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Eye tracking experiment using book covers. Visual data analysis in reference to mind space mapping

Veslava Osinska[1] and Grzegorz Osinski[2]
[1] Nicolaus Copernicus University in Torun, Poland
[2] College of Social and Media Culture, Poland

Abstract: The study of the eye movement provides us with the functioning of the visual perception of a human while observing images such as: book illustrations, book covers, posters and other standard publications. The current experiment was performed using the series of collections of book covers. The both configurations of layout and images data set constitute the variables. Due to given results several rules of visual composition for library users are formulated. However, usually the process of analysis relies on determining the areas of the highest concentration of visual attention, which is only interpreted in the frame of mind space mapping paradigm.
Keywords: eye tracking, book cover, visual perception, mind space, perception mapping.

1. Introduction

The research was inspired by the observation of cognitive strategy of students facing a collection of book covers. What is essential is the first contact between a potential reader and a book. If there are more than two or three books presented in the display case of a book exhibition, it is the first visual contact with the cover that affects the immediate perception of the selected item and reading its title or remembering its graphic look. In scientific institutions, the presentation of books by scholars has been accepted as a group scientific output of a department. In this way, it is possible, on the one hand, to promote a given organizational unit and, on the other hand, to disseminate knowledge on the interests of lecturers among colleagues and students. These publications usually concern a specific research stream resulting from the speciality of a given Faculty or Institute. On the other hand, their subject matter can be very diverse, which should be reflected in the graphic representation of the cover.

The fact that the cover is of great importance in the promotion of books has been proven in papers in the field of Book Studies oriented towards best sellers, book marketing, book market, etc. (McGee, 2016; Chesson, 2018). The cover is also supposed to introduce the audience to the work mood, and even inform

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them about the work features by means of colour and style. Bookstores usually promote a large number of items at the same time that are diverse in terms of colours and styles. A thorough examination of the visual selection criteria is therefore very difficult there due to too intense stimuli from both the environment and the context of the presentation. In the case of scientific book covers and the first contact situation described above, perceptual distraction makes it possible to reconstruct the conditions suitable for experimental research. The scientific book covers are characterized by specific styles and restrained design, whereas academic publishers have their own design patterns, not necessarily reflecting the latest trends. In the digital space, tabular presentations of cover series of recently published items are also often implemented, as it is done by the NCU Press (Figure 1). This study is based on observations of the user perception of digital cover layouts.

One of the questions the authors have asked themselves is how readers manage their perceptive attention when viewing a previously unknown series of covers.

Figure 1 Digital Publishing Platform for NCU Journals under DOAJ license, Source: http://apcz.umk.pl/en/.

Unfamiliarity with the covers became a necessary criterion in obtaining the study credibility. An experimental method of eyetracking was used to analyse the perception of previously prepared cover layouts. The paper authors, having knowledge about the current research in the field of neuroscience, simultaneously undertook to interpret the results from the viewpoint of universal artistic canons, imposed by painters over the centuries, and analysed in detail today by scientists.

2. What is Eyetracking

The advancement and wide availability of technology contributed to the “exit” of eyetracking from medical and military laboratories. Eyetracking has found

practical application in broadly understood marketing and market research, and recently also in the issues of usability of application interfaces and websites.

Eyetracking consists in tracking the movement of eyeballs. The eyetracker device measures, among other things, the timespan of subject eyes focus on a specific point on the screen. The position of the subject eyesight is recorded at a frequency of 60 Hz. This allows to record very short-term gazes. The major metrics used in eyetracking research are fixations, i.e. focusing sight on a given element and saccades which are quick movements of the eye between successive fixations (Holmqvist et al., 2011; Farnsworth, 2018).

The length and number of fixations tells us how the examined element is focusing (Poole and Ball, 2004). The mean fixation time for a text of 8 letters is 222 ms. When we search the visual area, the fixations are about 275 ms, and when we watch a complex scene, 330 ms (Rayner and Pollatsek, 1984). The lower the time to the first fixation the higher the ability of the tested element to focus. (Byrne et al., 1999). The number of fixations on a given element tells us, among others, about the searching efficiency of the examined object, its importance and noticeability in the process of eye scanning (Bergstrom and Schall, 2014; Duchowski, 2017).

Eytracker is also capable of showing the sequence of the watched elements in the form of so-called gazeplots which outline the path that the eyes have travelled when making successive fixations.

Eyeball movement is recorded in the form of raw quantitative data which can be analysed statistically and used to create a variety of metrics to interpret the perception of screen elements (e.g. a website). An example is the number of fixations in a specific area; a large number of fixations with a short duration is interpreted as a user experienced problem with comprehension (interpretation of content) of given area, e.g. an incomprehensible logo or an incomprehensible headline.

To analyse the observer's attention, it is a customary to use a heatmap. It is defined as the spatial distribution of attention paid to the examined element which is a component of the image. The heatmap, also known as thermal map, shows the total intensity of all the subjects' attention by means of colours. The general principle of map interpretation is that the more red ("warm") an area is the more attention is focused on it.

One should be very careful when interpreting the results of eyetracking tests and have realistic expectations about the questions that this method can answer. Eyetracking tests do not provide us, for example, with an unambiguous answer as to whether the user comprehends the content read. We get data on how they process it, but this data can be interpreted differently (Duchowski, 2017).

3. Experiment

In the experiment, 70 covers were presented in total, grouped into 3 sets of 21-25 pcs each. This number has been selected as the optimum one due to the screen resolution. Some of the most characteristic and meaningful for the cover perception appeared in the groups several times. Such selection was imposed by the small number of covers featuring a clear typography or human face. The collection of covers had to be changed several times during the experiment, because the subjects reported that in each successive picture they were trying to spot the previously presented elements which were the most memorable.

The first independent variable was a layout composed in two configurations: circular (C) and random (R), while the set was treated as the second independent variable. The circular layout is inasmuch important in the examination of visual perception as it lacks the extreme anchor points, specific for the reading processes: from left to right. This avoids the problem of imposing a perceptual definition of the observation beginning. For the same reason, the grid (table) layout was not used either, because a linear layout always imposes a hierarchy in perception. We expected that in the elliptical arrangement, the first fixation would focus on the most important area of perception, rather than on the inside – where there is an empty space. The prepared images, cover layouts, were processed by means of graphic filters in order to:

1) specify whether or not the random layout is optically balanced;
2) detect the greatest contrasts of light and shade;
3) compare the perceptions of a positive and a negative images.

25 subjects were examined, mainly students and scholars, who did not know the details of the scientific publications presented in the pictures. The average age was 28.4 of which 31% were men and 69% were women. All subjects have daily contact with books, which, unfortunately, is not a standard in modern society. The subjects were focused on the observation of a sequence of 9 images. Three sets of covers were arranged in two configurations – in this way 6 images were prepared for the analysis. For the other three, graphic filters were applied to determine the composition keys.

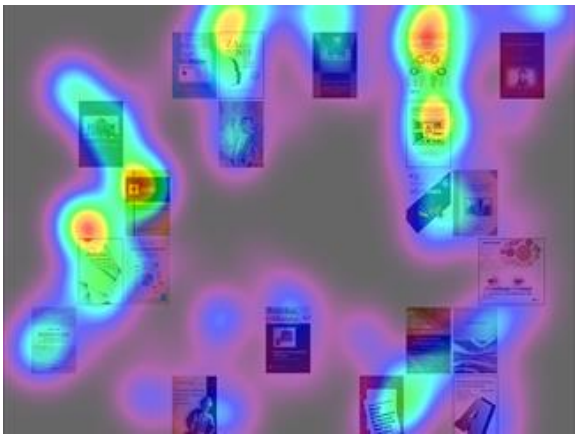
Each image was presented for 6 seconds; whereas such a time was established on the basis of still few experiments on static graphics perception (Weichbroth et al., 2017). Most of the images were normalised at: 1280x768 pixels. The experiment was conducted with The Eyetribe eyetracker, using a frequency sweep of 60 Hz. The maximum sensitivity for calculating the distance between the individual fixations was set to 20 px. The minimum amount of fixations that indicates the attestation perception point, i.e. the minimum number of samples that can be considered as confirmation of response, was 5. The analysis was carried out with the free software Ogama, version 0.5514 (Voßkühler, 2015).

The analysis resulted in visual pathway attention maps, gazeplots and fixation maps.

4. Results and interpretations

The results of the experiments are graphical representations of visual perception in the form of attention and fixation maps. They allow for a qualitative analysis of visual attention for individual sets of covers. The allocated publishing limits do not allow to present a complete series of eyetracking results for three configurations and three sets of covers. Maps of attention, maps of fixation and gazeplots in a resolution enabling a thorough analysis are posted on the website of a science blog maintained by the authors at the following address: http://www.wizualizacjainformacji.pl/eyetracking. The following are the attention maps for the first set of randomly configured covers (Figure 2).

For images presenting random layout of covers, graphic filters were applied: negative and monochromatic. The results of the visual perception analysis for the modified graphics of the layout analysed above are presented in Figure 3. Comparing the eyetracking results for the original images with the filtered images, we can see that the focal points of areas of interest are the same. Nonetheless, the fixations distribution is much more varied for the negative and less for the monochromatic image.

A 

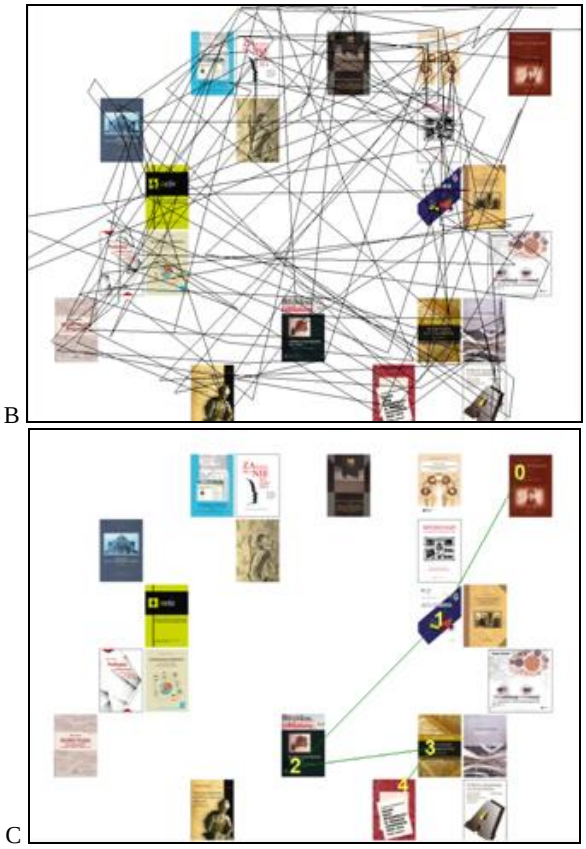


Figure 2 Thermal map (A), gazeplot (B) and initial 5 vision fixations (C) for the first set of covers in a random configuration.

As we can easily note, high contrast is always effective in attracting attention. This is how the covers act when they feature white background and the short text "No" in red. Those adjacent to areas with maximum cover contrast also gain attention. From the viewpoint of neuroscience, colour perception strongly affects the hierarchy of object perception depending on the cultural scale of popular colours (Arnheim, 1974; Ware, 2004). Special attention should be paid to the importance of the red colour which in our culture means warning and is treated as a strong stimulus. Another important perceptual stimuli are the simple geometric figures contrasting with the background (Arnheim, 1974). This is in line with Gestalt's principles applied in advertising design (Elam, 2011; Ambrose and Harris, 2011). A similar effect is used in designing graphic identifiers of commercial companies (e.g. Google, Microsoft), where basic shapes and RGYB colour palette are applied.

In addition to the main conclusions described above, some interesting observations were made. In the case of black background, contrasting typographic elements (Figure 3) attract the attention.

Figure 3 Heatmap of the layout subjected to a monochromatic-negative filter.

Since black background is not a natural environment for visual perception, the human visual system spots what it recognizes first. Therefore, shades that can activate the limbic system become a new element of the composition key. The visual system recognizes what is well known to it, and in the circle of our literary culture, these are the letters appearing in the text (Osinska & Osinski, 2018). Therefore, the "negative" composition key is much simpler, the elements of contrast and letters suffice, so it should be applied to emphasize the text contents in the prepared presentation.

Circular layout is associated with an interesting observation. The sequence of set images is insignificant here, but the characteristic graphic elements, which do not cause interest in the immediate neighbourhood, are vital.

5. Mind space mapping

A very important issue, that directly affects the results obtained by eyetracking, is considering the visual perception processes that occur in the human brain when viewing a complex image. The results of neuroscience studies show that similar shapes are analysed first and then internal correlations between the recognized shapes are recognized and a crystallized object is created, which is then transferred to the neural structures responsible for long-term memory. If the structure of interconnections is recognized, the virtual representation appears

in the mind space (Osinska, Osinski and Kwiatkowska, 2015). Everything that receives a visual perception system must have its own representation in the brain (Zeki, 2009). The search for the module location in the human brain, responsible for the synthesis of visual information and the creation of a suitable object in the space of mind, has not produced a satisfactory result so far. While we know that images are analysed in the visual cortex of the occipital part of the brain, we also know that visual impressions are created throughout the brain and have a decisive influence on the global phenomenon of visual consciousness. So in order to correctly interpret the results of eyeball movement experiments when viewing specific images, we are introducing a useful concept of mind space which is an abstract topological space where we will describe the functions that combine the brain activity with what are known as states of mind in terms of contemporary neurodynamics. The basic features of such a space of mind were defined by Duch (1998): "*Psychological spaces spanning axes related to the results of psychophysical measurements, treated as the arena for mental events, are necessary to create a language that allows for a precise description of mental events".*

We do not set a fixed value for the topological dimensions necessary to create visual perception representations, but define them generally as a set of all realistic observations available in an experimental study. In such a space, we can consider the dynamics of conscious eyeball movements during the recognition of objects. The application of such space will also allow to separate those eyeball movements that are generated automatically, without activating the correlates of visual consciousness, which is extremely important for a thorough analysis of interest in a given object (Osinski, 2018). Instinctive, automatic eyeball movements caused by the activity of fast neuronal pathways, not directly related to the image recognition processes, constitute a serious problem of interpretation in eyetracking experiments.

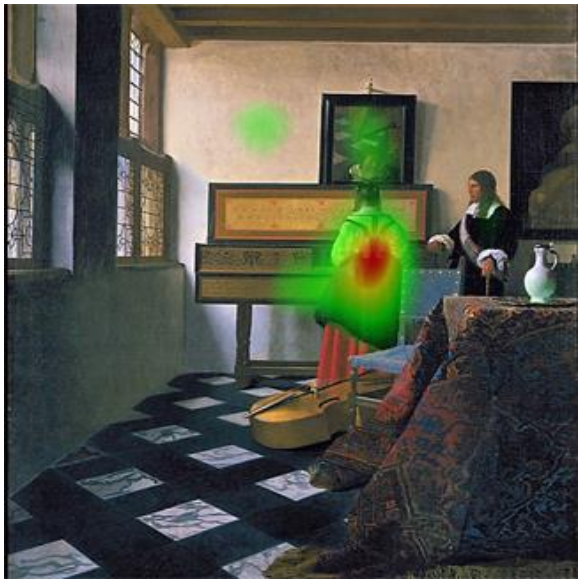
Automatic visual information processing modules, located in the human brain, are strongly coupled, not only with each other, but also with other parts of the brain. This feature makes the information usable as efficiently as possible depending on our current needs. Such an evolutionary accommodation has a posteriori features, i.e. acquired through multiple experiences, responsible for strategies of image recognition different than the conscious activities resulting from the coupling of cortical functions.

One of the automatic processes is the facial recognition module which in the neural systems of the limbic system creates an appropriate emotional complexion affecting the subsequent recognized images (Ramachandran, 2011). In Figure 4, we see the practical consequences of its actions. In order to create representations of the entire image of "Music Lesson" by J. Vermeer in the space of mind, the modules that automatically seek to recognize face also focus

on the profiles of people who certainly have such an attribute, even if they are turned back in the picture.

Without taking accounts of the mind-space representation, it would be impossible to explain the lack of focus traces on the white pitcher on the right side of the picture; the viewer eyes are not really concentrating on it, even though it is an important composition key. This is because the pitcher is quickly recognised as an object that is clearly distinguishable from the others in contrast and is well known and recognised "at first glance". Visual attention is focused on a backward-facing figure who should have a face, but the automatic module does not recognize it, so during the experiment, a large area of the thermal map is visible.

The composition key created by the artist, however, does not indicate as the most important element, the back of the student playing on the piano, but emphasizes other elements (pitcher, platform, window). Nonetheless, the examination of eyeball movement shows us the structure of mind-space neurodynamics, focusing on the object that forces attention to create visual traces around the object, because then our mind creates a complete representation of the image, consisting of recognized elements, around an "unrecognised" face.

A 

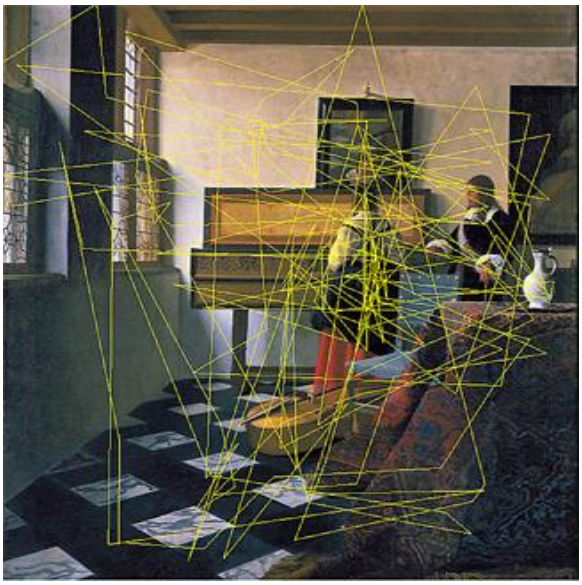
B 

Figure 4 Heatmap (A) and fixation plot (B) of J. Verneer's "Music Lesson" perception.

6. Conclusions

The presented qualitative and quantitative analysis refers to the strategy of perception of various book cover compositions. The presence of geometric shapes (rectangles) along with the title text significantly increases the perceptual attention. Therefore, the composition key should be supplemented with hierarchical elements in the text layout. Based on the experiments, we can distinguish general conclusions concerning the most important compositional elements of an image.

1. Colour composition – red shades are of particular importance. They were used both in artistic painting, e.g. as an imperial purple which attracted a lot of attention. The importance of red shades is also emphasized by the latest research on human perception of colours.
2. Contrast – appropriate use of the light-and-shade concept, that highlight contrasts, always catch the viewer's eye.
3. The shape of the human face – is always a particularly eye-catching element.
4. Composition dynamics – proper distribution of the composition key elements should direct the sight to the elements we want to expose. In the case of compositions created by the edges of book covers, they form a virtual grid that generates a "quasi-perspective". Therefore, the dynamics, measured by the number of traces of eyeball movements, is

the highest for vertical-horizontal systems, and lower for elliptical shapes.

5. The use of negative image, without the use of colours, is used if we want the person looking at the image to pay attention to the text.

The examination of the visual perception of a multi-cover image enables a dynamic analysis of the attractiveness of individual images which can be practically used in marketing strategies and the promotion of valuable literary positions.

For the devoted readers, it is natural to read intensively. When beginning reading one book, we can end up with a completely different item. The cover as a visual identifier of the book may be the only identification mark. Therefore, it is important to develop new and more effective methods of presenting book items, both in traditional and electronic form. Librarians usually make use of a theme key based on their own intuition and experience. It is worth exploring these issues in more detail for different subjects and in different academic centres. The results we have obtained can help librarians and organizers of exhibitions in the display of literature in a way tailored to the audience to a maximum, even for books with graphically unattractive covers.

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