Reflex – An Open-source Tool for Measuring Human Reaction Times

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***Abstract*—Understanding the effects of latency on interaction is important for building applications, such as computer games, that perform well over a range of latencies. For games that require quick reflexes, such as first-person shooter games, reaction times can be a key determinant for player performance. Unfortunately, measuring and reporting reaction times – and analysis thereof – is not done in many user studies, likely because most easy-to-use tools are only available online and do not provide the raw reaction time data of the participants. To address these shortcomings, this paper presents *Reflex* an open-source tool for measuring human reaction times. Reflex is implemented in JavaScript, allowing it to be run with only a local Web browser and provides the raw data for subsequent analysis. This paper also presents a data set composed of Reflex data gathered from eight previous user studies, with brief analysis comparing their reaction time results to illustrate Reflex's use.**

***Index Terms*—reaction time, latency, human-computer interaction, game performance, user study, web-based tool, first-person shooter, Reflex.**

I. Introduction

Computer games are one of the most popular forms of entertainment in the world, with global sales increasing at an annual rate of 10% or more. The largest esports prize pools are about $25 million USD [1], larger even than traditional sports who's prize pools range from about $2 to $20 million USD [2]. In many esports games, quick responses to visual and auditory stimuli are critical and even a few milliseconds can make the difference between winning or losing. Player reaction times are thus an important component for understanding the skill and performance of a game player.

Reaction time refers to the speed in responding to a stimulus. For game-related research that measures player performance through user studies, there is an opportunity to assess reaction time for participants within a laboratory setting. Participants can take a reaction time test as part of the study, either in an initial demographics-type survey or as part of the gameplay. Existing reaction time tests (e.g., [3]) are generally not designed for research purposes, lacking configurability, are not designed to be used in a standalone setup, or do not provide access to the raw reaction time data.

This paper presents *Reflex* – a tool for measuring human reaction times, suitable for measuring the reaction times of game players, say, as part of a user study. Reflex is implemented using basic HTML and standard JavaScript and so works on most Web browsers including Mozilla Firefox, Google Chrome, Apple Safari, and Microsoft Edge. Reflex runs locally and provides direct access to the reaction time results for subsequent analysis. This paper also presents a dataset combining Reflex data previously gathered from eight user studies with summary analysis to illustrate use of Reflex.

The rest of this paper is organized as follows: Section II describes work related to measuring reaction times; Section III details the implementation of Reflex; Section IV provides some examples of studies that have used Reflex; and Section V summarizes Reflex and presents possible future work.

II. Related work

This section presents related work on studies of human reaction times (Section II-A) and online tools for measuring reaction times (Section II-B).

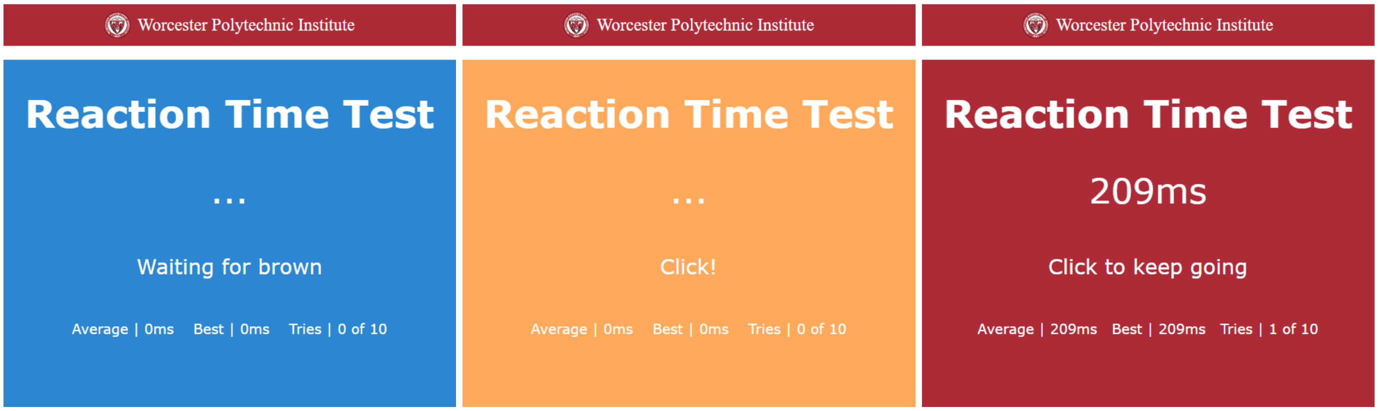
A. Studies of Human Reaction Times

There are many studies of the effects of reaction times for interactive applications. The human benchmark [3] reports that the average human reaction time is about 280 ms based on 81 million users. Kosinski [4] finds measured reaction times might differ because of the purpose of a study, age of participants and types of stimulus. Some studies show that gamers tend to have faster reaction times in general than non-gamers. Richardson et al. [5] depict that gamers who play over 4 hours on average of video games each week have about a 45 ms shorter reaction time than non-gamers. Aybuke et al. [6] show playing digital games has positive effects on reaction times.

These studies generally show research interest in reaction times, with particular benefits to game players.

B. Tools Measuring Reaction Time

Calcagnotto et al. [7] explore issues of measurement accuracy and precision in reaction time tools, offering validation methods that can inform the design of experimental systems. Zajdel and Nowak [8] introduce and evaluate a tool capable of measuring both simple and complex reaction times for diagnostic use, but do not make the tool available. There are various online tools that measure reaction times. A partial list of options include the Human Benchmark *Reaction Time*



(a) Blue - 1-3s before brown

(b) Brown - click as soon as possible

(c) Red - check results, repeat

Fig. 1: Screenshots of Reflex measurements. The blue screen (left) lasts for 1-3 seconds (random), then turns brown (middle) and participants click as soon as possible, turning red (right) and showing summary results once clicked.

Test [3], *Red Light - Green Light* [9], and AREALME's *Reaction Time Test* [10]. These tools are free to use online and can provide immediate results with some simple statistic analysis, but with little configuration.

However, none of above tools offer access to test results nor do they provide a history of previous tests. As such, they are primarily suitable for getting a one-off reaction time, and cannot easily be used as part of a user study.

III. REFLEX

Reflex is designed and developed for user studies. Features include:

- Immediate results upon testing
- Configuration of number of test rounds (default is 10)
- Customization of result format
- Results as human-readable text file

Reflex is implemented in standard HTML and JavaScript. All code described, as well as examples and documentation, are available in the public git repository:

https://xiaokunxu@bitbucket.org/XiaokunXu/reflex.git

A. Implementation

Reflex is a typical JavaScript application with three parts: The HTML file defines the basic structure of the interface; the CSS file defines the layout and style of the interface; and the JavaScript file defines the functionality. The basic functionality of one reaction time measurement experienced by a user is depicted in Figure 1. Upon test start, the Web page displays a screen that remains blue for a randomly chosen floating-point interval between 1 and 3 seconds, randomized so users cannot anticipate the change.[1] After the random interval, the screen turns brown and the user clicks as soon as possible. If users click before the screen turns brown, it is recorded as a "bad" click and the round is restarted. Upon successfully clicking during a brown screen, the screen turns red and summary results are provided – average time, best time, and progress.

[1]The 1-3 second duration was determined by pilot studies to balance user anticipation and reaction time validity, but can be easily adjusted in the JavaScript code to meet specific experimental requirements.

Listing 1: Reflex JavaScript pseudo-code

```
event_mousedown = function():
   while round < max_rounds do
      get state of click area
      if state == Red then
         call changeToBlue()
         change text to ``Waiting until brown''
         after random (1-3s)
            call changeToBrown()
            get time stamp T_c
      elif state == Blue then
         call changeToRed()
         change text to ``Too soon!'' // bad
         reset timer
      elif state == Brown then
         get time stamp T_d
         calculate reaction time: T_r = T_d - T_c
         call changeToRed()
         change text to summary results
      end if
   end while
   save data
```

The JavaScript code records the time when the color changes (T_c), and the time when participants press down the mouse (T_d) to get the reaction time: $T_r = T_d - T_c$. The logic is shown in Listing 1.

B. Usage

For Reflex in a user study, a researcher first configures the number of test rounds (a JavaScript constant `defaultTestNum`, defaults to 10) for each participant. Then, for each participant:

1) Proctor opens the Relfex HTML file with a browser
2) User reads the instructions
3) User clicks "Get started" when ready
4) User does one reaction time test as per Figure 1

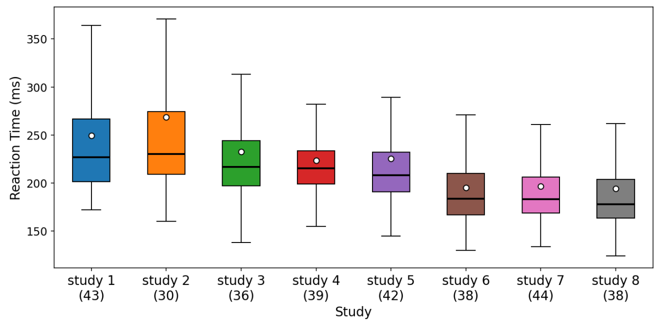


Fig. 2: Analysis of Reflex results from 8 user studies.

5) User repeats previous step until max rounds is reached
6) Proctor clicks "Save score" to save the results locally

C. Output

Reflex writes the results separated by commas into a text file. For example, for one user, the result:

`293,219,229,203,283,210,283,239,266,306,1`

indicates 10 reaction time measurements (in milliseconds), with 1 (the last number) bad click (the user clicked too early one time). The output format can be adjusted by modifying the `saveBtn.onclick` event in the JavaScript file.

IV. Evaluation

This section describes a dataset that combines Reflex data gathered from eight previous user studies, and provides analysis to illustrate the use of Reflex. The user studies are:

- Study 1: "Lower is Better? The Effects of Local Latencies on Competitive First Person Shooter Game Players" [11]
- Study 2: "The Impact of Latency on Navigation in a First-person Perspective Game" [12]
- Study 3: "The Effects of Network Latency on Competitive First-person Shooter Game Players" [13]
- Study 4: "Datasets: Moving Target Selection with Delay" [14]
- Study 5: "The Effects of Network Latency on Counter-strike: Global Offensive Players" [15]
- Study 6: "Effects of Adaptive Time Delay on Quality of Experience in First Person Shooter Games" [16]
- Study 7: "Pushing the Limits? Frame Rate Benefits to Players for up to 500 Hz in First-person Shooter Games" [17]
- Study 8: "Timing Matters: The Impact of Event-Specific Frametime Spikes in First-person Shooter Games" [18]

Each study had participants use Reflex after signing an informed consent, but before the main game tests from the study. We compute the reaction time for each user as the mean of their Reflex samples. We then summarize the distribution of reaction times, one per user, via a boxplot clustered by study. Figure 2 depicts these boxplots for the 8 user studies. The x-axis is the study number with the number of participants in parentheses shown underneath, and the y-axis is the reaction time. Each box depicts quartiles and median for the distribution, the whiskers span from the minimum to the maximum, and the white circles show the means. From the graph, reaction times for all studies are low compared to the general population (typically, around 300 ms), explained since all 8 studies solicited participation from game players and gamers tend to have reaction times that are lower than the population mean. All studies have slightly skewed distributions – means above the median – typical of human performance data with a hard lower bound but a potentially large upper bound. Studies 2 and study 3 have distributions that are somewhat higher than the other studies, explained by the large number of beginner gamers in the sample pool. Studies 4 - 7 have similar reaction time distributions with an average of about 220 ms. The variance across studies can be attributed to differences in study methodologies and participant demographics. For instance, some studies included a screening process to recruit experienced FPS players, while others did not, resulting in relatively more casual or beginner participants. These factors affect the overall distribution and spread of reaction times.

Detailed demographic data and experimental procedures for each study are available in the public repository for further analysis:

https://XiaokunXu@bitbucket.org/XiaokunXu/datasets.git

While we use mean reaction times to illustrate one possible use of Reflex data, other statistics (e.g., median, minimum) may offer additional insights – the full dataset is available in the repository for just such further analysis.

V. Summary

For applications that require quick reflexes, such as first-person shooter games, reaction times can be a key determinant for performance. Currently, most available tools to measure reaction times are difficult for researchers to use in user studies, either online-only, not being configurable or not providing the raw results.

This paper presents *Reflex*, a tool we designed and developed for measuring participant reaction times as part of a user study. Reflex is implemented as a Javascript application, allowing it to run locally in a standard Web browser, and provides raw data of participants' reaction times for further analysis. Reflex and the dataset from eight user studies are available via public git repositories. Analysis of the Reflex results for the 300 participants (mostly gamers) indicate that their average reaction time is about 50 ms faster than reaction time measurements reported for the general populace from online tools [3].

Although Reflex is introduced in the context of digital game user studies, it can also be used to provide meaningful participant data for other studies where reaction time measurement is relevant. Reflex does not tie the reaction time to games user research through spatial relationship [5]. Exploring this direction in future work could enhance its contribution to the games user research community, especially for FPS and RTS games.

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