Analysis of Finger Tapping Parameters in People with ADHD

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Abstract—Spontaneous finger tapping, a measure of spontaneous motor tempo is thought to reflect the pace of an internal attentional timing mechanism, capable of adapting to external temporal events.

Although people with ADHD display difficulties in timing of paced motor tasks and evidence altered time perception, studies have failed to show a difference in spontaneous finger tapping rate and have demonstrated inconsistent findings regarding finger tapping variability.

We hypothesized that a more detailed analysis of finger tapping, which included the two main finger tapping phases: the touch-phase, defined as the time between onset and offset of the finger tap, and the off-phase, the period between offset and onset, would reveal a significant difference between people with and without ADHD.

For this purpose, a highly sensitive system for finger tapping recording and analysis was developed. Finger tapping analysis was carried out on a total of 109 subjects; 68 had been diagnosed with ADHD, and 41 were without any diagnosis (control).

We found that the variability of the touch phase (onset to offset), as measured using the coefficient of variation of the touch phase in subjects with ADHD, was significantly higher than that of subjects in the control group, while no differences were found in other parameters such as the finger tapping rate or the off phase.

Index Terms—Internal Timing, Spontaneous Motor Tempo (SMT), Finger Tapping, Attention Deficit/Hyperactivity Disorder (ADD/ADHD)

I. INTRODUCTION

Spontaneous motor tempo (SMT), a term referring to an individual's rate of spontaneous motor functions, such as gait, speech and tapping, has been the subject of ongoing studies for more than a century [1]. Spontaneous finger tapping, the rate at which an individual taps his/her finger, when requested to do so at an even and comfortable rate, has been the most widely used measure of SMT [1] [2] [3]. Studies have suggested that SMT may reflect the pace of an internal attentional timing mechanism, capable of adapting to external temporal events [4] [5].

Discrimination of stimuli in time, for example (i.e., differentiation between simultaneity and succession of presented stimuli), was affected by finger tapping rate, with perception of smaller temporal intervals facilitated at tapping rates higher than the spontaneous tapping rate [5].

Attention has been linked to SMT, by advocates of the Dynamic Attending Theory [2] [6]. Central to this theory is the presence of an internal adaptive attention oscillator, the basic rate of which is reflected by an individual's spontaneous finger tapping rate. Evidence exists that attention to external rhythms is best at rhythms close to the individual's basic rate. For example, when people were asked to tap in synchrony with an external rhythm, they did so most accurately when the external rhythm was close to their spontaneous finger tapping rate [2].

Attention-deficit/hyperactivity disorder (ADHD) is the most common childhood psychiatric disorder, affecting 4% to 12% of non-referred 6- to 12-year-old children in epidemiological populations [7], while up to 65% of cases persist into adolescence [8]. People with ADHD have difficulties in timing paced motor tasks, and current theory and empirical work suggest that this may reflect a deficit in temporal information processing [9].

In addition, subjects with ADHD were demonstrated to be less accurate at replicating slow rhythms by finger tapping than normal controls, suggesting a difference in time perception in this population [10].

It follows from the above, that the characteristics of spontaneous finger tapping, as a reflector of an internal timing mechanism, should differ between people with and without ADHD.

Yet studies have failed to show a difference in finger tapping rate and have demonstrated inconsistent findings regarding finger tapping variability [11] [12]. Rubia et al. [13], for example, did not find significant differences in speed or variability of free tapping between groups of children with a clinical diagnosis of ADHD and a control group. An fMRI study of finger tapping related brain activity found decreased activity in parietal and motor cortices in ADHD children compared to controls, despite demonstrating no differences in finger tapping rate or variability [14].
One possible explanation for the inconsistent finger tapping findings in ADHD subjects versus controls, is that differences in tapping rate only occur at certain tempi. Another possibility is that a more detailed analysis of spontaneous finger tapping could reveal a difference. It is of interest that the majority of studies of finger tapping in general [15] [16] [17] have measured the whole tap cycle (onset of finger tap to onset of next finger tap). A study that measured the time from onset to offset of the same finger tap in the general population, demonstrated a significant lengthening of this phase with age [18], suggesting a differential contribution of the different tap phases. We hypothesized that a more detailed analysis of finger tapping, which included the two main finger tapping phases: the touch-phase, defined as the time between onset and offset of the finger tap, and the off-phase, the period between offset and onset, would reveal a significant difference between people with and without ADHD.

II. METHODS
A. Settings/apparatus and signal analysis

For this purpose, a highly sensitive system for finger tapping recording and analysis was developed, which included a touchpad mounted on a pressure transducer, connected to a data acquisition card. The pressure signal was sampled and digitized with a sampling rate of 1150Hz, recorded on a personal computer, using an interactive computer program, and saved for later analysis (Fig. 1).

Signal analysis consisted of a preprocessing in which median filtering was conducted to remove noise. Then, during the analysis stage, detection of onset and offset times of finger touch, based on the signal derivative, was carried out. Using these onset and offset times, the two main tapping phases were extracted: the touch-phase (defined as the time between onset and offset of the finger tap), and the off-phase (defined as the period between offset and the next onset). Outliers removal was employed to achieve only spontaneous phases. Finally, statistical parameters such as mean, standard deviation and coefficient of variation were computed for each phase, for the frequency of the finger tapping, and for the ratio between the touch phase and the whole cycle. A schematic block diagram of the recording and analysis system is described in Fig. 2.

B. Participants

One hundred and thirty two young adults (26.4±5.1 years), participated in the finger tapping test. Each subject was asked to tap using his/her index finger of a dominant hand on a surface, at a regular rate, most comfortable to him/her. The tapping duration was 15 sec. Participants signed informed consent and were compensated for their time.

From this group, 22 were excluded from the analysis due to improper diagnosis or taking methylphenidate (Ritalin) shortly before the test. After exclusion there were 68 ADHD subjects (26.8±5.8 years) and 41 control subjects (27.8±5.1 years), matched by age.

III. RESULTS

The mean and standard deviation of each parameter of the finger tapping are summarized in Table 1. As can be noticed, the average finger tapping rate (cycles/minute) of the ADHD group and the control group is quite similar (105.8 and 109.7 cycles/minute, respectively, p=0.874). Similar to [13], we also did not find significant differences in the variability of tapping rate, namely, the intra-subject standard deviation between the ADHD group and the control group (357.8 and 348.4 cycles per minute, respectively, p=0.892). The same was true for the average touch phase and average off phase durations. However, the coefficient of variation of the touch phase was significantly higher in the ADHD group (31.3) compared to the control (25.4), i.e., the touch phase was more variable in the ADHD group (MW test, p=0.003, Fig. 3).
TABLE I. ANALYSIS OF FINGER TAPPING PARAMETERS

<table>
<thead>
<tr>
<th>Finger tapping parameters</th>
<th>ADHD</th>
<th>Control</th>
<th>t1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_{\text{touch}}$ (t-touch, msec.)</td>
<td>122.3±81.6</td>
<td>120.7±71.5</td>
<td>0.01</td>
</tr>
<tr>
<td>$\sigma_{\text{touch}}$ (t-touch std, msec.)</td>
<td>13.0±8.6</td>
<td>10.1±7.3</td>
<td>1.83</td>
</tr>
<tr>
<td>$\mu_{\text{off}}$ (t-off average, msec.)</td>
<td>445.0±195.1</td>
<td>439.7±211.4</td>
<td>0.13</td>
</tr>
<tr>
<td>$\sigma_{\text{off}}$ (t-off std, msec.)</td>
<td>26.8±14.6</td>
<td>32.6±19.6</td>
<td>0.77</td>
</tr>
<tr>
<td>$\mu_{\text{cycle}}$ (whole finger tap cycle, msec.)</td>
<td>567.3±212.4</td>
<td>560.4±230.5</td>
<td>0.16</td>
</tr>
<tr>
<td>$\sigma_{\mu}$ (std t-cycle, msec.)</td>
<td>167.5±187.0</td>
<td>172.2±148.4</td>
<td>0.870</td>
</tr>
<tr>
<td>$C_v_{\text{touch}}$ (t-touch coeff. of variation)</td>
<td>31.3±14.2</td>
<td>25.4±9.5</td>
<td>*U=942</td>
</tr>
<tr>
<td>$r_{\text{touch}}$ (t-touch to t-cycle ratio)</td>
<td>0.227±0.109</td>
<td>0.234±0.096</td>
<td>0.359</td>
</tr>
</tbody>
</table>

1 t-test. Number of degrees of freedom = 108
2 Mann-Whitney test (used when Levene’s test for equal variance was significant).
* Statistically significant difference, after Bonferroni correction for multiple comparisons.

Fig. 3. Coefficient of variation of touch-phase of the control group (left) and of ADHD group (right). Mean data is marked by the rectangles. Error bars are ±1 standard error of the mean.

IV. DISCUSSION AND CONCLUSION

Spontaneous (self paced) finger tapping, a measure of spontaneous motor tempo is thought to reflect the pace of an internal attentional timing mechanism, capable of adapting to external temporal events. Previous studies suggested that subjects with ADHD have difficulties in tasks which involve temporal information processing, and have shown that ADHD subjects exhibit poor performance in such tasks compared to normal subjects [19].

Therefore, studies of finger tapping in people with attention deficit disorder are of interest. Do ADHD subjects display differences in finger tapping compared to controls? So far, the evidence does not support a difference in finger tapping rate and is inconsistent regarding finger tapping intra-subject variability [11] [12] [13].

We hypothesized that a more detailed analysis of finger tapping, which included the two main finger tapping phases: the touch-phase, defined as the time between onset and offset of the finger tap, and the off-phase, the period between offset and onset, would reveal a significant difference between people with and without ADHD.

The subjects chosen for this study were adult ADHD college students. This is a group of interest since age is beyond the developmental stage and academic status speaks for relatively high intellectual abilities.

The results were conclusive. Using a specifically designed and highly sensitive system for finger tapping recording and analysis, we found that the only parameter that differed between ADHD subjects and controls was the coefficient of variation of the touch phase. This parameter was significantly higher in the ADHD group. In other words, the ADHD group had a significantly more variable touch phase than controls, while all other parameters, including durations and variability of the whole tap cycle and the off phase were similar.

Self paced finger tapping is a time reproduction task in which the subject is asked to produce successive equal time intervals by tapping a finger at a self chosen regular rate.

We propose that the touch phase of self paced finger tapping serves as reference phase in time. During this phase the brain must perceive the event of the finger contacting the pad, assess the temporal interval elapsed from the previous touch phase and reproduce it as accurately as possible. This means that the touch phase involves both tasks of attention and timing. Indeed time reproduction tasks have been explained using both attentional and internal timing models. The attentional gate model [20] involves an attentional gate that opens when a person attends to time. A pulse count flows through this gate into a working memory store during the duration of attendance. In contrast to an attentional gate that functions on a per-need basis, internal timing models involve continuously functioning pacemaker–counter [21] or oscillator apparatuses [22].

The increased variability of the touch phase in adult ADHD subjects can therefore be interpreted as fluctuations or instability in attention performance, timing performance or both. The lack of difference in the off phase (the period between onset and offset, i.e., the finger stroke itself) speaks against a predominantly motor mechanism.

This novel finding suggests that studies of ADHD children and adults should employ a more detailed analysis of finger tapping using specific measurements of the different finger tap phases. Does the finding of increased touch phase variability in ADHD adults also apply to children with ADHD? Do other touch phase characteristics such as length of the touch phase differ in children?

Exploring these questions may perhaps lead to better characterization of differences in self paced finger tapping between ADHD and controls at different ages and if findings are significant, perhaps they may aid in diagnosis and follow up.
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