Qualitative features of finger movement during the Halstead finger oscillation test following traumatic brain injury

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Abstract
Qualitative and quantitative performance on the Halstead Finger Tapping test may help differentiate brain dysfunctional patients from normal controls. “Normal” and “abnormal” finger tapping patterns during this task have been characterized and illustrated pictorially. Data from 65 patients with traumatic brain injury (TBI) and 15 normal controls support the dual proposition that (1) abnormal finger tapping patterns are more commonly observed in TBI patients than in controls and (2) the frequency of abnormal finger movements may relate to the severity of TBI during the acute stages after trauma. Future prospective studies are needed to replicate these findings. (JINS, 2003, 9, 128–133.)

Keywords: Finger tapping, Speed, Abnormal patterns, TBI

INTRODUCTION
Speed of finger oscillation (or finger tapping) may provide useful quantitative information about the presence or absence of brain dysfunction (Halstead, 1947). A number of studies have confirmed that the average number of taps per 10-second interval on the Halstead Finger Tapping Test (HFTT) can distinguish brain dysfunctional patients from normal controls (e.g., Reitan, 1955; Vega & Parsons, 1967) and psychiatric patients (Prigatano & Parsons, 1976).

Speed of finger tapping also has been related to lateralization of cerebral lesions (Prigatano & Wong, 1997; Reitan & Wolfson, 1994), severity of initial traumatic brain injury (TBI) (Dikmen et al., 1995), recovery from mild to moderate TBIs (Haaland et al., 1994), and the achievement of rehabilitation goals after unilateral cerebral vascular accidents (CVAs) (Prigatano & Wong, 1997). A recent pilot fMRI study using the HFTT suggest that multiple brain regions contribute to performing the task (Johnson & Prigatano, 2000). This helps explain its sensitivity as a neuropsychological measure.

In addition to speed measures, qualitative features associated with performing this task may have diagnostic value. In a preliminary study, Prigatano and Hoffman (1997) characterized four qualitative patterns of finger movements in a small group of brain dysfunctional patients. Pattern 1 was described as a “normal” pattern, in which individuals tapped “their index finger while not moving or lifting fingers adjacent to the index finger while it was tapping” (p. 16). Pattern 2 was considered abnormal: “It was difficult for the patient to inhibit movements of the middle finger while the index finger tapped. As the index finger depressed the lever, the adjacent finger lifted off the board and the patient apparently could not inhibit the movement despite repeated instructions to do so” (p. 16). Pattern 3 was also abnormal: “Not only did the middle finger lift off the board while the index finger tapped, but the other fingers also failed to rest on the board. In some instances, the entire hand lifted off the board as the individual attempted to tap at fast rates of speed . . . this pattern was judged to occur when the subject could not inhibit the movement despite repeated instructions” (p. 16). Pattern 4 consisted of other not easily classified abnormal patterns. For example, a patient who had an
oligodendroglioma in the right hemisphere tapped very slowly with the left nondominant hand (mean of 20 taps/10 sec). When tapping with the right hand, she had notable difficulties coordinating finger movements and tended to show an exaggerated version of Pattern 3. Thus, her patterns could not easily be classified as Patterns 2 and 3 and were categorized (for the time being) as Pattern 4. Of their 15 control patients, 14 (93.3%) showed the normal pattern (Pattern 1) compared to only 7 of the 15 (46.6%) brain dysfunctional patients. Prigatano and Hoffman (1997) noted that their findings were preliminary and suggested that a more extensive investigation be conducted.

The purpose of this investigation was to conduct such a study to compare the frequency of abnormal finger movements in normal controls to TBI patients who varied in their severity of injury. It was predicted that brain dysfunctional patients would show a higher incidence of abnormal finger movement patterns compared to normals. Also, the frequency of abnormal finger movements was expected to increase with severity of TBI. This latter hypothesis was based on clinical observation.

**METHODS**

**Research Participants**

Sixty-five (65) patients with an admitting diagnosis of cerebral concussion or contusion served as the experimental subjects (Table 1).

Participants were a “convenience sample” taken from the records of the Department of Clinical Neuropsychology, Barrow Neurological Institute, St. Joseph’s Hospital and Medical Center in Phoenix, Arizona. Patients were classified as having “severe,” “moderate,” or “moderate-to-mild” injuries based on their diagnostic imaging studies and admitting Glasgow Coma Scale (GCS) scores (Jennett & Teasdale, 1974), which were obtained in the emergency room. Neuroimaging studies revealed a high incidence of space-occupying lesions in all groups (i.e., contusions, hemorrhages, and hematomas).

All participants diagnosed with a TBI were referred for a clinical neuropsychological evaluation as a part of their neurological or rehabilitation evaluation. The inclusion cri-

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**Table 1. Characteristics of TBI groups and controls**

<table>
<thead>
<tr>
<th></th>
<th>Severe GCS = 3–8 n = 26</th>
<th>Moderate GCS = 9–12 n = 12</th>
<th>Mod-Mild GCS = 13–15 n = 27</th>
<th>Controls n = 15</th>
<th>F</th>
<th>p</th>
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<tbody>
<tr>
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<tr>
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<td>19.82</td>
<td>9.61</td>
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<tr>
<td><strong>Gender % Male</strong></td>
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<td>75</td>
<td>77.8</td>
<td>46.7</td>
<td>6.33*</td>
<td>.097</td>
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<tr>
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<td>67%</td>
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*Chi Square analysis. *severe group different from mod-mild group; *severe group different from moderate and mod-mild groups; *controls different from severe, moderate, and mod-mild groups.
teria for TBI patients were as follows: (1) Participants were hospitalized and were within 90 days of their documented TBI. (2) Their admitting GCS score and neuroimaging studies classified the severity of their injury. (3) Participants were able to take a brief neuropsychological screening test as a part of their clinical evaluation. (4) Participants had no history of either prior TBI or significant psychiatric illness. (5) Finally, participants spoke English as their primary language (to insure no misunderstanding of instructions).

Fifteen participants from the general population served as controls. They were friends of either the patients’ families or the experimenters. Control subjects reported no history of psychiatric or neurological disease. Their demographic characteristics are listed in Table 1.

**Procedures**

All participants (patients and controls) were interviewed and administered the Barrow Neurological Institute (BNI) Screen for Higher Cerebral Functions (BNIS; Prigatano et al., 1995) followed by the HFTT (Reitan, 1955) by either a staff clinical neuropsychologist or a postdoctoral resident in clinical neuropsychology. The HFTT was not administered to any subject with a peripheral or orthopedic injury to the hand or arm.

**BNIS**

The BNIS provides a bedside screening of higher cerebral functions and typically requires 10 to 25 minutes to administer. Scores obtained from the BNIS include a total score (range of raw scores = 3 to 50 points) and seven subtest scores. Higher scores indicate a higher level of functioning. Total raw scores are converted to age-corrected standard (T) scores (see Prigatano et al., 1995).

**HFTT**

The HFTT produced by the Reitan laboratories was used and is described elsewhere (Halstead, 1947; Reitan, 1955). Participants were instructed to place their index finger on the key and to rest all other fingers on the board. The palm of the hand was also to rest on the back of the board. The fingers did not have to lay flat on the board, but the fingertips needed to remain on the board while performing the task. Failure to do so resulted in a reminder by the examiner. After one reminder, no other reminders were given.

Because participants often fatigue rapidly with this task, they were given three consecutive trials with the dominant hand followed by three consecutive trials with the nondominant hand. They then were instructed to tap for at least an additional two trials with their dominant hand followed by at least two additional trials with their nondominant hand. The procedure was continued until five trials were obtained in which the mean number of taps per ten seconds was within five points of each other. This methodology, which deviates somewhat from the initial instructions by Reitan (1955), has been used in our clinical setting for a number of years.

Participants were classified as having “abnormal” finger tapping patterns if they showed an abnormal pattern of tapping (i.e., Patterns 2, 3, or 4) on two or more of the five trials. This classification was chosen since participants were initially instructed to keep all fingers on the board while tapping with the index finger, and were reminded one additional time if they failed to do so. Thus, they were allowed one trial of abnormal tapping, at which time instructions were repeated. If they showed abnormal tapping on any of the subsequent trials, they were classified as having “abnormal” tapping patterns. Participants classified as having normal finger tapping patterns showed abnormal patterns on no more than one out of five trials and in most instances were completely normal on all trials. Figure 1 illustrates Patterns 1, 2, and 3.

**Data Analysis**

One way analyses of variance (ANOVA) were conducted to determine differences in age and education across groups. Gender differences were analyzed across the three groups using chi-square analysis. A Group by Hand ANOVA was conducted on the raw mean speed of finger-tapping scores with group being the main factor and hand dominance treated as a repeated measure (dominant, nondominant). Paired-wise comparisons between the groups were established using the Bonferroni correction. Paired sample t-tests were calculated for each group to identify differences in speed of finger tapping in the dominant and nondominant hands.

Qualitative performances in finger tapping were first examined by generating a total frequency count of “normal” and “abnormal” responses for each group on dominant and non-dominant trials. For both TBI patients and normal controls, qualitative finger tapping patterns were analyzed by generating the frequency of each pattern and calculating the corresponding percentages of normal and abnormal responses (i.e., Pattern 1 vs. Patterns 2, 3, and 4).

Finally, participants were individually classified as demonstrating a normal or abnormal pattern. A participant was classified as having an abnormal finger tapping pattern if Patterns 2, 3, and 4 occurred on two or more of the five finger tapping trials. A Phi coefficient was used to calculate the degree of relationship between severity of injury and the presence of abnormal finger movements.

**RESULTS**

**Demographic Comparisons**

The TBI patients and controls did not differ in terms of age (F(3,76) = 1.38, p = 0.374) or education (F(3,76) = 0.57, p = 0.635, Table 1). The ratio of males to females was comparable across groups (χ² = 6.32, df = 3, p = 0.097). The majority of each group was right handed (Table 1).
As expected, time of testing after TBI varied across groups ($F(2,62) = 9.11, p = 0.000$; Table 1). The Pearson Product Moment Correlation coefficient between the BNIS total score (raw score) and time since injury for the TBI groups was not statistically reliable ($r = 0.135, p = 0.282$). The correlation between mean speed of finger tapping in TBI patients and time since injury was statistically significant for both the dominant ($r = 0.371, p = 0.002$) and nondominant hands ($r = 0.538, p = 0.000$).

As expected, patients performed worse on the BNIS total score compared to controls. Based on age-adjusted $T$ score values, patients with moderate and severe injuries were at least three standard deviations below the mean. Patients with moderate to mild injuries also were about 2.5 standard deviations below the mean. This finding documents that these patients, despite their GCS admitting scores, were showing significant neuropsychological impairment at the time of this investigation, which undoubtedly is related to why they were hospitalized.

**Quantitative Performances on the HFTT**

A significant group effect was obtained ($F(3,73) = 9.24, p = 0.000$) and a hand effect ($F(1,73) = 12.22, p = 0.001$), but no interaction effect ($F(3,73) = .74, p = -.533$). Patients with severe TBIs tapped slower in their dominant hand than controls and patients classified as having mild-to-moderate injuries (Table 2). Patients and controls consistently tapped faster with the dominant hand. The mean raw scores are comparable to what other investigators have reported for controls in patients with severe TBI (Dikmen et al., 1995; Haaland et al., 1994).

**Qualitative Performance on the HFTT**

In 96% of the HFTT trials using the dominant hand, control subjects showed a normal pattern (i.e., Pattern 1). When the severity of injury was collapsed, all TBI patients showed a normal pattern on 68.1% of such trials. A similar trend was observed when assessing qualitative features using the nondominant hand, but the finding was not as robust. In this instance, on 97% of the trials using the nondominant hand, control subjects showed a normal pattern in contrast to 83.4% of TBI patients.

Collapsing across trials, 44% of the severe TBI patients showed abnormal finger movements in the dominant hand compared to 23% with moderate injuries and 24% with moderate-to-mild injuries. In terms of nondominant hand performance, 20% of the patients with severe injuries showed abnormal finger patterns compared to 9% with moderate injuries and 17% with moderate-to-mild injuries. TBI patients were more frequently classified as having abnormal
finger movements in the dominant hand than controls (Phi = 0.380, p = 0.009). A similar but less robust finding was observed with the nondominant hand (Phi = 0.271, p = 0.134).

Pattern 2 was the most frequent abnormal pattern observed in all TBI groups: 59% of the severe group, 52% of the moderate group, and 75% of the moderate to mild group. In contrast, none of the normal controls exhibited this pattern. Pattern 3, however, was equally present in the patients with severe and moderate TBIs: 40% of the former and 47% of the latter. Pattern 3 was observed in 25% of the patients with moderate to mild injuries. Only patients with severe TBIs exhibited Pattern 4 (1%).

**Classification of Individual Subjects As Showing Normal or Abnormal Patterns of Fingertapping**

Using the criteria of showing Patterns 2, 3, or 4 on two or more trials, 20% of normal subjects were classified as “abnormal” using their dominant hand. In contrast, 72% of severe TBI patients were classified as “abnormal.” Patients with moderate-to-mild injuries fell in the range between 40 to 45% (Figure 2).

**DISCUSSION**

The quantitative findings of this investigation replicate the findings of other investigations. Speed of finger tapping is slower in TBI patients than controls, with patients classified as having severe injuries typically exhibiting the slowest speeds (Dikmen et al., 1995).

In a recent functional MR imaging study with the right hand (Johnson & Prigatano, 2000), activations in regions of the contralateral and ipsilateral primary motor cortex, left lateral premotor cortex, left dorsolateral prefrontal cortex, and ipsilateral cerebellum were activated in normal individuals performing the HFTT. Thus, diffuse damage could easily account for the bilaterally slow speed of finger tapping associated with severe TBI.

The present study also found a negative relationship between the speed of finger tapping and time since injury. Slower speeds were observed in patients who were examined after more time had elapsed since their brain injury. Levin et al. (1990) noted that patients with severe TBI needed a longer time to recover before they could be examined with neuropsychological measures. In this study, acutely injured TBI patients exhibited a similar trend.

**Qualitative Findings**

Most normal individuals have no trouble inhibiting adjacent finger movement when performing the HFTT (Prigatano & Hoffman, 1997). In the present study, controls showed Pattern 1 on more than 90% of the trials with both the dominant and nondominant hands. In contrast, TBI patients showed a much higher frequency of abnormal finger movements or patterns. On almost 32% of the trials, TBI patients showed an abnormal pattern in the dominant hand compared to 3% of the normal controls. Patients with severe TBIs showed an abnormal pattern on 44% of the trials with that dominant hand. These findings suggest that the level of severity of TBI may relate to the inability to inhibit adjacent finger movements when performing the HFTT. This finding, of course, has to be replicated before it can be used as a reliable sign of brain dysfunction. Without such replication, a false-positive error could be made.
Possible Mechanisms of Disinhibition of Finger Movements

The prefrontal cortex plays an important role “in the execution or inhibition of movements” (Fuster, 1997, p. 107). Although the motor system is complex and lesions at various points in the motor pathways can produce slow or disinhibited movements during finger tapping, damage to prefrontal cortex may be especially important. This area is at high risk after severe closed head injury (Prigatano, 1999a). In normal individuals, the lateral and dorsolateral prefrontal cortex shows increased activations of fMRI imaging when performing this task (Johnson & Prigatano, 2000). Finally, TBI patients with prefrontal injuries often show many behavioral (as well as motor) signs of disinhibition (Prigatano, 1999b). Further studies may wish to explore the relationship between prefrontal lesions and problems of inhibiting adjacent finger movements when performing the HFTT during acute and postacute stages after TBI.

Additional explanations should also be explored. Pattern 2 appears to reflect an underlying problem of failure to inhibit while Pattern 3 often gives the impression of a subtle underlying apraxic component to the problem. In this instance, the entire hand is being used as a single finger or lever for depressing the tapping key. Lesions in the frontal and parietal regions as well as colossal lesions have been implicated in various apractic disorders (Heilman & Gonzalez Rothi, 1993). Lesions of the corpus callosum are also common after severe acceleration/deceleration TBIs (Johnson, Pinkston, Bigler, & Blatter, 1996). The relationship between abnormal finger movements when performing the HFTT and lesions of the corpus callosum also needs to be explored. This study does not address the question of clinical-anatomical correlation for the various patterns observed.

REFERENCES


