Use of Eye Tracking in Cognitive Pretests (Version 1.0)

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Use of Eye Tracking in Cognitive Pretests

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Abstract

Cognitive pretesting is generally considered to be indispensable for the successful development of new survey questions, and hence for the quality of the data obtained by the survey. Supplementing cognitive interviewing with the method of eye tracking offers the possibility to observe eye movements of respondents in real-time providing additional information about cognitive processes of respondents. Research suggests that combining both methods helps to identify additional problems with questions that would remain undetected if only one method was applied. This contribution provides an introduction to cognitive interviewing in combination with eye tracking. The following questions are addressed: What is the rationale behind combining cognitive interviewing and eye tracking? How should eye tracking be implemented into cognitive interviewing? How can eye-tracking data be used and analyzed in the context of cognitive pretesting?

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1. Introduction

The awareness of survey researchers that it is necessary to test whether respondents understand the questions in a survey as intended by the researcher, to assess how difficult they are to understand and answer, and whether they pose other cognitive problems for the respondents prior to fielding them has increased in recent decades (Conrad & Blair, 2009; Presser et al., 2004). Cognitive pretesting methods aim to uncover such difficulties and to point to possible solutions (Conrad & Blair, 2009; Yan, Kreuter & Tourangeau, 2012). A broad and growing set of pretesting methods are available for evaluating questionnaires, for instance the frequently used method of cognitive interviewing (see Lenzner et al., 2016). Each cognitive pretesting method has its own strengths and weaknesses and, given that different methods are likely to uncover different question problems, researchers often use a combination of methods to pretest survey questions (Groves et al., 2004). Research suggests that combining both methods helps to identify additional problems with questions (Neuert & Lenzner, 2016a). This contribution provides an introduction to cognitive interviewing in combination with eye - tracking methodology to evaluate survey questions.[1] First, the method of cognitive interviewing is briefly described, followed by a description of what eye tracking is and why it might be beneficial to incorporate eye tracking into cognitive interviewing. Section 2 is concerned with the practical implementation of eye tracking into cognitive interviewing, that is, equipment, set-up, and interview material and interviewing. The last section is considered with the analysis of eye-tracking data.

1.1 Cognitive interviewing

A cognitive interview is typically a semi-structured, in-depth interview that focuses on respondents' cognitive processes that take place during the answering of survey questions. It is qualitative in nature and intended to produce verbal material that is used to diagnose problems respondents potentially have with understanding and answering the questions and to find out how questions should be modified to make them easier to comprehend and answer (Forsyth & Lessler, 1991; Willis & Miller, 2011).

Cognitive interviews are usually conducted with small sample sizes of 10 to 30 people. The most commonly used techniques are "think aloud" and "verbal probing" (Willis, 2005). If using the "think aloud" method, respondents are asked to report everything that comes to their mind while they work on a question and form an answer. During "verbal probing", the interviewer asks direct questions, or probes, after administering the test questions to obtain more information about how respondents interpreted and answered them or about how they interpreted specific terms (Beatty & Willis, 2007; Willis, 2005). Probing questions can either be asked immediately after the respondent has answered the survey question to be tested (concurrent probing) or at the end of the interview (retrospective probing; Collins, 2003; Willis, 2005; Willis & Miller, 2011). In addition to pre-scripted probing questions that are developed prior to the interview, conditional (spontaneous) probing questions can be asked in response to what the respondent says or does during the interview (Willis & Miller, 2011).

After the interview, the verbal reports produced have to be analyzed and interpreted to define whether or not a question poses a problem for respondents. To analyze the data, the comments of the respondents are successively aggregated and summarized for each survey question. For more

[1] For more information on this topic we refer readers to Neuert (2016).

information on cognitive interviewing, we refer interested readers to Lenzner et al. (2016) for a short hands-on overview or to Willis (2005) for a more comprehensive review.

1.2 Eye tracking

Eye tracking is a technique that records people's eye movements while they process visual stimuli such as texts, images, or websites to provide information on where respondents look at any given time, for how long they look at something, and in which order (Romano Bergstrom & Schall, 2014). When used for questionnaire pretesting, one can observe where respondents are looking and for how long while they are reading and answering survey questions. Respondents' eye movements provide information about their reading behavior and can be used to indicate question difficulties (Galesic & Yan, 2011; Graesser et al., 2006). As respondents tend to fixate longer on unknown or difficult words and complex sentences, fixation durations can be used to detect difficult questions in a survey (Lenzner et al., 2011; Galesic & Yan. 2011). Additionally, eye tracking can be used to observe respondents' behavior without having to rely on their reports. Problems such as respondents not being aware of certain cognitive processes or not wanting to make truthful statements about them can be avoided and thus, eye tracking makes it possible to answer the following questions:

- Do respondents read survey questions completely or do they skip (parts of) survey questions?
- Do respondents read all relevant parts of a survey question (e.g., question stem, instructions, definitions, response options) sufficiently careful, or do they just quickly scan them?
- Do respondents read survey questions in the intended order?
- Do some aspects of a survey question (e.g., words, phrases, response options) attract particular attention on the part of respondents?

1.3 The rationale behind supplementing cognitive interviewing with eye tracking

Although there is general agreement about the value of cognitive interviewing, it also has some limitations (Collins, 2015; Presser et al., 2004). Some of these can be mitigated when supplemented with eye tracking.

First, cognitive interviewing is a qualitative method that produces verbal data that needs to be interpreted by the researcher which is why any conclusions drawn on the basis of these data are subjective (Beatty & Willis, 2007; Conrad & Blair, 2009). Second, some respondents find it difficult or are unable to express themselves verbally (Graesser et al., 2006). And, not all of the cognitive processes are conscious to them (Collins, 2015; Willis, 2004). In particular, respondents with relatively low levels of education or low cognitive skills often have problems reporting on these processes (Galesic & Yan, 2011; Sudman, Bradburn, & Schwarz, 1996). Another related challenge is that respondents may not always be aware of having difficulties with comprehending or answering the question (Campanelli, 2008). Third, cognitive interviewing focuses on the individual question and not on the questionnaire as a whole. Hence, it does not provide information on length or flow of the questionnaire. And finally, the interview situation itself can influence the way in which respondents answer the questions (Collins, 2015). The cognitive techniques used and the behavior of the interviewers, for instance, may have an impact on the ways respondents answer the questions (Beatty & Willis, 2007; Conrad & Blair, 2009; Willis, 2005).

In contrast, recording respondents' eye movements is rather unobtrusive and basically non-reactive. Eye tracking allows the detection of respondents' conscious and unconscious reactions to survey questions and provides more objective information about how respondents interact with the questionnaire under

natural conditions and without the presence of an interviewer. Therefore, it may better indicate whether problems actually exist (Neuert & Lenzner, 2016a). Moreover, eye tracking is independent of respondents' verbal abilities, problem awareness, and willingness to report them to the interviewer (Galesic & Yan, 2011; Romano Bergstrom & Schall, 2014). Eye-tracking data provide the survey researcher with additional information on the response process and might point to difficulties with comprehending and answering the survey questions. The information gained from observing respondents' eye movements can also be used to select questions that should be considered more closely during the interview, and thereby increase the efficiency of pretesting. A further benefit is that analyzing eye-tracking data allows comparing more objective quantitative eye-movement data with the verbal data gathered from cognitive interviewing.

However, eye tracking does not provide direct access to a respondent's thoughts and cannot identify the *causes* for question problems. It can indicate whether a problem exists, but eye movements do not provide information about what the exact problem is. Moreover, eye-tracking data cannot always be unambiguously interpreted. For instance, long fixation durations may indicate problems with a question, but they can also signal that the respondent finds the particular topic of the question interesting or they can represent a conscientious response behavior (Lenzner et al., 2011). Thus, eye-tracking data must be enriched with additional information from the respondents, so that researchers can verify their interpretations of the eye-tracking data.

To summarize, supplementing cognitive interviewing with eye tracking offers additional insights into the respondents' cognitive processes while comprehending and answering survey questions. Potential problems with a question would possibly remain undetected if only one of the two methods were used (Neuert & Lenzner, 2016a). An experimental study by Neuert & Lenzner (2016a) that compared the hybrid method of cognitive interviewing and eye tracking with the method of cognitive interviewing alone found that combining both methods was more productive in identifying both questionnaire problems and problematic questions.

The combination of cognitive interviewing and eye tracking is suitable for all survey modes, as cognitive interviews are particularly concerned with the comprehension of survey questions, regardless of the mode in which they are asked. When testing web surveys by means of eye tracking, this has the additional advantage that information about usability and visual design elements of the questionnaire can also be assessed (e.g., where to place information, how to design the screen, how to layout instructions etc.; Couper, 2008; Galesic & Yan, 2011).

2. Implementation of eye tracking in cognitive interviewing

2.1 Eye-tracking equipment and set-up

Most of the eye trackers currently used in usability labs are so called video-based eye trackers. These eye trackers usually work with (near-)infrared light and a video camera to capture the eye. The camera is located either underneath or next to a computer monitor on which the user is performing a task (remotely mounted) or mounted on the user's head (head-mounted). Head-mounted eye trackers allow more freedom of movement of the body, but are comparatively invasive. Remote eye trackers are less obtrusive, more comfortable, and allow a more natural experience for the users (see Figure 1).

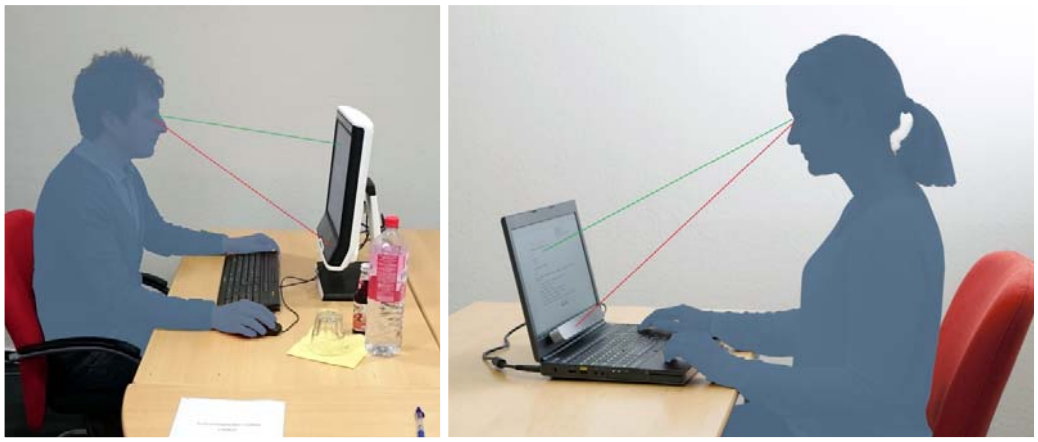

Figure 1. Eye tracker implemented in the frame of a 17" TFT monitor of a desktop computer (left); eye tracker mounted on the bottom frame of a laptop monitor (right).

With the pupil center/corneal reflection method, near-infrared light is directed into the eye where it meets the retina causing a reflection. The back-reflected light is then captured by the infrared-sensitive camera. The image captured by the camera is used to identify the center of the pupil and the location of the corneal reflection. The separation of these two features is analyzed (using advanced image processing algorithms) to determine where the user is looking (Duchowski, 2003; Jacob & Karn, 2003). In order to set the eye tracker up for each respondent and to reduce gaze tracking errors due to individual differences, a calibration procedure is required. During the calibration the respondent looks at dots appearing on the screen. The eye-tracking system measures characteristics of the user's eyes and records the pupil-center/corneal reflection and the value that corresponds to each gaze position (as x-y coordinates; Duchowski, 2003).

2.2 Procedure

When supplementing cognitive interviewing with eye tracking, the testing session is divided in two sequential parts: 1) respondents fill in the questionnaire on a device with eye-tracking technology, conspicuous reading patterns or behaviors are observed and coded simultaneously by an interviewer; 2) conduction of a cognitive interview.

Respondents come to the cognitive laboratory and after an introduction they are placed in front of an eye tracker. The respondent should be instructed to fill in the questionnaire to be tested at their usual pace. During completion of the questionnaire, the interviewer monitors the respondents' actions and eye movements in real time on a computer screen in an adjacent room. Thereby, the interviewer notes conspicuous respondent behaviors and peculiarities which are later discussed in the cognitive interview. In this regard, it is advisable to switch on the respondent's webcam and display their face on the second monitor. Then, the interviewer can observe facial expressions and gestures (e.g., frowning, head shaking, looking at the ceiling as a sign of intensive reflection) and can also see why the eye movements sometimes disappear from the screen. For noting peculiarities in a question it is helpful to use a coding scheme where interviewers have to check a box if they observe one of the behaviors listed. An example is provided in Figure 2. The coding scheme can be extended depending on the test objectives. There are some indicators that can give very concrete indications of problems in survey questions (Lenzner et al., 2011; Neuert & Lenzner, 2016a):

1) Long or repeated fixations on words or phrases: the longer one is looking at something, the longer it is cognitively processed. Complex, unusual and unfamiliar words are fixated longer than common words, for example.

2) Re-readings of the whole question or question parts: Re-reading of text takes place when not everything was understood at first reading. When text is difficult to process, the frequency of re-readings and the duration of fixations increase. For example, ambiguous or unfamiliar words are read multiple times.

3) Several switches of eye movements between the question text and the answer categories might indicate uncertainty or confusion and are often accompanied by a longer period of reflection.

	Observations Question 1
☑	Long and repeated fixations on words or phrases: R fixated long and repeatedly on the term "somatic"
☑	Re-readings of specific words or text passages: R read the question stem 3 times
☑	Regressions from answers to question text: Several times, back and forth
☑	Correction of the chosen response category: R changed answer from agree to neither/nor
❑	Skipping question
☑	Other: R did not read the instruction

Figure 2. Coding checklist with examples in handwritten font.

This coding scheme is helpful in framing conditional probes that are asked during the cognitive interview. Examples of conditional probes are:

- I noticed that when you answered the question on the computer, you looked at the term X repeatedly. Was there a specific reason for this?
- When answering the question on the computer, you switched back and forth between the question text and the answer options several times. Can you explain to me why you did this?
- What occurred to you that caused you to change your answer?

It is advisable to provide an "other" box to note peculiarities that were not foreseen, but should be addressed during the subsequent cognitive interview.

After respondents have completed the questionnaire, the eye-tracking session is followed by a cognitive interview (see Figure 3). In addition to probing the questions specified in the cognitive interview protocol (see section 2.3), interviewers are instructed to probe those questions for which they noted conspicuous respondent behaviors or other peculiarities in the eye movements during the eye-tracking session.

Figure 3. The picture illustrates the set-up of a cognitive interview session with eye tracking. Respondents first answer a questionnaire while their eye movements are tracked. Afterwards, a cognitive interview is conducted at the table.

2.3 Interview protocol and interviewer instructions

The cognitive interview is conducted on the basis of a semi-structured interview protocol. Interview protocols provide the interviewer with information on which cognitive techniques should be used and how they should be administered. In addition to the cognitive techniques, the interview protocol should also include information on testing aims and measurement objectives (Collins, 2015). Otherwise it is difficult to decide whether the question measures what is intended to measure as well as whether it is working as intended. The use of pre-scripted probes ensures the comparability of results for later analysis across several pretest respondents.

For long questionnaires, it is generally not possible to test every question in a questionnaire. Based on an interview duration of 60-90 minutes and depending on the number of cognitive techniques applied per question, between 20 and 25 questions can be tested (Lenzner et al., 2016). For all other questions, interviewers are instructed to ask additional conditional probes, if conspicuous respondent behaviors or other peculiarities in the eye movements were observed during the eye-tracking session. For each question in the questionnaire, the interviewer has to check whether the interview protocol contains pre-scripted probes or whether the respondent showed signs of uncertainty while answering.

When conducting cognitive interviews supported by eye tracking, it is reasonable to ask probing questions only retrospectively. Otherwise, respondents' response behavior might change and they might produce eye movements that they would not normally do, for instance, people looking away from the screen when talking to the interviewer (Pernice & Nielsen, 2009). In contrast to retrospective probing, concurrent probing might also make respondents more aware of the fact that their eye movements are being tracked.

However, retrospective probing has the drawback that respondents may have forgotten key information or the information about their problems whilst answering may be no longer accessible when they are later asked to answer the probing questions (Willis, 2005).

In case probing questions are not administered immediately after respondents have answered the questions in a web-based mode during eye tracking, it is advisable that respondents receive a paper version of the questionnaire during the cognitive interview to remind them of their thought processes (Neuert & Lenzner, 2016a). Another solution to aid the respondents' memory is the use of a gaze video cue, that is, respondents are shown a replay of their eye movements during the cognitive interview. In the video replay, the eye movements appear as red dots that represent where respondents were looking when answering the questions (see Figure 6 below).

This enables respondents to see how they read and answered the question. If this method is used, it is essential that respondents receive an instruction, which could read as follows: *'You are now going to watch a recording of your eye movements while answering question x. The red dots that you are going to see in the replay show how you read and answered the question and represent where you were looking. The longer you were looking at something, the larger the red dot becomes. After you have watched the replay, I would like you to tell me how you came up with your answer and what you were thinking when answering the question.'* (cf. Neuert & Lenzner, 2016b). It must be said that showing a gaze replay does not (immediately) work for all participants in a way that they report on their cognitive processes. Some will simply look at their eye movements and will describe what they see without referring to the question itself (Neuert & Lenzner, 2016b). Showing respondents a video of their eye movements is particularly useful when layout or navigation issues are investigated as well (e.g., questions with lookup databases, see Lenzner et al., 2015).

3. Analysis of eye tracking data

There are several ways to analyze eye-tracking data to understand visual attention (Rayner, 1998). The main measurements which are typically analyzed are fixations and saccades. Fixations are moments in which the eyes remain relatively motionless. While fixating an object, information is extracted and encoded. Fixations can be measured by the frequency and length of time with which an object is viewed. Saccades are rapid eye movements between fixations. Saccades serve to reorient the eye and to bring target words into foveal focus, so that they can be fixated and processed. No eye-movement data can be recorded during saccades (Duchowski, 2003; Rayner, 1998; Staub & Rayner, 2007).

By defining so-called areas of interest (AOIs), sub-regions of the stimuli displayed are selected and metrics can be extracted specifically for each of these regions. Figure 4 displays a survey question where the question stem and the response categories are defined as two separate AOIs. Aggregated metrics such as how long respondents looked at a respective area or how many fixations were counted within this area can be displayed separately for each of the AOIs.

Figure 5. Illustration of areas of interest (AOI) for the question stem and the response options, respectively.

Besides analyzing metrics such as time to first fixation, fixation duration, or fixation count, an eye tracker also allows researchers to generate heat maps and gaze plots. Heat maps (see left side in Figure 5) can be used to visualize certain areas that attracted a lot of attention. The different colors represent the intensity with which each part of the questionnaire page is fixated; with red areas suggesting a high number of gaze points (increased level of attention), followed by yellow and green.

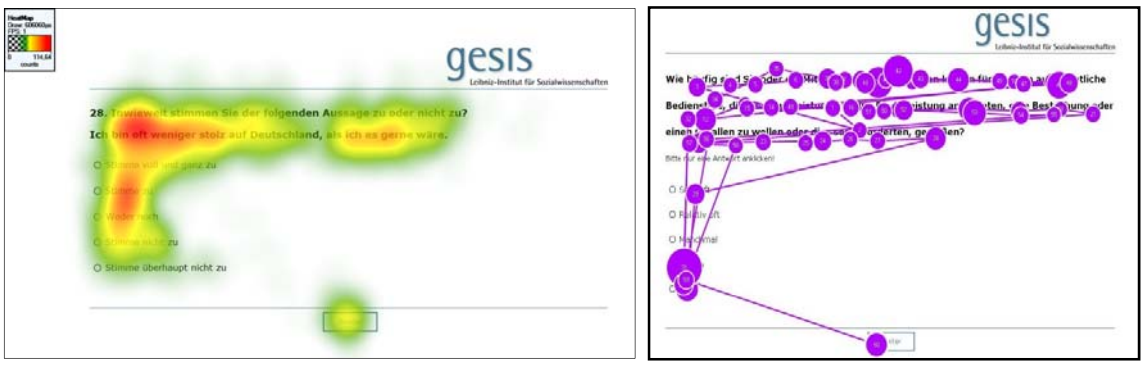

Figure 6. Illustration of two types of eye-tracking visualizations: a heat map (left) and a gaze plot (right).

Gaze plots (see right side in Figure 5) show the order and sequence of respondents' eye movements as they move across the screen. Within gaze plots, the eye movements are represented as lines. Fixations are marked with a dot. The larger a dot is, the longer a fixation lasted. Heat maps and gaze plots can be produced for one respondent, for some respondents or for all respondents. Gaze plots are useful for illustrating typical behaviors displayed when navigating and completing survey questions (Romano Bergstrom & Schall, 2014).

The verbal data from the cognitive interviews are analyzed analogously to traditional cognitive interviews (see Lenzner et al., 2016). By observing respondents' eye movements, the interviewer is able to ask more targeted probing questions and to gain more information, for example on why a respondent read a certain question several times or why a question was skipped. This additional information helps to detect problems that are not consciously apparent to the respondents. In addition to providing information for conducting the interview, the eye-movement data can be compared with the verbal data gathered from the cognitive interviews to cross-validate and confirm the conclusions drawn and to underpin them visually. On the basis of these findings, recommendations for reviewing the survey instrument can be developed. By combining eye tracking and cognitive interviewing, the main difficulties during the response process can be identified. We refer readers interested in the application of this hybrid method to our GESIS pretest database (pretest.gesis.org), in which pretest projects using this method are documented, for instance, Lenzner et al. (2015).

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