Coin Rotation Task (CRT): A New Test of Motor Dexterity

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Accepted 11 June 2009

Abstract

Coin-rotation task (CRT), a measure of rapid, coordinated finger movements, was devised as a convenient, easily administered bedside test of motor dexterity; however, very little psychometric data exist regarding this task. The current project was undertaken to (a) provide preliminary normative data, (b) examine the convergent and discriminant validity of the task when compared with other standardized motor measures, and (c) examine the diagnostic accuracy of the CRT. The sample of 86 male participants included 60 controls and 26 patients with unilateral lesions of the left (n = 13) and right (n = 13) hemispheres. The CRT was not significantly correlated with age or education; non-adjusted left- and right-hand normative data are provided. The CRT demonstrated good convergent and divergent validity when compared with other standardized motor measures. The CRT was successful in differentiating control and brain damaged groups with mild motor impairment, and demonstrated an overall classification rate of 84.9%. Levels of sensitivity and specificity of the CRT were comparable with or better than other standardized tests of manual dexterity. The CRT offers a valid, quick, and convenient bedside measure of subtle motor impairment.

Keywords: Manual dexterity; Motor tests; Bedside assessment; Validity

Coin Rotation Task (CRT): A New Measure of Motor Dexterity

Assessment of elementary upper-extremity motor function has been recognized as an integral part of neuropsychological investigation since Halstead (1947) demonstrated that assessment of these abilities could be useful in evaluating the integrity of brain functions. Commonly utilized tests for the assessment of subtle motor impairment include measures of speed and dexterity such as finger tapping (Dodrill, 1978) and Grooved Pegboard (Spreen & Strauss, 1991), and strength (e.g., hand dynamometer).

Neuropsychologists are often called upon for consultations in settings necessitating bedside assessments, particularly in cases of acute conditions such as mild stroke, transient ischemic attacks (TIAs), or traumatic brain injury (Kessler, 2006). Many of the commonly used tests of motor function [e.g., finger tapping test (FT), Grooved Pegboard] require the use of expensive and/or cumbersome equipment that may not always be convenient or conducive to bedside exams. The CRT was developed as a quick and convenient measure for assessing subtle residual lateralized motor impairment in patients diagnosed with TIAs who often evidenced no such deficits on routine neurologic examination (Mendoza, Apostolos, & Hendrickson, 1995). Previous research demonstrates the ability of the CRT to detect subtle hemispheric differences in motor ability post-TIA (Hanna-Pladdy, Mendoza, Apostolos, & Heilman, 2002); however, additional information regarding the
psychometric properties of the instrument is necessary. Thus, the current study was undertaken to evaluate the construct validity and the diagnostic accuracy of the CRT as well as to provide preliminary normative data.

**Materials and Methods**

**Research Participants**

The study sample was recruited and tested at a southern VA medical center. All participants gave informed consent before taking part in this IRB-approved study. The standardization sample consisted of 60 right-handed men aged from 40 to 79 years ($M = 58.9$, $SD = 10.8$). For validation, a neurologic group consisting of 26 right-handed men with unilateral cerebral lesions of recent onset was also tested. There was no difference between patient groups in age [$F(2, 83) = 1.0032$, $p = ns$] or education [$F(2, 83) = .1879$, $p = ns$], see Table 1.

Participants were excluded from the standardization group if they had a history of: (a) neurological or psychiatric illness, (b) significant alcohol/drug misuse as evidenced by available medical records or subject self-report, (c) any non-neurological disease that could cause motor disability, (d) had any evidence of somatosensory deficits, or (e) if they could not complete all motor tasks with both hands. Somatosensory functioning was screened by asking each subject to identify the denominations of various coins placed in their hands; in addition, perception of light touch and suppression on bilateral simultaneous stimulation were employed to detect any somatosensory deficits. In the validation sample, 13 patients had clinical signs and/or CT/MRI scan evidence of neuropathology consistent with left hemisphere lesions (LHs), and 13 had right hemisphere lesions (RHs). Lesions were primarily infarctions ($n = 17$; 65%) and neoplasms ($n = 15$%). For two (8%) participants, neuroimaging revealed only general atrophy, while computerized tomography (CT) scans were within normal limits for the remaining three (12%) participants, despite significant clinical signs (for detailed clinical and lesions data for all participants, see Hanna-Pladdy et al., 2002). All patients in the neurologic (validation) group had a rating of 4/5 or 5/5 on neurologic motor examination.

**Materials**

The measure of interest in this study was a test of motor speed and dexterity, the CRT, which was developed by the primary author. This task requires the participant to rotate a U.S. nickel through consecutive 180° turns, using the thumb, index, and middle fingers, as rapidly as possible for 20 rotations; depending upon the participant’s preference, the coin was rotated either toward or away from the participant. Three trials were given for each hand and the examiner measured the time to completion. If a coin were dropped (rare in all groups), it was immediately returned to the subject while the clock continued to run. To minimize drops that would make quick retrieval difficult and therefore overly penalize the patient, the test was conducted over the patient’s bed sheet, over a desk, or with the examiner cupping his hands under the subject’s hand so that any dropped coin could be immediately retrieved. If the elapsed time was more than a couple of seconds (such as when a coin fell to the floor), the stopwatch was stopped while the coin was retrieved.

To examine the relative utility of the CRT in detecting lateralized motor deficits, it was compared with more traditional measures of fine motor skill, dexterity, and strength. The comparison measures utilized in this study included the Grooved Pegboard test (GP), the FT, and grip strength (GS). The GP is a measure of manipulative dexterity using a pegboard containing 25 holes in a 5 x 5 array with randomly positioned slots. The pegs have an edge along one side that must be rotated to match the slot before they can be inserted. The time to completion of the task was recorded. The FT was administered on a standard version of this task in which the examinee taps the forefinger of the dominant and nondominant hand as quickly as possible for 10 s per trial. The score for each hand consisted of the mean number of taps using the index finger only across 10 trials. GS, measured in kilograms, was assessed using the Stoelting hand dynamometer; the examinee holds the device by his side and squeezes the grip as tightly as possible. Scores for the dominant and nondominant hands were averaged across three trials. Each subject was tested on all motor tests in a counterbalanced order.

Table 1. Means (SD) of demographic characteristics by group

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>LH</th>
<th>RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>59.98 (10.8)</td>
<td>58.54 (9.8)</td>
<td>63.38 (10.2)</td>
</tr>
<tr>
<td>Education</td>
<td>10.91 (3.5)</td>
<td>11.38 (4.2)</td>
<td>10.5 (3.3)</td>
</tr>
</tbody>
</table>

*Note: LH = left hemispheric damage; RH = right hemispheric damage.*
Results

The mean and standard deviation of raw scores on the CRT are presented in Table 2, which also serves as preliminary normative references. Neither age nor education was significantly correlated with performance on the CRT for either the right ($r = .136$ and $-0.25$, $p > .05$, respectively) or left hands ($r = .147$ and $-0.024$; $p = .05$, respectively). Consequently, further analyses do not control for age or education. T-scores for all tasks by location of lesion for the validation sample (with the standardization sample used as the reference group) are presented in Fig. 1.

Scores from the right and left hands was significantly correlated with each other for the CRT ($r = .545$, $p < .0001$), GP ($r = .739$, $p < .0001$), and FT ($r = .788$, $p < .0001$). The deviation between the right and left hands on the CRT task was greater than that of the more traditional motor measures used for comparison.

To assess the construct validity of the CRT, scores were compared with the traditional measures administered. To examine convergent validity of the CRT, CRT test scores were correlated with scores obtained on the GP and FT tests. The correlation between CRT scores and GP scores was significant for the right (RH, $r = .538$, $p < .0001$) and left (LH, $r = .434$, $p < .0001$) hands. Similarly, the correlation between the CRT scores and the scores on the FT was $r = -0.282$ ($p < .03$) for the right hand and $r = -0.400$ ($p < .002$) for the left hand (note that the negative correlation between the CFT and FT reflects the opposite measurement scales of the tasks, higher scores on the FT are better whereas lower scores on the CRT are better). These correlation coefficients are comparable with those between FT and GP for nondominant ($r = 0.571$, $p < .001$) and dominant ($r = -0.508$, $p < .001$) hands. As an initial examination of divergent validity, CRT scores were compared with a measure of global upper-extremity strength (GS), which were not significantly correlated.

To further evaluate the construct validity of the CRT, separate direct multinomial logistic regression analyses were performed to determine the accuracy of this test in predicting lateralization of lesions, with scores on each assessment individually predicting group membership (controls [C], left [LH] or right hemisphere [RH] lesion). Scores on the CRT ($\chi^2 = 71.69$, $p < .01$) and FT ($\chi^2 = 49.07$, $p < .01$) demonstrated the highest classification rate, successfully classifying 84.9% of subjects into their respective groups. For both tests, performance in the nondominant (left) hand reliably predicted membership in the RH group ($p < .001$ for both), and performance in the dominant (right) hand reliably predicted membership in the LH group ($p = .001$ for both). Similar results were found for GP ($\chi^2 = 61.79$, $p < .01$); however, the classification rate of this test was slightly lower (81.4%). Again, nondominant (left) hand performance significantly predicted membership in the RH group ($p = .02$) and dominant (right) hand performance significantly predicted membership in the LH group ($p = .003$). A classification rate of 81.4% was also found for GS ($\chi^2 = 53.63$, $p < .01$); performance in both the dominant and nondominant hands predicted

<table>
<thead>
<tr>
<th>Coin rotation</th>
<th>Hand</th>
<th>40 (n = 15)</th>
<th>50 (n = 15)</th>
<th>60 (n = 15)</th>
<th>70 (n = 15)</th>
<th>All ages (n = 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>R</td>
<td>12.9 (2.7)</td>
<td>12.5 (2.5)</td>
<td>12.5 (1.9)</td>
<td>14.7 (4.44)</td>
<td>13.2 (3.1)</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>14 (2.6)</td>
<td>14.14 (2.6)</td>
<td>14.3 (2.5)</td>
<td>15.4 (2.7)</td>
<td>14.5 (2.6)</td>
</tr>
</tbody>
</table>

Fig. 1. Mean T-scores across motor tasks for control and brain-damaged groups. Note: GP = Grooved Pegboard; CRT = coin rotation task; GS = grip strength; FT = finger tapping test; D = dominant hand; ND = nondominant hand; RH = right hemispheric damage; LH = left hemispheric damage.
RH membership (dominant hand \( p = .03 \), nondominant hand \( p = .001 \)), while only performance in the dominant hand predicted membership in the LH group (\( p = .001 \)).

Next, the diagnostic accuracy of the CRT was examined through a receiver operating characteristic (ROC) and estimates of sensitivity (SN), specificity (SP), positive predictive power (PPV) and negative predictive power (NPV) as well as overall classification efficiency (EFF) are presented in Table 3. Sensitivity and specificity of the CRT for detecting motor impairment due to brain damage (combined left and right hemispheric lesions) was maximized at a time-to-completion of more than 19 s in the left nondominant hand (SN = 0.692, SP = 0.850) and more than 15 s for the right dominant hand (SN = 0.846, and SP = 0.717).

An ROC curve was plotted (see Fig. 2) for scores on the task in both the dominant (right) and nondominant (left) hands. The area under the curve (AUC) statistics, a global index of diagnostic accuracy, indicates an 82% probability for the dominant hand and 81% for an individual picked at random from the “non-diseased” group will have a

<table>
<thead>
<tr>
<th>DH cut score</th>
<th>SN (95% CI)</th>
<th>SP (95% CI)</th>
<th>Eff</th>
<th>PPV</th>
<th>NPV</th>
<th>NDH cut score</th>
<th>SN (95% CI)</th>
<th>SP (95% CI)</th>
<th>Eff</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;35s</td>
<td>0.077 (0.010–0.251)</td>
<td>1.000</td>
<td>0.723</td>
<td>1.000</td>
<td>0.717</td>
<td>&gt;35s</td>
<td>0.077 (0.010–0.251)</td>
<td>1.000</td>
<td>0.723</td>
<td>1.000</td>
<td>0.717</td>
</tr>
<tr>
<td>&gt;30s</td>
<td>0.115 (0.025–0.302)</td>
<td>1.000</td>
<td>0.735</td>
<td>1.000</td>
<td>0.725</td>
<td>&gt;30s</td>
<td>0.231 (0.090–0.437)</td>
<td>1.000</td>
<td>0.769</td>
<td>1.000</td>
<td>0.752</td>
</tr>
<tr>
<td>&gt;25s</td>
<td>0.192 (0.066–0.394)</td>
<td>1.000</td>
<td>0.758</td>
<td>1.000</td>
<td>0.743</td>
<td>&gt;27s</td>
<td>0.385 (0.202–0.594)</td>
<td>0.983 (0.911–1.000)</td>
<td>0.804</td>
<td>0.907</td>
<td>0.789</td>
</tr>
<tr>
<td>&gt;23s</td>
<td>0.308 (0.143–0.518)</td>
<td>0.983 (0.911–1.000)</td>
<td>0.781</td>
<td>0.886</td>
<td>0.768</td>
<td>&gt;25s</td>
<td>0.500 (0.299–0.701)</td>
<td>0.967 (0.885–0.996)</td>
<td>0.827</td>
<td>0.867</td>
<td>0.819</td>
</tr>
<tr>
<td>&gt;21s</td>
<td>0.385 (0.202–0.594)</td>
<td>0.950 (0.861–0.990)</td>
<td>0.781</td>
<td>0.767</td>
<td>0.783</td>
<td>&gt;21s</td>
<td>0.577 (0.369–0.767)</td>
<td>0.900 (0.795–0.962)</td>
<td>0.803</td>
<td>0.712</td>
<td>0.832</td>
</tr>
<tr>
<td>&gt;19s</td>
<td>0.462 (0.266–0.666)</td>
<td>0.900 (0.795–0.962)</td>
<td>0.769</td>
<td>0.664</td>
<td>0.796</td>
<td>&gt;19s</td>
<td>0.692 (0.482–0.857)</td>
<td>0.850 (0.734–0.929)</td>
<td>0.803</td>
<td>0.664</td>
<td>0.866</td>
</tr>
<tr>
<td>&gt;17s</td>
<td>0.462 (0.266–0.666)</td>
<td>0.833 (0.715–0.917)</td>
<td>0.722</td>
<td>0.543</td>
<td>0.783</td>
<td>&gt;17s</td>
<td>0.731 (0.522–0.884)</td>
<td>0.650 (0.516–0.769)</td>
<td>0.674</td>
<td>0.472</td>
<td>0.849</td>
</tr>
<tr>
<td>&gt;15s</td>
<td>0.846 (0.651–0.956)</td>
<td>0.717 (0.586–0.826)</td>
<td>0.756</td>
<td>0.562</td>
<td>0.916</td>
<td>&gt;15s</td>
<td>0.885 (0.699–0.976)</td>
<td>0.450 (0.321–0.584)</td>
<td>0.581</td>
<td>0.408</td>
<td>0.901</td>
</tr>
<tr>
<td>&gt;14s</td>
<td>0.885 (0.699–0.976)</td>
<td>0.567 (0.432–0.694)</td>
<td>0.662</td>
<td>0.467</td>
<td>0.920</td>
<td>&gt;14s</td>
<td>0.923 (0.749–0.991)</td>
<td>0.283 (0.175–0.414)</td>
<td>0.475</td>
<td>0.356</td>
<td>0.896</td>
</tr>
<tr>
<td>&gt;12s</td>
<td>0.962 (0.804–0.999)</td>
<td>0.317 (0.203–0.450)</td>
<td>0.511</td>
<td>0.376</td>
<td>0.951</td>
<td>&gt;13s</td>
<td>0.923 (0.749–0.991)</td>
<td>0.183 (0.095–0.304)</td>
<td>0.405</td>
<td>0.326</td>
<td>0.847</td>
</tr>
<tr>
<td>&gt;11s</td>
<td>0.962 (0.804–0.999)</td>
<td>0.117 (0.048–0.226)</td>
<td>0.371</td>
<td>0.318</td>
<td>0.878</td>
<td>&gt;13s</td>
<td>0.923 (0.749–0.991)</td>
<td>0.183 (0.095–0.304)</td>
<td>0.405</td>
<td>0.326</td>
<td>0.847</td>
</tr>
</tbody>
</table>

Note: DH = dominant hand; NDH = nondominant hand; SN = sensitivity; SP = specificity; CI = confidence interval; Eff = overall efficiency/hit rate; PPV = positive predictive power; NPV = negative predictive power.

![ROC curve](Fig. 2. ROC curve for the CRT dominant and nondominant hands. Note: AUC for the dominant hand = 0.819, AUC for the nondominant hand = 0.805.)
better time-to-completion score than an individual randomly picked from the “diseased” group. The AUC for the CRT was not significantly different ($p > .05$ for all) from the AUCs for the FT (dominant hand = 0.785, nondominant hand = .789), GP (dominant hand = .801, nondominant hand = .823), or GS (dominant hand = .784, nondominant hand = .773) tasks, suggesting comparable diagnostic accuracy of the CRT to these more commonly used tests.

**Discussion**

These results provide support for the CRT task as a valid, rapid, less cumbersome bedside measurement of motor deftness with right-handed men. The CRT significantly correlated with established measures assessing fine motor speed and dexterity (convergent validity) and did not correlate with a global measure of upper-extremity strength (divergent validity). Despite the statistical significance of the relation between the CRT and other similar measures, the correlations were typically in the moderate range suggesting that, while the CRT overlaps domains with these traditional measures, this new measure taps into some areas of motor function not assessed by the GP or FT tasks. Interestingly, the discrepancy between scores in the dominant and nondominant hands on the CRT was greater than that on other motor tasks. This discrepancy between preferred and nonpreferred hands on the CRT has been discussed previously (Hanna-Pladdy et al., 2002) and likely reflects left hemisphere motor control of precise coordinated finger movements. Further research is needed to validate the divergent properties of the CRT. While the GS task does not require the fine motor dexterity needed to accomplish CRT, FT, and GP tasks, it is a measure of motor skill. In addition, the primary clinical signs present within the neurological sample included hemiparesis or unilateral weakness, both of which probably contributed to poor performance on a task requiring upper-extremity strength (GS). Comparing the CRT with measures that do not require any motor skills would provide stronger support for divergent validity.

Construct validity of the CRT was also supported by data demonstrating successful detection of subtle lateralized motor impairment at comparable, or better, rates than traditional measures. Specifically, in logistic regression, time to completion on the CRT task successfully classified 84.9% of individuals as controls, left-hemisphere damaged, or right-hemisphere damaged; all other motor tasks, with the exception of the FT (which was comparable to CRT), demonstrated mildly lower levels of classification though the significance of these differences in classification rates was not examined due to small sample sizes.

The standardization study is satisfactory in terms of presenting a representative cross-section of middle-aged and older right-handed male veterans. However, normative data for women and younger adults stratified by age and sex are needed for standardization to be complete. Although in this sample performance on the CRT task did not significantly change with age, this finding may have been due to low power associated with small sample sizes. Additionally, given the greater difference between the dominant and nondominant hand on the CRT, it will be important to include standardization of left-handed individuals at some later date. It should be noted that the current study did not control for medication use; given the age of the sample (40 and above), it is likely that subjects, particularly in the neurologic group, were prescribed medications that may have affected motor functioning and weakness. However, there is no a priori reason to suggest that medication use would lead to lateralized effects, and thus the sensitivity of the CRT as a measure of lateralized deficits should have been unaffected. Finally, participants in the current sample presented with a diversity of lesions, with cerebral infarctions being the most frequent diagnosis. Given that there was no absolute consistency of localization, except for hemispheric, there is no way to dissociate the potentially confounding effects of pathology type from specific localization of lesion. However, the CRT is, ideally, sufficiently robust to be sensitive to lateralized lesions independent of the specific pathology. Thus, the neurologic diversity of the sample is believed to constitute a relative strength of this study.

Overall, these results suggest that the CRT is a valid instrument that demonstrates comparable diagnostic accuracy to traditional assessments of motor functioning and preliminary normative data are provided. What makes this task unique is its portability and convenience. While it is not suggested that the CRT replace more traditional, standardized methods, this task does provide a quick and practical assessment of fine motor abilities. This new task would be an ideal addition to neuroimaging studies examining motor functioning. Further research is needed to determine the psychometric properties of the CRT in other populations, such as those with traumatic brain injury or infection.

**Conflict of Interest**

None declared.
References


