Mobile Reaction Time
Overview and Scoring System of the Sway Reaction Time Beta
September 12th, 2014
**What is Reaction Time?**

Reaction time is a measure of sensory and neuromotor function that encompasses stimulus recognition and processing followed by the initiation of a neuromotor response. Reaction time can be tested with varying levels of difficulty in the sensory phase, or the neuromotor response phase. The Simple Reaction Time (SRT) test is the most elementary form of reaction time measurement, which looks at signal processing of a single stimulus with a defined physical response, such as pressing a button.

**Measuring Reaction Time**

Reaction time is typically evaluated digitally with a computer program, measuring the time lapse between stimulus presentation on the screen and the touch of a keyboard or click of a mouse. More practical and accessible tools for reaction time assessment have been suggested\(^1\), however these tools are typically not digitally connected for archiving individualized comparative measurements and require equipment that is not always available outside of the clinic.

Computerized testing is generally accepted as the gold standard for reaction time assessment despite mouse and keyboard latency variations of 20 to 50 milliseconds\(^2,3\) between commercially available models. The main practical limitation of computerized testing is the immobility of the testing platform. Recent efforts to promote cognitive assessment on mobile devices have attempted to address the portability issue in computerized testing with the use of touch screen devices. A transition to touch screen reaction time assessment has been slowed due to latency in the touch identification mechanisms of mobile devices. Recent studies have failed to produce statistical equivalence between touch-based reaction time assessment and computerized testing\(^4\).
REACTION TIME ON MOBILE

The portability of a mobile device provides a perfect medium for assessment in the clinic and in remote settings. Limitations in the current hardware specifications of most mobile devices should cause concern for accurately measuring response time with touch. Touch event detection accuracy is based on measurements from a projected-capacitive touch screen used in most modern mobile devices. The projective-capacitive touch recognition occurs in electrical pulse cycles varying between 20 and 200 milliseconds, depending on device size, age and other hardware specifications. The continuous and cyclical “searching” for a touch event creates a variable delay based on where in the cycle the capacitive signal is when contact occurs.

Hardware testing has shown variability in device size as the main factor for touch latency, with average scores ranging between of 50 to 150 milliseconds for current Apple, Samsung and Windows mobile devices. Mobile phones exhibit the least variability with a smaller screen and shorter signal cycle, which was confirmed in Sway's paired samples comparisons of touch to high-speed camera analysis.
An additional element of delay occurs within signal processing, or a delay from input detection to operating system notification. Software processing lag can delay the measurement once the input has been detected, but before the software measures a response. Estimated touch screen latency and input lag have been analyzed in small samples with neurocognitive testing platforms on a mobile device. The results showed slower and more variable measurements of response times when compared against computerized models.

**Motion Based Reaction Time**

Sway Medical’s proprietary motion based reaction time assessment presents an alternative to touch screen measurements. Using the built-in motion sensors of the device, at a frequency of 500 to 1000 hertz (one to two milliseconds), Sway’s Reaction Time module presents a portable tool with improved accuracy over touch screen implementations.

To perform a Sway Motion Reaction Time test, the user is instructed to hold the device in landscape with both hands on the device. The user then presses “Begin Test” to initiate the test. A randomly selected fore period is used to prevent anticipation of the stimulus. When the screen turns orange, the user must move the device in any direction. Once the movement exceeds a small threshold, a proprietary algorithm is used to estimate initial movement in response to the stimulus. Once five trials are completed an overall reaction time score is computed.
**Motion/Touch Comparison**

Results from paired samples testing comparing touch and Sway Motion Reaction Time to high-speed camera (GoPro Hero3; 240 fps) showed motion to have a significantly ($\alpha = 0.01$) smaller latency compared to video analysis as a gold standard. Motion was also more consistent across device size, with touch latency increasing as the device screen size increased from iPhone to iPad mini to iPad. Sway Motion Reaction Time did not show device size related variations in latency.

---

**Reaction Time Scoring**

Sway uses the raw measurement of reaction time, over five trials, to calculate an overall reaction time score for each test session. The fastest and slowest reaction time scores are dropped and an average of the remaining three scores is stored. Additionally, the standard deviation of the scores is kept as a variable of consistency within each test.

A Sway Score is derived using a proprietary algorithm to convert the reaction time score and variability to the 100-point Sway scale for comparison. A perfect Sway score is 100, indicating high reaction time speed. Any score faster than 150 milliseconds, will convert to 100 on the Sway Reaction Time scale. The average reaction time score (in milliseconds) is also presented in the results screen on both the mobile and web platforms to improve the comparison with traditional reaction time tests and normative data.
**WHAT DOES MY SCORE MEAN?**

The Sway score is intended to provide an individualized baseline of each athlete or patient’s own sensory and neuromotor function. Previous research on simple reaction time using computerized modalities have established normative scores for different populations based on age, which shows an improvement following adolescence, a peak in young adulthood and a slow decline with age\(^7,^8\).

<table>
<thead>
<tr>
<th>Age Range</th>
<th>&lt; 18</th>
<th>18 - 25</th>
<th>45 - 60</th>
<th>60+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (ms)</td>
<td>357</td>
<td>243</td>
<td>280</td>
<td>302</td>
</tr>
<tr>
<td>SD</td>
<td>95</td>
<td>32</td>
<td>40</td>
<td>62</td>
</tr>
<tr>
<td>Sway Score (Estimated)</td>
<td>56.64</td>
<td>72.32</td>
<td>66.09</td>
<td>63.10</td>
</tr>
<tr>
<td>SD (Estimated)</td>
<td>11.21</td>
<td>6.10</td>
<td>6.31</td>
<td>8.95</td>
</tr>
</tbody>
</table>

*Estimated scores are based on conversion of milliseconds to Sway score.*

Normative scores can be used to compare neuropsychological performance, but individualized baselines, for simple reaction time, have been shown to be more accurate for individual evaluation than normative comparisons\(^9\).

**IDENTIFYING IMPAIRMENT**

The establishment of an individualized baseline is important to provide the most accurate benchmark for each athlete or patient. Neurological injury has been shown to induce a decline in simple reaction time between 40 and 150 milliseconds\(^10,^11,^12\) depending on severity of the injury and modality of reaction time testing. Sway’s Motion Reaction Time beta is currently in clinical studies evaluating deficits resulting from mild traumatic brain injury and neurological conditions.

**MEASURING RELIABILITY**

The Sway Balance system analyzes score distribution, over multiple tests, and assigns a “normal range” established using a confidence interval \((\alpha = 0.05)\). The confidence interval provides an individualized range, with 95% confidence that any new score will fall into the range, if the test is performed without a change in independent variables. Sway uses a color-coded system to determine whether consistency has been established. Green indicates low variation over at least three tests. Yellow shows moderate variability with at least three baseline tests. Red indicates either a high variability in test score or not enough tests have been completed. If an athlete shows a red confidence band, the athlete should be retested until a yellow or green confidence band is established.
WHAT IF I HAVEN’T ESTABLISHED A BASELINE?

Every athlete should establish a reaction time and balance baseline, however this does not always occur. In athletes that have not established a proper baseline, the test administrator should use caution in relying on any single test. If a concussion is suspected, the athlete should be immediately removed from participation.

A Sway test should be performed on the sideline if the athlete appears to show no obvious signs of concussion, and does not report symptoms. If the athlete does exhibit signs of concussion or performs poorly on their Sway test, the athlete should be removed from participation until they are released to return to play by a qualified medical professional.

IT IS IMPORTANT TO USE THE SWAY SOFTWARE AS ONLY ONE TOOL IN A MULTIFACETED APPROACH TO THE EVALUATION OF AN ATHLETE WITH A SUSPECTED CONCUSSION. BALANCE AND REACTION TIME SHOULD NOT BE RELIED UPON AS THE ONLY FACTOR IN MAKING A RETURN TO PLAY DECISION.

Sway can also be used to track a player in recovery from a concussion when a baseline is not available. Medical professionals should consider administering a Sway test daily to see if scores continue to improve or if they have plateaued. If the athlete is scoring consistently, it may be an indication that scores have returned to normal. With any test, there is a brief period of familiarization, so it is important to take multiple tests before using data from the Sway system to assist in any clinical judgment.

CONCLUSION

Recommendations from the 4th International Consensus Statement on Concussion and the National Athletic Trainer’s Association (NATA), suggest the establishment of a neuropsychological and balance baseline for every player. Establishing an individualized baseline for each player, with the simple Sway test, provides an objective assessment for testing on the sideline and in recovery. The use of Sway makes return to play decisions much less about judgment and more about quantitative measures. To establish an effective baseline, athletes should be tested at least three times, with Sway scores falling within an acceptable range of variation.
REFERENCES


