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# Chapter 7

## Flashlight as a Process Tracing Method

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### ABSTRACT

*Flashlight is an open source process-tracing tool that records mouse movements in real time during an information search task (Schulte-Mecklenbeck, Murphy & Hutzler, 2011). Using this tool, acquisition behavior and visual attention can be recorded in an unobtrusive way with a wide variety of different stimuli. Because of the structure of the stimuli in Flashlight, information acquisition behavior can be measured similarly to how eye tracking works, but unlike eye tracking systems, Flashlight can be implemented without any special equipment. The motivation for developing a new process-tracing tool comes from experience with existing process tracing methods and their limitations. Other existing process tracing tools restrict the structure of information (often in a rigid matrix similar to an information board); require a fixed and confided laboratory setup; and need specialized hardware and software that is both expensive to purchase and operate. Flashlight solves these issues by providing a free open source adaptable software package that can work via a Web browser on any Internet connected personal computer. Moreover, the researcher has great flexibility in how stimuli are constructed and presented, and Flashlight also enables easy access to a large number of participants through Internet based experiments.*

### INTRODUCTION

Process tracing, i.e., collecting multiple data points instead of just looking at one response from a participant, is a data collection approach that includes a diverse set of different methods like thinking aloud protocols, eye-tracking or mouse-tracking (Schulte-Mecklenbeck, Kühberger, &

Ranyard, 2011). A bundle of methods is available today, ranging from collecting verbal utterances of participants in thinking aloud protocols to the recording of eye or mouse movements in information board studies. When developing Flashlight, an online attention tracking software, we had in mind that 1) eye-tracking is cost intensive, 2) information boards (matrix setup of information as

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can be found on comparison websites) offer only limited means of presenting information and 3) researchers should be able to adapt the code to their specific needs at any time. With our software it is possible to overcome the above mentioned issues.

## **BACKGROUND**

The collection of process data has seen a growing interest in recent years. In a review of scientific journal articles on process tracing tools in decision making research, Schulte-Mecklenbeck, et al., (2011) found a steady increase in this literature in a large variety of methods during the last 30 years. Methods like information boards (Payne, 1976; Todd, & Benbasat, 1987; Willemsen & Johnson, 2011), eye-tracking (Reeder, Pirolli, & Card, 2001; Cutrell, & Guan, 2007; Buscher, Dumais, & Cutrell, 2010; Russo, 2011), active information search (Huber, Huber, & Schulte-Mecklenbeck, 2011) or log file analysis (Tauscher & Greenberg, 1997) have been used to investigate a) psychological processes in information acquisition, b) questions in human computer interaction with computer programs or websites or c) usability issues in interface design (Schulte-Mecklenbeck, Kühberger, & Ranyard, 2011).

The development of Flashlight has been motivated by these methods and has the following aims: (1) we want broad flexibility in the type of stimuli presented to participants (e.g., overcome the common rigid matrix setup of stimuli), (2) we aim for a cost-effective method, at best free of charge, (3) we want to record multiple participants in parallel to minimize experimental trial time and cost, (4) we want data collection within the laboratory as well as online, and (5) we want to enable other researchers to use and modify our code (open-source availability) according to their needs and innovations.

## **METHODS THAT RECORD PROCESS DATA**

A considerable number of process tracing tools have been discussed in the literature. In what follows we will introduce different tools that collect data in the laboratory or over the Internet and which had conceptual influence on how Flashlight was developed.

**Eye tracking.** The observation of eye movements in psychological research has a long history. Rayner (1998) provides an excellent overview over the historical and technical development as well as the basic characteristics of eye movements. In contrast to the rather laborious recording of eye movements in earlier days (e.g., Javal, 1878), the technical advances in recent years have resulted in ready-to-use, computer-based eye trackers with relatively low technical demand to the end user. While there are a variety of different methods to measure eye-movements, recording corneal reflection (video based eye-trackers) is the most common method used today (Duchowski, 2002). High performance eye-trackers record observations often over 1000 times a second and thus deliver data at resolutions of over 1000Hz. This resolution allows for the measure of both rapid micromovements (i.e., saccades), as well as fixations (i.e., resting of the gaze on a single location) with high precision.

**MouseTracker** (Freeman & Ambady, 2010) records mouse movements produced by participants while they are confronted with visual or auditory stimuli. The purpose of the program is to track trajectories of mouse movements while categorizing stimuli into different classes. Discrepancies between an initial categorization and the final response are shown in deviations from a linear movement of the mouse to one of the response alternatives. MouseTracker comes with a straightforward setup tool, a data recording program, and a package for analyzing and exporting collected data. The validity of the approach has been shown in several publications mainly

in the area of stereotyping (e.g. the effects of gender or race; Freeman, Pauker, Apfelbaum, & Ambady, 2010).

While the above-mentioned methods are laboratory bound, we will focus on MouselabWeb next, a method that enables the researcher to run studies on the Internet as well as in a laboratory. Before that we will briefly describe important developments in online research. The collection of data via the Internet is well into its second decade by 2010. Multiple websites offer services for online data collection or list ready-made experiments for interested participants. Examples are the ‘Psychological Research on the Net’ site (Krantz, 2009) which lists over 400 experiments or the ‘Web experiment list’ (Reips, 2009) with over 500 available studies (Reips & Lengler, 2005). Even large organizations, such as the American Psychological Association (APA), acknowledge online data collection methods in their ‘Online Psychology Lab’ (American Psychological Association, 2009) a site dedicated to teaching online research methods.

**MouselabWeb** (Willemsen & Johnson, 2011) is an extension of the well-established Mouselab program for usage on the Internet. Mouselab itself is based on the idea of information boards in which information is presented to the participant in a matrix setup of covered information cells. The mouse is used as a pointing device that automatically uncovers and reveals information in cells upon moving the mouse pointer into a cell area. As soon as the mouse pointer is moved out of the cell area, the information is covered again. Through this process the number of opened cells, their inspection length and sequence can be recorded. MouselabWeb uses Web technology (Javascript, PHP and MySQL) to record information acquisition on the participant’s computer. The process data is sent and stored on a server which enables easy, centralized analysis.

## **METHOD OF FLASHLIGHT**

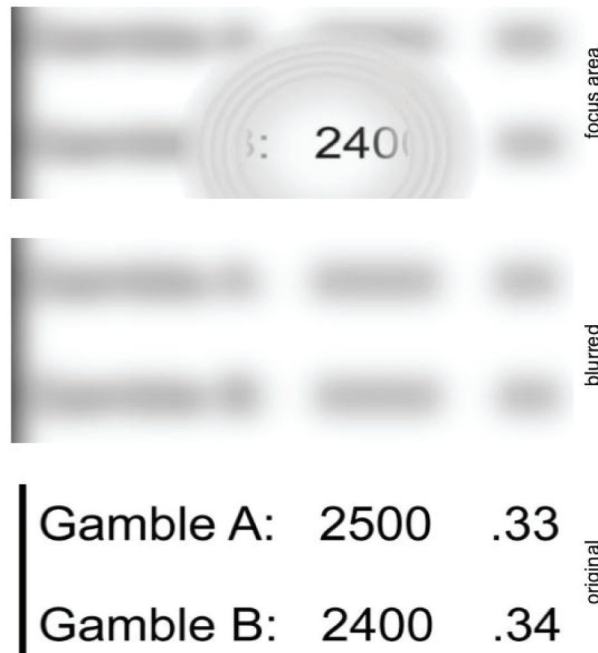
In what follows we will describe how an experiment in Flashlight is setup and which steps are important in this process. Stimuli in Flashlight consist of two parts: a bottom layer constituted by the original stimulus and a top layer, a blurred version of the original stimulus. In Figure 1 we present an example of the original stimulus of a gamble at the bottom, the blurred version of this stimulus in the middle and the blurred version + the focus area at the top of the figure.

Upon starting a trial the participant sees only the blurred version (middle part of Figure 1) and the mouse cursor with a surrounding circular area which we call the focus area. Like a Flashlight beam, controlled by the participant, moving the mouse over the stimuli reveals clearly and instantly the underlying bottom layer within the focus area (top part of Figure 1). Code written in Javascript takes care of this revelation process, revealing information where the mouse is pointed and obfuscating the remaining field of the stimulus, all the while updating in real time as the participant moves the mouse. Additionally the position of the focus area is recorded at a rate of about 10 times a second (10 Hz resolution) and the collected data is saved together with a time-stamp into a database for further analysis. The temporal resolution can be increased beyond this level but is ultimately limited by the speed of the client computer and the capabilities of Javascript to record mouse positions. In any case, for a large number of research instances a 10 Hz resolution is sufficient to measure participant’s behaviors, especially in judgment and choice tasks.

The whole source code plus scripts for analysis are available at the projects webpage: <http://vlab.ethz.ch/Flashlight>.

## Flashlight as a Process Tracing Method

Figure 1. Construction of a stimulus with the original layer at the bottom, the blurred version in the middle and the final version with the focus area at the top



### Requirements

A user of this tool would need a web server (at a hosting provider or one of your own) to run Flashlight, which has to meet the following minimal requirements: Disk space for the scripts (< 1Mb) and the stimuli (depending on your experiment this can be several Mb), MySQL 4.1.0 or later, PHP 4.3.2 or any later PHP 4 version, or PHP 5.x, MySQL4 or MySQL5 PHP library (standard with most hosting providers), sessions (standard with most hosting providers). There are a large number of providers for hosting web experiments. Take a look at the web hosting Wikipedia page: <http://en.wikipedia.org/wiki/Webhosting> to get a basic idea. Searching for the keywords: 'web hosting' or 'shared web hosting' will get you a long list of options too.

### Download Flashlight

The script is hosted at: <http://vlab.ethz.ch/Flashlight/>. One can download the current installation package from this location after registering to the mailing list.

### Unpack Flashlight

Once you downloaded the .zip file to your computer uncompress it to a directory of your choice.

### Information about the Server

In order to setup the script correctly you need the following information about your server: the URL of your script (e.g.: <http://MYDOMAIN/Flashlight/>), the location of your MySQL server (e.g.: localhost), the name of your Flashlight MySQL database (e.g.: Flashlight), the username and password for your MySQL database.

## Configure Flashlight

Open the config.php you will find in the /Flashlight/ directory in your favorite text editor. There are two sections, the first is called ‘database configuration’ and it is mandatory to add the correct information about your web- and database server in this section, otherwise Flashlight will not function. The second section is called ‘Flashlight configuration’ and deals with appearance issues of Flashlight for the user. Updates to this section are optional. In the database configuration section you will find four variables to update: \$dbHost: Database server location, in most cases ‘localhost’ will be fine, \$dbName: Database name, \$dbUser: Database user name, \$dbPass: Password to access the database. Enter the four values in the appropriate lines between the ‘’, e.g. in the first line (database server location) will look like this in the original file \$dbHost = ‘; and like this after adding localhost as the server address: \$dbHost = ‘localhost’; The Flashlight configuration section mainly organizes how the focus area looks like, which size it has and where the default position of the focus area is in a trial. The first setting defines which overlay to use, i.e., what form the focus area will have. In the default setup the focus area has a circular form you can see when opening the file circle0.png in /pics in the Flashlight directory. The focus area can take any desired form which you define through the picture you upload and the setting below. Currently only one form per experiment is possible (in our example the circle). In the config.php file define the location of the focus area picture as follows:

```
$imgsrc = “pics/circle0.png”;
```

This will ensure that Flashlight finds the desired file and displays the focus area in a correct way. In addition to the form of the focus area it is also possible to define the size of the focus area. Several parameters can be set in this section. First of all the size of the area where the stimulus is

actually shown can be defined using the following two lines: \$sCircleOutWidth = 300; \$sCircleOutHeight = 300; Finally you can change the starting position of the focus area in a new trial. The area will be reset to this position after each trial to ensure that each participant starts from the same position on a stimulus. Use the following two lines to define x and y values, in pixels, for this position: \$sStarty = 200; \$sStartx = 200.

## Upload the Files to the Webserver

Use an FTP program to upload the files to your web server. Make sure that the whole directory structure is actually uploaded.

## Create and Populate the Database

Create a database on your server (use the database name from above) and upload the db upload.sql file to this database. You will receive a database with the following tables: moves, params and tasks. The tasks-table contains the name of the filenames for the stimulus (each stimulus consists of two files - see below for details) and an associated task number. The params-table contains parameters for fine-tuning the application like the inner and outer circle width and starting position of the search window. Finally, the moves-table contains all collected data (see below), connected to these are the participant-id and the task-id.

## Accessing a Stimulus and Recording Data

In your browser go to the following link: <http://MYDOMAIN/Flashlight/main.php?task=1>

We use the GET function to access the task number from the provided URL changing this number will change the displayed stimulus. There are four different stimuli: add, read, choice, search with the task numbers ranging from 1 to 4 (respectively) available as examples. Each stimulus consists of two files: the picture of the stimulus and



a blurred version of this picture (these .jpg files are stored in the /pics directory, your own stimuli will have to go into this directory, too). In our examples we use the following naming schema: for the picture of the stimulus we use ‘stimulus name + number + .jpg’, i.e., read1.jpg. For the blurred version we add ‘- blur’ to the stimulus type, i.e., read-blur.jpg, this is useful when you have only one blur mask for a stimulus type. In some situation it might be necessary to generate a blurred version for each stimulus -in that case we suggest adding the stimulus number to the blurred version, too, i.e., read1-blur.jpg.

### **FLASHLIGHT VERSUS THE EYE-TRACKER**

A reference measure for many studies regarding acquisition and attention processes in the area of psychology, but also in other areas like human computer interaction, is eye tracking. The reasoning being: if a method shows similar results to eye tracking it may answer similar questions, but without the substantial costs and technical complexity associated with eye tracking. Comparing eye-tracking with mouse-tracking several differences are important: Pointing at a target with the mouse has to be slower than pure eye movements towards a target because it always involves both (eye- and hand-movements). Naturalness of a decision situation might differ when a stimulus is inspected by simply looking at it (like in eye-tracking) or attention has to be inferred from mouse movements into a specific cell of a matrix. Overall there is evidence for a “strong relationship between gaze position and cursor position” (p. 281, Chen, Anderson, & Sohn, 2001) when web pages are evaluated. Looking into cognitive psychology we find a similar message, namely, that motor movements are not the end product of a cognitive process but are updated “online” (Freeman, Ambady, Rule, & Johnson, 2008; Spivey, Grosjean, & Knoblich, 2005).

Flashlight was evaluated regarding its capabilities to represent acquisition processes, choices and acquisition patterns in comparison to a laboratory bound eye-tracking system in Schulte-Mecklenbeck, Murphy and Hutzler, 2011. The authors used three different tasks run with an internet sample using Flashlight or a laboratory bound eye tracker in a between subjects design. The tasks were from three domains: choices, reading and adding. They were evaluated on different parameters: Outcome parameters checked for choice patterns (choice), correct answers (reading) or correct sums (adding). Process parameters checked for number of fixations (resting of the mouse or the eye on one location for a minimum amount of time), length of fixations and patterns of acquisitions (sequence of information acquired). For all three task types very similar outcome patterns were found indicating that the method has only a small influence on the actual performance of participants (note however that the method was confounded with the participant group, hence an effect of differences between groups cannot be ruled out). Looking at the process measures fixations were similar in terms of frequencies. For the length of acquisitions participants using Flashlight showed longer fixation times for reading than participants in the eye-tracking condition. This can be explained through the rather unnatural setup for reading with Flashlight where no saccades (jumps between words) are possible due to the limited scope of the focus area. Clearly tasks involving reading mark a limitation of the Flashlight method. For the other two task types (adding and choice) no differences in fixation length were found. Finally for transition the choice task was further investigated. Patterns were analyzed between the different components of the choices (outcomes and probabilities in two option gambles). The dominating transitions between adjacent outcome-probability pairs were found with both methods and replicated earlier findings with MouselabWeb (Johnson, Schulte-Mecklenbeck, & Willemsen, 2008).



Overall we are convinced that Flashlight offers an easy possibility to collect and analyze process data for beginners and experts. Through the flexibility in stimuli construction and the ease to collect data from large sample via the Internet we add a method to the large number of process tracing methods in Psychology and related disciplines.

## FUTURE RESEARCH DIRECTIONS

We want to apply Flashlight to a diverse set of experimental questions from decision making, game theory and food science. Additionally the usability of the code will be improved to lower the entry barrier for newcomers to process tracing. Finally, the analysis codes will be transferred to R to ensure open access.

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## ADDITIONAL READING

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