An Eye-Tracking Study on Differences in Information Transfer by Infographics

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Abstract

Information graphics are commonly used to display information. Nevertheless, the retention of information can differ depending on the presentation of the content.
A topic that is currently present to all of us in the media is the refugee influx to Europe. As it caused a lot of chaos, confusion and anxiety, the transfer of information played and still plays a crucial role, which is why we chose two different graphics visualizing facts and information about refugees.
Our aims were to get insights into the readers' information behavior dealing with information graphics and to find differences in information transfer.
Therefore, we conducted eye-tracking experiments and analyzed the fixation time and the fixation count on both textual and non-textual elements of the infographics. After reading, the retention of information was tested using free text questions and summed up in a score that was evaluated.
Results showed that the subjects had spent most of their time on textual elements for each infographic. The viewing behavior did not differ significantly between the two graphics. Despite this, we found significant differences in information transfer. This might be because one infographic had fewer subtopics. Each of these sub-topics was backed up by the repetition of several textual and non-textual elements as well as additional details, which broadened the context.

In: M. Gäde/V. Trkulja/V. Petras (Eds.): Everything Changes, Everything Stays the Same? Understanding Information Spaces. Proceedings of the 15th International Symposium of Information Science (ISI 2017), Berlin, 13th—15th March 2017. Glückstadt: Verlag Werner Hülsbusch, pp. 50—61.

Keywords: eye-tracking; information graphic; textual elements; pictorial elements

1 Introduction

Last year, the German government had to deal with more than 650,000 asylum applications in the period from January to September. This represents an increase of about 134% in comparison to the same period for the previous year.[1] People from the Near East, Africa or other crisis areas had fled from civil wars and violence. The arrival of the refugees ignited political debates, xenophobia and even riots in some countries. In contrast, many people are willing to help the fugitives and try to understand their problems.

To do so, it is essential that information about the origins, the backgrounds and the motives of the refugees is provided. There are many different ways to transport information, e.g. plain text articles, images or videos. In this study, we focused on a special combination of text and visualization: infographics. The following paper deals with two questions. How do readers interact with these two components of infographics and does the way the information is displayed make a difference regarding the transfer of knowledge?

2 Related work

The background of this current issue is how to use the transfer of information and knowledge in an appropriate way. Users should get an easy and quick overview of purified and well-arranged information in order to fulfil their information need. Growing data sets produced by statisticians or collected by supercomputers provide the need of a suitable presentation form (Schumann, 2000). For many years, information graphics have been in use now to display

1 Bundesamt für Migration und Flüchtlinge, "Aktuelle Zahlen zu Asyl" 09/2016, http://www.bamf.de/SharedDocs/Anlagen/DE/Downloads/Infothek/Statistik/Asyl/aktuelle-zahlen-zu-asyl-september-2016.pdf?__blob=publication <11.11.2016>

data and facts in a simple and comprehensible way (Bouchon, 2007). Bouchon defines an infographic as a combination of graphical elements, e.g. photos, drawings or pictograms, which draw attention and convey information that is perceivable at first glance, and typographic components like letters, digits, or mathematical symbols, which point out connections, functions and chronological sequences. For her, it is only through this combination that infographics convey additional information (ibid.). Especially daily newspapers frequently apply this way of visualizing information. The increasing popularity of infographics supports their claim to represent a good way to transfer and report information.

Information graphics are the object of scientific investigations often. Especially their possibilities to transport and display information and their usefulness in the communication of the digital age have been analyzed for numerous times.

A study by Holmqvist and Wartenberg (2005) showed that the presentation of information had an impact on reading behavior. They compared a graphic with integrated text and images and a graphic with separated text and pictures. Results showed that readers focused more on the images when both elements were separate. When the pictures were integrated in the text, readers looked at the images and read the text equally (ibid.).

Based on these results Holsanova et al. (2009) recorded eye-movements to evaluate the interaction of readers with given information graphics. They additionally used different design laws such as spatial contiguity or arrows pointing towards related elements to evaluate the impact on the understanding of the context and information transfer. The evaluation of the eye-tracking data showed that readers tend to jump from the headline to graphic elements directly when text and graphics are separate. In comparison to this, readers who had to read the text with integrated graphics, both elements, pictures and text blocks, were read together (ibid.).

Another study by Dagmar Gehl (2012) compared two magazine articles, which were either original or manipulated a distinct way, in order to find influences on the knowledge transfer. The original version of each article consisted in textual and graphical elements. In the modified version, the important pieces of information from pictorial elements were converted into text and the images were removed. For assessment, every subject had to fill in a questionnaire and a concept map. The results proved that in both parts of the test, the participants that had to read the unmodified article with graphics achieved better results. The eye-tracking data supported this.

Further analysis proved that graphics catch the reader's eye. A redundant information presentation and a strong interaction with the content influence the information transfer in a positive way (ibid.).

However, information graphics do not automatically transfer knowledge. They can only be helpful, if the user assess the information as relevant for his information need (Burmester & Wenzel, 2013).

Information graphics are always created in a user-centric design. This creates a gap between user and creator: The user wants to fulfil his information needs relating to a current subject, while the designer tries to convey specific information (ibid.).

The related work shows that recipients remember information better when textual elements are enriched and even integrated by graphical elements. However, it is important to note that each person interprets things differently and that information has to be assessed as relevant by the reader to be remembered.

3 Experiment design

The information behavior was assessed in an eye-tracking experiment on subjects reading infographics. The transfer of information was measured by a score based on questions about information covered by each graphic.

3.1 Selection of stimuli

There are many information graphics that transfer details about the numbers of refugees, their migration paths, and numerous other facts about fugitives. The stimuli to be analyzed were selected by the following criteria:

As we focused on differences in information processing, the graphics had to be comparable, but not too similar. Furthermore, the graphics needed to contain textual elements enriched with images or pictograms. The textual elements should not be longer than a few lines, and images or other non-textual elements, such as charts, diagrams or maps had to be memorable but not too dominant. Moreover, a balanced mixture of textual and non-textual elements was considered ideal for our research purposes and the overall quantity of textual elements had to be similar for both graphics.

In order to assess the information transfer, a common questionnaire had to be used, so each graphic had to cover all the information needed to answer it. We chose two graphics from the web presence of a German governmental institution[2], which was considered a reliable source concerning the content.

The two selected infographics differ mostly in their appearance: The first graphic "*Flucht in Zahlen*" (fig. 1) can be roughly translated as "Refugee Facts in Numbers", and is referred to as 'NUMBERS' in this text. This graphic is designed in light colors like grey and white. Textual elements are arranged around rather big images, marking the center of the graphic. In addition, big numbers symbolize important values. This graphic contained a total amount of 498 words.

Fig. 1 'Flucht in Zahlen' ('Refugee Facts in Numbers', referred to as 'NUMBERS')[3]

The second information graphic "*Der Weg über das Wasser*" (cf. fig. 2) means "The Route over the Water" and is referred to as 'ROUTE'. This graphic is kept in darker colors such as black, blue and red. Textual elements are scattered all over the graphic. Instead of concise images, pictograms are used to reveal information about related textual elements. 'ROUTE' has a count of 408 words.

2 Bundeszentrale für politische Bildung (Federal Agency for Civic Education)

3 http://www.bpb.de/shop/zeitschriften/213674/bpbmagazin-2-2015 <15.11.2016>

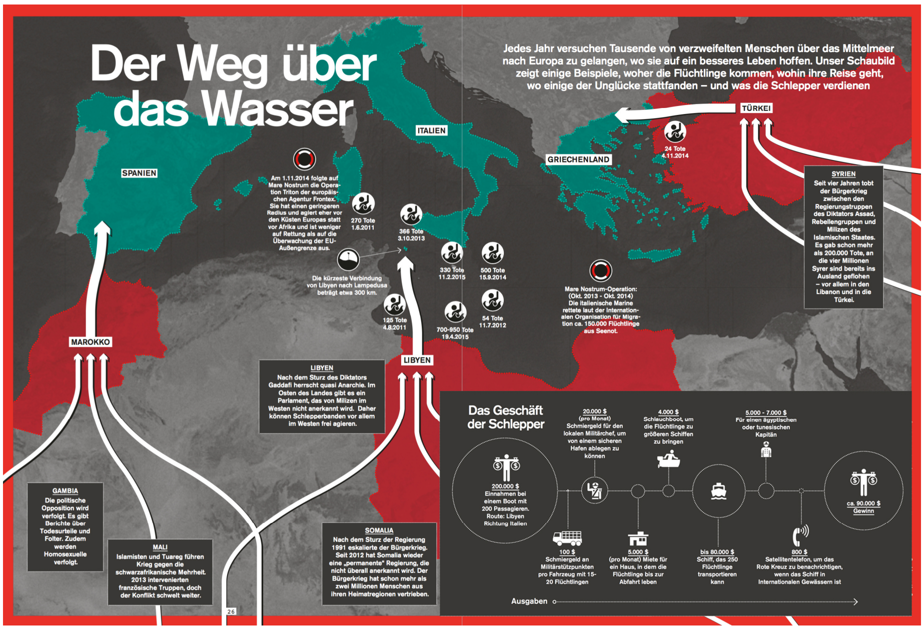

Fig. 2
‘Der Weg über das Wasser’ (‘The Route over the Water’, referred to as ‘ROUTE’)[4]

3.2 Assessment of information transfer

A questionnaire was designed to assess the amount of information transfer. It contains questions about information that both ‘NUMBERS’ and ‘ROUTE’ cover. Some pieces of information are present in textual elements of each graphic, whereas others are displayed evidently in the center of ‘NUMBERS’ but wrapped up in text in ‘ROUTE’. According to Bloom’s learning target taxonomy, we focused on the category ‘knowledge’, i.e. remembered facts (Bloom & Engelhart, 1976). The subjects were asked three questions to be answered in free text.

The first question referred to the title of the graphic. The information required to answer questions two (death count of refugees) and three (earnings of smugglers) was depicted in the text and in corresponding pictograms. We additionally asked the subjects demographic questions like age and gender. The collection of these data was carried out via Google Docs.

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4 http://www.bpb.de/shop/zeitschriften/fluter/208588/flucht?blickinsbuch (pp. 26–27) <15.11.2016>

3.3 Experimental procedure

Each subject was randomly shown either 'NUMBERS' or 'ROUTE'. The experimental setup took place in the eye-tracking laboratory at the chair of information science. Data was recorded using a SMI 250 Hz remote eye-tracking device. Every subject was placed at a distance of about 60 to 70 cm in front of the screen. After instructions and calibration the graphic was displayed. The participant had no time limit while reading the information graphic. The last step was to answer questions about the presented content.

After two pre-tests for adjusting the experimental set-up we tested 30 subjects. 15 subjects were shown the graphic 'NUMBERS' or 'ROUTE', respectively. Their age ranged between 15 and 62 years with an average age of 27.3 (SD = 11.9) years. 18 of the subjects were male and 12 were female.

All subjects were familiar with the topic. Each of them had either graduated from high school or had a university degree.

3.4 Data preparation

We focused on the reading behavior on text snippets and the viewing behavior on images. Within each infographic, we separated the textual and the non-textual elements into two different groups of areas of interest (AOIs) in order to compare these elements.

We determined different parameters like the fixation time in seconds and the fixation count, i.e. the number of fixations, for both groups of AOIs (textual and non-textual elements) as well as the first and the second fixation on the stimuli. The fixation time tells us how long the reader's eye has remained on a specific area and is the most frequently reported parameter in eye-tracking research (Holmqvist et al., 2011). The fixation time is associated with cognitive processing according to the eye-mind hypothesis (Just & Carpenter, 1980). That means the longer an area is fixated the deeper is the information processing. The fixation count tells us the number of individual fixations per AOI. In combination with the fixation time, this provides additional information. For example, whether an area is fixated frequently but for a short time or consists of few fixations with a long duration (Holmqvist et al., 2011). Longer fixation time and a higher fixation count refer to a deeper understanding of the text (ibid.). Concerning the viewing behavior on pictorial elements, higher fixation time and count indicate information that is considered relevant by the viewer (Loftus & Mackworth, 1978).

Furthermore, we investigated starting points. The first and second fixation on a stimulus tells us which elements are most salient. The first entry point is unconscious and not influenced by characteristic properties of the stimulus. The second fixation, however, is executed actively und reflects the reader's processing (Holmqvist et al., 2011).

To evaluate the retention of information, the results of the questionnaire were summed up in a score. Each correct answer was credited with two points. When asked for a number, the subject was credited one point when his answer was within a range of plus or minus five percent of the correct number. No answer or wrong answers were credited with zero points. The answers were summed up in a normalized score (number of points obtained divided by maximum points) between 0 and 1.

4 Data analysis

Firstly, we wanted to check if information transfer is different between the two graphics. The created score ranges between 0 and 1 and the level of measurement is metric. A Shapiro-Wilk test showed a non-Gaussian distribution of the score for both groups (p-values < .05). In order to compare the scores, we used the non-parametric Mann-Whitney U test. We found a significant difference between the two groups ($Z = -3.1854$; p-value < .01). The mean score for the graphic 'NUMBERS' was 0.17 (SD = 0.19), 'ROUTE' had an average value of 0.42 (SD = 0.20). Interestingly, the median of the infographic 'NUMBERS' was at zero which means that half of the participants did not score a single point in the questionnaire. The second graphic 'ROUTE' on the other hand showed a score of 0.4. In table 1 the dispersion of the values is shown.

Table 1: Score summary for each graphic

graphic	min	25th percentile	median	mean	75th percentile	max
'NUMBERS'	0.0	0.0	0.0	0.17	0.33	0.5
'ROUTE'	0.0	0.4	0.4	0.42	0.42	0.8

The mean score of the two infographics differed by 0.25. Keeping in mind the overall range of just 1, this also supports the hypothesis of different ways of information transfer in the two graphics. Accordingly, the 75^{th} percentile and the maximum were much higher in the infographic 'ROUTE'.

To sum it up, the participants remembered more information from the graphic 'ROUTE'.

To understand why the participants had a higher rate of information transfer from one of the graphics, we scrutinized their way of reception by determining several eye-tracking parameters on certain areas of the infographics.

In general, textual elements were fixated longer than non-textual elements in both infographics. For 'NUMBERS' the average fixation time of textual elements was three times higher than the one of non-textual elements. On average, the textual elements were fixated for 99.82 seconds (SD = 69.31 sec), the pictorial elements were fixated 33.39 seconds (SD = 14.65 sec). The same phenomenon was observed in the graphic 'ROUTE' with average values of 92.56 seconds for textual elements (SD = 35.84 sec) and 26.70 seconds for pictures (SD = 9.59 sec). The fixation count corroborated these results. The number of fixations on textual elements (M = 182.3, SD = 90.87) in the graphic 'NUMBERS' was higher as the count on the images (M = 106.7, SD = 43.75). The mean fixation count on textual elements in the graphic 'ROUTE' was 182.4 (SD = 45.34) and on non-textual elements 77.5 (SD = 31.74). A subject spent on average 2.22 minutes (SD = 71.9 sec) on 'NUMBERS' and 2.07 minutes (SD = 48.0 sec) on 'ROUTE'. Due to different sizes of the AOIs, the fixation time of each was normalized by division through the total fixation time to grant comparability.

We checked for differences between the two infographics regarding the whole of textual and non-textual AOIs, respectively. Non-parametric Mann-Whitney U tests were used as there was no Gaussian distribution either as shown in a Shapiro-Wilk test (p-values < .001).

First, we compared the fixation time in percent on textual elements between the two infographics. There was no significant difference between both groups ($Z = -0.477$; p-value > 0.05) with the medians of 78.44 percent on 'NUMBERS' vs. 79.65 percent on 'ROUTE' as shown in table 2. So the participants spent about the same amount of time on textual elements in the graphics 'ROUTE' and 'NUMBERS'.

Additionally, we had a look at the normalized fixation time on pictorial elements. As well as the normalized fixation time on textual elements, there was no significant difference ($Z = 0.477$; p-value > 0.05) between the two graphics ('NUMBERS' median: 21.56; 'ROUTE' median: 20.35).

Table 2: Summary for normalized fixation time on AOIs

graphic	min	25th percentile	median	mean	75th percentile	max
textual elements						
"NUMBERS"	13.99	64.88	78.44	68.36	83.06	84.56
"ROUTE"	46.59	74.76	79.65	76.64	82.54	89.42
non-textual elements						
"NUMBERS"	15.44	16.94	21.56	31.64	35.12	86.01
"ROUTE"	10.58	17.46	20.35	23.36	25.24	53.41

We also analyzed the reading intensity by dividing the fixation time on textual AOIs (in seconds) for each participant through the number of words in the respective graphic. Student's t-test was used in this case as the data were distributed Gaussian (Shapiro-Wilk test, $p > 0.05$) with homogenous variances (Bartlett test, $p > 0.05$). The test revealed no significant differences but the average reading intensity was slightly higher in the graphic 'ROUTE' (M = 0.24; SD = 0.11) than in 'NUMBERS' (M = 0.2; SD = 0.13).

Table 3: Summary for reading depth

Graphic	min	25th percentile	median	mean	75th percentile	max
"NUMBERS"	0.01	0.13	0.18	0.2	0.26	0.55
"ROUTE"	0.06	0.15	0.21	0.24	0.33	0.49

The last parameters we analyzed were the subjects' first and second looks at the graphics. The analysis revealed that 90 percent of the first fixations were located in the center of the infographic. These results go along well with Tatler (2007), who stated that people tend to fixate the center of stimuli presented on a computer screen. We furthermore examined the subjects' second fixations. About 80 percent of the participants moved their eyes from the center to the heading of the graphic. In this study, both of the headings were placed in the top left corner and had about the same size and the same color.

5 Discussion

To sum it up, textual elements received more attention than non-textual elements in both infographics. Images might be perceived at first glance whereas more time is needed to read a text paragraph.

Although no significant differences in information behavior could be stated, we observed a significant difference in information transfer between the two graphics. The subjects remembered more information from the graphic 'ROUTE'. This might be because fewer sub-topics are covered by this infographic. Each of these sub-topics is backed by either the repetition of textual and non-textual elements or additional details, which broaden the context. Another point is that 'ROUTE' mostly represents information with the help of pictograms, which are used repeatedly. The infographic 'NUMBERS', on the other hand, uses many different photos of real objects to illustrate its great variety of sub-topics. These differences reasonably explain the fact that the subjects could remember more information, but this study provides no data to either prove or disprove these hypotheses. What this study showed, however, is that the sole investigation of the viewing behavior is not sufficient to explain differences in information transfer. Therefore, confounding parameters need to be reduced, e.g. by using just one infographic that is displayed in different ways. Furthermore, plain text might represent an appropriate way to determine a sort of baseline. Besides that, the group of subjects needs to be increased either in numbers or, at the expense of external validity, in homogeneity. To sum it up, more variables than just the viewing behavior need to be considered to investigate information transfer in infographics.

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