Construct Validity of the In-Hand Manipulation Test: A Discriminant Analysis With Children Without Disability and Children With Spastic Diplegia

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Objective. This study examined the construct validity of the In-Hand Manipulation Test (IMT) by assessing the test's ability to discriminate between samples of children with and without known fine motor problems.

Method. The IMT was administered to 55 children without known fine motor problems and 24 children with spastic diplegia who had mild to moderate fine motor problems. Construct validity was estimated by evaluating how accurately the IMT classified the children as having or not having fine motor problems on the basis of total score.

Results. A discriminant analysis indicated that IMT total score correctly classified 83.33% of the participants as having or not having fine motor problems.

Conclusion. The IMT has adequate construct validity to classify the participants of this study and for continued use as a research instrument to assess children's in-hand manipulation skills. Additional validity studies of the IMT are needed with other samples of children before its use for clinical purposes.


In-hand manipulation, which is defined as the ability to move an object within the hand after grasp (Exner, 1992), is used by children to efficiently accomplish a variety of school-related and daily living tasks, such as writing, scissoring, buttoning, and eating. Children who have developmental disabilities frequently demonstrate inefficient in-hand manipulation skills that limit their occupational performance at school and home (Case-Smith, 1993, 1995; Exner, 1992; Humphry, Jewell, & Rosenberger, 1995). Specifically, children who have mild cerebral palsy often demonstrate decreased control of the intrinsic hand muscles and poor active control of metacarpophalangeal flexion, finger abduction and adduction, and interphalangeal extension (Danella & Vogtle, 1992), movements that are necessary for efficient in-hand manipulation of objects (Exner, 1992; Long, Conrad, Hall, & Furler, 1970).

Despite the importance of these skills, none of the standardized assessments used by occupational therapists specifically measure the quality of children's in-hand manipulation skills. The In-Hand Manipulation Test (IMT) is being developed by Exner to assess the quality of in-hand manipulation skills in children between the ages of 3 years 0 months and 8 years 11 months who have developmental disabilities, learning disabilities, or neurological impairments (Exner, 1992). One purpose of the test is to identify in-hand manipulation problems in children who...
have or are at risk for developing mild to moderate developmental disabilities.

Literature Review

Three of the four phases in the instrument-development process outlined by Benson and Clark (1982) have been completed with the IMT. In the planning phase (Phase 1) of instrument development, several pilot studies were completed to assist in the development of format and test items for the IMT (Exner, 1990a, 1990b). Exner (1990a, 1990b, 1992) also developed and refined a classification system for the types of in-hand manipulation skills used by children during spontaneous play. She classified in-hand manipulation skills into five specific categories: (a) finger-to-palm translation, (b) palm-to-finger translation, (c) shift, (d) simple rotation, and (e) complex rotation. Each type of in-hand manipulation may occur with or without simultaneous stabilization of other objects within the hand (Exner, 1992).

During the test's construction phase (Phase 2), the tables of specifications and test items were revised on the basis of study results, and content validity was evaluated by expert review (Exner, 1993). The quantitative evaluation phase (Phase 3) was conducted in 1993 and 1994 with interrater and test–retest reliability studies (Allen, 1994; Behm, 1993; Flanagan, 1994; Geier, 1993; Haddaway, 1994; Harper, 1993; Maiocco, 1994; Miles, 1993; Schminky, 1993; Sefret, 1993). The IMT was shown to have adequate interrater (.90) and test–retest (.95) reliability.

Currently, the IMT is in the validation phase (Phase 4) of the instrument-development process. In this phase, the validity of a test is evaluated to determine the extent to which the test measures the construct it claims to measure and to determine the test’s clinical usefulness (Benson & Clark, 1982; Cronbach, 1971; Dunn, 1989). Construct validity, defined as the degree to which an instrument actually measures a particular trait, is the most vital type of validity to estimate during the instrument-development process (Benson & Clark, 1982; Cronbach, 1971; Dunn, 1989). One method of estimating construct validity is to assess the test's ability to discriminate between known groups. Construct validity of an instrument is supported if significant differences in test performance exist between groups with known characteristics (Dunn, 1989). For example, one group known to possess a high degree of the construct to be measured is compared with a group known to possess a low degree of the construct. If the instrument has adequate construct validity, it will discriminate between the groups (Benson & Clark, 1982).

The ability of the IMT to accurately discriminate between groups of children known to have good and poor in-hand manipulation skills is crucial to assess before its clinical use. One purpose of the IMT is to identify in-hand manipulation problems in children with mild to moderate developmental disabilities. If the IMT were unable to accurately discriminate between children with varying degrees of in-hand manipulation skills, its construct validity and clinical usefulness would be questionable. One population of children who typically have poor in-hand manipulation skills and for whom the test is designed is children with mild cerebral palsy. Therefore, the purpose of this study was to compare the performance on the IMT of a sample of children who have spastic diplegia and mild to moderate fine motor problems with a sample of children without identified fine motor problems as one measure of the test's construct validity. This study was designed as one of a series of studies examining the IMT's validity.

Method

Sample

Children without known fine motor problems. This sample consisted of children between 3 years 0 months and 8 years 11 months of age without identified fine motor problems who participated in the 1994 test–retest reliability study of the IMT (n = 55). The children were enrolled in day-care programs or before-school and after-school programs in the Baltimore metropolitan area. Each child was described by his or her parent on a questionnaire as having fine motor skills that were average or above average compared with other children of similar age and as having no known disability that would affect hand function. The characteristics of this sample of children are presented in Table 1.

Children with spastic diplegia. This sample was recruited for the study from a group of children who have spastic diplegia and considerable fine motor problems and who were receiving direct occupational therapy services at the Kennedy Krieger Institute in Baltimore. The sample included 24 children between 3 years 0 months and 8 years 11 months of age with spastic diplegia (n = 21) or spastic diplegia with hemiplegia (n = 3). Each child had a combined IQ of 70 or above as determined by school report or clinical psychology evaluation within 1 year of participation in the study. These children also had no uncorrected visual or auditory deficits, as documented in the medical record and as reported by the child’s primary occupational therapist.

Each child's occupational therapist completed a ques-

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<td><strong>Children Without Known Fine Motor Problems and Children With Spastic Diplegia</strong></td>
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*Note. n = 55 for children without known fine motor problems; n = 24 for children with spastic diplegia.*
tionnaire that reported standardized fine motor test scores and rated the child's fine motor problems as very mild, mild, or moderate. Twenty-one of the children with spastic diplegia had fine motor test scores, as measured by the Peabody Developmental Fine Motor Scale (Folio & Fewell, 1983) or Bruininks-Oseretsky Fine Motor Composite (Bruininks, 1978) that were 1 to 2 standard deviations below the mean for their chronological ages. The other 3 children had fine motor test scores that were within 1 standard deviation of the mean, but they were rated by their occupational therapists as having considerable fine motor problems and were receiving treatment to improve in-hand manipulation skills. Overall, 6 children were rated as having very mild fine motor problems, 13 were rated as having mild fine motor problems, and 5 were rated as having moderate fine motor problems in the preferred hand.

Instrument

The IMT is used to assess each of the five types of in-hand manipulation, with and without simultaneous stabilization of other objects in the hand. The quality portion of the IMT consists of 10 scales and 60 items; 30 items are completed with stabilization and 30 are completed without stabilization. A speed portion of the IMT was developed in 1994; it was not used in this study because the sample of children without fine motor problems tested in 1994 was not given this portion of the test.

The test items consist of a variety of age-appropriate materials for young children. The test materials represent four shape categories and three size categories. The shapes of materials include cubes; dowels or cylindrical objects; thin, flat objects; and thin, round objects. The sizes of objects are categorized as tiny (1/2 in. or smaller), small (1/2 in.–1 in.), or medium (1 in. or larger). The test materials include nickels, keys, markers, chips, puzzle pieces, tickets, pegs, and ice cream sticks.

Each item is scored with a 4-point quality rating scale. The scale ranges from 0, given if a child does not manipulate an object within a single hand or transfers the object to the nonpreferred hand, to 3, given when a child performs a smooth, quick in-hand manipulation skill with distal finger contact during the manipulation. Each item is administered twice to the child's preferred hand, with both scores recorded. The higher of the two scores for each item is used to obtain a sum for each scale and the total test score. The total possible score is 180. The number of times objects are dropped and any substitution patterns used by the child are also recorded on the score sheet.

Procedure

Approval for the study was obtained from the Towson State University Institutional Review Board and the Johns Hopkins Joint Committee on Clinical Investigation. The parent of each child signed consent forms, and each child assented at the time of testing. The children with spastic diplegia were administered the IMT at the Kennedy Krieger Institute according to the test protocol, which requires the child to be positioned directly across from the examiner, at an elbow-height table and in a chair with adequate seat depth and foot support. Their scores were compared with the scores obtained by the sample of children without fine motor problems in the first administration of the IMT during a previous test–retest reliability study.

Data Analysis

The statistical computer program SPSS for Windows, Release 6.0 (Norusis, 1993) was used to analyze the data. The means and standard deviations were calculated for the IMT total score for all the children. A t test was calculated for the mean IMT total score to determine whether significant differences in IMT performance existed between the group without fine motor problems and the group with spastic diplegia.

Because a combination of multiple continuous and categorical variables was used in this study, two multivariate analyses were conducted to assess the construct validity of the IMT. First, a discriminant analysis was conducted to determine how accurately the children could be classified into the spastic diplegia group or the group with no known fine motor problems, using total IMT score, age, gender, and hand preference as predictive variables. This analysis uses multivariate analysis of variance (MANOVA) procedures to calculate the percentage of correct classifications into groups on the basis of the dependent variables (Pedhazur, 1982). Second, a stepwise multiple regression was used to estimate the relative value of scale scores and individual participant variables in the discriminant properties of the IMT. In this analysis, MANOVAs are calculated for each dependent variable. Each variable with a significant Wilks's lambda is entered into a discriminant analysis to predict group membership (Pedhazur, 1982). This analysis was completed to determine which scale and participant characteristic variables were the best predictors of group membership.

Results

For the group without fine motor problems, the mean total score was 126.13 (SD = 26.33); for the spastic diplegia group, the mean total IMT score was 87.17 (SD = 30.12). A significant difference in the mean total scores of the two groups was found, t = 5.47, p < .001.

The classification results of the discriminant analysis of IMT total score, age, gender, and hand preference are reported in Table 2. The scores of one child were eliminated from the analysis by the computer program because at least one discriminating variable was missing. The overall percentage of all children correctly classified by the discriminant analysis was 83.33%.

All four of the participant variables were significantly correlated with total IMT score. Age (r = .427) and hand preference (r = .433) were significantly correlated with the
total test score at the $p < .001$ level. Gender was significantly correlated with total IMT score at the $p < .05$ level ($r = .258$). Hand preference was significantly correlated with total IMT score ($r = -.433$, $p < .01$).

To assess the impact of the participant variables on the classification of groups, discriminant analyses were conducted using only total IMT score and age or IMT score, age, and gender. For each analysis, the overall percentages of all children correctly classified were 79.49%. This represents inaccurate classification of only three children more than that obtained using these variables and hand preference. These three additional misclassifications were with children without fine motor problems.

The correlation of total IMT score with hand preference is the result of significantly more left-handed children being in the group with fine motor problems than in the other group, which increased the possibility that classification may be based primarily on hand preference. To determine whether the significance of hand preference as a predictor of IMT performance was affected by the composition of the study sample, a $t$ test was conducted to determine whether a significant difference in IMT total score existed between children with spastic diplegia who have right-hand and left-hand preferences. No significant difference was found, $t = 1.26$, $p = .220$.

A stepwise regression procedure conducted for the total IMT score indicated that total IMT score, hand preference, and age were significant predictors of group membership at the $p < .001$ level, confirming the correlations discussed above. Table 3 presents the results of the stepwise regression procedures for IMT scale scores and individual variables. In the stepwise regression of all scale scores with age, gender, and hand preference variables, the following variables were the most significant predictors of group membership and are listed in order of significance: palm-to-finger translation score, drops score, complex rotation score, shift with stabilization score, finger-to-palm translation with stabilization score, and hand preference. These variables were all significant at the $p < .001$ level. The remaining scale scores, age, and gender did not significantly enhance the predictive value of the regression equation. The overall percentage of children correctly classified with the six significant variables was 96.20% (see Table 3).

### Discussion

The results of this study indicate that the total score of the IMT accurately discriminates between children without identified fine motor problems and children who have very mild to moderate fine motor problems as a result of spastic diplegia and who are between 3 and 8 years of age. This classification is enhanced by inclusion of the factors of age, gender, and hand preference.

In the discriminant analysis for the total IMT score, some of the children without known fine motor problems who were misclassified may actually have unidentified fine motor problems rather than constitute a misclassified group. The literature indicates that approximately 10% of a typical population of school-age children have unidentified motor coordination problems or clumsiness (McHale & Cermak, 1992). Thus, although these data suggest that up to 13% of children without fine motor problems could be identified with the IMT as having a problem, the actual percentage may be smaller. Further studies would be needed to determine whether the IMT identifies children with problems who have not otherwise been identified as having a fine motor problem.

Six (25%) of the 24 children with spastic diplegia were incorrectly classified on the basis of the discriminant analysis with total score, age, gender, and hand preference. This percentage seems to be clinically acceptable with a population of children with spastic diplegia because these children will likely be given other tests of motor function in clinical situations. A composite of tests will likely reveal any major problems with fine motor skills. Additionally, children with fine motor problems may have difficulty with some aspects of fine motor control but not others. The 3 children who had spastic diplegia and fine motor skills that were less than 1 standard deviation below the mean for chronological age, as documented by standardized fine motor testing, were among the 6 children with spastic diplegia who were misclassified. Therefore, not all children with fine motor problems in the study may have difficulty with in-hand manipulation skills, although their primary occupational therapists had reported considerable fine motor problems on the basis of clinical observations. However, this study did not assess the speed of children's performances, which may have been more affected in some of the children than the quality of their skills.

In addition to individual characteristics, intervention may have affected the classification of the children. Because all of the misclassified children had been participating in occupational therapy programs to address in-hand manip-
ulation skills, this intervention may have improved these children’s quality of in-hand manipulation skills.

The stepwise regression completed as part of the discriminant analysis identified four IMT scales that contributed a significant amount of between-group variance. Using scores from the palm-to-finger translation, complex rotation, shift with stabilization, and finger-to-palm translation with stabilization scales, in combination with number of drops and hand preference, 76 (96.20%) of the 79 children were correctly classified into their respective groups. This finding suggests that these scales may have greater predictive value than the other scales in discriminating between children with and without fine motor problems. An abbreviated form of the IMT using these scales may have discriminant validity equal to or better than the current form of the test. This information may be used in revision of the test structure or its scoring when used for identification purposes. For example, revising the test structure to cluster these scales at the beginning of the test may allow therapists to identify children who do not have considerable in-hand manipulation problems without administering the entire test. The scoring system of the IMT may be revised to provide greater weight to the scales that have greater predictive value. The entire test may provide information that would be useful in treatment planning and documentation of improvement after intervention.

This study has several limitations. The small sample size may have contributed to the increased percentage of misclassified children with spastic diplegia and limits the confidence of generalization of the results to other children who have spastic diplegia. In addition, the findings should not be generalized to children who have other conditions. The disparity in the size and hand preference distribution of the two groups of children limits confidence in the results. However, the hand preference difference is likely to occur in future studies because of the larger number of children with disabilities being left-handed than those without disabilities.

Conclusion
This study examined the construct validity of the IMT for children who are 3 to 8 years of age without known fine motor problems and with mild to moderate fine motor problems due to spastic diplegia. The children with spastic diplegia demonstrated significantly poorer quality of in-hand manipulation skills than the children without known fine motor problems. The IMT total score discriminated accurately between the two groups at a clinically useful level, indicating that the test has adequate construct validity on the basis of the known-groups method for these groups. A stepwise regression procedure correctly classified 96.20% of the children using only palm-to-finger translation, complex rotation, shift with stabilization, finger-to-palm with stabilization, number of drops, and hand preference, indicating that a revised format of the IMT may be valid and clinically useful for the purpose of discriminating between children with and without problems with in-hand manipulation skills. The other test scales may provide additional information useful in planning and evaluating treatment for in-hand manipulation problems. Continued validation of the IMT should proceed with children who have other conditions. Factor analyses are also needed to determine whether there may be an abbreviated cluster of scales on the IMT, which, when used as a group, increases accuracy of group classification with the test. Determining the presence of such a subgroup of IMT scales may be useful in developing a shorter form of the IMT that would accurately identify children with in-hand manipulation problems. Once standardization is complete, the IMT can be used for clinical research studies and as a component of a comprehensive occupational therapy evaluation of children’s hand skills. ▲

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