

A Consideration on Comic Reader's Behavior using Gaze Path and Pupil Size

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Abstract Comics are composed of texts and images, and there are no specific rules for their arrangements as well as concrete rules on how to read. There are some studies on reader's preference and behavior of book while that of comic has not been well studied. Motivated by above questions, this study reports user's behavior using gaze path and pupil size in order to analyze which part of comic reader is most interested in. Base on the analysis, gaze path and pupil size show the different interest of each user that can be used to analyze not only the users' behaviors but also their emotions.

Keyword Pupil Size, Gaze Path, Comic Reader's Behavior

1. Introduction

Comic is described as narrative artwork in the form of separate panels that represent individual scenes, often accompanied by dialog (usually in word balloons) as well as including brief descriptive prose[1]. There are no specified rules for panel arrangements as well as concrete rules on how to read comics. It varied from one reader to another and readers could do it at their own pace and reading pattern.

After the first comic books were introduced in Japan in the 18th century[1], thousands types of comics had been composed in different styles including texts and images. Because the order of the arrangement of the sequences is not defined and there are no specific rules on reading comics, the way of reading comics differs from one to another. This fact brings the different reading behaviors according to one's preference.

In this paper, we conduct an experiment of users to read a short comic to find out how differently comics have been read in order to find out the readers preferences and behaviors that can be used for comic recommendation system, for example. We use an eye tracker to track the eyes of readers on their reading process and record the gaze path which is used to assist in determining the eye movement of the readers, in order to investigate how each reader starts reading comics and how readers' styles differ from one to another. We also record the pupil size of the readers to explain whether they have any interests in any particular points of the comics while they are reading.

2. Related Works

The experiment of Omori et al. has aimed at understanding

while reading comics, why readers skip some certain panels and only focus to the others[2]. They have explained it as a strong effect of balloons which might depress the occurrence of skips, so they have conducted another experiment on a comic, which contains fewer balloons. Interestingly, they have found that the sequence of eye-movements is not so fixed and the attention is paid more on the section readers like and ignored many elements of the page.

Partala et al. have mentioned about a finding by Hess and Petrovich in 1987 that pupil size has a communicative meaning in human-human communication of emotion[3]. They have mentioned that the change of pupil size has relation with unpleasant or distasteful feeling. So they conducted an experiment to measure subjects' pupil responses while listening to 10 negative and 10 positive highly arousing sounds and 10 emotionally neutral sounds. Interestingly, they have found out that larger pupil size from both negative and positive emotional stimuli as human nervous system is sensitive to highly arousing sounds. They have also pointed out that the pupil size can be used as a computer input signal to utilize user's emotional reactions. According to their result, pupil dilation to emotional stimuli was not affected by gender.

The study of Ong et al. on classification on video shots based on human affect[4] has monitored human emotion by capturing viewers' pupil sizes and gazing points while they are watching the video. From the result of their experiment, cumulative pupil response (CPR), which represents the pupil size response, is anticipated to be able to be utilized as indicator of arousal level of video. On the other hand, there have been no further reports mentioning on frequency content with human emotion.

3. Experiment

The subjects are explained about the experimental procedure and asked to read a short comic at their own pace while the system records their eye gaze data, pupil sizes and background activity data of brain.

3.1 System Overview

Figure 1 shows our experimental method and analysis. The pupil sizes, gaze paths and the background activities are measured while the subjects are reading the comics. The obtained data are sent for some re-arrangement to fit the requirement of the neural network analysis.

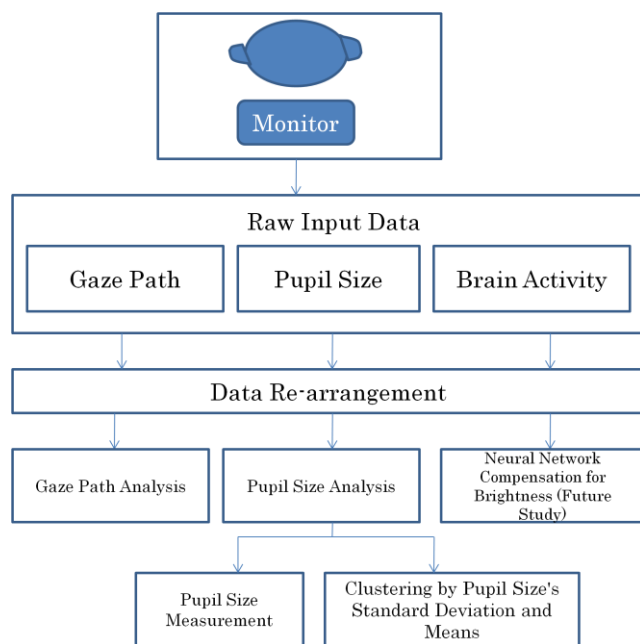


Figure 1 Experimental System Architecture.

Raw input data are obtained from the experiment including pupil size, gaze path and background activity data. The pupil size is used to study on the interest level when the user reads the comic. The gaze path is used to determine the location the comic reader is gazing at, and to see the reading pattern or preference of the comic readers. The background activity data is not used for this report but kept for human's emotion analysis in assisting with pupil size and gaze path in our future study.

3.2 Data Re-arrangement

During the experiment, the data generated by the eye tracker contains the lacking data which are caused by the blinking of an eye. We need to make this data usable by applying the linear interpolation method to rearrange the unusable data through Equation (1) where m represents good data before lacking part,

n represents good data after lacking part, s represents line/step from prior good data and i is the steps from prior good data.

$$R = \frac{(m-n)(i+n)}{s} \quad (1)$$

3.3 Variance of Pupil Size

In order to apply the clustering method on pupil size to analyze the tendency of it, the sample variance and standard deviation are calculated using the obtained data.

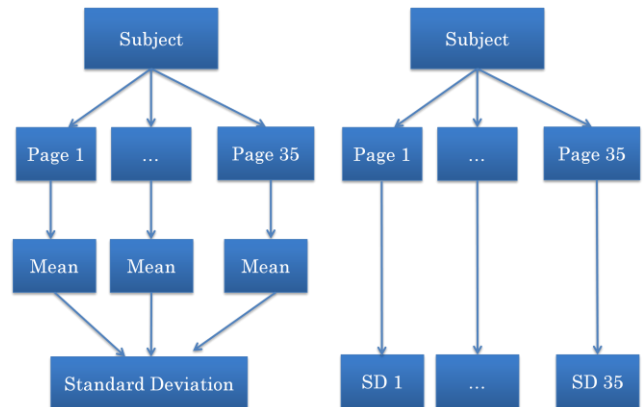


Figure 2 Sample Variance and Standard Deviation by Subject (Left-side) and by Page (Right-side)

As illustrated in Figure 2, we calculate the standard deviation and the means of pupil size per subject. If the calculated standard deviation is high, the frequent change of pupil size on that particular page may be occurred. The means value and the standard deviation are used for clustering analysis based on Partitioning Around Medoids (PAM) algorithm.

4. Experimental Setting

4.1 Equipment

The gaze path data and pupil size were captured by Tobii X60 Eye Tracker (60Hz both eyes independent recording) made by Tobii Technology while Brain Athlete (512Hz single channel recording; probe on forehead equivalent to the average of Fp 1 and 2 of 10-20 system) made by B-Bridge International was used to record the background activity. The test comic, taken from the work of Mr. Hirohiko Araki, was scanned and presented on 23 inch LCD monitor (EIZO Nanao Corporation). The recording of experimental data was controlled by the custom software written by the authors.

4.2 Test Comics

As the purpose of this experiment is to study the comic reader's behavior, the comic to be used for the experiment should be able

to test the reader's reading preference clearly. The chosen comic was a short version which contains of 35 pages titled “死刑執行中脱獄進行中(‘The process of jailbreak during execution’, translated by the authors)” by Mr. Hirohiko Araki. This comic is composed of enough texts and images and contains many interesting scenes such as a criminal eating fish in the prison, the blooded scene which are associated with fearful and negative emotion. Moreover, this comic emphasizes all elements of the story including introduction, development, turn and conclusion. To be noted that all the comic images shown in Section 5 are drawn by the authors based on the original comic to avoid the copyright issue.

4.3 Subject

10 subjects (6 males, 4 females) volunteered for this experiment with the age range from 20 to 49 years old. They all had experiences in reading comics before but none of them had read this test comic before the experiment.

4.4 Procedure

The subjects were first briefly explained about the experimental system which allowed them to read the comic. The calibration was performed by instructing the subject to look at nine points in the windows screen. Then, they were also instructed to read the comic at their own pace and without any external interference. Finally, the readers were given questionnaires to point out which part they were interested in and whether they liked the comic in general. The gaze path, pupil size and the background activity of the subjects while reading the comic were recorded. Figure 3 shows the experimental setup.

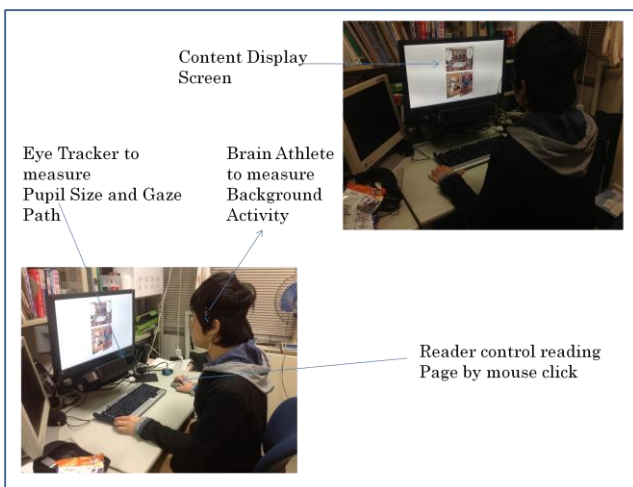


Figure 3 Experimental Setup

5. Experimental Results and Discussion

5.1 Gaze Path Analysis

In Figure 4 and 5, the gaze paths of 4 subjects are represented by the three-color arrows which are red, green and blue. The first red color arrow represents the start point where subject starts reading and continues to the green and blue arrows.

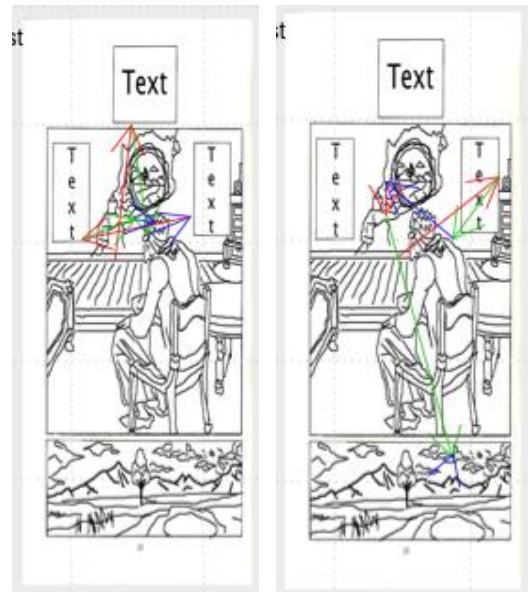


Figure 4 Gaze Path Measurements on Page 34 of Subject 7 (Left Side) and Subject 10 (Right Side)

In Figure 4, on the left-side picture, Subject 7 focused on the center image rather than moving around while the other subjects did not. As in Figure 4, Subject 7 did not change the gaze between texts in the square balloons. However, Subject 10 started the reading from the text in the right box, and followed to the image to the last panel of the page.

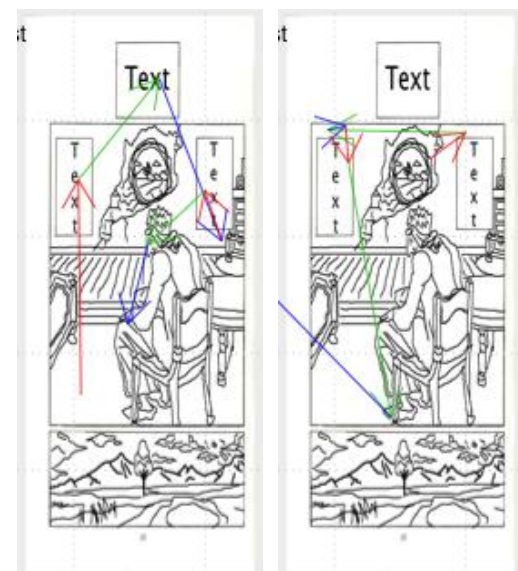


Figure 5 Eye Movement Measurement on Page 34 of Subject 6 (Left Side) and Subject 8 (Right Side)

In Figure 5, on the left-side picture, Subject 6 started his reading differently from the other subjects by focusing on the left box text and then the top box following to the right box text. The subject only changed the gaze to the image in the center after finishing reading all the texts. It seems that Subject 6 read texts more carefully but paid less attention to the image. Similarly, according to the image on the right side, Subject 8 read the texts in both left and right balloons before moving the gaze off to the image. Both Subject 6 and Subject 8 have a different reading preference from Subject 7 and Subject 10 as shown in Figure 4.

From the results, we see that these subjects read differently and do not follow any patterns. Interestingly, according to the gaze path analysis data, some subjects only focused on one interesting part in a particular page, instead of jumping around the entire area of the page. Noticeably, subjects started reading from different points; i.e. it did not matter to read the text first and then looked at the image later. It can be implied that every subject has his/her own reading preference as some start reading from the right to left, up to down while some focus on texts in the balloon before moving to the images.

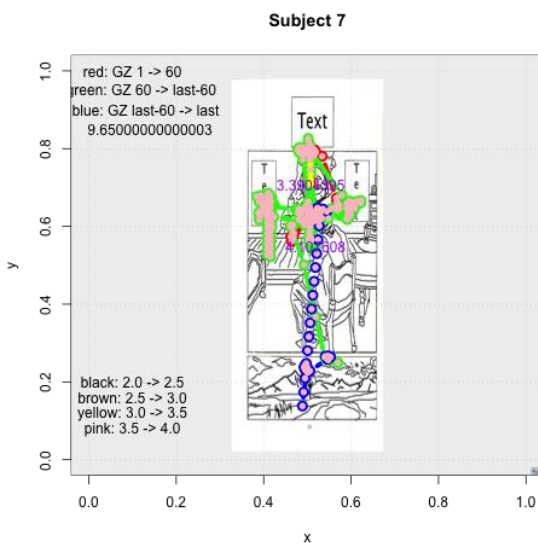


Figure 6 GAZE Path and Pupil Size of Subject 7 on Page 34

As mentioned above, while reading the comic, readers start without order and focus on any part they find interesting. Owing to the experimental analysis, time spent interval for reading the page 34 ranged from 5 to 10 second, for example. We notice that most of the readers focused more on the images than texts. The maximum size of the pupil size also appears in the image area as shown in Figure 6 and Figure 7, where the red-color dots represent the first second of the gaze path while the blue ones represent the last second of it. The gaze path between the first and the last second is represented by the green-color dots. Pupil

size measurement is also shown in Figure 6 and 7 in black, brown, yellow and pink color, where the pupil size from 2.0 - 2.5mm is in black color, that from 2.5 - 3.0mm is in brown color, that of 3.0 - 3.5mm in yellow color and that of 3.5 - 4.0mm and the above is in pink color.

According to the result in Figure 6, the pupil size of Subject 7 is one of the highest among all the subjects. We can see that within 9.65 seconds while reading page 34, with his pupil size reaching 4.1mm at maximum, Subject 7 seems to have the high interest among all part of the page.

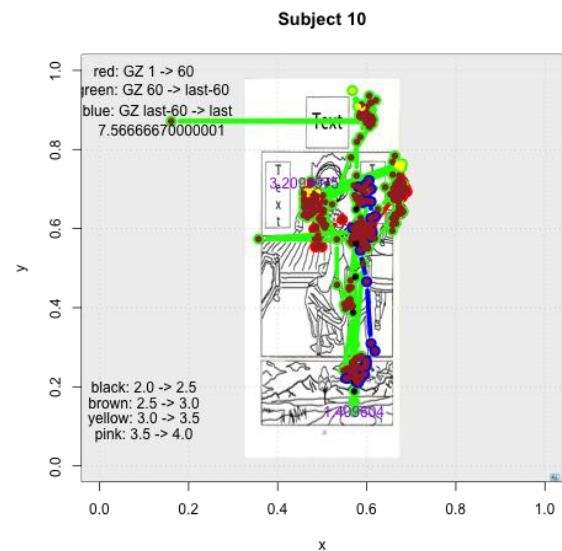


Figure 7 GAZE Path and Pupil Size of Subject 10 on Page 34

According to Figure 7, Subject 10 does not have much interest in reading this page as his/her pupil size in brown color is relatively low compare to the other subjects. The yellow-color dots which represent the pupil size between 3.0 and 3.5mm appear in the center image part. Subject 10 spent 7.56 seconds reading this page.

5.2 Pupil Size Analysis

5.2.1 Pupil Size Measurement

First, we discuss the actual result obtained from the experiment comparing with the result of questionnaire answered by the subjects. According to the questionnaire results of all the subjects, Subject 4, 5, 6 and 8 have reported they have interest in page 34. In Figure 8 and 9, their pupil sizes are shown, where the horizontal axis “Time” represents the duration of each subject reading this particular page in seconds while the vertical axis “Pupil Size” represents the raw input data from the experiment in the range from 2.0 to 5.0mm.

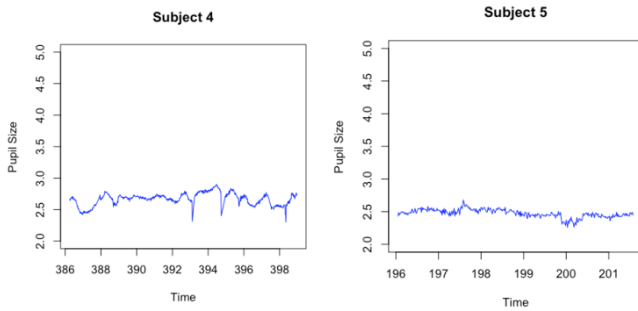


Figure 8 Pupil Size of Subject 4 and 5 on Page 34

Figure 8 illustrates the pupil size comparison between Subject 4 and Subject 5. According to the questionnaire, they both reported their interests in this page; however, based on the result obtained from their actual data, we see that both of them have almost the average pupil sizes compared to the other subjects who did not report their interests on this page.

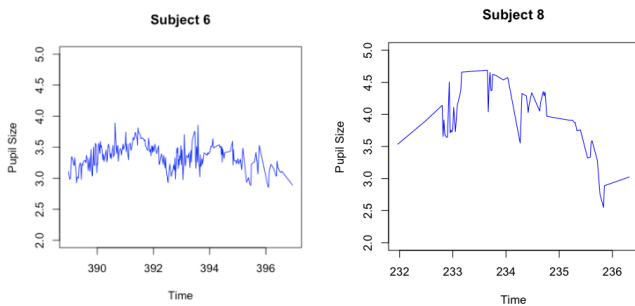


Figure 9 Pupil Size of Subject 6 and 8 on Page 34

Figure 9 shows that Subject 8 has one of the highest pupil size compared to the other subjects while the Subject 6 gets relatively the average pupil size compared to the rest whose data result into quite low value of pupil size. Nevertheless, their high average pupil size data might be caused by brightness from the display. Hence, we still cannot conclude that Subject 6 and Subject 8 both have interests on this page 34 according to this result.

5.2.2 Clustering by Pupil Size's Standard Deviation and Means

To investigate whether we may find some specific pupil reaction for a particular part of the comic (e.g., page or panel with strong impact or touching scene), we have applied PAM clustering method on the calculated sample variance and standard deviation on pupil size for each page as mentioned in Section 3.3. It is assumed that if we are able to divide pages into clusters, pupil size data may reflect readers' interests or emotions.

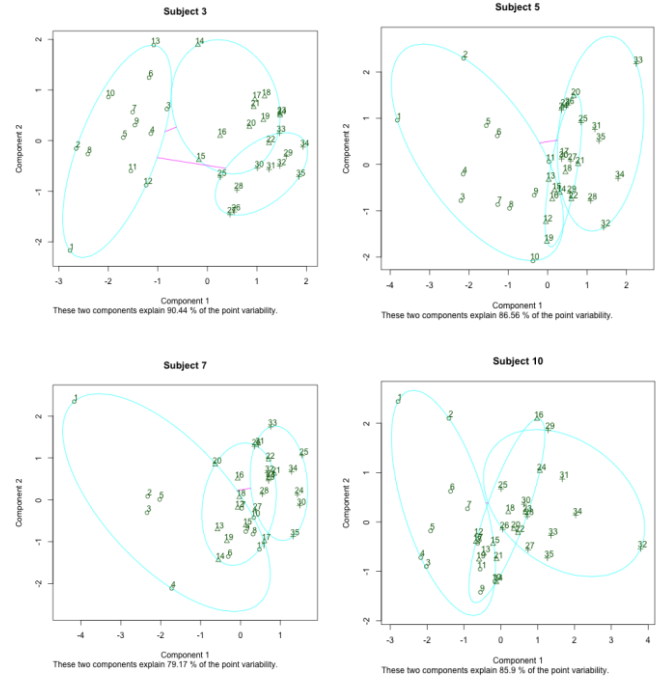


Figure 10 Clustering by Pupil Size's Standard Deviation and Means

Figure 10 shows the clusters of 35 pages from 4 subjects. Each point represents each page of the comic for each subject, and the blue circles show the boundaries of clusters.

From the result, we can see that the first few pages and the last few pages are classified into same clusters. As for the first few pages which are just the introduction of the story, the emotion of the readers might not differ. On the other hand, the middle part is not always grouped into the same category. For the middle part, there are many different scenes which may not be liked by all the subjects. Furthermore, most of the results from other subjects are also similar to the results in Figure 10. We consider that unstableness of the categorization of the middle part reflects such difference between the subjects. As the fact that the first few pages are fallen into the same group and the pupil reaction is related to emotion, it could be implied from these results that the page of the comic may be categorized by readers emotion.

6. Conclusion and Future Works

To contribute to the better understanding in comic reader's behavior, this paper examines the gaze path and the change of the pupil size. The result shows that readers read comic differently according to their own preferences and the behaviors of reading. According to the gaze path data, subjects start reading from different panel and some also end differently. The gaze path where readers have focused on while the pupil size of each subject is somehow different according to how they felt.

Throughout the observation of the results, the gaze path or the pupil size itself cannot be used to judge whether subject has any interests in the page; therefore, further investigation is needed to find the interest level of the parts readers have pointed out. For example, we need to apply the pupil size compensation applying brightness change model on the actual pupil size data because brightness can affect subjects' pupil size. Subsequently, the trained data from the neural network will be used to find the interest level of each subject on each part of the comic.

In addition, we have applied clustering on the sample variance and the standard deviation of pupil size. As the few pages are grouped into the same category, pages of comic may be categorized by readers' interests or emotions. It is our next task to conduct a detail interview with readers on their particular interesting part to compare their interest with those results.

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