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Pretesting Flow Questionnaire Design Using Eye-Tracking: An Exploratory Study[1]

Abstract: The aim of this study is to evaluate an online self-administered questionnaire for measuring flow, using eye-tracking. We were specifically interested in objectively monitoring *when, where* and *what* individuals look at and also in *quantifying their visual attention while completing an online flow questionnaire*, using the direct and the indirect measurement approaches. Flow is the holistic sensation that people feel when they act with total involvement (Csikszentmihalyi, Larson & Prescott 1977). The main flow measurement methods involve direct and indirect approaches, using questionnaires. Eye-tracking has been used in the field of survey methodology by scholars to infer the cognitive processing of visual layout, instructions, and items. We ran an experiment with 43 participants, using Gazepoint GP3 eye-tracker. After eye-tracking data validation, we obtained 36 valid observations. A series of Wilcoxon Signed-ranks tests indicated a significant difference between direct and indirect flow measurement AOI, based on the time to first fixation, average fixation, time viewed, number of revisitors, and number of average revisit metrics. The main contribution of our study consists in outlining that the indirect measurement of flow requires more time and a higher cognitive effort to be processed than flow description used in direct measurement procedures. Thus, scholars should use the appropriate flow measurement approach and consider participants' willingness and ability to process the text. Finally, we conclude that eye-tracking is a useful method in pretesting self-administered questionnaires.

Keywords: eye-tracking, flow, questionnaire design, measurement, visual attention

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1. Introduction

Questionnaires are the most commonly used tools in social sciences for collecting data about people's attitudes, values, behaviours, and experiences (Groves, Fowler Jr., Couper, Lepkowski, Singer & Tourangeau 2004). From a methodological perspective, scholars need to develop and pre-evaluate survey instruments in order to check their validity and reduce measurement errors. An important aspect of collecting data using questionnaires is the need to formulate the items that are easily and consistently interpreted by respondents, according to the researcher's intention (Collins 2003; Fowler 1995). Groves *et al.* (2004) explain that measurement errors occur if respondents misinterpret words, concepts or entire questions, have difficulties in retrieving the information sought, or encounter problems when formatting their answers while completing a questionnaire. Thus, to ensure that the survey is measuring constructs in an adequate way, scholars using questionnaires need to evaluate the cognitive difficulties posed by their survey questions (Collins 2003).

Researchers evaluate survey questions and design using different methods, such as: conventional pretests, cognitive interviews, behavior coding, latency response measurement, formal respondent debriefings, and expert reviews (Presser, Couper, Lessler, Martin, Martin, Rothgeb & Singer 2004). In addition to these methods, a new promising approach in pretesting self-administered questionnaires is using eye-tracking (Galesic & Yan 2011). Modern eye-tracking involves an array of infrared or near-infrared light sources and cameras that track the gaze behavior of one (monocular) or both (binocular) eyes (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka & Van de Weijer 2011; Hansen & Ji 2010). This technology provides valuable insights into the distribution of visual attention over a scene and is restricted to monitoring foveal vision (i.e., a small region in the center of the retina involved in processing light from the center of the visual field, with a dense concentration of cone receptors that provide high visual acuity) and lacks peripheral vision (i.e., parafoveal vision) (Holmqvist *et al.* 2011).

Eye-tracking has been used in the field of survey methodology by different scholars to: (1) asses visual designs of branching instructions (Redline & Lankford 2001), (2) evaluate visual designs of branching instructions (Redline & Lankford 2001), (3) test different response formats (Lenzner, Kaczmirek & Galesic 2014), (4) investigate response order effects (Galesic, Tourangeau, Couper & Conrad 2008), (5) examine the effects of wording on question comprehensibility (Graesser, Cai, Louwerse & Daniel 2006; Lenzner, Kaczmirek & Galesic 2011), and (6) study cognitive processes in answering rating scale questions (Menold, Kaczmirek, Lenzner & Neusar 2014).

Galesic & Yan (2011) explain that in pretesting questionnaires, eye-tracking can be used to assess how much visual attention respondents have paid to information and can reveal how users really interact with instructions, items, or questions that are difficult to understand or flawed. The process of inferring cognitive processing using eye-tracking can be based on Just & Carpenter's (1980) immediacy assumption (i.e., words or visual objects that are fixated by the eyes are immediately processed) and eye-mind assumption (i.e., words or objects are fixated as long as they are being processed). Thus, these eye movements provide direct information about what individuals are processing now and how much cognitive effort is involved.

In Rayner's (1998) opinion, the text hard to process (e.g., questionnaires instructions and items) can be inferred by analyzing the respondent's frequency of regressions and duration of fixations. Usually, individuals need more time to process the items that are difficult to comprehend; the results are longer fixation times and patterns of repetitive or multiple fixations (Graesser *et al.* 2006; Lenzner *et al.* 2011).

In questionnaires pretesting, eye-tracking can be used to evaluate the visual layout or specific visual design elements, such as: colors, pictures, position of important information, screen design, response list options (Couper 2008), and to identify stimuli or sets of stimuli that are given too much or too little attention (Galesic & Yan 2011). Thus, eye-tracking is independent of the respondents' memory, verbal abilities, problem awareness, and subjective judgments (Galesic & Yan 2011; Bergstrom & Schall 2014). Considering the arguments from literature, in this paper, we propose to use eye-tracking technology to pretest an online flow questionnaire design. The importance of our study is based on the need to reduce the measurement errors of an instrument before assessing the individual's flow state.

Measuring flow using questionnaire

Csikszentmihalyi (1975, 1988) conceptualizes *flow as the holistic sensation that people feel when they act with total involvement*. The term “flow” (also called *optimal experience*), is a metaphor used by several participants to Csíkszentmihályi's interviews (1975) to describe the experience that occurred during different activities, associating it with being carried along by the water current. Different levels of flow intensity can be experienced by individuals while performing an activity (Csikszentmihalyi & Csikszentmihalyi 1988). However, an important issue in flow literature is developing and using an appropriate method to measure this construct. The main flow measurement methods are the questionnaire, the Experience Sampling Method, and the standardized scales of the componential approach (Moneta 2012). In flow studies, the vast majority of scholars use questionnaires to assess some or all components of flow, especially when conducting empirical studies (Engeser & Schiepe-Tiska 2012).

Usually, flow questionnaires respondents indicate if they experienced it in a global manner or researchers infer the presence and the intensity of it based on the model (Engeser & Schiepe-Tiska 2012). Flow questionnaires contain a description, a set of items and ask respondents to rate their optimal experience using Likert scales (Moneta 2012). Due to the fact that flow is a subjective experience, self-report measures, such as questionnaires, are appropriate because they can measure optimal experience without interrupting the person in flow. In the past 45 years, flow researchers have developed, refined, and validated different standardized questionnaires to assess flow, but using the appropriate method is still a debate in literature due to different measurement errors. In this paper, we pretest an online flow questionnaire design using eye-tracking technology.

The flow questionnaire we pretested in this study, built online and designed according to recommendations from literature, measured flow experience using an integrated approach: direct and indirect measurements. The direct approach proposes a flow description and asks respondents to report whether or not they had similar experiences, using a Likert-type scale. The indirect approach considers flow a composite construct, contains 4 dimensions and 11 items, using a 5-point Likert scale: (1) time distortion, (2) perceived control, (3) concentration, and (4) intrinsic interest. The instrument validity and reliability was tested and confirmed in previous studies (Obadă, 2014; 2015).

2. Methodology

Participants

Following approval of the Ethics Committee of the Faculty of Philosophy and Socio-Political Sciences within the "Alexandru Ioan

Cuza" University of Iasi, which certified that the project is in compliance with ethical standards, 42 students agreed to participate in our study. The participants voluntarily accepted to take part in the research, being rewarded with credits for their practice.

Research aim and research questions

The aim of this study is to explore how much visual attention respondents have paid to information from the online flow questionnaire. We were specifically interested in objectively monitoring *when, where* and *what* individuals look at and also in quantifying their visual attention while completing an online flow questionnaire, using the direct and the indirect measurement approaches.

Research questions:

RQ_1: Which *Area-Of-Interest* (AOI) from the online flow questionnaire attract immediate attention?

RQ_2: Which elements from the online flow questionnaire don't attract the participants' attention?

RQ_3: Are there any elements from the online flow questionnaire being ignored?

RQ_4: In which order are the elements of the online flow questionnaire noticed?

RQ_5: Is there a significant difference between direct and indirect flow measurement AOI?

Instrument

The participants' visual attention was captured using GP3 HD Professional Bundle eye-tracker, a machine-vision camera, recommended for academic studies (www.gazept.com). The GP3 HD eye-tracker has 0,5 - 1,0 degree of visual angle accuracy, 60 Hz or 150 Hz sampling rate, 5- or 9-point calibration. This high-performance eye-tracking is used in many social sciences studies. Eye-tracking data was analyzed using Gazepoint Analysis Professional Edition and SPSS Statistics package.

Procedure

The protocol for conducting the experimental study was developed based on recommendations from eye-tracking literature and aimed to standardize researchers' actions: (1) the participants were invited to the experimental laboratory and were asked to feel comfortable; (2) they completed a pre-selection questionnaire; (3) the subjects that suffered visual impairments, which could interfere with the eye-tracking device, were excluded from the study; (4) they received the informed consent which they carefully read and signed as a result of their agreement to participate in the study; (5) the participants were invited to sit on a chair in front of a PC monitor, where the eye tracker was located; (6) we presented the instructions for calibrating the device, adjusted the participant's seat and performed the calibration test of the eye-tracking system with 5 points; (7) the participants started the navigation task according to the flow questionnaire instructions; (8) after the online questionnaire was completed, we finished the data collection session; (9) the participants received a copy of the informed consent and were reassured of data confidentiality; (10) finally, we thanked the participants for their time and offered to send a copy of the research report after publication.

3. Results

Eye-tracking data validation

The validity of collected data with the eye-tracker was assessed using the system function through which we can verify if the camera has identified and recorded the subject's eyes movements. After analyzing the video files, we concluded that 36 experiments were valid and 6 were invalid. **Figure 1** illustrates a case of eye-tracking system calibration failure during the experimental study.

Figure 1: System calibration failure during the eye-tracking experiment

In **Figure 1**, no gaze points, fixations or saccades are depicted because the camera captured the participant's face and not the eyes. The eye-tracking device has an operating distance of 50 cm - 80 cm; in some cases, the distance between the eye-tracking and the participant's eyes was less than 50 cm; therefore, the device no longer identified and recorded the eye movements.

Gaze points - Bee Swarms Graphic

Gaze points are fundamental metrics gathered by eye-tracking, and *represent one sample of data regarding the user's gaze with x-y coordinates and a timestamp*, in order to determine *where the participant was looking* and *when* at a specific moment in time. **Figure 2** illustrates the gaze points of 36 participants represented through circles of different colors, during the stimuli exposure. This graphic representation of *bee swarms* is useful to easily understand where the gaze of the participants was fixed, as well as their eye movements.

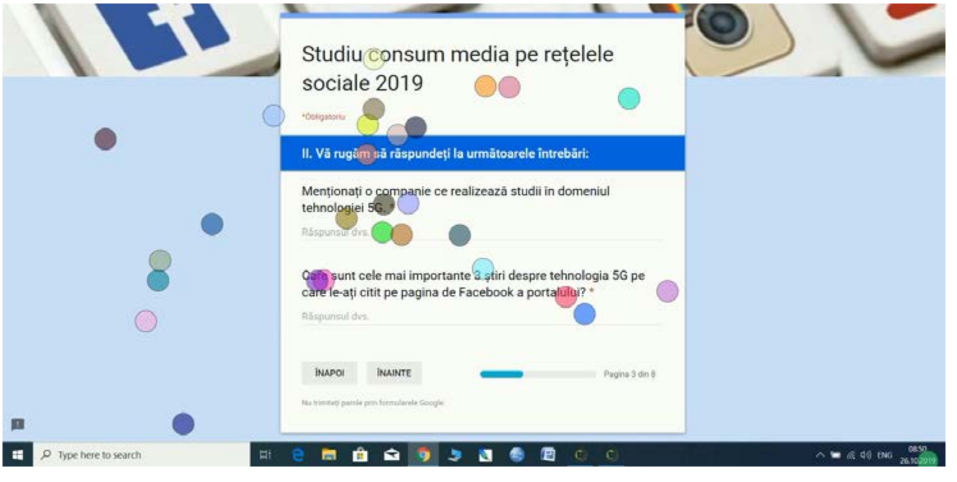

Figure 2: *Bee Swarms* depicting the 36 fixations

Furthermore, the dynamic representation of collected data (i.e., from the video file) shows circles of different colors, representing the fixations of the participants' eyes, similar to *bee swarm*, moving and flying around different areas of interest. Analyzing **Figure 2**, we can argue that some participants did not look at the flow questionnaire items, but answered to the questions. These responses are invalid due to the fact that participants did not read the questionnaire instructions or items.

Fixation count & fixation duration - Fixation Map

Henderson, Malcolm & Schandl (2009) state that *fixation count* represents *the number of times the eye fixates in a particular region of interest*, related to the salience of the area, the informational value of the area, how much information is available in a single fixation, or the processing difficulty at least.

Fixation duration is also an important metric of eye-tracking and *describes how long the eye fixates on a region prior to a saccade*, related to the difficulty in processing the information in that region, the value of it available in that region, the time needed to plan the next saccade, and the predicted value of information available following the next saccade (Sumner 2011). **Figure 3** depicts a fixation map aggregated for 36 participants while completing the online flow questionnaire.

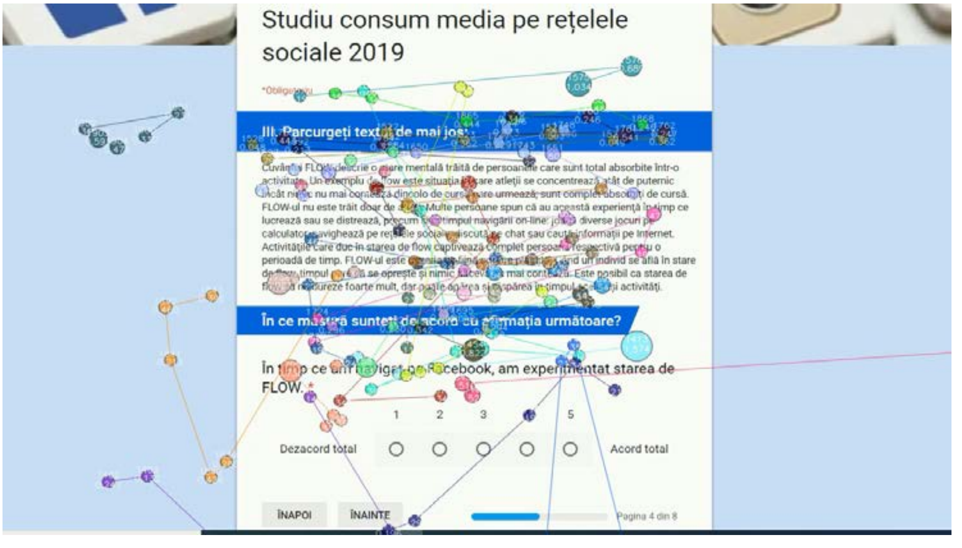

Figure 3: Fixation Map for the 36 participants while reading flow description

We notice in **Figure 3** *the number of fixation*, *fixation duration* and *fixation map* for the 36 participants of our study, while reading flow instructions. Most participants read the flow description and completed the items, but a few were distracted by the background color.

Dynamic Aggregations of Gaze Points & Fixations – Heat maps

The *heat map* illustrates *the distribution of visual attention given by the participants to the flow questionnaire*. The name *heat map* suggests that *the areas represented by the red color are hot* and *the blue ones are colder* (Pernice & Nielsen 2009). Pernice & Nielsen (2009) explain that heat maps of the gaze are quantitative representations of the fixations of multiple individuals because they are based on statistical data.

Analyzing **Figure 4**, we find that the areas represented by the red color indicate a large number of gaze points, the areas illustrated by the yellow and green color show a smaller number of the gaze points, and the blue color depicts the areas where the visual system of the study participants was the least focused.

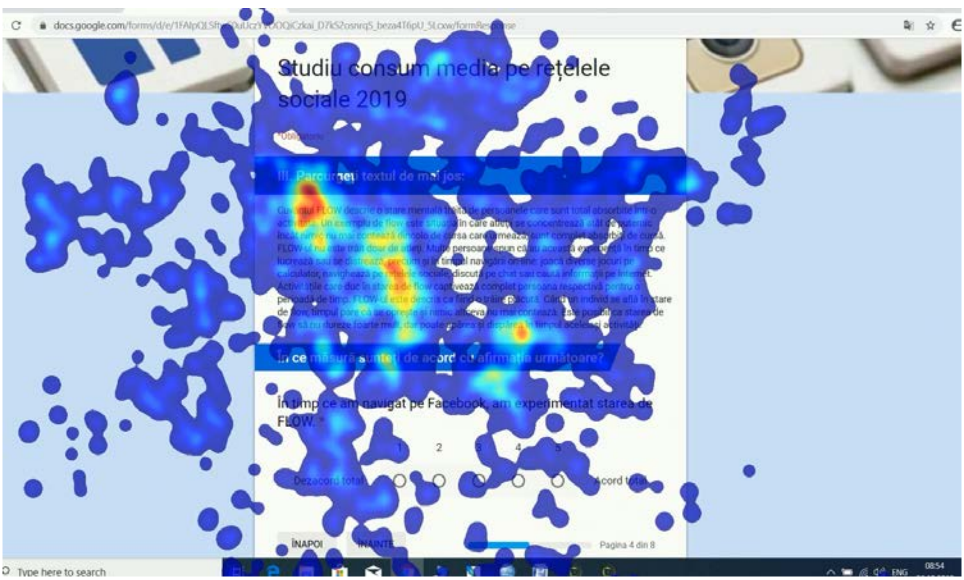

Figure 4: Heat maps for 36 participants while reading flow description and flow items

The data collected from 36 participants indicate, both in a static and in a dynamic manner (i.e., video file), the areas where their visual attention was fixed. We notice that some participants were distracted by stimuli displayed in the header of the webpage (e.g., Facebook logo, Instagram logo), as well from the footer (e.g., the icon folder, the Microsoft Office icon, and the Gazepoint Analysis Professional icon), therefore, they should be removed.

Dynamic Aggregations of Gaze Points & Fixations – Opacity maps

Opacity maps are *the reverse of heat maps and depict which areas are viewed more often or for a long time by participants*. The main advantage of the opacity map is data representation in an aggregated and easy manner to be visualized as a spotlight view of fixations. Using the opacity map, we can see the world through the participants' eyes and better understand which elements the respondents have scanned or omitted. This information is essential for calibrating the data collection instrument. **Figure 5** illustrates the opacity map with aggregated data for 36 participants in the study.

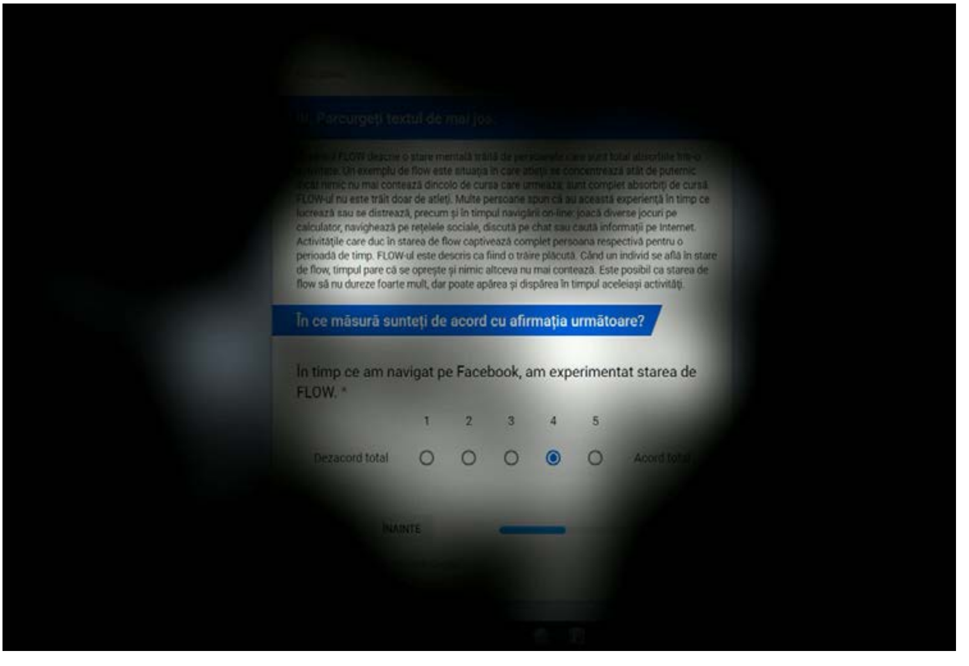

Figure 5: Opacity Map for 36 participants while reading flow description and flow items

Analyzing **Figure 5** we can identify the areas of the questionnaire to which the students fixed their gaze, containing flow state description, as well as flow items. Data suggest that the respondents stopped their gaze on flow description and visually scanned the text before they answered the flow items from the questionnaire.

Area-Of-Interest (AOI) Statistics & Analysis

AOI is *an eye-tracking tool to select regions of a displayed stimulus and to extract metrics specifically for those regions, such as*: *time to first fixation, average fixation, time viewed, number of revisitors, and number of average revisits*. ***Area of Interest (AOI) is a quantitative analysis***.

We created 4 areas of interest (AOI) and extracted metrics for: *Flow Description, Flow Items, Flow Direct Measurement, and Flow Indirect Measurement*. In this section we report the main AOI metrics and statistics computed in Gazepoint Analysis Professional Edition.

The Average Time to 1st View is *the mean time for each selected viewer to look at the AOI, from the time the stimuli were first shown to them* and is measured in seconds. *The Average Time to 1st View of Flow Description (AT1STV-FD)* was 721.184 and *the Average Time to 1st View of Flow Items* (AT1STV-FI) was 787.263. *The Average Time to 1st View of Flow Direct Measurement* (AT1STV-FDM) was 715.700 and *the Average Time to 1st View of Flow Indirect Measurement* (AT1STV-FIM) was 794.396. These results can be explained by the fact that in the flow questionnaire the 4 AOI's were presented successively. Thus, this data proved that respondents first viewed flow description and after that, they completed the items. This is a critical issue in flow measurement (i.e., when using the direct approach) because individuals need to read and understand the flow description after auto-reporting their subjective experience.

Furthermore, *the Average Time Viewed (sec.)* is *the mean (over all selected viewers) of the total duration of time spent in the AOI by viewers*. *The Average Time Viewed (sec.) for Flow Description (ATV-FD)* was 20.201 and for *Flow Items (ATV-FI)* was 3.515. Thus, respondents needed more time to read flow description due to a higher cognitive effort, than to respond to flow items. This argument is supported also by analyzing *the Average Fixations* which *indicate how long the average fixation lasted for an AOI*. In our case, *the Average Fixation for Flow Description (AF-FD) AOI* was 66.603 and for *Flow Items (AF-FI)* was 8.651. This result indicates that respondents looked more at *Flow Description AOI* than at *Flow Items AOI*. Moreover, *the number of revisits* which *indicate how many times a participant returned his gaze to a particular spot, defined by an AOI*, allowed us to examine which areas repeatedly attracted the respondent. *The Average Number of Revisits for Flow Description (ANR-FD)* was 26.22 and 29 *Revisitors* from 36. In *Flow Items AOI* case, *the*

Average Number of Revisits (ANR-FI) was 1.78 and 23 *Revisitors* from 36. We notice that this data indicate the overall difficulty and degree of cognitive effort required to process reading text of flow questionnaire: flow description and flow items. The results are consistent with other recent studies from eye-tracking literature (e.g., Jian 2018) and prove that students devoted more cognitive effort to read the flow description because the text was longer than the one for the flow items.

Analyzing the data for *Flow Direct Measurement AOI* and for *Flow Indirect Measurement AOI*, we noticed that *the Average Time to 1st View of Flow Direct Measurement (AT1STV-FDM)* was 715.700 and *the Average Time to 1st View of Flow Indirect Measurement (AT1STV-FIM)* was 794.396. The results can be explained by the fact that in the questionnaire, we first presented the text and the items for flow direct measurement approach and afterwards the items for indirect measurement procedure. Furthermore, *The Average Time Viewed (sec.) for Flow Direct Measurement (ATV-FDM)* was 40.851 and for *Flow Indirect Measurement (ATV-FDM)* was 59.153. Thus, respondents needed more time to read and respond to the items from *the Flow Indirect Measurement AOI*, rather than to read flow description and items from the *Flow Direct Measurement AOI*. This argument is also supported by analyzing *the Average Fixations for Flow Direct Measurement (AF-FDM)* = 122.941 and for the *Flow Indirect Measurement (AF-FIM)* = 195.897. This result indicates that respondents looked more at *the Flow Indirect Measurement AOI*, than *Flow Direct Measurement AOI*. *The Average Number of Revisits for Flow Direct Measurement (ANR-FDM)* was 16.94 and 31 *Revisitors* from 36. In *the Flow Indirect Measurement AOI* case, *the Average Number of Revisits (ANR-FIM)* was 24.86 and 27 *Revisitors* from 36. This data indicates the overall difficulty to process reading the flow questionnaire text: students revisited *the Flow Indirect Measurement AOI* more than *Flow Direct Measurement AOI*.

A set of Shapiro-Wilk's tests ($p > .05$) and a visual inspection of the histograms, normal Q-Q plots and box plots showed that the variable scores were not normally distributed. Thus, we tested the significant differences between 8 pairs of variables using the non-parametric Wilcoxon Signed Ranks test.

The Wilcoxon Signed-ranks tests indicated significant differences between: (1) *AT1STV-FI (Mdn. = 786.82)* and *AT1STV-FD (Mdn. = 715.646)* scores: T = 351, Z = -2.437, $p = .015$; (2) *AT1STV-FIM (Mdn. = 793.658)* and *AT1STV-FDM (Mdn. = 715.316)*: T = 435, Z = -3.198, $p < .001$; (3) *ATV-FI (Mdn. = .877)* and *ATV-FD (Mdn. = 16.774)*: T = 30, Z = -4.165, $p < .001$; (4)

ATV-FIM (Mdn. = 44.638) and *ATV-FDM (Mdn. = 36.61)*: T = 397, Z= -2.487, *p* = .013; (5) *AF-FI (Mdn. = 4)* and *AF-FD (Mdn. = 56.493)*: T = .00, Z = -4.782, *p* < .001; (6) *AF-FIM (Mdn. = 29)* and *AF-FDM (Mdn. = 114)* scores: T = .00, Z = -4.937, *p* < .001, (7) *ANR – FI (Mdn. = 1)* and *ANR-FD (Mdn. = 29)*: T = .00, Z = -4.784, *p* < .001, and (8) *ANR-FIM (Mdn. = 21)* and *ANR-FDM (Mdn. = 13.5)*: T = 351, Z = -2.438, *p* = .015.

The results of the Wilcoxon Signed-ranks tests support the idea of a statistically significant difference between the 4 AOI's eye-tracking scores.

4. Conclusions

Online questionnaires are the most commonly used tools in social sciences for collecting data about the individual's optimal experiences. From a methodological perspective, scholars need to pretest survey instruments by considering the cognitive difficulties posed by their survey instructions, descriptions and items, to reduce errors and to ensure measurement validity. Eye-tracking provides valuable insights into the distribution of visual attention while completing a questionnaire, and can be used in the pretest phase.

In flow studies, the vast majority of scholars use questionnaires to assess flow, but an important issue in literature is developing and using the appropriate measurement method. Thus, the aim of our experimental study was to explore how much visual attention respondents have paid to information from an online flow questionnaire, in order to pretest two flow measurement approaches: direct and indirect.

The gaze points data collected by eye-tracking determined where the participants were looking and when, while completing the online flow questionnaire. The results highlight that some participants did not look at the flow questionnaire items, but they answered the questions – generating measurement errors. The fixation count, fixation duration and fixation maps revealed that most participants read the flow description and completed the items, but a few were distracted by the background color – thus, researchers should consider and pretest this aspect when designing an online questionnaire. The heat maps illustrated the distribution of visual attention given by the participants to the online flow questionnaire. The resulting heat maps depicted some participants being distracted by a set of stimuli (i.e., icons, logos) displayed on the questionnaire webpage in the header and footer. Therefore, these stimuli should be removed.

We assessed the order of the online flow questionnaire elements that have been noticed, using opacity maps. The results suggest that respondents stopped their gaze on flow description and they visually scanned the text before they answered the flow items from the questionnaire. This insight is extremely important in the direct flow measurement procedure case because participants need to first read flow description and afterwards to report if they had a similar experience. The metrics analysis for Flow Description, Flow Items, Flow Direct Measurement, and Flow Indirect Measurement AOI's support these conclusions. The results are consistent with other recent studies from eye-tracking literature (Jian 2018) and prove that students devoted more cognitive effort to read the flow description, than to read and complete the flow items. Furthermore, we tested the significant differences between the scores for Time to 1st View, Time Viewed, Fixations and Revisits for 2 sets of AOI: Flow Description AOI – Flow Items AOI and Flow Direct Measurement AOI – Flow Indirect Measurement AOI. The results of the Wilcoxon Signed Ranks tests indicated significant differences between the median scores of the variables pairs.

The main contribution of our study consists in arguing that the flow indirect measurement text required more time to be processed and determined more revisits than the text of the direct measurement approach. This is a critical issue in flow measurement because scholars need to use parsimonious scales for measuring flow and consider participants' willingness and ability to process the text.

We conclude that researchers can use eye-tracking to explore if some elements from an online questionnaire are being ignored or overlooked, and identify where respondents look and how much time they spend in processing visual and textual information, using objective measure.

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