sessions, children in this group sometimes refused to play with the puppets in later classes, sometimes bit the puppets' clothes, and sometimes preferred playing with their hands instead of the puppets.

The ANOVA results in Table 3 showed no significant difference between the two groups (e.g., wrist ROM, $F = 0.010$, $p = 0.921$) in the pretest. Posttest results were analyzed by ANCOVA to study the between-group difference over time in hand kinematics and PPS results. A comparison of the original and adjusted means reveals the role of the covariates in the pretest scores. Significant differences were observed in most of the kinematics (wrist ROM, $F = 6.91$, $p = 0.011$; MP ROM, $F = 6.66$, $p = 0.012$; PIP ROM, $F = 13.16$, $p = 0.001$) after rehabilitation with remodeled glove puppetry ($p < 0.05$). The changes in PPS (space management, $F = 8.98$, $p = 0.004$; material management, $F = 10.04$, $p = 0.002$; pretense-symbolic, $F = 9.39$, $p = 0.003$; participation, $F = 25.17$, $p = 0.000$) also showed that the training of remodeled Chinese puppets in the experimental group can promote play performance in children. Only two hand kinematics (DIP ROM, $F = 0.977$, $p = 0.327$; press force, $F = 0.380$, $p = 0.540$) did not show any significant difference among the ANCOVA results. In summary, the experimental group demonstrated improvement in finger-tapping coordination, hand muscle power, and functional hand position.

Discussion

Our main finding was that repeatable motor tasks promote several motor performance, and highly motivating activities build better performance in play scales in children with DD. The mean PPS scores increased (posttest results were better than pretest results, as shown in Table 2) for two reasons: first, the participants found the puppet interesting; and second, this device simplified participation. The results of this study support the understanding that adaptations to puppet toys can enhance participation in pretend play [4, 9]. Since robotic therapy offers treatment options for children with DD to learn motor skills, EV3® Mindstorms robots made with low-cost materials were found in this study for motor development in children with severe impairments. Robots are portable, affordable, and controllable by finger tapping, making it usable for pretend play, as well as helpful for motor coordination in children with motor DD. These findings concur with that of previous studies on adaptive toys or puppets providing children with DD to pretend play while exercising finger movement, which also improves hand coordination [4, 21]. Thus, robotic-assisted training should be considered for long-term use by parents and teachers at home and at school. However, the press force did not improve in this study, which may be due to the design of the EV3® switches, as the switches did not offer different resistances to train pressing power.

Our study, along with previous literature, not only describes the use of puppet play as a therapeutic and educational tool, but also shows the benefits of technology for children with mild motor disabilities [14, 22]. Moreover, the addition of exaggerated facial characteristics on the glove puppets attracted children with DD; thereby increasing participation in our puppet play scenarios. As suggested by the motivation study, rehabilitation effects also had a correlation with patients' motivation, which needs to be considered as a good rehabilitation strategy [9, 23]. Therefore, we also found puppets not only enhance the hand kinematics of children with DD, but also facilitate play behaviors after modification with EV3® switches as teaching tools in inclusive childhood classrooms.

One of the major issues in such training for children with DD and other motor disabilities is that the development of motor skills requires many repetitions of the same movement to establish motor patterns. This remodeled glove puppetry included interesting and repetitive concepts while manipulating the puppet in the play scenarios (e.g., finger pressing and releasing). In the puppet play scenario, the EV3® bricks utilized the children's fingers in manipulating the puppets. Another finding, in agreement with that of previous studies, was that targeted or simple movement training is good for children with motor disabilities [12, 23].

The findings demonstrate that modifying the interface to manipulate a robot puppet can provide practice with targeted hand movements. This may be because the simplification of movements (control puppets through EV3® switches) allowed children with DD to use their affected hands with motivation, which can promote class participation in puppet play. This remodeled puppet study also identified the relationship between motivation and target movement practice using the finger to improve play performance.

Limitations

The results of this study must be interpreted with caution, and a number of limitations should be considered. A follow-up study is needed to determine the long-term effects of remodeled glove puppetry. Carryover to daily tasks also needs to be tested. The EV3® robot platform used in this study may be difficult for some researchers or parents because of programming and engineering components; using other commercial robot toys may overcome this technical limitation. Future studies on remodeled puppet therapies should further investigate the relevance of fine motor training and play behavior for more clinical headcount, and use different assessment tools correlated to real-world functions.

Conclusion

In this paper, we studied the effects of remodeled glove puppetry with an EV3® robot for children with DD. The results showed that adaptive play material is important for children with DD in rehabilitation. The estimation indices for hand and developmental capacities have significantly improved. Simplified operation of the puppet by the EV3® robot can promote finger control and functional hand use. Repeatable motor actions with high motivation can establish motor skills in children with DD. While working with children during remodeled glove puppetry, therapists may use familiar puppets to allow positive communication and interaction. Furthermore, remodeled glove puppetry with EV3® robots can increase the motivation of children with DD to operate the puppet and overcome resistance using both hands.

Abbreviations

DD: Developmental disabilities

DIP: Distal interphalangeal

MP: Metacarpophalangeal

MAND: McCarron Assessment of Neuromuscular Development

PPS: Revised Knox Preschool Play Scale

PIP: Proximal interphalangeal

ROM: Range of motion

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

We would like to thank all the teachers of Research Center for Education and Mind Sciences in National Tsing Hua University, who helped us by giving us advice and providing the equipment which we needed. Furthermore, the authors wish to express their gratitude to all children who participated in this study.

Funding

Hsieh, Hsieh-Chun has received a grant (MOST 110-2511-H-007-008) from Ministry of Science and Technology Fund to support this puppy study.

Author information

Affiliations

1. **Department of Child Care, Ling Tung University, Taiwan**

Chia Ching Lai

2. **Department of Special Education, National Tsing Hua University. N0.521, Nanda Rd., Hsinchu City, Taiwan**

Hsieh-Chun Hsieh

3. **Department of Occupational Therapy & Graduate Institute of Behavioral Sciences, College of Medicine, Chang Gung University, Taoyuan, Taiwan**

Hsin-Yung Chen

4. **Department of Psychiatry, National Taiwan University Hospital, Chu-Tung Branch, Hsinchu, Taiwan**

Chien-Heng Lin

Authors' Contributions

Hsieh made substantial contributions to experimental design, data analysis, interpretation, prepare figures and tables. visualization and wrote the main manuscript text. Lai and Chen help to collect the data and data analysis. Lin made substantial contributions to interpretation and visualization. All authors reviewed the manuscript.

Ethics declarations

Ethics approval and consent to participate

The study was approved by the Research Ethics Review Committee National Tsing Hua University (REC number: 107011HT075) and conformed to the guidelines of the Declaration of Helsinki. All the parents or legal guardians of participants provided written informed consent on behalf of the child.

Consent for publication

I confirm that all authors have approved the manuscript for submission and confirm that the content of the manuscript has not been published, or submitted for publication elsewhere.

Competing interests

The authors declare that they have no competing interests.

References

1. Pieters S, De Block K, Scheiris J, et al. How common are motor problems in children with a developmental disorder: rule or exception? Child Care Health Dev 2012; 38: 139–45. doi:10.1111/j.1365-2214.2011.01225.x.
2. Laverdure P, Beisbier S. Occupation- and activity-based interventions to improve performance of activities of daily living, play, and leisure for children and youth ages 5 to 21: a systematic review. Am

J Occup Ther 2021; 75: 7501205050p1–7501205050p24. doi:10.5014/ajot.2021.039560.

3. Hume M, Gellman H, Mckellop H, Brumfield, R. Functional range of motion of the joints of the hand. J Hand Surg Am 1990; 15: 240–3. doi:10.1016/0363-5023(90)90102-W.
4. Hsieh HC. Effectiveness of adaptive pretend play on affective expression and imagination of children with cerebral palsy. Res Dev Disabil, 2012; 33: 1975–1983. doi:10.1016/j.ridd.2012.05.013
5. Bayon C. Robotic therapies for children with cerebral palsy: a systematic review. Transl Biomed 2016; 7: 1–20. doi:10.21767/2172-0479.100044.
6. Hseih HC. Effects of a gaming platform on balance training for children with cerebral palsy. Pediatr Phys Ther 2018; 30: 303–308. doi:10.1097/PEP.0000000000000521
7. Ash T, Bowling A, Davison K, Garcia J. Physical activity interventions for children with social, emotional, and behavioral disabilities—A systematic review, Journal of Developmental & Behavioral Pediatrics: July/August 2017; 38: 431–445. doi: 10.1097/DBP.0000000000000452
8. Gilliaux M, Renders A, Dispa D, et al. Upper limb robot-assisted therapy in cerebral palsy: a single-blind randomized controlled trial. Neurorehab Neural Repair 2015; 29: 183–192. doi:10.1177/1545968314541172
9. Hsieh HC. Effects of ordinary and adaptive toys on pre-school children with developmental disabilities. Res Dev Disabil 2008; 29: 459–466. doi:10.1016/j.ridd.2007.08.004.
10. Li-Tsang CWP. The hand function of children with and without neurological motor disorders. Br J Dev Disabil 2003; 49: 99–110. doi:10.1179/096979503799104093
11. Shih CH. A finger-pressing position detector for assisting people with developmental disabilities to control their environmental stimulation through fine motor activities with a standard keyboard. Res Dev Disabil 2012; 33: 1360–5. doi:10.1016/j.ridd.2012.03.011
12. Muratori LM, Lamberg E, Quinn L, Duff S. Applying principles of motor learning and control to upper extremity rehabilitation. J. Hand Ther 2013; 26: 94–102, quiz 103. doi:10.1016/j.jht.2012.12.007
13. Knox S. Development and current use of the Knox Preschool Play Scale. In: Parham LD, Fazio LS, editors. Play in Occupational Therapy for Children. St. Louis: Mosby Yearbook, Inc., 1997, 35–51.
14. Hsieh HC, Liu CK, Chen, PKH. Lego robots in puppet play for children with cerebral palsy. *Universal access in human-computer interaction: Design approaches and supporting technologies* 2020; 465–76. doi.10.1007/978-3-030-49282-3_33.
15. McCarron LT. McCarron Assessment of Neuromuscular Development (3rd ed.). Dallas, TX: McCarron-Dial Systems Inc., 1997.
16. Sakpal TV. Sample size estimation in clinical trial. Perspect Clin Res 2010; 1: 67–9. PMID:21829786.
17. Wang M. et al., Piston finger device for restoring the motor function of chronic plegic fingers: Development of the device and verification of the effectiveness,2017; 17th International Conference on Control, Automation and Systems (ICCAS), 2017; pp. 1387–1390, doi: 10.23919/ICCAS.2017.8204209.

18. Shin H, Moon SW, Kim GS, Park JD, Kim JH, Jung MJ, Yoon CH, Lee ES, Oh MK. Reliability of the pinch strength with digitalized pinch dynamometer. Ann Rehabil Med. 2012;36(3):394–9. doi: 10.5535/arm.2012.36.3.394. Epub 2012 Jun 30. PMID: 22837976; PMCID: PMC3400880.
19. Harrison H, Kielhofner G. Examining reliability and validity of the Preschool Play Scale with handicapped children. Am J Occup Ther 1986; 40: 167–73. doi:10.5014/ajot.40.3.167.
20. Bledsoe NP, Shepherd JT. A study of reliability and validity of a preschool play scale. Am J Occup Ther 1982; 36, 783–88. doi:10.5014/ajot.36.12.783.
21. Gmez-Portes C, Lacave C, Molina AI, Vallejo D. Home rehabilitation based on gamification and serious games for young people: a systematic mapping study. Appl Sci 2020; 10: 8849. doi:10.3390/app10248849
22. Salmon MD, Sainato DM. Beyond pinocchio: puppets as teaching tools in inclusive early childhood classrooms. Young Except Child 2005; 8: 12–19. doi:10.1177/109625060500800303.
23. Hsieh HC, Lin HY, Chiu WH, Meng LF, Liu CK. Upper-limb rehabilitation with adaptive video games for preschool children with developmental disabilities. Am J Occup Ther 2015; 69: 1–6904290020p5. doi:10.5014/ajot.2015.014480.

Tables

Tables 1-3 are available in the Supplemental Files section.

Figures

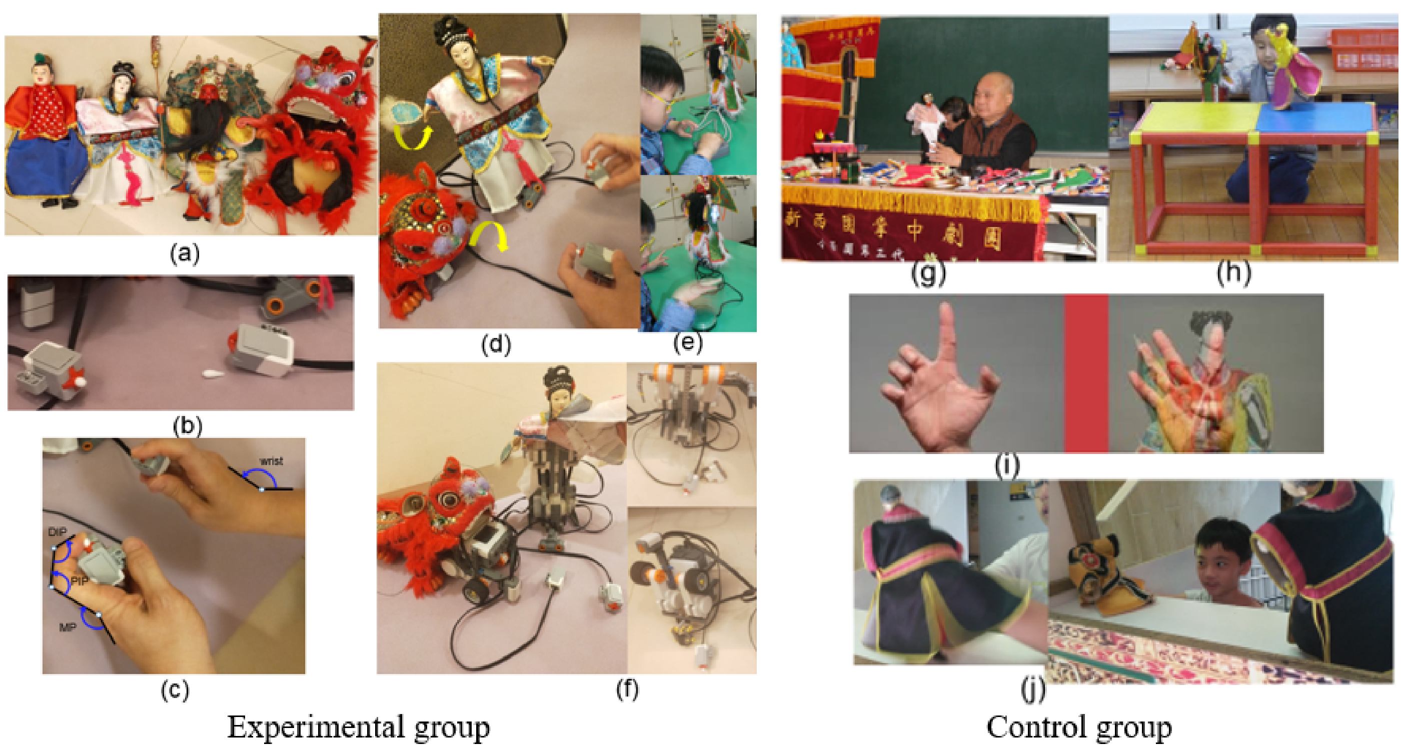

Figure 1

experimental and control group (Photographs used with parents' permission)

(a) Chinese glove puppetry

(b) Four switches (two touch sensors and two light sensors) and a cotton swab, which was used in the touch sensors for efficient finger-pressing control

(c) Locations of kinematic markers for assessing the range of motion in the wrist, MP, PIP, and DIP joints (kinematic markers: MP, metacarpophalangeal; PIP, proximal interphalangeal; DIP, distal interphalangeal)

(d) Children playing with remodelled glove puppetry with Lego switches

(e) Child playing with a puppet with modified plate and big button switches

(f) Skeleton created using EV3® bricks of Lego

(g) Famous puppeteer puts his hand into the opening of the puppet to demonstrate how he manipulates the puppet in a local drama course.

(h) Children learning to use the movement of their palm to move the puppets.

(i) Participant's index fingers, thumb, and remaining fingers control the puppet's head, right hand, and left hand, respectively.

(j) Participants try to control the puppet behind the stage with the "Three Kingdoms" musical story

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supportinginformation.docx
- table2docx.docx