Measuring experimental software timing errors in the presentation of visual stimuli

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Nowadays psychology researchers have a wide range of experimental software alternatives to present visual stimuli. Nevertheless, most of these tools have to deal with two main issues: most devices used for the presentation of the stimuli have low refresh rate (typically at 60-85 Hz) and the most widely used platforms (e.g. MS Windows on a PC) are not real-time systems.

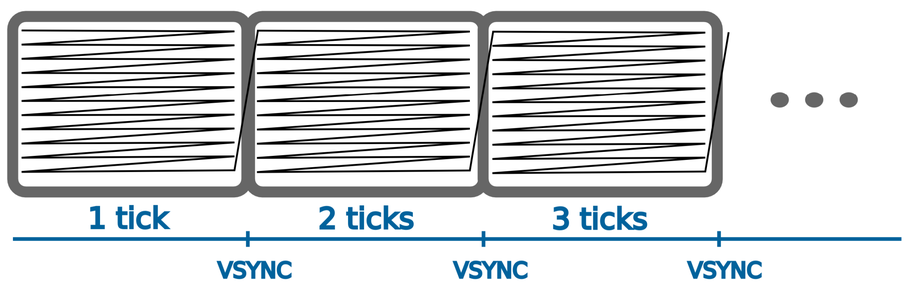


Figure 1. Representation of the refreshing process in a CRT display. This process is slightly different in TFT displays, but both types of displays are constrained by their refresh rates (1 tick = 16.67 ms at 60 Hz). Therefore, visual changes with durations shorter than the vertical synchronization signal (VSYNC) interval should not be scheduled.

Figure 2. Non real-time and real-time operating systems metaphors. A non real-time OS works like a yield, maximizing the throughput of the road, but being not predictable. A real-time OS works like traffic lights, where predictability and fairness are preferred towards maximum throughput.

Method

An array of specialized software for delivering visual stimuli accurately on PCs was tested using the Black Box Toolkit [1]:

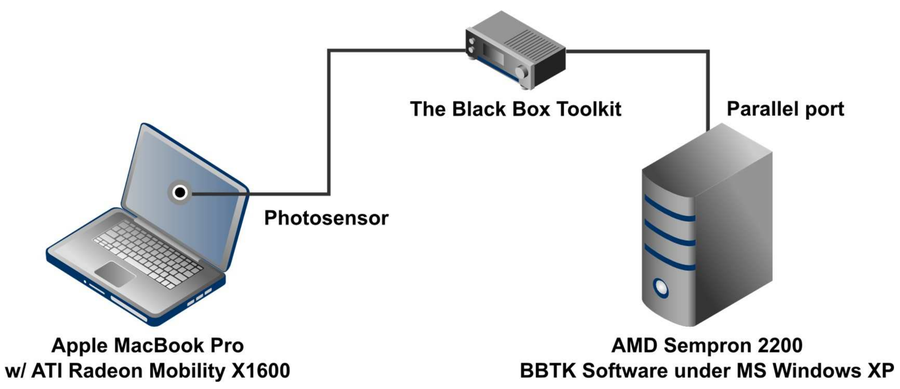


Figure 3. Presentation and measurement equipment.

Figure 4. OS and software combinations tested. E-Prime 2.0.8.90 [2], DMDX 4.0.4.8 [3], and Psychopy 1.64.00 [4] under Windows 7 Professional 32-bit edition; and Psychopy 1.64.00 and the OpenGL based software proposed by Stewart [5] under Linux 2.6.33-29-realtime.

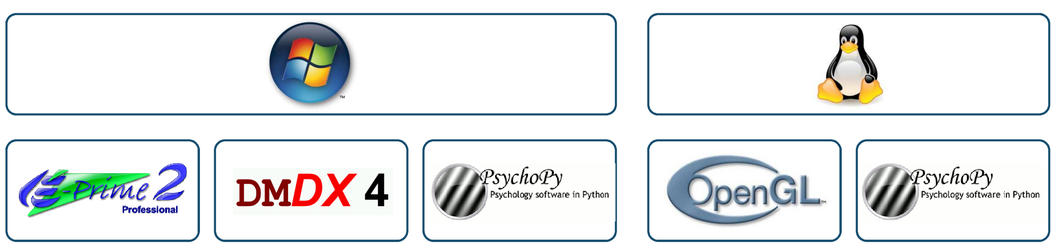
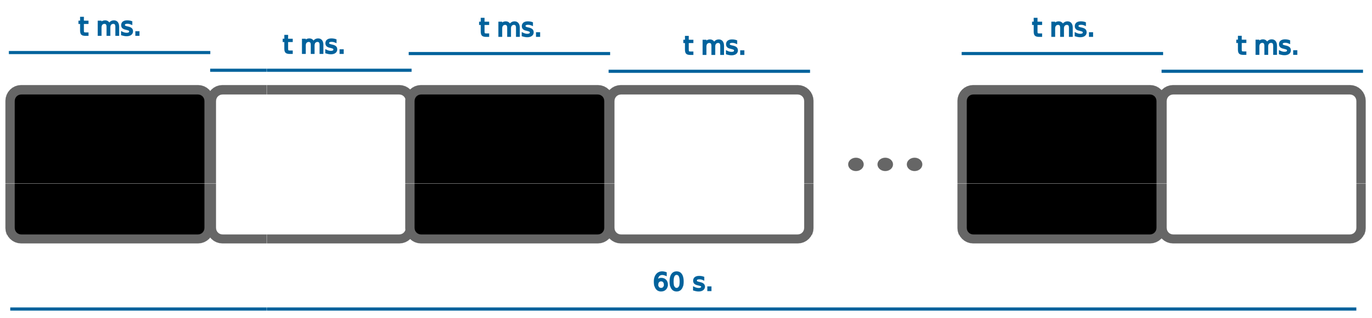


Figure 5. Black-to-white animations used in the tests [6]. Each animation was scheduled to be repeated with frame durations of t=16.67 ms, t=50 ms, t=100 ms, t=200 ms, t=500 ms, and t=1000 ms, in 5 independent series of 60 seconds. In order to discard unstable measurements, the first and the last 5 seconds were discarded in every test, resulting in 250 seconds of measurements for each frame duration and software combination.



Results

		16.67 ms			50 ms			100 ms			200 ms			500 ms			1000 ms		
		M	SD	Lost	M	SD	Lost	M	SD	Lost	M	SD	Lost	M	SD	Lost	M	SD	Lost
Win	E.Prime	0.07	2.82	85	16.54	2.17	1896	16.53	4.78*	1098	16.22	2.29	585	15.62	2.29	250	14.61	2.24	130
	DMDX	-0.03	1.97	1	-0.10	2.10	0	-0.20	1.91	0	-0.41	1.91	0	-1.00	1.93	0	-2.06	1.94	0
	Psychopy	8.44	7.33	4921	8.57	6.48	1073	0.46	13.05	753	0.84	2.12	6	2.11	1.94	0	4.22	2.00	0
Linux	Stewart'06	0.47	4.17	551	-0.05	2.27	12	-0.05	2.36	5	-0.05	2.62	5	-0.02	3.43	7	-0.09	4.35	8
	Psychopy	0.07	3.09	37	2.19	6.40	459	1.70	3.73	36	3.28	3.61	15	-0.26	7.05	18	-0.51	2.78	0

Table 1. Results summary. Errors in the duration of each black or white frame (mean, S.D, and lost frames) for each program and interval combination.

***** A delay of 214 ms in a frame caused this value.

Discussion

Despite of the apparent accuracy shown in the results by the software, some caveats can be mentioned. Some of the variance of all tests can be explained by the underlying hardware used to present the visual stimuli (a TFT display) [1]. However, as long as CRT monitors are less common in laboratories, researchers should face the challenge of adapting their experiments to new displays' features.

The E-Prime allows setting up stimuli duration in milliseconds (and not in ticks). This can be easier for experimenters but has its drawbacks. Allowing to set up presentation times not multiple of refresh rate may lead to timing errors (smaller than the duration of one tick). Even visual stimuli with a duration multiple of the refresh rate may have to wait to be synchronized with the VSYNC signal of the display, resulting in larger presentation times of the previous stimulus. Using DMDX, stimuli durations are defined in ticks, but it is necessary to remember that stimuli with very short durations have to be aggregated as frames of a single trial in order to be presented without inter-trial delays (in our tests, it happened with stimuli of three ticks –or less- of duration). This peculiarity can also interfere with other aspects of the experimental design (e.g. non-visual stimuli presentations, reaction times measurement, etc.) or be overlooked by experimenters.

Psychopy tests revealed another remarkable detail: A black frame with a duration of 1 tick is always presented at the end of each trial using this software. Our experimental configurations in Psychopy took into account this issue subtracting the duration of 2 ticks to the duration of each black frame of the black to white transitions (e.g. in 1000ms tests, white frames duration was 1000ms, but black frames duration was set to 966.67ms). In the tests with transitions of one tick of duration, no black frames were configured, assuming that Psychopy will add a black frame to each white frame presented.

Finally, using a real-time operating system (Linux 2.6.33-29-realtime) does not seem to affect the precision and accuracy of tests measurements. However, using multi-platform software (e.g. Psychopy) allows to take advantage from the reliability provided by the underlying real-time operating system, as opposed to the typical uncertainty of preemptive multitasking systems (e.g. MS Windows).

References

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