The Perception of Information and Advertisement Screens Mounted in Public Transportation Vehicles - Results from a Mobile Eye-tracking Study

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Abstract: This research deals with perception of information and advertisement screens mounted in public transport vehicles. We have conducted an exploratory field study with 106 participants. Our main research question was aimed at finding out to what extent people do look at such screens and for how long they fixate them. Further we investigated correlations between content type and the amount of focus time as well as the amount of time a person fixates on such a screen and the number of things one can reproduce freely or recognize shortly after the exposition. We researched whether certain content types can be considered as attention catchers and if certain combinations of content-types have the power to bind persons' focus-time longer than others. Results suggest high awareness of the info-screens among participants but no correlations between fixation time and content respectively fixation time and recall/recognition of content.

1 Introduction

Display Screens have become a very common element of public space recently. A walk through almost any modern urban area is sufficient to confirm this. A glance at the "Digital Signage in Europe: Opportunities for digital out-of-home advertising" [SG07] report confirms this notion by stating as one of it's key findings that digital out of home advertising revenues in Western Europe will quadruple over the next five years. Technological progress, enabling us to build screens that are flatter and lighter than previous ones, paired with increasing affordability of digital displays can be seen as the key to this development.

One application area for digital displays is public transport. In public transport such screens often are used to communicate with passengers, providing passenger information, news, entertainment, and also advertising. As large numbers of people everyday use public transport in urban areas to travel from A to B display screens mounted within these vehicles have the potential to reach a big audience. However, it is unclear whether passengers actually do pay attention to these screens and how much information presented they ultimately remember. Also, questions dealing with optimal content representation for this rather new form of advertising and the identification of specific attention catchers remain unanswered so far. In order to find answers for these questions we conducted a field study using state-of-the-art mobile eye tracking equipment. We hereby had the opportunity to work with a large sample of test subjects: 106 subjects were recruited for the project and conducted a test ride using a tram with mounted displays. Of all test subjects we captured eye tracking data and recorded the user's field of view (scene video). Scene data then was analysed using computer vision algorithms for the detection of the information screens. This way we had the possibility to study the users gaze behaviour in a naturalistic context but still have the ability to process the data of a big sample.

What sets our study apart from many other eye-tracking studies is the context in which it was conducted. Many studies using eye-tracking technology are performed in the lab. That allows researchers a good control of experimental settings and therefore enables the study of very specific aspects of human behaviour under controlled conditions. This approach, as good as it is, is somewhat limiting because we can not expect results being applicable to the real world or being representative for it. Too many factors are being eliminated and the context is highly artificial. In contrast to that approach we decided to go out into the field to study gaze deployment and attention behavior, thereby allowing for all the unforeseeable events and distractions that form and shape our everyday life. Clearly, this approach has its drawbacks as it does not support good control of experimental conditions. On the other side, our experimental design allowed for a 3D representation of the context in which the display screens were presented. In the lab often a 2D representation of the context and the stimulus is used. In order to make the findings of our study as representative and relevant as possible we recruited more than 100 subjects covering different age spans.

2 Related Work

Related work in the domain of out of home media stem from a broad range of disciplines and research techniques. Marketing research, Neuroscience and Psychology are all contributing to the field. Prominent research methods include the use of eye-tracking technology and questionnaires. Shavitt et al. conducted a survey to assess attitude towards different kinds of media channels for advertisement. The authors categorized available media channels regarding self selected (e.g., catalogue) vs. highly intrusive (e.g., tv). Results of the survey suggested that media channels allowing for self selected experiences were favoured over highly intrusive ones [SVL04]. The Digital Out of Home Awareness Study, conducted in 2007 in the USA [OS07], investigated the effectiveness of digital out of home media by focusing on awareness, attention, impact and attitude towards advertising on digital signage and other media. Key findings of the study suggest that digital signage has the "power to stop people" and catch their attention (63% of adults). That is the highest level reported of all media surveyed in the study, including TV, the Internet, billboards, magazines, newspapers, radio, and mobile phone advertising. Digital signage was rated more positively than any other type of media. The awareness with digital signage advertising, according to the study is very high. Sixty-two percent of adults say they have seen ads on digital signage over the past 12 months, and the figure is even higher for young adults between 18 and 24, at 75%.

Eye tracking as a means to measure the movement of the eye is being used for more than 100 years now (it began in ca. 1879) [Da02]. The reason why deployment of human gaze for a long time has been studied almost exclusively limited to 2-D picture viewing is because only in the last few years systems have become compact enough for use outside of labs.

The Outdoor advertising association of America (OOOA) conducted several research studies on the topic. One two year study, carried out over the period of 1999 to 2000 in Los Angeles, New York and Minneapolis revealed that 70% of outdoor posters in the visual field of subject were seen. Of these 63% were likely to be read. The authors of the study made a visibility vs. recall study and the results indicated that visibility was about 3 times higher than aided recall levels (26%) would indicate. Additionally subjects claimed to recall boards and brands that were never posted [OO00].

Maughan et al. have investigated – also using eye-tracking - if people in a street scene (the scene was presented as a virtual image on a computer screen) would notice bus shelter advertisements. Their findings suggested that although posters did get attention they were not the most salient features in the street scenes: only in 11.1 % of cases participants did make their first fixation on the poster. The authors conclude that the emotional appeal of a poster had effect on both exposure and memory [MGS07].

Wedel M. and Pieters R. developed a model of the processing that takes place to store information in long term memory: It is assumed that the number of fixations not their duration is related to the amount of information a consumer extracts from an ad. The authors applied the model to a sample of 88 consumers who were exposed to 65 print ads in its natural context, two magazines. Results support the assumptions [WP00].

Grundland G. and Eizenman M. conducted a study on consumer exposure and awareness of Outdoor advertising: eye-tracking was used to measure peoples attention towards out of home media such as trio boards, standard posters, super boards and bus shelter advertisements while driving a certain route in a car under various driving conditions and different times of the day. Data came from both drivers of the car and passengers. As in our work subjects were not informed about the aim of the study. Over 55% of the ads were seen. Passengers were more likely to see ads, than drivers. Among those, who looked at the advertising, on average they looked 2.04 times on a single drive by [GE06].

Visual perception research currently is not so much focused on where we look, but more on why we look (where we look). In the field this new focus in research emerged some years ago: away from the experimental understanding from where in a scene the eyes fixate in an image, to why the eyes choose a location [HB05]. According to Ballard D. and Hayhoe M. three principal complementary advances in research can be seen as the cause of the shift in focus:

The description of the role of eye movements in executing everyday visually guided behavior driven by the development of portable eye-trackers, the recognition of the role of internal reward in guiding eye and body movements and thirdly theoretical developments in the field of reinforcement learning. Together, these three developments have allowed the simulation of reward based systems incorporating realistic models of eye-movements over extended time scales [HB05].

Findings from this new approach have resulted in two fundamentally different approaches that exist in current research: bottom up and top-down [RBH07]. “Attention can be focused volitionally by "top-down" signals derived from task demands and automatically by "bottom-up" signals from salient stimuli.” [BM07]

Also other theories and hypothesis are being investigated. Karacan and Hayhoe [KH08] investigate whether attention is drawn to changes in familiar scenes. They examined mechanisms that control attention in natural scenes. The results of the study support the hypothesis that humans learn the structure of natural scenes over time and that attention is attracted by deviations from the stored scene representation. Though promising concepts and models of human gaze have been developed, none of them so far can explain fully what mechanisms direct eye movement.

3 Goals

The driving idea behind our work was to investigate human attentional behavior towards digital display systems in urban public transport under natural conditions. Are people aware of them and what is the attitude towards them? Can those displays act as attention catchers? Do different content-types result in different fixation times? Is some content more appealing and how long do subjects fixate on the screen on average? Further we investigated correlations between content type and the amount of focus time as well as the amount of time a person fixates on such a screen and the number of things one can reproduce freely or recognize shortly after the exposition.

4 Method

In order to answer these questions we conducted a field study using state-of-the-art mobile eye tracking equipment. In the rest of this section we will describe the field study in detail.

Field Study Context. The info-screen is a screen mounted in trams in the city of Graz in Austria and it is used to display out of home media. A typical configuration is shown in Figure 1. There are 4 info-screens installed in each tram. The size of the screen is 17 inch. Two of them are mounted towards the middle of the train and two in the front part. They are either pointing against the driving direction or sideways, as seen in the Figure 1. Visibility towards the screens is different depending on the location in the tram. Subjects were standing in different places within the tram and so the viewing distance was different as well. The info-screen is broadcasting its content in cycles that get repeated. One cycle lasts for 14 minutes (840 seconds), which is about the length subjects were in the tram in one direction. The categories forming a cycle at the time of the experiment were the following: Advertisement, News, Culture, Entertainment, Sports/Weather, Event-tips and passenger information.

Figure 1: Two info-screens in a tram

Participants. Invitation of test participants was based on a random sample of the population of the Austrian city of Graz, where the study took place. We started with the intention to have a representative sample, but unfortunately due to practical reasons (mainly willingness to participate in the study) we had to allow for an unbalance towards younger people. Alltogether 106 persons (47,9% female, 52,1% male) participated in our study. Mean age was 30 years, and participants were drafted from different educational (bachelor, master) and professional (apprenticeship, teacher) backgrounds. Due to technical problems (malfunction of the information displays in the tramway respectively problems with the mobile eye-tracking system) the date of 6 subjects could not be used for analysis.

Procedure. Participants were contacted by phone based on a random sample. Study participants were left uninformed about the detailed aims of the study, but they were provided with a general explanation of what the study was about: “to measure the attention behaviour in public spaces.”

Participants were invited for a certain time and date to come to one of the researcher’s office. After the participant arrived at the institute we would show the mobile eye-tracker and provide a description of the study, not telling that it was about the measurement of attention towards the info-screen in trams.

After this outline of the experiment subjects were asked if they still would like to participate in the experiment or not. If they agreed to do so the next steps consisted of calibrating the eye-tracker once subjects had the helmet on their head. The calibration was done using a 5-point calibration target. We checked the calibration again at the time subjects left the institute and when they came back from the public library to see if the helmet had gotten out of place.

The eye-tracker that was used in the experiment was an iView X HED mobile eye-tracker from SMI that consists of a size adjustable, lightweight helmet and a tablet pc that is carried in a daypack. The sampling rate of this eye-tracker is 50 Hz. Figure 2 shows the helmet with the mounted eye-tracker that was used in the experiment.

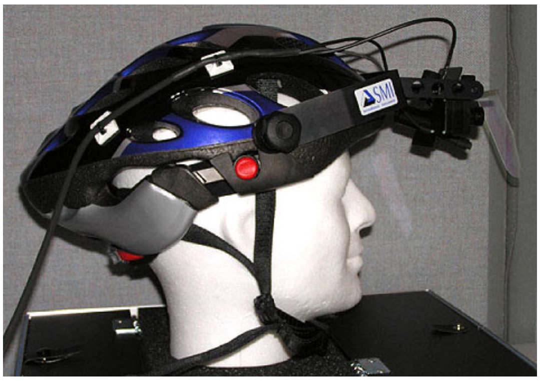

Figure 2: The mobile eye-tracker

Each subject was asked to carry out a simple task. We had borrowed books and magazines from a public library that is located about 25 minutes away from the institute were we met subjects. Subjects were asked to bring back a book to the library and then return to the institute using tramways. Participants were also instructed to use only the newest generation of tramway types, as in the older generation trams info-screens are not mounted in all vehicles.

We had prepared a detailed description of the route that subjects were supposed to follow including pictures describing the way from the institute to the tram station, the model of the tram subjects were supposed to take and the way from the station where subjects got of the tram to the public library. Outside of the public library a box is located enabling people to return books 24 hours a day. Subjects were told to just use this box to return books. Also this was documented using pictures in the description of the task. Subjects were also asked to make a note of the number of the tram they were riding in. This description was given to subjects together with a mobile phone in case they would have any additional questions on their way. Two more things were given to subjects: a ticket for the tram ride and an umbrella for the case of sudden rain to protect the eye-tracking system.

In total subjects were on their way for about 50 minutes. Weather conditions and time of day were recorded in a protocol.

When subjects returned they were asked to fill out a questionnaire consisting of 22 questions covering the following topics:

- had subjects realized and seen the info-screens in the tram
- subjective measurement of how long they in their opinion had paid attention to the info-screen
- recall and recognition of content shown on the info-screen; for recognition we provided a list with the ads actually shown on the info-screen including fake ones
- did subjects feel bothered by the helmet and the daypack
- general feeling about the info-screens
- questions about their usual behavior on the tram
- general questions about the content – what content did they like and what not
- questions covering advertisement – whether or not subjects like advertisement, what kind of advertisement they prefer (emotional vs. informative), which medium they prefer for advertisement
- demographic data

The questionnaire – presented in an electronic form - was filled out by us with subjects sitting nearby providing the answers. This was done that way because we also had subjects that were not familiar with computer technology.

Data resulting from the experiment. As described above subjects wore a mobile eye-tracker while on their way. The data from the eye-tracker, consisting of the scene video and the data of the eye movements, was recorded on the tablet pc that had been carried in a daypack. The company operating the info-screens provided us with the corresponding time-stamped log-files. The log-files, put together with the data from the eye-tracking provided us with a solid set of quantitative data about each participant's behavior. This data was supplemented by data resulting from the above described questionnaire.

5 Results

2.1 Eye Tracking Results

Of the 100 subjects 61% fixated the info-screen. Subjects spent a total of 48.7 hours in the tram. Of this time in 23.06 %, that is 11.23 hours, the info-screen was in the visual field of subjects. In 3.64% of the 48.7 hours attention was directed towards the info-screen. That is: in 16% (1.7 hours) of the time in which the info-screen had been in the visual field of subjects they were focusing on it. Attentive participants focused on the info-screen between 0.08 seconds and 9 minutes. Since the distribution is right-skewed we use median and interquartile range (IQR) to describe location and dispersion: the median of the sum of fixation time on the info-screen over all participants is 74 seconds (1853 frames); the IQR is 135 seconds (3399 frames). Figure 3 on the horizontal axis shows fixation time in minutes and on the vertical axis the according proportion of participants in percent, e.g. 42.6% of attentive participants fixated on the info-screen up to one minute.

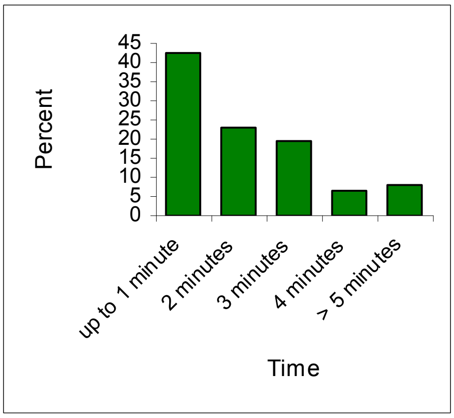

Figure 3: Fixation proportion in percent

As described above the content on the info-screen was composed of 7 different categories, not of equal length. Figure 4 provides an overview of the distribution of the different content-types over all participants in descending order, e.g. “News” was broadcasted in 27.6% of the total time.

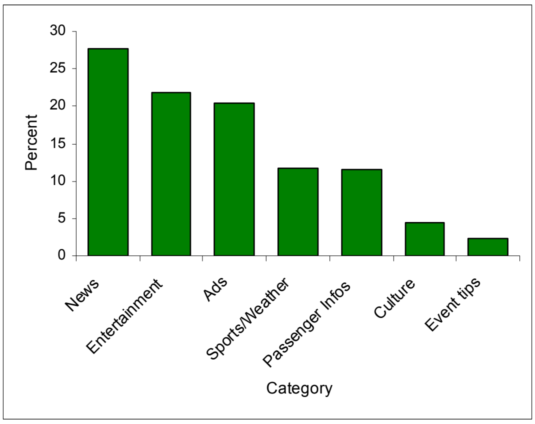

Figure 4: Distribution of different Content-types in percent

One of the main questions in this research was to find out about correlations between focus time and content-type. Does the type of content have an influence on the time participants fixate on the info-screen? To answer this question we have compared the proportions of fixation time for each of the 7 content types. To explain further: We have summarized fixation time (measured in frames) over all participants for each category. Then we computed for each category the ratio between the sum of fixated frames over all participants and the sum of frames this category had been displayed and expressed this in percent. So results indicate the percentage of fixation for each category. Figure 5 shows the resulting distribution of fixation-time against content types in percent. The content type "News" was fixated in 4.54% of the time it has been displayed, followed by "Sports/Weather" (3.98%) and "Entertainment" (3.81%). Remaining categories got around 3 percent except for "Culture" which was fixated in 2.65 % of the available time.

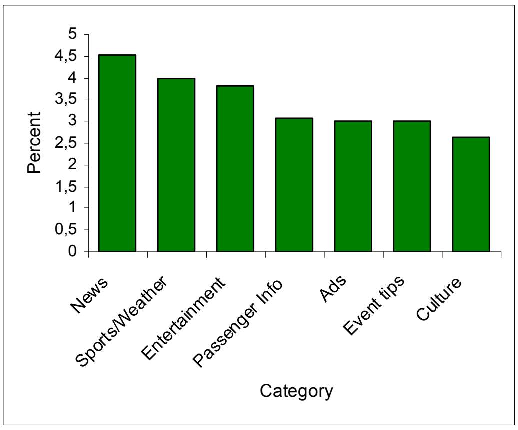

Figure 5: Distribution of proportion of attention against content types in percent

Next we investigate the same question but address potential influence of category on fixation time for each individual participant: We have computed the ratios between the sum of frames a participant fixated a certain category and the sum of frames this category was displayed and expressed this in percent. We only considered participants having fixated more than zero frames. This way we obtain for each participant and each category the proportion s/he was fixating on the info-screen, based on the total amount the info-screen has been available. The following image resulted: Over all categories the distributions are right-skewed and the medians reflect relative similarity (min=3.4; max=7.4). The skewness of a distribution indicates outliers in the data; in this case they can be interpreted as participants focusing many more frames compared to the average participant. The similarity of the medians indicates no big differences in focus time between categories. To test whether differences between content types are statistically significant we performed a Kruskal Wallis Test. The result (p = .392) is not significant at an α-level of 0.05. Figure 6 shows for each category over all participants individual the distribution of proportions of fixated frames over participants.

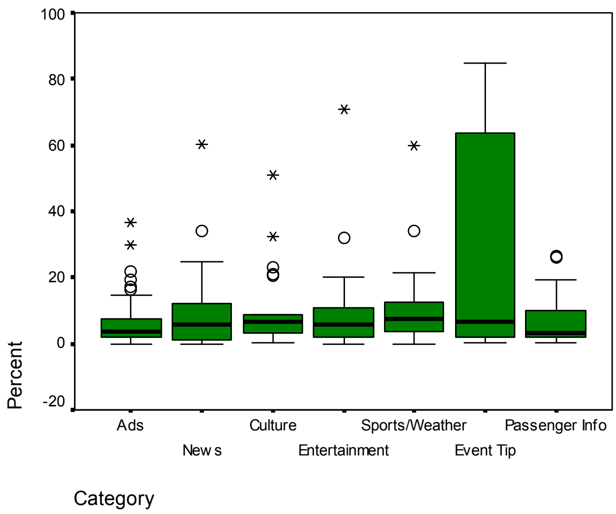

Figure 6: box-plots showing distribution of proportion of fixated frames (in percent) for each category and all persons

From the obtained results we conclude that the content type does not necessarily have an influence on the fixation time on an info-screen under the given circumstances. We addressed the question whether one content type is of greater interest than another also in the questionnaire: we asked participants to indicate whether a given content type interests them or not. Due to an organizational error in the beginning of the study we were left with data from only 96 participants instead of 106. "News" and "Event-tips" were rated by most participants as interesting content-types, followed by "Weather" and "Sports". The questionnaire data and the data from the eye-tracker do not correspond fully here. There are some discrepancies between the actual fixation-behavior in the tram and the way participants rated contents at the end of the study. For example, few participants found "Advertisement" interesting (see Figure 7). None the less the number of participants' fixating on "Ads" did not differ from any other content type. One possible explanation for this could be the fact that fixation time on the info-screen does not automatically mean that the participants' eyes were actively following the content presented; it just means that the participants' eyes were focusing on the info-screen. So, even while participants were having their eyes on the info-screen they might have thought about something completely else. We address the issue of length of fixation time and its correlation with the memorized content in greater detail below.

Figure 7: Interest in Content shows in percent how many of the participants rated a given category as interesting or not.

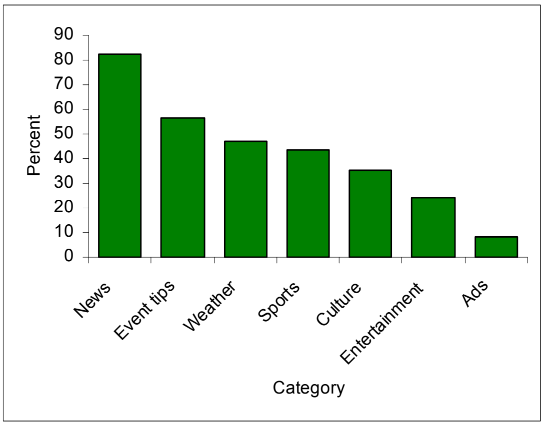

Figure 7: Interest in Content-category in percent

We were also interested in finding out whether time of day has an influence on the fixation behavior towards the info-screen. Figure 8 (x*100 = percent) shows peaks of mean fixation time on the info-screen between 8 and 10 a.m. and again between 14 and 16 p.m. A possible explanation for this might be the fact that in the morning-hours participants' interest for news is higher than during the rest of the early day hours. However, the even higher peak in the afternoon remains unexplained.

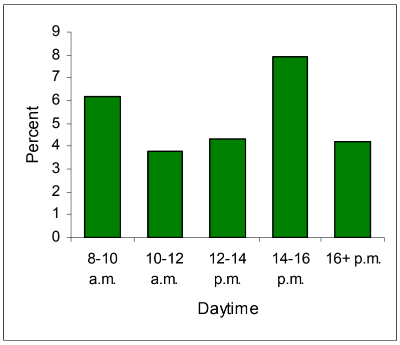

Figure 8: Influence of day-time on fixation on info-screen

2.2 Questionnaire

As described above additionally to the eye-tracking data we have used a questionnaire in this research. We have done so to complement and compare the two sources of data and to assess participants' thoughts on the subject.
Participants were not bothered much by the helmet and the daypack: 23% of the participants were not disturbed at all, 70% reported to be disturbed a little bit and only 5% felt severely disturbed by the equipment. Also, most participants reported to not feeling nervous (64%) during the ride at all, 34% felt a little nervous and only 1% reported having felt very nervous.

88 participants reported to have seen the info-screen; that number is not in line with the data we obtained from the eye-tracking (61 participants were fixating the info-screen for at least one frame (1/25 of a second) on the info-screen). Subjects were asked to measure their subjective feeling about the attention-span towards the info-screen. Four possibilities were given: no attention, up to 2 minutes, between 2 and 5 minutes and more than 5 minutes. Most subjects thought about their attention-span being up to 2 minutes, which corresponds to the measured average value of attention-span of 104 seconds. Figure 3 also shows that most subjects fixate the info-screen up to 2 minutes.

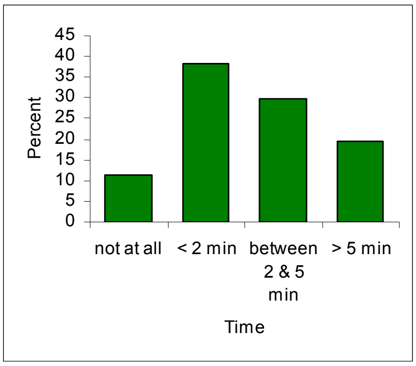

Figure 9: how long (do you think) have you looked at the info-screen

As already mentioned above we researched an eventual correlation between the length of fixation on the info-screen and the amount of content memorized. To measure what participants had memorized from the content presented on the info-screen we asked them after they returned from the library to tell us in no specific order which content they had seen during their ride. The remembered contents were categorized by us. Additionally, subjects were asked to recall what specific ads, logos and brand names they could remember. From all participants 80 were able to recall categories. On average, subjects recalled three different categories. 27 subjects were able to recall specific spots and logos. 18 persons recalled brand names.

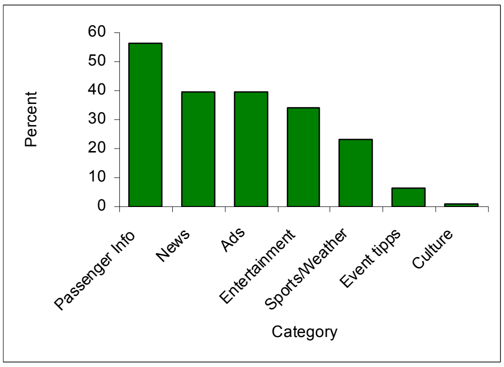

Figure 10: recall of categories in percent

Additionally to letting participants reproduce what they had remembered we measured recognition. For this purpose we composed a list of ads actually being broadcasted with ads that were not shown on the info-screen. 43 of the participants were able to recognize spots correctly; however, they only recognized few spots, between 1 and 4 ads (average: 1.37).

The hypothesis of an eventual correlation between fixation time on the info-screen and recall/recognition was tested next. Although intuition might suggest a correlation between the two our data does not support that hypothesis; correlations are r = 0,102 between number of frames fixated and number of content recalled respectively r = 0,341 between the number of frames fixated and number of ads recognised correctly. One explanation for this result might lie in the experimental setup: participants had no idea about the purpose of their ride and no order to look at the info screen or to even remember any of the content being broadcasted. Another explanation could be the fact that, as already mentioned above, fixating the eye-tracker does not automatically mean perceiving its content.

Ultimately we would like to report on results describing the phenomenon info-screen and what participants think about it in general as well as preferences regarding the medium of advertisement. Two thirds of the participants rated the presence of the info-screen as being good, 20% where indifferent and 10% didn’t like it at all. Subjects in the questionnaire were asked about their preferred media for advertising: TV-ads and posters were the preferred medium.

6 Discussion

The results we obtained suggest that more than half of the participants did focus on the info-screen and nearly nine out of ten of our participants reported to have noticed the screen. Content type does not influence length of fixation time, nor does any noteworthy correlation between length of fixation on the screen and memory or recall exist. One has to take into account that an eye-tracker only can track where a person does look, not what the person is doing when looking. Regarding content types as attention catchers we identified “News” as the content type on which most attention chains started; a change from “News” to “Sports/Weather” provided the content combination that was followed through most often. We think that - considering the fact that participants did not know what the research was aimed at (attention behavior towards info-screen) and the natural environment the study was carried out in - those results are very interesting because of their explorative character. We learn from this study that fixation time on a digital screen in public transport seems not to depend on content-type. Also, fixation time per se does not seem to be a suitable indicator for content-memorization. This result directs towards the findings from [WP00]. Future research could focus on an eventual correlation between the frequency of fixations on content and its memorization. Despite the eye-tracking results we have found that on average participants recalled three different categories out of seven. That seems to be a good proof that the content presented on the info-screens comes through to people. The findings from this work can serve as a basis for future research; e.g. can we actively and reliable catch people’s attention in a natural environment like this one (or any other urban environment) and how can we optimize content for such a new and challenging form of advertising to improve content memorization? We shall not forget that digital screens positioned in the urban area despite their similarities with TVs do miss a channel for communicating with its audiences - the audio part.

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