Latency in sensorimotor synchronization experiments: Comments on Schultz and van Vugt (2015)

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Abstract

Schultz and van Vugt (2015) compare their Tap Arduino system for finger tapping experiments against a more complex system made up of FTAP software (Finney, 2001a), a PC, the Linux operating system, a USB-MIDI interface, and a MIDI percussion pad. They report that the FTAP system showed high latency between tap and sound, with high variability, and suggest that this is due to latency introduced by USB-MIDI and the multi-component complexity of the FTAP system. However, their own data indicate that the specific MIDI drum pad they used for input in their FTAP configuration was the primary source of the latency attributed to FTAP. The FTAP-MIDI system itself both collects and generates MIDI data with demonstrable millisecond accuracy and precision.

Keywords: Auditory feedback, millisecond resolution, USB, Musical Instrument Digital Interface (MIDI), Linux, FTAP

Schultz and van Vugt (2015, henceforth SVV for brevity) describe an Arduino-based input device that produces auditory feedback for use in sensorimotor synchronization experiments, and compare it against personal computer systems that use MIDI devices for input and output in such experiments. They report that both FTAP and Max (software applications that run on PCs running Linux and MacOS, respectively) have a 15 ms latency between tap and generated auditory feedback (with high variability), and suggest that Tap Arduino might be a better tool for running such experiments. However, their own data indicate that the specific percussion pad that they used in their FTAP and Max conditions was the major source of their measured 15 ms latency. As such, their paper shows deficiencies with one particular model of percussion pad, but does not demonstrate any problems with FTAP or Max.

SVV start with the misconception that the complexity of a PC system will necessarily add significant latency that will not be present in an Arduino environment. They repeatedly claim that USB processing of MIDI data will add latency, referring to delays resulting from

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"USB communication", "MIDI-USB conversion", and 8-ms USB polling. However, their own data show that these claims are false. The FTAP distribution includes a loop test that allows users to confirm that their own system processes MIDI input and output data with millisecond accuracy and precision (see Finney, 2001a, 2001b, the FTAP documentation, and the FTAP web page for further detail). It is a rigorous test of the entire "FTAP-MIDI system": the FTAP software, the PC hardware, the Linux OS, the Linux device drivers that process MIDI and USB, and the hardware MIDI interface (e.g., a USB-MIDI adapter). SVV report that the loop test ran successfully on their system, demonstrating that FTAP processed approximately 1000 MIDI keystroke events per second simultaneously on both input and output. USB and MIDI processing added no delays that were relevant for millisecond data collection, contrary to their claims.

A second issue is that SVV confound the particular input device (the Roland HPD-15 percussion pad) used in their PC conditions with the software package. A PC-MIDI system running FTAP or Max needs to be attached to a MIDI input device (a percussion pad or keyboard) to collect a participant's taps, and to a MIDI output device (a synthesizer or sampler) to generate audio. The end-to-end latency of such a system (what SVV report as "FTAP" or "MAX" latency) will be the sum of 3 independent components: input device latency, PC-MIDI system latency (close to zero in the case of FTAP, as shown above), and output device latency. SVV repeatedly report "percussion pad" and "FTAP" latency as if these measures were independent, when percussion pad latency is actually the major component of their "FTAP" latency (and also of their "MAX" latency: the fact that the "FTAP" and "MAX" latencies are frequently not differentiated by their statistical measures is not a coincidence). This confound is worsened by the fact that SVV used an input device in their FTAP and Max comparisons (the Roland HPD-15 percussion pad) that was *obviously faulty* (it missed taps and generated superfluous taps, as reported by the authors). They provide data showing that the HPD-15 has an internal audio latency of 9 ms, and admit (p 10) that "it appears that the percussion pad is accountable for the majority of the [FTAP/Max] latency". Although they assume that the HPD-15 is a representative percussion pad, they provide no evidence that that is the case (in fact, another paper co-authored by Schultz (Mills, van der Steen, Schultz, & Keller, 2015) reported that the Roland Handsonic 10 percussion pad had a significantly lower MIDI latency, between 0 and 5 ms).

Finally, Tap Arduino's limitations should be noted. It is basically a microprocessor-based button box with debounced input that can generate auditory feedback; it is not much different (other than cost) from a classic button box (e.g., Cohen, MacWhinney, Flatt, and Provost, 1993). Tap Arduino can run no interesting experiments without being attached to an external PC for stimulus presentation and experimental control, and the PC configuration is critical to the real-time performance of any experiment using Tap Arduino. SVV do not provide any measurements of the overall performance of such a complete system. In particular, using two separate devices (with independent hardware clocks) for the input and output of an experiment raises a host of issues related to synchronization (e.g., clock drift, and how to accurately calculate asynchrony data) which SVV do not satisfactorily address. These issues do not arise with PC-MIDI systems such as FTAP and Max, which are also able to provide a high degree of control over feedback manipulations that is not available in other software packages (see Finney, 2001a). Finally, although SVV rigorously demonstrate that Tap Arduino produces immediate auditory feedback, they provide no

evidence that the timing data collected by Tap Arduino is accurate or precise.

SVV raise the valid point that it is important to do end-to-end measurement of experimental systems (a point repeatedly made by Richard Plant and colleagues, e.g., Plant, Hammond, and Turner, 2004), and they demonstrate the latencies that can result when a poorly performing input device is used. Validating such systems is non-trivial, and FTAP and Max users need to be careful with their choice of input and output devices. An accurate, validated, portable Arduino-based input or output MIDI device that could be used with FTAP or Max would be a useful contribution. However, SVV's results provide no basis for concern about the millisecond real-time capabilities of PC systems using Linux, USB, Max, or FTAP.

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