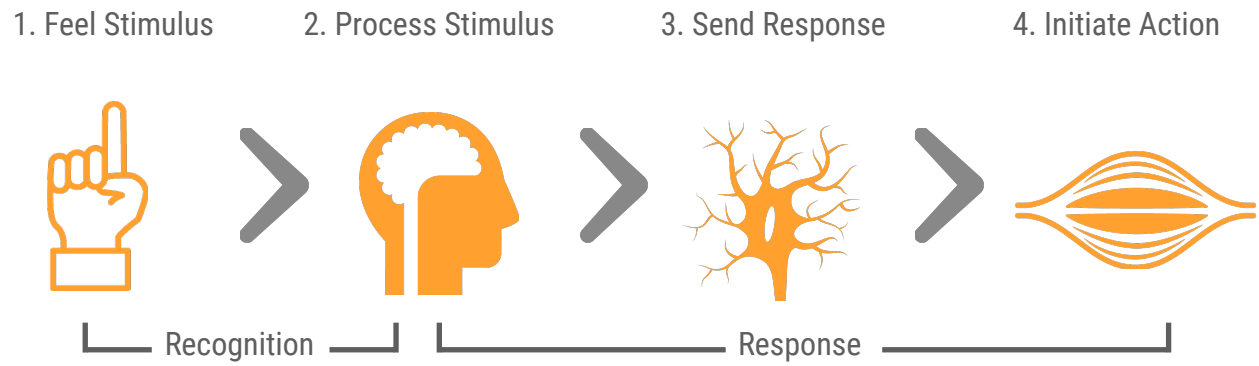

# Reaction Time and Reaction Time Variability

## Overview of Reaction Time and Variability
## Testing Methods and Procedures

March 15th, 2018

# What Is Reaction Time?

Reaction time is a measure of sensory and motor function that encompasses stimulus perception and processing followed by the initiation of a motor response. The Simple Reaction Time test is the simplest form of reaction time measurement, which looks at signal processing of a single stimulus with a defined physical response, such as pressing a button, but its much harder to measure accurately than you might realize. Reaction time has been used as a generalized measure of cognitive function for over a century (Merkel, 1885), and it is used by a rapidly growing number of clinicians and clinical researchers for evaluating a wide spectrum of neurological disorders.




# Why Tactile Reaction Time?

As early as the late 1950s, it was pointed out that tactile reaction time would be a higher fidelity test of the nervous system than visual reaction time. The visual RT test involves many levels of confounding factors with the transmission of the visual signal (Leonard, 1959) and it was Leonard that first stated that tactile stimulation would be the best way to obtain an accurate measure of pure reaction time with minimal distractions. Additionally, since that time, it has become well established that visual signals engage multiple redundant pathways that diminish the effectiveness of the visual RT as a test – damage one of the many pathways and the individual taking the test can "re-route" the test through another pathway (e.g., simplest way to think about this is that both eyes receive the input signal and covering one eye will not diminish the RT performance). Although tactile reaction time was recognized decades ago as a potentially useful cognitive assessment tool, very few studies deployed the method simply because of the difficulty and/or cost in administering the test.

# Measuring Reaction Time

Reaction Time is typically measured with a computer program, calculating the time lapse between a stimulus presentation and the touch of a screen or click of a mouse. The majority of the reaction time tests available to clinicians today use either a visual (screen flash) or auditory (loud beep) stimulus to trigger the subject to respond. Although it is easy to program a smartphone app to flash its screen or make a noise, this is not the ideal way to measure reaction time.

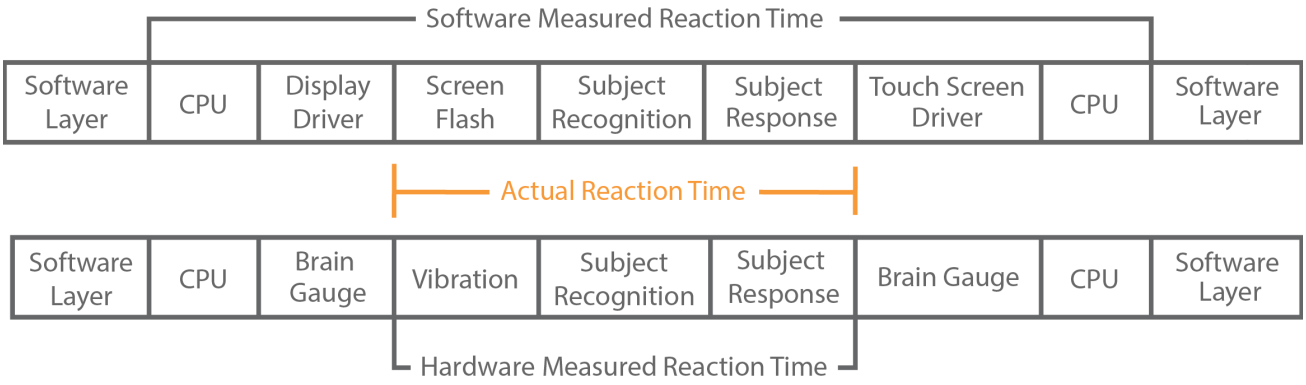
Computerized testing is generally accepted as the gold standard for reaction time assessment despite the fact that there are inherent delays introduced by the computer system. Delays are introduced by both stimulus presentation (e.g., screen refresh rate) and the user response (e.g., integration of keyboard or mouse with the operating system). The computer screen is typically only refreshed at a rate of 60Hz. This means that even in the most ideal scenario, a screen flash occurs within 17 ms of the time it is instructed to do so. Recent efforts to make cognitive assessment more portable have involved much of this computerized testing taking place on touch screen devices, like tablets and mobile phones. These touch screen devices actually compound the latency, by using a visual stimulus (refreshed once ever 17ms) with an inferior method for the subject to respond. The touch based drivers and even the capacitive sensing screens that have revolutionized mobile computing were not built with speed in mind. Recent studies have failed to produce statistical equivalence between touch-based reaction time assessment and computerized testing.

# Reaction Time with Brain Gauge

The Brain Gauge approaches true measurement of a subject's absolute reaction time: it minimizes errors introduced by the computer and operating system. A strong tactile stimulus is applied to the finger tip of the subject to ensure that the subject can't blink and miss the stimulus. Regardless of the environment, such as ambient noise and lighting conditions, the vibration will be felt by the subject. In order to respond, the subject depresses the second tip, which touching their opposite finger. The subject only has to press the tip down 0.5 mm to trigger a response; even the most sophisticated gaming mice have displacement thresholds of 2mm. The Brain Gauge is built to be the most accurate reaction time measurement available on the market today.

# Reaction Time Delay Comparison

Latency in Software vs Hardware Reaction Time

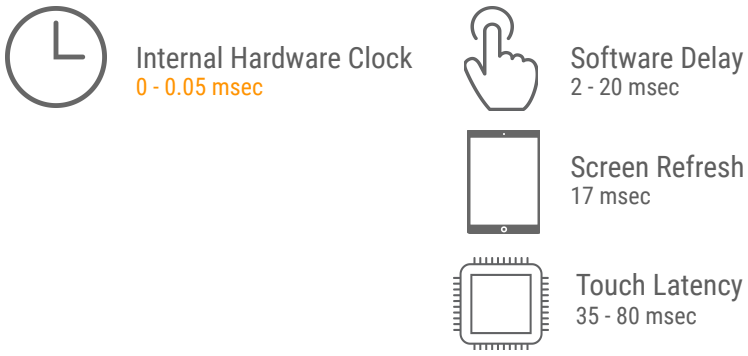



## Software vs Hardware

The Brain Gauge's hardware reaction time offers a significantly more accurate and more precise method of measuring reaction time than virtually any other commercially available system. A typical software reaction time task (such as ImPACT or Sway) relies on accurate time-measurement by using a smartphone or desktop PC's computer processor. This approach is problematic for a number of reasons. Most reaction time tests use a visual or auditory beep to trigger the subject to respond, this requires driver level interaction on the PC/tablet/ smartphone and can vary by 2-20ms based on the age/performance of the device. Most monitors and smartphone screens refresh at a rate of 60Hz, in other words the image on screen only changes once ever 17 ms. Touch-screens and mice introduce another driver level delay as either the USB bus or the touch screen

# Reaction Time Delay Comparison

Latency and Variability in Software vs Hardware Reaction Time

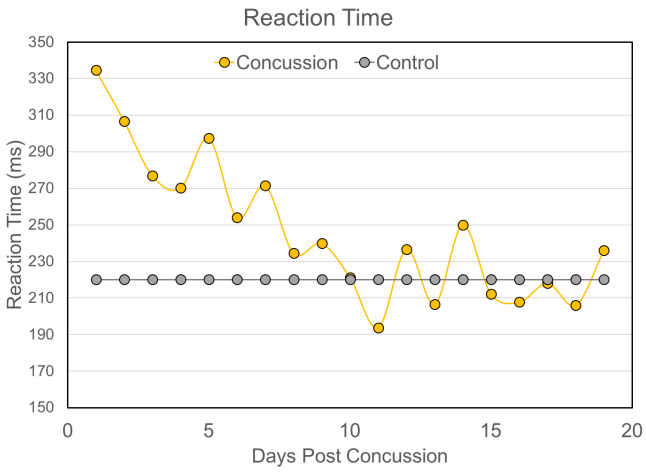


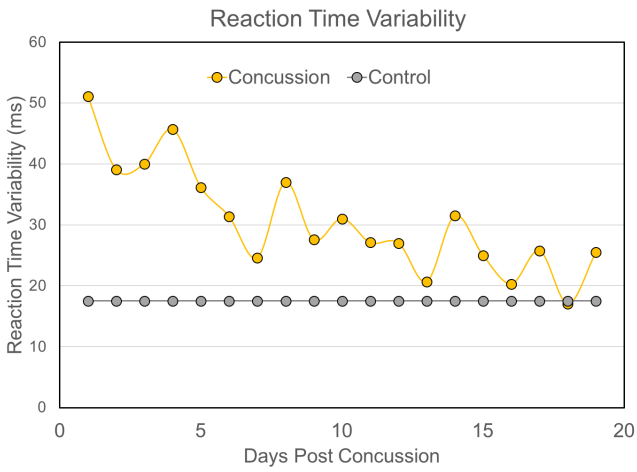
driver is polled by the CPU. This introduces a minimum of 35 ms latency in the reaction time measurement. All of these problems are inherent to visual reaction time tests, there is no way to account for the delays with software.

Hardware reaction time eliminates systematic delays from the equation, resulting in a true measurement of a user's reaction time. The Brain Gauge has a microprocessor completely devoted to measuring the reaction time of the subject; it's not impacted by processes running in the background and it does not degrade with age. The Brain Gauge will always measure reaction time with the same incredibly precise resolution. Without the inherent delays of a software reaction time test, one can trust that Brain Gauge offers the best, most accurate measure of reaction time.

# Reaction Time Variability Measure

The Brain Gauge's ability to precisely measure reaction time, opens the door to a new, potentially ground-breaking measurement. Reaction Time variability, when measured accurately, is a metric that recognizes the most sensitive changes in the user's performance - something that is extremely useful for detecting mild cognitive deficits, albeit a mild concussion or any number of neurocognitive conditions. Unlike other commercially available online neurocognitive tests, which have 50-100 millisecond resolution, Brain Gauge has sub-millisecond resolution which allows for an accurate measure of reaction time variability.

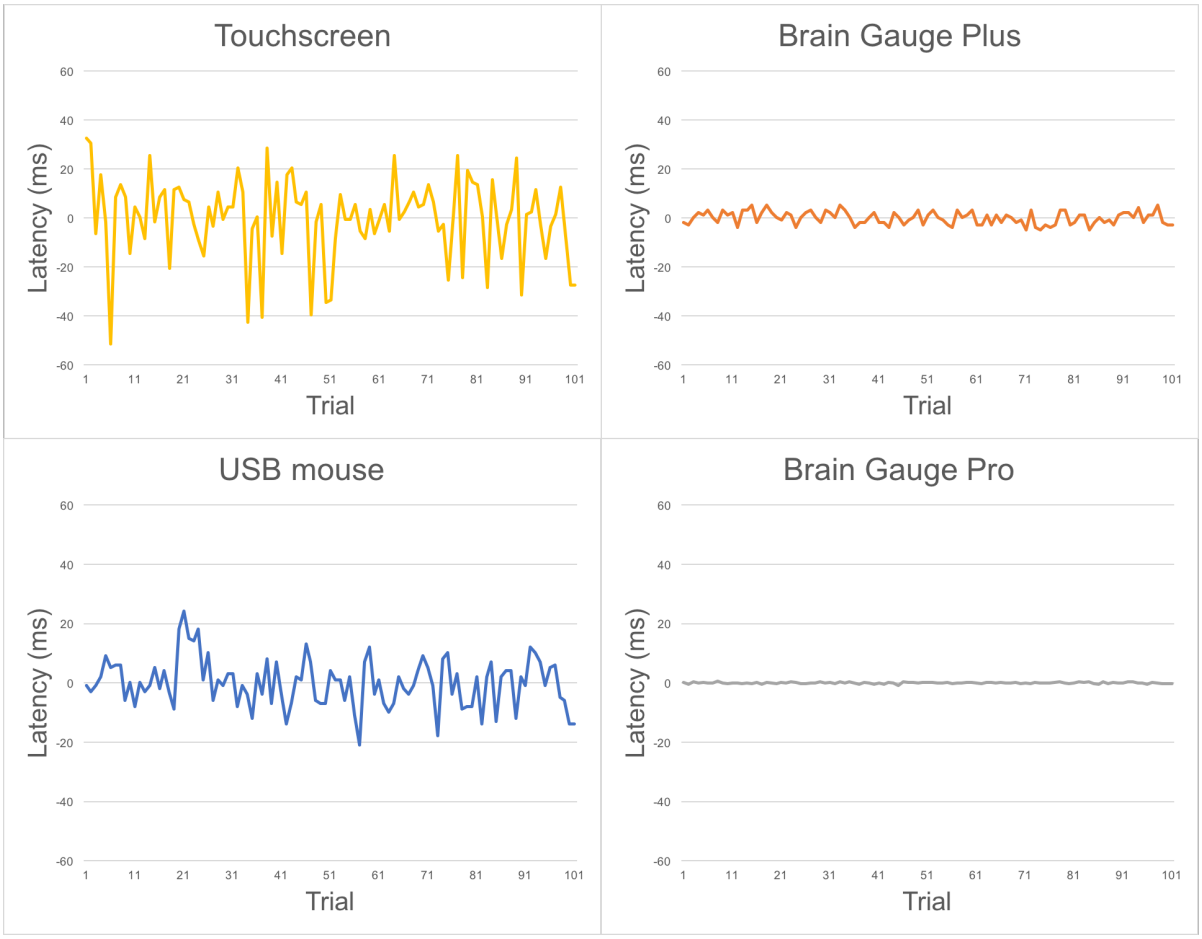


The reaction time variability measure has been proven to be an important in assessing cognitive function after mild traumatic brain injury (Cole, 2018), and even appears to be more sensitive than reaction time in tracking recovery from concussion. The time course for reaction time variability to return to baseline after a concussion is significantly longer than the time course for simple reaction time to return to baseline; reaction time variability may give more accurate information about complete and true recovery than does reaction time.

# Real World Examples

We compared analogs to common mobile-touchscreen (e.g. iPhone) and USB mouse (ImPACT) reaction time tests with our own dedicated-hardware protocols. Both the touchscreen and USB mouse introduced significant latencies and had high variability even after adjusting for average delay, while both the Brain Gauge Plus and Pro were consistently within 5 and 1ms, respectively, of true reaction time. While other protocols fail to produce consistent results, the Brain Gauge delivers a reaction time test that allows you to make reliable inferences about brain health.



# Reaction Time Scoring

The Brain Gauge uses raw measurements from multiple trials of reaction time to calculate an overall reaction time score. The software uses a machine-learning algorithm to produce a score representative of the user's performance on the task. Our population database contains reaction time measures for over 10,000 subjects spanning hundreds of clinical studies. The average reaction time for healthy college athletes aged 18 - 22 is shown in the table and can be referenced when determining when an individual has recovered from a concussive event. Reaction time and Reaction time variability have been shown to be impacted by a number of neurological conditions.

| Metric | Healthy Average | Concussed Average |
|---|---|---|
| Reaction Time | 220 ± 3 ms | 303 ±14 ms |
| Reation Time Variability | 18.1 ± 1 ms | 47 ± 5 ms |

# Conclusion

Brain Gauge provides a better, more objective assessment of reaction time and reaction time variability. With higher resolution and minimized delays, the Brain Gauge offers the best method of assessing neurocognitive function through reaction time and reaction time variability. With no required baseline, a user can easily test and view their results within a number of minutes. The use of Brain Gauge makes return to play decisions much less about judgment and more about quantitative measures.

# References

Cole, W., Gregory, E., Arrieux, J., Haran, F. Intraindividual Cognitive Variability: An Examination of ANAM4 TBI-MIL Simple Reaction Time Data from Service Members with and without Mild Traumatic Brain Injury. *J Int Neuropsychol Soc. JINS* **24,** 156-162 (2018).

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