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Original Paper

Development of a Modified Apparatus for Hand Dexterity Evaluation — interrater and test-retest reliability —

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Key words: hand dexterity, modified apparatus, interrater reliability, test-retest reliability

Abstract

Objectives: Hand dexterity encompasses three basic elements: spacing, grading and timing. However, no evaluation method simultaneously addresses all three elements. In 1998, development of a new apparatus was begun, and an initial prototype was completed in 1999. In a previous study, it was noted that the apparatus needed improvement. Modifications were initiated in 2003, and completed in 2004. Interrater reliability and test-retest reliability of this modified apparatus were examined.

Subjects and Methods: Twenty-seven healthy subjects participated in the study. Of the total of 54 hands, three were excluded from the study due to data deficiency. All subjects were evaluated simultaneously by two faculty researchers to determine interrater reliability, and then reevaluated by the same researchers about one week later to determine test-retest reliability.

Results: The results for interrater reliability showed significant reliability for grading and timing, but not spacing. In test-retest reliability, significant reliability was found for timing, but not spacing and grading.

Conclusions: This study indicated that the modified apparatus was not completely reliable. This is consistent with the difference in relative difficulty of each element. It is important that time intervals are set based on the subjects' abilities. At the same time, it is necessary to initiate clinical studies which include actual patients in the sample.

Introduction

In rehabilitation medicine and occupational therapy, dexterity includes fluency and skill of manual movement. Kamakura[1] stipulated that dexterity was an ability to manipulate small objects with the hand. Ishida[2] proposed that dexterity was a smooth manual movement pattern. In a comprehensive assessment of upper extremity function, dexterity is an important component that the occupational therapist must consider[3].

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Dexterity encompasses three basic elements: spacing, grading and timing. The function of spacing includes moving the hand in the right direction. Grading allows adjustment of the force and strength of hand movements. Timing allows for adjustment in the timing of hand movements. In order to fully evaluate dexterity, an evaluation method must be developed that objectively incorporates all three elements[4].

In medical treatment and engineering fields, a conventional quantitative analysis of dexterity has been done. A tracing profile using a light emitting diode was included in those methods. In addition, a kinesiological analysis using an electromyogram has also been used[5]. Movement analysis using a video camera is currently popular. Many occupational therapists use standardized dexterity tests to evaluate the fine or gross motor abilities of their clients[6]; however none of these evaluation methods simultaneously addresses the three elements. One reason is that the evaluator may subjectively be more inclined to analyze one of the three elements. A second is related to limitations of the technology and sensitivity of the testing apparatus.

In 1998, development of a new apparatus was begun, and an initial prototype was completed in 1999. Validity and reliability of the apparatus was examined using healthy volunteers and patients. This previous study suggested that the apparatus was effective in evaluating of hand dexterity; however, it was noted that the instrument size and sensor could be improved[7]. Based on these findings, development of a modified apparatus was begun in 2003, and completed in 2004. The interrater reliability and test-retest reliability of this modified apparatus were examined.

Problems with the Initial Apparatus and Study

The initial apparatus (see Fig. 1 and 2) included a control box, printer and primary switch and secondary switch. The primary switch included pressure and touch sensors. The secondary switch was a single switch, and included touch sensor. The control box was 13.5 cm high, 28.5 cm long and 30.0 cm wide. The printer was 19.0 cm high, 40.0 cm long and 50.0 cm wide. The primary switch was 10.0 cm high, 25.0 cm long and 35.0 cm wide. The gross weight of the apparatus was approximately 20.0 kg. At these dimensions, the apparatus was bulky and heavy, which made transport and set-up cumbersome and inefficient.

During the initial study, problems were encountered with the sensor. In timing, the data was expressed as a variation index, which was defined as the standard deviation divided by the mean. When aberrations of timing were uniform, the variation index was smaller; therefore it was decided that a sensor which detected time lag was necessary.

Pressure sensors of the primary switch detected digital forces to a precision of 100g. It was decided that this precision threshold was too low to accurately measure digital forces applied by subjects. Therefore, it was decided to increase sensitivity of the sensor.

There are currently no evaluation methods which simultaneously address the three elements. In other words, there is no 'gold' standard for comparison or validation; however, it was deemed important to examine the reliability of the modified apparatus.

Materials and Methods

Subjects

Twenty-seven subjects participated in this study. Occupational and physical therapy students were recruited as volunteers and gave informed consent before participating. Any individual with a history of neuromuscular or orthopedic dysfunction that would significantly affect hand dexterity was excluded. The

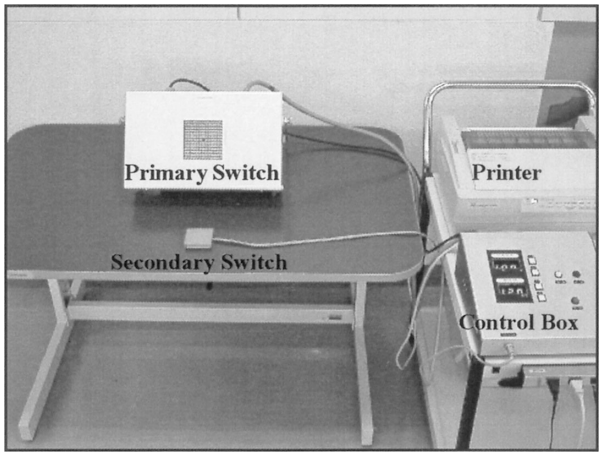

Fig. 1 The initial apparatus Whole view

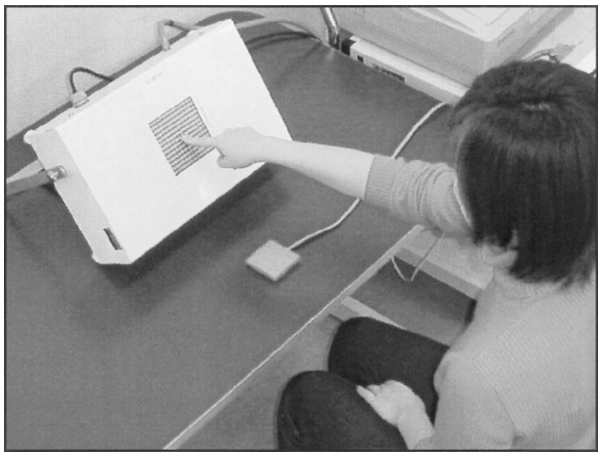

Fig. 2 The initial apparatus An evaluation scene

27 subjects were comprised of 7 males and 20 females ranging from 19 to 26 years of age, with an average age of 21.33 years. Twenty-five subjects were right-hand dominant, one was left-hand dominant and one was ambidextrous. Of the total 54 hands, 3 hands ware excluded from the study because of data deficiency. As a result, the data from 51 hands were included in the study.

Modified apparatus

The modified apparatus (Fig. 3 and 4) was also comprised of a control box, printer and primary switch and secondary switch. The modified apparatus was very compact in comparison to the previous model. The control box and the printer were 14.0 cm high, 23.0 cm long and 20.0 cm wide. The primary switch was 6.0 cm high, 15.0 cm long and 20.0 cm wide. The control box weighed 3.0 kg. The printer weighed 2.5 kg and the primary switch weighed 2.0 kg. The gross weight of the modified apparatus was 7.5 kg. As a result, ease of transport and assembly made it possible to move the apparatus to different evaluation rooms.

The primary switch was a 10 cm square panel with 169 sensors, each with a right and left and top and bottom position, arrayed in a 13 $\times$ 13 grid. The central sensor was painted red, and subjects were instructed to push it as the target. The primary switch functioned to activate the pressure and touch sensors. The pressure sensor detected the digital force applied by the subject to a precision of 100g. We were unable to increase the precision of the pressure sensor due to cost constraints.

The touch sensor detected the position that the subject pushed and the length of time contact was maintained to a precision of 0.01 seconds. In the same manner, the secondary switch also activated the touch sensor, and sensed the time that the subject pushed to a precision of 0.01 seconds. The two sensors were designed to perform the new function of detecting time lag.

A speaker in the control box produced two different, distinct sounds at constant time intervals. The evaluator could dictate and set time intervals and examination time. The primary and secondary switches were installed in the front of the desk.

Procedure and tasks

The subject was instructed to sit in on a chair directly in front of the modified apparatus. The evaluator was seated to the subject's right and explained the purpose and procedures of the study. When different

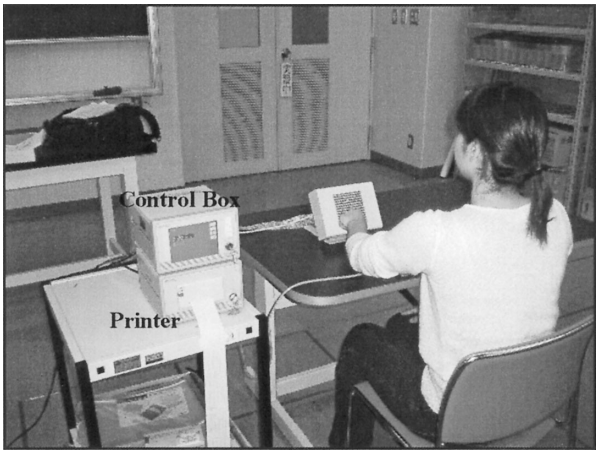

Fig. 3 The modified apparatus Whole view

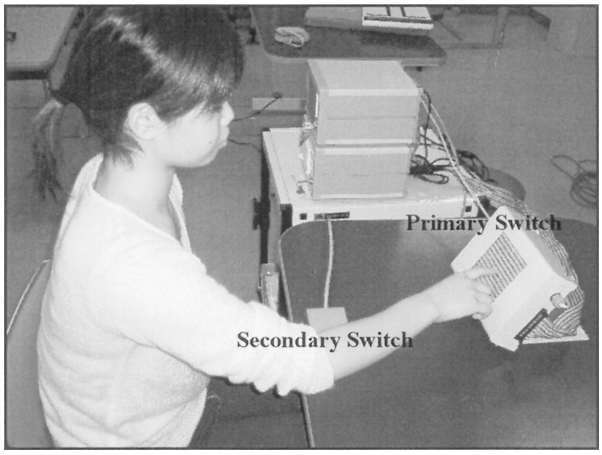

Fig. 4 The modified apparatus An evaluation scene

distinct sounds were heard, the subject was instructed to push the two switches in turn with the fingertips. Conditions of the tasks were as follows: spacing, subject was to consistently push the central pressure sensor without deviation; grading, subject was to consistently push the primary switch with the same force; timing, subject was to consistently move his or her hand with the same rhythm and speed. The subjects were given a brief practice test before the actual test to ensure understanding of the procedure. The right hand was tested first, followed by the left. At the end of the task, a printer printed out the test results of spacing, grading and timing.

Measures

As a result of the pilot study, the time interval was set at one second, because this interval was deemed suitable for evaluation of a clinical patient. For the same reason, the number of cycles was set at 20.

For spacing, the total number of deviations was determined. For grading, the variation index of the force of the push was determined. For timing, the variation index of the time that the hand moved and the total times of time lag were determined.

Interrater reliability study

All subjects were evaluated simultaneously by two faculty researchers who independently timed and recorded test scores to determine interrater reliability.

Test-Retest reliability study

All subjects were then reevaluated by the same researchers about one week later at the same time of day. The subjects were reevaluated using the same procedures to determine test-retest reliability.

Data analyses

To evaluate reliability, both the interrater and test-retest reliability values were calculated using the Pearson correlation coefficient. Interrater reliability values were calculated using the Intraclass correlation coefficient [ICC (2,1)], and the test-retest values were calculated using the Intraclass correlation coefficient

[ICC (1,1)]. The statistical software "SPSS ver. 13.0J for Windows" was used for the analyses.

Results

Interrater reliability

The results of the interrater reliability portion of the study are presented in Table 1 and Table 2. The first evaluator's data correlated with the second evaluator's data in grading and timing, but no significant correlation was found in spacing.

Test-Retest reliability

The results of test-retest reliability are presented in Table 3 and Table 4. Data from the first evaluation correlated with the data of the second evaluation in timing, but no significant correlations were found in spacing and grading.

Table 1 The Pearson correlation of data comparing the first and second evaluators for interrater reliability

	Spacing	Grading	Timing①	Timing②
Correlation coefficient	0.199	0.454**	0.282*	0.681**
Significant probability	0.161	0.001	0.045	0.000
N	51	51	51	51

Note. Correlation coefficient = The Pearson correlation coefficient
Timing① = A variation index of the time that a hand moved
Timing② = The total times of time lag
**.p<0.01 *.p<0.05

Table 2 The intraclass correlation of data comparing the first and second evaluators for interrater reliability

	Spacing	Grading	Timing①	Timing②
Correlation coefficient	0.175	0.445**	0.275*	0.598**
Significant probability	0.087	0.000	0.022	0.000
N	51	51	51	51

Note. Correlation coefficient= The intraclass correlation coefficient(2,1)
Timing①= A variation index of the time that a hand moved
Timing②= The total times of time lag
**.p<0.01 *.p<0.05

Table 3 The Pearson correlation of data comparing the first and second evaluations for test-retest reliability

	Spacing	Grading	Timing①	Timing②
Correlation coefficient	0.044	0.117	0.453**	0.635**
Significant probability	0.758	0.412	0.001	0.000
N	51	51	51	51

Note. Correlation coefficient= The Pearson correlation coefficient
Timing①= A variation index of the time that a hand moved
Timing②= The total times of time lag
**.p<0.01

Table 4 The intraclass correlation of data comparing the first and second evaluations for test-retest reliability

	Spacing	Grading	Timing①	Timing②
Correlation coefficient	-0.057	0.101	0.460**	0.603**
Significant probability	0.657	0.236	0.000	0.000
N	51	51	51	51

Note. Correlation coefficient= The intraclass correlation coefficient(1,1)
Timing①= A variation index of the time that a hand moved
Timing②= The total times of time lag
**.p<0.01

Discussion

Interrater reliability

Significant reliability was confirmed for grading and timing, but not for spacing. These results are consistent with the differences in relative difficulty of each element. The time interval was set at one second because this time interval was considered suitable for clinical patients, but was too long for healthy subjects.

When the speed was slow, grading and timing became difficult, but spacing became easier. The results of spacing may change due to minor influences, and significant correlations were not observed. If actual clinical patients were included in the sample and asked to perform the same functions, the results maybe different.

Test-Retest reliability

Significant reliability was found in timing, but not in spacing and grading. These results were slightly different from the interrater reliability portion of the study. Several reasons were considered for these outcomes.

In our previous pilot study with healthy subjects, the time interval was set at 0.5 seconds. Fourteen subjects (occupational therapy student volunteers) participated in that study. The 14 subjects included 6 males and 8 females ranging from 20 to 26 years of age, with an average age of 22.0 years. Eleven subjects were right-hand dominant, one was left-hand dominant, and two were ambidextrous. The result showed a significant reliability for spacing and grading, but not for timing (Table 5). These results were completely opposite to the findings in the present study. When the speed was too fast, spacing and grading became difficult, but timing became easier. That is the reason significant correlation was not observed in timing in the previous pilot study.

Table 5 Correlation of data comparing the first and second evaluations for test-retest reliability in the previous pilot study

	Spacing	Grading	Timing
Correlation coefficient	0.629**	0.557**	0.044
Significant probability	0.000	0.002	0.823
N	28	28	28

Note. Correlation coefficient = The Pearson correlation coefficient
Timing = The total times of time lag
**.p<0.01
This study was presented at the thirteenth project study report meeting of Kawasaki Medical Welfare University (in 2006).

In summary, it is important that the time interval is set based on the subjects' abilities. At the same

time, it is necessary to initiate clinical studies which include actual patients in the sample. Further studies are required to establish evaluation settings and studies must done with a larger number of patients. This study did not clearly demonstrate the reliability of the modified apparatus. Occupational therapists must develop a dexterity evaluation model that simultaneously incorporates the three elements. Through clinical practice and expertise, occupational therapists must establish systematic training methods that also include the three elements[8]. In the future, we plan to improve our apparatus and continue to review evaluation methods.

Acknowledgments

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