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Validation of the Coin Rotation Task: A Simple, Inexpensive, and Convenient Screening Tool for Impaired Psychomotor Processing Speed

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Abstract

The coin rotation task (CRT) is a simple, convenient, and cost-effective measure of psychomotor processing speed that has been used in neurologic examinations at the Louisiana State University Health Sciences system for almost 20 years. In the CRT, participants rotate a coin through serial 180-degree turns using the thumb, index, and middle fingers for 10 seconds. In the current study, we sought to validate the CRT on a hospital-based sample by determining the task's sensitivity and specificity in detecting psychomotor processing speed impairment on a criterion measure, the Grooved Pegboard Test (GPT). Participants included a sample of 161 participants obtained in a hospital setting. The CRT was found to be significantly correlated with a number of measures of motor functioning. Using a binary ROC curve analysis, the CRT predicted impairment on the GPT with .80 sensitivity and .62 specificity for dominant hand performance and .83 sensitivity and .43 specificity for nondominant hand performance when a cut score of 13 or fewer coin rotations was utilized. These results support the utility of the CRT as a convenient and inexpensive psychomotor processing speed screening tool in clinical settings.

Introduction

While clinicians in many different areas of health care utilize information regarding motor functioning diagnostically, evaluation of manual strength, dexterity, and psychomotor processing speed varies between disciplines and clinical settings. The Halstead-Reitan Neuropsychological Battery (Reitan & Wolfson, 1985) evaluates motor coordination and speed by means of the Finger Tapping Test (FTT) and evaluates gross strength of the upper extremities by means of the Grip Strength Test (GST). The Grooved Pegboard Test (GPT) is often used as an adjunct to the battery in order to provide a more specific index of fine motor coordination of the distal upper extremities and is included in the Halstead-Russell Neuropsychological Battery (Russell & Starkey, 1993). These tests are commonly used by

clinical neuropsychologists because they are easy to use and minimally affected by education and intellectual functioning (Strauss, Sherman, & Spreen, 2006). Such tests also provide an important index of hemispheric functioning as performance on these tasks requires activation of contralateral motor cortex. Therefore, large discrepancies between dominant and nondominant hand performance may help to localize areas of cortical dysfunction. In other situations lateralized deficits can be ascribed to ipsilateral cerebellar pathology.

It is often desirable for neurologists, psychologist, and other health care practitioners to measure motor strength and coordination to determine neurological integrity as well as functional ability. However, the price and bulk of the devices used for the GPT, FTT, and GST (hand dynamometer) serve to discourage their widespread use in hospital-based clinics, particularly settings that primarily serve groups low in socioeconomic status. Additionally, a test such as the Grooved Pegboard may require 5 minutes or more to complete, approximately a third of the typical 15-minute consultation time in medical settings.

Neurologists and residents in the Louisiana State University Health Sciences (LSUHS) system have historically evaluated fine manual dexterity by asking patients to rotate a coin (usually a quarter) and making qualitative notes with regard to coordination and speed. They have traditionally called this task the Coin Rotation Test (CRT). A modified version of this task has also been used to assess lateralization asymmetries in patients with hemispheric damage (Hanna-Pladdy, Mendoza, Apostolos, & Heilman, 2002). The potential advantages of using a coin versus a bulky and costly device such as the GPT to evaluate motor functioning in a clinic setting are obvious. The coin costs less, is more easily acquired, more easily replaced, does not lose calibration, and is more easily carried by the clinician. Additionally, this testing paradigm requires only a few seconds per hand. However, while others have examined this task (Mendoza, Apostolos, & Hendrickson, 1993), the validity of this assessment technique has not been extensively evaluated previously.

Our aim in the present study was to investigate the validity of using the CRT as a measure of psychomotor processing speed. Additionally, as a transformed coin rotation score (rotations – [(coin drops × .10) × rotations]) has been utilized in the past (Barkemeyer, Santa Maria, Browndyke, Callon, & Dunn, 1998) as a global measure of performance that incorporates potentially clinically important information provided by number of coin drops, this study also examined the unique variance that was accounted for by number of coin drops in GPB performance. Finally, though a cut score of 10 coin rotations or less (one rotation per second) has been used by some neurologists in the LSUHS system to indicate likely fine motor impairment, this cut score was not empirically derived. As such, this study also sought to derive empirically-based cut scores for this task and to examine the sensitivity and specificity of the CRT compared to a criterion variable. It was hypothesized that the CRT would demonstrate convergent validity with other measures of motor functioning and would effectively predict which individuals are likely to demonstrate impaired performance on measures of psychomotor processing speed.

Method

Participants

To be included in the utilized dataset, participants had to have at least a 7th grade education and have 3 or fewer drops on the CRT. Our clinical sample consisted of 86 patients referred to a neurology specialty clinic for a variety of neurologic conditions (seizure disorder, cerebrovascular accident, multiple sclerosis, and Parkinson's disease were the primary diagnoses). A demographically similar sample of 79 participants was recruited from the waiting area of a family practice clinic. These samples were combined for all analyses and

provided a diverse sample of individuals with both normal and impaired motoric performance and psychomotor processing speed ensuring good variability in scores. Additionally, such a group realistically approximates the type of patients that would be screened using the CRT in clinical practice. Four subjects were removed (all from the clinical sample) as the Mahalanobis distance statistic revealed that they were multivariate outliers for GPT, FTT, and GST performance leaving a final clinical sample of 82 patients. Removal of these participants helped to ensure that consistent motoric performance was examined in subsequent analyses. No other univariate (excess of 3.29 SD; Tabachnick & Fidell, 2001) or multivariate outliers were found in the data. Also, data were found to meet necessary statistical assumptions such as normality, homogeneity of variance, and lack of skew. The final combined sample utilized in this study ($n=161$) was 64.0% female, 70.8% African-American (the remainder was Caucasian), and 88.2% right hand dominant with a mean age of 35.6 years ($SD=12.8$; range=17–76 years), and mean education level of 11.8 years ($SD=2.1$; range 7–19 years).

Materials, Design, and Procedures

Participants completed the Coin Rotation Task (CRT), the Grooved Pegboard Test (GPT), the Finger Tapping Test (FTT), and the Grip Strength Test (GST). For CRT trials, the coin used was a common United States quarter. The participant was instructed to use only one hand and turn the coin 180 degrees using only the thumb, index and middle fingers. This process was demonstrated to the participant by the examiner prior to testing. It was also explained that the examiner would count how many 180 degree rotations of the coin the participant could complete in 10 seconds. A small timer with alarm was attached to the examiner's clipboard. The alarm was set to sound after ten seconds so that the examiner could observe and count coin rotations without having to visually keep track of time. During the CRT, if a participant dropped the quarter, the participant was given a new ten seconds and allowed to attempt the task again. Up to three drops were allowed for the CRT with additional drops resulting in exclusion from the study. The CRT variables interest were total complete rotations in 10 seconds (both dominant and nondominant hands) and total number of coin drops during testing.

The other measures used in this study were the GPT, FTT, and GST (Strauss et al., 2006). The GPT measures coordination, fine manual dexterity, and psychomotor processing speed. The participant is instructed to place grooved metal pegs into a metal board with 25 holes as quickly as they can using one hand. Previous studies have found that the GPT loads on a factor separate from other tests of motor functioning (Baser & Ruff, 1987; Stafford & Barratt, 1996). In contrast to the GPT, the FTT (also known as the Finger Oscillation Test) measures internally-driven gross manual motor speed. The participant is instructed to lay their hand flat on a board on which a tapper counter is attached. This counter records the number of times the tapper lever is pushed down and released up by the stroke of the individual's index finger. The GST is a measure of gross manual grip strength. The participant grips the handle of a device called a dynamometer which they squeezed by holding the device pointed towards the floor with the arm fully extended. Administration of GPT, FTT, and GST followed instructions outlined by Reitan (1959). Scores which derive from these tasks were recorded for both dominant and nondominant hands and include: time to complete GPT, GPT number of pegs dropped, FTT mean for five trials with scores within five taps of one another or for ten trials if five trials within five were not recorded in ten attempts, GST mean of two trials in kilograms. Raw scores on all measures are summarized on Tables 1 and 2.

Data were analyzed using SPSS 15.0 (SPSS, 2006). Means and standard deviations were calculated for each of the measures along with Pearson's product-moment correlation coefficients. Multiple regression was utilized to determine the amount of variance accounted

for by number of coin drops. Finally, receiver operator characteristic (ROC) curve analysis was used to empirically determine the best cut-score that should be utilized for the CRT.

Results

Correlations

Pearson's product-moment correlations were calculated for all measures for both dominant and nondominant hands (see Tables 1 and 2). Significant correlations were found between all measures. However, the strongest relationship was noted between the CRT and GPT suggesting that the CRT is indexing a construct most similar to the ability assessed by the GPT. The GPT is a well-validated measure, is reported to have the highest reliability of the three measures utilized (Strauss, Sherman, & Spreen, 2006), and has been described as a cognitive motor task (Mitrushina, Boone, Ranzani, & d'Elia, 2005) further supporting its use as the best criterion variable. Therefore, GPT performance was used as the criterion variable in further analyses.

Multiple Regression

Multiple regression was performed to determine the amount of variance accounted for by number of coin drops in the GPT criterion variable. As participants covered a wide age range and age is known to affect GPT performance (Bornstein, 1985; Mitrushina et al., 2005), participant age was entered on the first step of the model followed by number coin drops. Two analyses were performed, one for dominant hand performances and the other for nondominant hand performances. While age of the participant was found to account for a significant amount of variance in GPT performance (adjusted $R^2 = 15.7$ for the dominant hand and 13.5 for the nondominant hand), number of drops accounted for no significant amount of additional variance (<1% for both hands) strongly suggesting that number of drops does not need to be incorporated into interpretation of the CRT.

Classification of Impaired and Unimpaired Performance

As it had previously been decided that performance on the GPT would function as the criterion variable for this study, this variable was utilized to classify participants as being either impaired or unimpaired in psychomotor processing speed ability. Therefore, GPT raw time to completion scores for each hand were converted to t -scores using norms published by Heaton, Grant, and Matthews (1992). Raw scores were normed according to participants' gender, age, and level of reported education. These t -scores were then used to categorize the level of performance. A binomial categorization was used where a t -score of 25 or below was considered indicative of impaired performance and a t -score greater than 25 categorized as unimpaired. This resulted in 37.3% of sample being categorized as impaired for GPT performance with their dominant hand and 36.5% of the sample being categorized as unimpaired on the GPT for their nondominant hand. The present categorization system was utilized as the general intent of the study was to validate the CRT as a screening method for likely impaired psychomotor processing speed and not as an actual measure. Therefore, it was decided that identification of those with moderate to severe impairment was a suitable goal.

ROC curve

To determine the cut score that would maximize sensitivity and specificity for categorizing impaired or unimpaired performance on the GPT, two ROC curve analyses were utilized. One focused on predicting dominant hand impairment while the other predicted nondominant hand impairment. For the dominant hand analysis, the area under the curve was .75 (SE = .04, $p < .001$, see Figure 1). For the cut score of 10 or less that was

traditionally used in the LSUHS system, sensitivity was .43 and specificity was .88. However, at a cut score of 13 or less, sensitivity was increased to .78 while specificity declined to .63. The results for the ROC analysis of the data for the nondominant hand was nearly identical to the previous results as the area under the curve was .74 ($SE = .04$, $p < .001$, see Figure 2). For the cut score of 10 or less, sensitivity was .52 and specificity was .84. Similar to the dominant hand, a cut score of 13 or less increased sensitivity to .83, though specificity declined to .43. Though even greater sensitivity could have been achieved by raising the cut scores for both dominant and nondominant CRTs, the corresponding decrease in specificity was judged to decrease the clinical utility of the CRT as a screening tool. The cut score of 13 for both hands provided the best balance between sensitivity and specificity values for the task.

Discussion

The results of the present study demonstrate the validity of the coin rotation task (CRT) as an indicator of impaired manual dexterity and psychomotor processing speed. While the (CRT) demonstrated convergent validity with all of the tests of motor functioning used in this study, it was most strongly related to the GPT, a commonly used measure of fine motor performance that is also sensitive to cognitive processing speed (Mitrushina et al., 2005). It is interesting that a simple task requiring only the rotation of a coin for 10 seconds correlates more highly with a sophisticated motor task such as the GPT than with simpler measures of gross motor ability such as the GST or FTT. We believe this is due to fact that speeded performance on the CRT requires more than just intact manual motor functioning, also requiring a high degree of cognitive involvement in the form of monitoring the location of the coin and sequencing the thumb, index, and middle fingers to rotate the coin. Nevertheless, the results of the present study should not be interpreted as suggesting the CRT is a proxy for more sophisticated measures of psychomotor processing speed, such as the GPT.

We view our current results as supporting the use of the CRT as a convenient and inexpensive screening method for determining which individuals are likely to display psychomotor processing speed impairment. Specifically, while it is probable that the biomechanics of the CRT likely impose a ceiling effect on number of coin rotations possible in the allotted time, the task has no significant floor effect making it sensitive to impairments in manual dexterity. As such, the CRT could be effectively used in clinic settings by non-neuropsychologist to efficiently and economically determine which patients should be referred for further neuropsychological evaluation of psychomotor processing speed. Such a simple and cost-effective task has utility as a screening tool for a number of different clinical groups where impaired psychomotor processing speed has diagnostic implications, such as patients who are HIV positive (development of HIV dementia complex) or those with known or suspected cerebrovascular disease. Future research should examine the reliability of the CRT to further substantiate the robustness of the task.

Several other interesting findings were noted. First, while age did account for a significant amount of variance in performance on the GPT (between 16–14%), it accounted for only about half the amount of variance in performance that others have reported (Heaton, Miller, Taylor, & Grant, 2004). Second, the number of coin drops accounted for less than 1% of the variance in performance on the criterion variable. Therefore, no type of correction for coin drops is necessary for this task as has been previously proposed (Barkemeyer et al., 1998). Also, while a cut score of 10 coin rotations or less has traditionally been used for this task to indicate likelihood of fine motor impairment, the present study found that a cut score of 13 rotations or less provided much greater sensitivity to impairment on the criterion measure,

though there was a tradeoff with regard to specificity of identifying psychomotor processing speed impairment.

In sum, given the increasing need to conserve more costly resources (such as neuropsychological assessments) due to budgetary considerations in modern healthcare, the development of inexpensive and effective screening tools to identify those likely to benefit from further in-depth assessment is a timely area of research. The present results support the coin rotation task as a simple, inexpensive, and convenient screening tool for identifying individuals who are likely to demonstrate impaired psychomotor functioning. Such a screening tool has obvious applications in a variety of clinic settings where impaired psychomotor processing speed has diagnostic significance.

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ROC Curve

Diagonal segments are produced by ties.

Figure 1.
ROC Curve Analysis for Dominant Hand Number of Coin Rotations Predicting Impaired Grooved Pegboard Test Performance.

ROC Curve

Diagonal segments are produced by ties.

Figure 2.
ROC Curve Analysis for Nondominant Hand Number of Coin Rotations Predicting Impaired Grooved Pegboard Test Performance.

Table 1
Dominant Hand Raw Scores of All Measures and Pearson's Correlation Coefficients

Measures	Mean(SD)	1	2	3	4
1. Coin Rotation	13.01(3.97)	1.00	-.70	.46	.40
2. Grooved Pegboard	94.81(54.88)	-	1.00	-.51	-.30
3. Finger Tapping	40.55(11.33)	-	-	1.00	.29
4. Grip Strength	30.48(13.65)	-	-	-	1.00

All correlations were significant at $p = .01$

Table 2

Nondominant Hand Raw Scores of All Measures and Pearson's Correlations

Measures	Mean (SD)	1	2	3	4
1. Coin Rotation	11.81(3.58)	1.00	-.64	.38	.31
2. Grooved Pegboard	99.13(51.12)	-	1.00	-.52	-.28
3. Finger Tapping	36.23(10.79)	-	-	1.00	.30
4. Grip Strength	28.66(12.84)	-	-	-	1.00

All correlations were significant at $p = .01$