Attentional Behavior of Users on the Move towards Pervasive Advertising Media

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Abstract: In this chapter we analyze the attention of users on the move towards pervasive advertising media. We report the findings of two multi-sensor eye tracking studies designed to provide a better understanding of the actual attentional behavior of users on the move in different public environments. In the first study 106 participants were equipped with eye tracking technology and asked to use public transportation vehicles equipped with information and advertising screens. In a second study 16 participants were asked to stroll through a shopping street for about 15 minutes, and during this time different indicators for their behavior and focus of attention (eye tracking, movement and pose tracking) were captured. Motion and pose data was correlated with eye tracking data to identify typical patterns of attention. We report the results of these studies, then discuss the implications of the main findings for pervasive advertising and finally reflect on the used research methodology.

1 Introduction

Measuring the attention towards different kinds of advertising media is of high interest in marketing research. Most existing research in this area focuses on a person's attention towards indoor advertising media like printed advertisements and in-store placement. The more uncontrolled environment of outdoor advertisements has not been targeted and analyzed in detail yet, mainly due to limitations of available methods for tracking the user's focus of attention.

Different investigators try to overcome the methodological difficulties of unrestricted situations by using virtual representations of the real world. This approach allows studying a person's attention in a controllable way. However, due to the rather artificial situation concerns regarding the external validity arise, i.e. whether

the results obtained in the virtual representation are comparable to those in real life situations.

To investigate the characteristics and mechanisms of successful outdoor advertisement design reliable data and knowledge about the detailed visual attention of users on the move is needed. By knowing how people perceive different kinds of advertisements in a realistic outdoor setting, the impact of pervasive marketing approaches can be increased through better design and placement of advertising media.

In this article we describe two studies aiming to advance the current knowledge and methods in the field of visual attention on advertisement media of users on the move. We investigated the participants' visual fixations on digital displays in public transport (study 1) and on brand logos while walking through a pedestrian shopping street (study 2). With the results of the studies' explorative field trials we want to answer basic questions about the perception of these outdoor advertisement media. The data can also act as a reference for further research about visual attention in public spaces.

2 Related Work

In this section we present previous work related to our studies. The main focus is on visual attention, eye tracking technology and attention to public displays and advertisement.

2.1 Special Importance of Attention in Pervasive and Mobile Computing

Mobile computing technology allows having electronic devices available whenever and wherever we want. However, designers and developers of mobile applications like palmtop computers, PDAs, and mobile phones have to face unique challenges, because location and environment are usually less predictable than in desktop applications (Barnard et al. 2007). Similar restrictions apply also to public displays. Furthermore mobile computing devices have the common problem of rather small visual displays and limited input techniques, wherefore performance is often substantially worse than in the desktop context (e.g. Neerincx and Streefkerk 2003). Multitasking and support for task interruption are of high relevance, since in a mobile context the frequency of distracting events is much higher than for a desktop application (Dunlop and Brewster 2002) and tasks with interruptions take longer to complete on a mobile device than with a desktop application (Nagata 2003). Therefore special interest is on the increased competition

with regard to attracting the users' attention and on interaction as a non-primary task in a certain context – which is also an issue for public displays.

2.2 Human Visual Attention and Perception

Humans are continuously confronted with a vast amount of information and stimuli, but they are not able to process all of it in parallel. Therefore it is believed that the human information processing includes a bottleneck where attentional systems decide which information an individual processes. In visual attention this bottleneck is quite obvious defined by the fovea, an area of the retina with the highest resolution. In foveal vision humans tend to fixate objects which they are attentive to. However humans are also able to attend objects which are in their peripheral visual field and 24 degrees distant from the fovea (Posner et al. 1980). The spotlight metaphor considers visual attention as a kind of spotlight which can be moved around to focus different objects in the visual field. The size of this spotlight can vary (Erikson and St. James 1986) and the smaller the attentional area is the higher is the processing capacity for that area. When an individual wants to attend another object in the visual field the "spotlight" has to be moved. Is a person involved in a visual search task, the feature integration theory (Treisman and Gelade 1980) postulates the existence of a pre-attentive subsystem, which at the earliest stage of visual processing decomposes a visual stimulus into its elementary features. At a more focused attentive level, these independent basic features are recomposed in order to obtain an integrated perception of an object and the world.

2.3 Development of Eye Tracking Technology

To analyze a person's gaze behavior is not a new idea. Research on eye tracking is conducted since over 100 years. In the last decades a strong focus was on eye movement recording systems, with the aim to gather objective and quantitative data of a person's visual attention (Duchowski 2002). Early eye tracking methods were quite invasive, e.g. electro-oculographic techniques or contact lenses covering cornea and sclera (Poole and Ball 2005).

Today we can look back to a variety of eye tracking systems, differing in terms of their appearance and their eye detection techniques and algorithms (Hansen and Ji 2010). Basically eye tracking can be infrared-based, i.e. the different reflection of infrared light between cornea and pupil is used to determine the line of sight (e.g. Poole and Ball 2005) or appearance-based, i.e. computer vision techniques are used to find the eyes and their orientation (e.g. Tan et al. 2002). Furthermore eye trackers can be head-mounted, build into the computer screen, and - since

about the last decade - even portable. The development in the direction of more and more non-intrusive and mobile eye trackers enables researchers to observe close to natural behavior unaltered by limitations of the technical equipment. With mobile eye trackers it is possible to go into the real world and gather data in realistic settings (Hayhoe and Ballard 2005).

Eye tracking technology is further developed towards more light-weight and low-cost systems (e.g. Babcock and Pelz 2004) which enable eye tracking in various situations and activities and to make it affordable for the general public. Most recent developments try to expand the application of eye tracking to infants, for whom the portable eye trackers for adults are ill-suited (Franchak et al. 2010).

2.4 Eye-tracking in Public Spaces

The development of portable and less intrusive eye trackers enables attention measurements in the public space. However, only a rather small body of research exists using eye tracking in real environments. This probably can be explained by two factors. Firstly, investigations with mobile eye tracking imply a reduced controllability of the setting and consequently difficulties to realize an experimental design arise. Secondly, it is a big challenge to deal with the free movements of head and body. These movements make it harder to map eye tracker coordinates onto world coordinates, and often require a laborious, manual processing of the data (Henderson 2006). Thus, many researchers rely on virtual environments simulating a real setting (e.g. Maughan et al. 2006, Rothkopf et al. 2007) to investigate visual attention in an environment as natural as possible but nevertheless allowing experimental control. In this regard Hayhoe and colleagues (2002) pointed out the necessity to validate performance in virtual environments by investigations in real environments and - the other way around – to use gaze behavior in the real world to generate hypotheses tested in a virtual environment.

Early attempts to obtain measurements of eye movements in a natural context and with free head and body movements typically concern everyday activities like driving a car (Land and Lee 1994, Harbluk et al. 2002), playing golf (Fairchild et al. 2001), washing hands (Pelz and Canosa 2001), or making a sandwich (Hayhoe et al. 2003).

More recent research also targets the visual attention in public spaces mainly with explorative field trials. For example Wessel and colleagues (2007) investigated the gaze behavior of science museum visitors to examine which eye movements are related to exploration behavior and cognitive elaboration. The authors could identify a common pattern. All participants first scanned each exhibition wall as a whole, and then explored single exhibits in their vicinity. Results show an initial quick skimming of pictorial information, which is a rather automated process, followed by processing like reading text – an elaboration pattern commonly assumed in research.

Gaze patterns usually depend on the given task of a person. This was shown by Droll and Eckstein (2009) who investigated gaze and memory for objects while walking around a building with the aid of a mobile eye tracker. Participants being told that they will be asked about what they saw following their walk were much more likely to notice exchanged objects along their path. They also fixated objects longer prior to the change than participants being simply instructed to walk around the building. The authors state that this result suggests task demand to have an influence on gaze control. Another study (Hart and Einhäuser 2009) investigated natural gaze behavior while ascending and descending a hill in an urban environment for two different terrains (street with constant slope and irregularly spaced sidewalk steps). The conditions resulted in different gaze distributions and the authors claim that the task strongly affects gaze behavior even when instructing participants and environment are kept identical.

Concrete implications for the placement of wayfinding information in nursing homes could be drawn by a mobile eye tracking study of Schuchard and colleagues (2009). The authors investigated wayfinding in a nursing home of older adults with mild dementia. They could support earlier findings that participants look mainly at the floor and lower part of hallway, and therefore rarely look at areas where wayfinding information is usually placed.

The various insights in gaze patterns in public spaces are only possible due to the evolving mobile eye tracking technology. Although authors point out constraints like limited conclusions on cognitive processing, obtrusiveness of measurement, limited temporal and spatial accuracy, and laborious data analysis (Wessel et al. 2007), mobile eye tracking has the potential to explore eye movements in a more natural setting than every other technology before.

2.5 Attention in Guidance Systems and Driver-Environments

The user in public spaces who is typically on the move in public transport or car traffic has to face the challenge of filtering out the relevant information from the large number of available information. To facilitate this filtering process the design of signs in guidance systems (like platform numbers or speed limits) is essential. Early studies in this regard are concerned with differential effects in traffic sign perception, like smaller reaction times for warning than for regulatory signs (Dewar et al. 1976) and longer reaction times for extravert participants (Loo 1978). More recent research in this field (Ben-Bassat and Shinar 2006) could show that ergonomic design principles play an important role in the comprehension of traffic signs. The results show a strong relationship between the comprehension level and the three principles of compatibility, familiarity, and standardization for drivers of different cultural backgrounds. Ng and Chan (2007) considered the participant's experience with icons. They identified semantic closeness as being most important for signs not learned before, and that sign fea-

tures determining sign usability change as the experience with the sign grows. The authors conclude from this result that designers of traffic signs should consider different user groups.

Research was also conducted on how the attention of drivers can be distracted from relevant information like traffic signs, e.g. by advertisement. Since for the advertising industry it is desirable that roadside advertisements gain a lot of attention, it can be a seen as source of distraction, increasing the complexity of drivers' visual environment (Wallace 2003). In the worst case this can result in a fatal accident. An interesting question in this regard is how much attention different kinds of roadside advertisements really attract. A driving simulation study found that roadside advertisements increase mental load and eye fixations and can distract the attention from more relevant road signage (Young and Mahfoud 2007). However, the visual attention on ads is high especially in situation which are monotonous and with a lower workload. Another driving simulation study investigated differences between static and video adverts (Chattington et al. 2009). The authors found that video advertisements cause a significantly greater impairment of driving performance than static ones (indicated for example by longer and more fixations and a greater variation in lateral lane position). Besides the type of advertisement also placement seems to be an influencing factor for amount of attracted attention. Crundall and colleagues (2006) used eye tracking of participants watching a video clip to study the influence of different locations of adverts. They found that adverts placed at the height of bus shelters attract and hold attention at inappropriate times compared to adverts placed in three meters altitude. The findings have direct implications for the representation of roadside billboards as means of marketing. Nevertheless they shouldn't be a risk for car drivers.

2.6 Attention in Advertisement

The question how people attend advertisements in general has concerned many researchers in the fields of marketing, psychology and neuroscience. Research was done for all kinds of media including print advertisement in magazines and papers, in-store marketing and outdoor advertisement.

Effects of the placement and appearance of advertisement on the amount of visual attention of observers is a frequently researched topic in printed advertisement. A study investigating eye movements while choosing businesses from yellow pages (Lohse 1997) could show that 93 percent of the consumers notice quarter page display ads but only 26 percent of the plain listings, and that color ads are noticed before and viewed longer than non-color ads. Furthermore consumers spent 54 percent more time viewing ads they end up choosing than ads they didn't choose, which demonstrates a certain relationship between visual attention and choice behavior. A study by Drèze and colleagues (1994) investigated the consumer choice for brands on different shelf levels in the context of in-store market-

ing. The authors found brands on shelves near the eye or hand level being chosen more often than brands on the lowest shelf. Similar results were found with a study applying eye tracking technology (Chandon et al. 2009). Investigations of the visual attention of (potential) observers of outdoor advertisement are also often about whether and how long the observer looks at specific aspects of boards, brands, banners, or posters. Basically outdoor posters catch a lot of attention, e.g. in a study of the OAAA (1999-2000) 70 percent of outdoor posters in the visual field of the subject were seen, and 63 percent of these were likely to be read. Maughan and colleagues (2007) found a correlation between the fixations of participants on advertisements and whether they liked the advertisement or not. Interestingly there is a strong relationship between increasing number of fixations and increasing preference for the advertisement, though nothing can be told about the direction of causality – i.e. which factor is the cause and which the effect.

To provide passengers of public transportation systems with advertisements on digital displays is a rather new advertisement medium, thus there is still a lack of research investigating the mechanisms of this type of advertisement. Research on attention towards public displays in general provides valuable information also for digital displays in public transport. Huang and colleagues (2008) for example state that attention towards public displays is difficult to attract and hold, and define valuable design recommendations regarding e.g. positioning and content format.

2.7 Methods of Attention Measurements in Advertising

As measurement of the effect of specific marketing strategies, researchers frequently rely on recall and recognition as a measure of attention to the advertisement in question (e.g. Barlow and Wogalter 1993). This approach follows the rational that objects gaining more attention will also be remembered more likely. But the relationship between attention and recall is not unambiguous as was shown by a series of studies of the OAAA (1999-2000). The studies reveal that people tend to recall only a third of outdoor boards they looked at and also recall boards which were never shown. This is why the authors claim unaided recall not being the best method to assess ad effectiveness, and consider aided recall and recognition as more accurate. Another possibility frequently used in marketing is to measure brand choice or numbers of sales (e.g. Drèze et al. 1994). On the one hand these measures seem comfortable in the context of outdoor advertisement, since they are a simple assessment and deliver valuable insights about the effectiveness of pervasive advertisement. On the other hand it is questionable if these rough measures can really teach us detailed about the person's attention in a complex advertising situation including many factors moderating between attention and memory (and respectively purchase). Justifiably, researchers claim for better marketing metrics of visual attention than self-reported recall or number of sales (Chandon et al. 2009).

In the context of advertisements eye tracking is a promising and increasingly used method, since it supplements subjective measures like questionnaires with objective data, telling if people really look at specific objects in their visual field. Eye tracking provides rich data about the gaze behavior, more accurate than questionnaires and can't be easily manipulated by the person (Wessel et al. 2007). Considering the little amount of research using mobile eye trackers in a realistic context, much work has to be done in technical and conceptual regards to advance findings in this field.

3 Attention in Public Transport towards Digital Displays (Study 1)

The driving idea behind the first study was to investigate human attentional behavior towards digital displays (so-called info-screens) in urban public transport with the aid of mobile eye tracking under natural conditions. More specifically the focus was on the attention, awareness, attitude and memory of people related to such displays, as well as the influence of different content-types, like advertisements and news.

3.1 Method

Field Study Context. The info-screen is a display mounted in trams in the city of Graz in Austria (see Fig. 1a). Four info-screens with a size of 17 inches are installed in each tram (two in the middle of the train and two in the front part). They are either pointing against the driving direction or sideways, wherefore their visibility and the viewing distance varies depending on the observers' location in the tram. The info-screen is broadcasting its content in cycles that get repeated every 14 minutes, which is about the length participants were in the tram in one direction. The content-types forming a cycle at the time of the experiment were advertisement, news, culture, entertainment, sports/weather, event-tips and passenger information.

Participants. A random sample of 106 people (51 female, 55 male) with a mean age of 30 years took part in the study. Participants were located in Graz and had different educational (bachelor, master) and professional (apprenticeship, teacher) backgrounds. Due to technical problems (malfunction of the information displays in the tram and problems with the mobile eye tracking system) six participants were excluded from the data analysis.

Material. The eye tracker used in the experiment was an iView X HED mobile eye tracker of the company SMI, consisting of a size adjustable, lightweight helmet, tablet pc (carried in a daypack), and a sampling rate of 50 Hz (see Fig. 1b).

After the eye tracking in the public space a questionnaire consisting of 22 questions was provided, which includes the following topics: subjective measurement of how long participants paid attention to the info-screen; inconvenience by the helmet and the daypack; attitude about the info-screens; likability of the content-types; likability of different kinds of advertisement media; and demographic data. Furthermore recall and recognition of content shown on the info-screen was assessed. As a recall test participants were asked to tell in no specific order which content they had seen during their ride. Then participants were asked to recall which specific ads, logos and brand names they could remember. For measuring recognition participants' were provided with a textual list including ads actually being broadcasted and ads that were not shown on the info-screen.

Fig. 1 a) Placement of two info-screens in tram either pointed against the driving direction or sideways b) Mobile eye tracking system

Procedure. Participants were informed about the general aim of the study to measure attentional behavior in public spaces, but not that the focus lies on the attention towards the info-screens. After presenting the mobile eye tracking system participants could decide if they still wanted to participate in the study.

The actual testing procedure started with the calibration of the eye tracker once subjects had the helmet on. The calibration was done using a five-point calibration target. Then participants were asked to carry out the simple task to bring back books and magazines to the return box of a public library located about 25 minutes away from the starting point, and then to come back. With a detailed description of the route, a ticket, a mobile phone (in case they have additional questions), and an umbrella (to protect the eye tracker in case of sudden rain), participants left. The calibration was checked again when the participants left to go to the public library and when they came back to see if the helmet had gotten out of place. In total participants were on their way for about 50 minutes.

When the participants returned the questionnaire, presented in electronic form, was filled out by the facilitators with the participants providing the answers, because some participants were not familiar with the computer technology.

Data analysis. 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 the daypack. The operators of the info-screens provided the corresponding time-stamped log-files. The quantitative data set (with the log-files and the eye tracking data) enabled to determine on a frame by frame basis if the info-screen was in the visual field of a participant and which content was displayed. With the questionnaire it was possible to compare whether a participant's memory and self-assessment regarding length of attention towards the info-screen was consistent with the quantitative data.

3.2 Results

Participants' attitudes towards testing and advertisements. First of all we investigated how inconvenient participants felt because of the testing equipment. Overall participants reported in the questionnaire that they were not bothered very much by the helmet and the daypack (23 percent of the participants were not disturbed at all, 70 percent were disturbed a little bit, 5 percent felt severely disturbed by the equipment). Furthermore most participants reported that they didn't feel nervous (64 percent) during the ride at all, 34 percent felt a little nervous and only one percent reported having felt very nervous. Regarding the participants attitude towards the info-screen two thirds of the participants rated the presence of the info-screen as being good, 20 percent where indifferent and ten percent didn't like it at all. The preferred advertising media in general assessed with the questionnaire were television and posters.

Attention towards the info-screen. The eye tracking data reveals that of the 100 subjects included in the data analysis 61 percent fixated the info-screen at least once. The respective data from the questionnaire is not in line with the eye tracking data since 88 participants reported to have seen the info-screen.

From the 48,7 hours all participants together spent in the tram, 23,06 percent of the time the info-screen was in the visual field of the participants, and in 3,64 percent of the time attention was directed towards the info-screen – i.e. the info-screen was fixated. Participants focused on the info-screen between some seconds and 9 minutes - on average for 104 seconds (see Fig. 2a for the frequency of fixations durations overall participants). Subjects were also asked in the questionnaire to measure their subjective feeling about the attention-span towards the info-screen. Most subjects thought about their attention-span being up to two minutes (see Fig. 2b), which corresponds to the measured average value of attention-span.

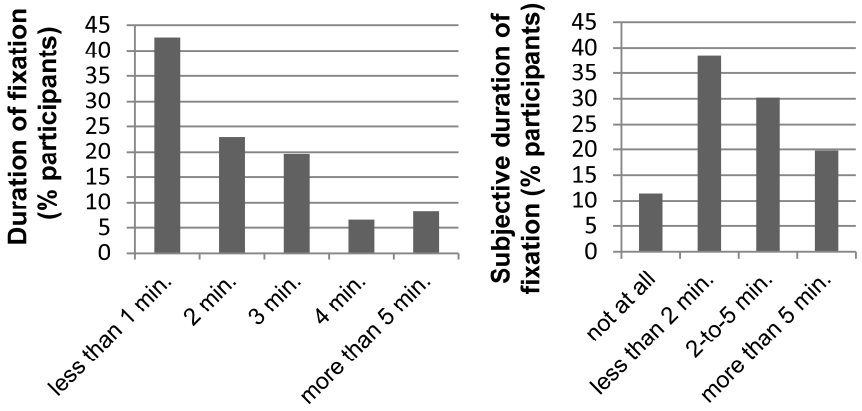

Fig. 2 a) Percentage of participants' duration of fixation on the info-screen over the whole time spent in the tram b) Participants' estimation about the overall duration of fixation

Differential effect of content-type. One of the main questions in this research was to investigate the visual attention on different types of content. Analyzing the fixation-time of different content-types shows that "news" got most fixation-time (4.54 percent of the overall testing time) followed by "sports/weather" (3.98 percent) and "entertainment" (3.81 percent). The remaining categories got around 3 percent except for "culture" which got 2.65 percent of the overall testing time. A further analysis with the distributions of the number of fixated frames on the info-screen for each participant and content-type, shows no significant differences between the content-types ($p = 0{,}39$).

The differential effect of content-type was also addressed in the questionnaire by asking the participants whether one content-type is of interest for them or not. The (due to an organizational error left) 96 participants rated "news" and "event-tips" as most interesting, followed by "weather" and "sports" (see Fig. 3). These differences in interest towards the content-types can't be found in the eye tracking data in terms of a higher number of fixations.

Differential effect of daytime. The investigation of the attention towards the info-screen at different daytimes shows the longest mean fixation times between 8 and 10 a.m. and between 2 and 4 p.m. (see Fig. 4). A possible explanation for this might be the fact that in the morning participants' interest for news is higher than during the rest of the early day hours. The even higher peak in the afternoon could result from a relationship between the daytime and the number of travellers in the tram, which is in the early afternoon probably small.

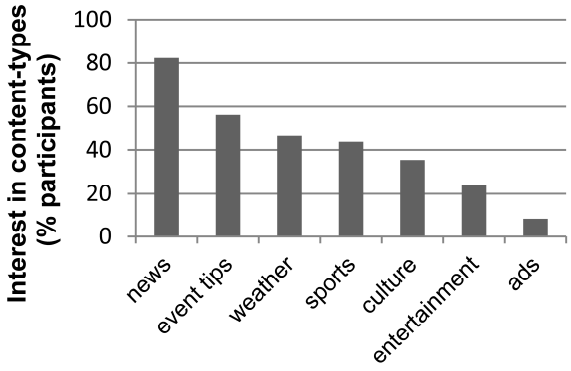

Fig. 3 Percentage of participants rating the different content-types as interesting in the questionnaire

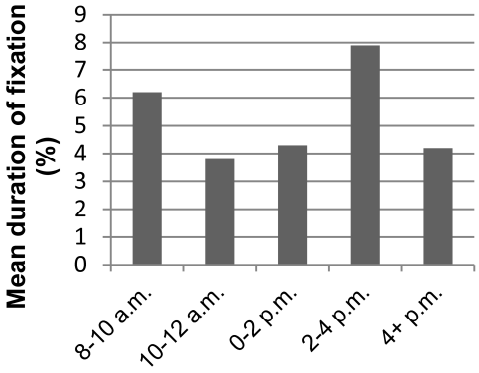

Fig. 4 Mean duration of fixation on the info-screen (in percent of the whole testing time) of participants' at different daytimes

Recall and recognition of the info-screen information. From all participants 80 percent were able to recall categories, and on average participants recalled three different categories. 27 percent were able to recall specific spots and logos and 18 percent recalled brand names. In the recognition task 43 percent of the participants were able to recognize spots correctly, but they only recognized between 1 and 4 advertisements (mean 1.37).

The correlation between fixation time on the info-screen and recall/recognition was tested next. The results show no significant correlation between number of frames fixated and number of content recalled ($r = 0{,}102$) and respectively content recognized ($r = 0{,}341$).

3.3 Discussion

The results of this study show that according to eye tracking data more than half of the participants did focus on the info-screen, and nearly nine out of ten reported to have noticed the screen. Therefore the info-screen gains a considerable amount of attention of the participants - even under the given free-exploration condition.

The content-type seems not related to the length of fixation time. For example few participants found “advertisement” interesting, but nevertheless the fixations on “advertisement” did not differ from any other content-type. A possible explanation for this could be the fact that fixation time on the info-screen does not imply that participants’ were actively following the presented content. Or maybe participants’ have the mental model of ads being not interesting.

Further, no significant correlation between duration of fixation on the screen and recall/recognition exist. One explanation for this result might be the experimental setup that participants had no idea about the purpose of their ride and no order to look at the info-screen. Another explanation could be the fact that - as already mentioned above - fixating the eye tracker does not implicitly mean perceiving its content.

Considering the fact that participants did not know about the aim of the study and the natural environment, those results are very interesting because of their explorative character. We learn from this study that fixation time on digital displays 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.

The findings from this study can serve as a basis for future research, e.g. if we can actively and reliably catch people’s attention in a natural environment like this one (or any other urban environment) and how we can optimize content for such a form of advertising to improve content memorization. Despite their similarities with TVs digital displays like the info-screen do miss audio as a channel for communicating with its audience, which requires separate considerations for pervasive advertisement.

4 Attention in Shopping Streets towards Logos (Study 2)

In this section we describe the second field study which aimed to better understand, which areas and objects receive attention by pedestrians in an urban setting (shopping street). The basic research question was whether there is a significant influence of the users’ movement on the direction of attention. Additional research questions address the influence of context variables (e.g. daytime and frequentation) on the relation of motion and attention and the effects of the relation of motion and attention on memory.

4.1 Method

Field Study Context. The study was conducted in the inner city of Graz (Austria) in a pedestrian shopping street, which represents a realistic urban setting.

Participants. 20 participants - males without contact lenses or glasses (to ensure a stable recording of eye tracking data) - were recruited. A financial allowance as a compensation for the participants' effort was offered. Because four of the participants could either not be tested because of bad weather or cancelled their participation, 16 study participants remained.

Material. The same mobile eye tracking system as in the first study was used to capture gaze movement data and scene video. Additionally built-in sensors of the Google Nexus One smartphone were used to capture GPS-position data. The position fixing component of the device is a GPS receiver, which is integrated directly within the chipset. The device is also equipped with integrated accelerometers and a tilt compensated magnetic sensor. Only the GPS-data will be used as the sensors do provide more accurate data. The conducted questionnaires include questions regarding e.g. demographic data, familiarity with the test area (Herrengasse), and free recall of shops in the test area.

Procedure. The study started with a detailed briefing. The aim of the study to investigate the visual attention in a shopping street was not revealed to the participants – instead of that they were informed that the study focuses on the improvement of eye tracking equipment. The participants were asked to act as natural as possible and try to ignore the eye tracking equipment as far as possible. Test participants signed a consent form and were asked to fill out a pretest-questionnaire. Then participants were equipped with the technical test setup and accompanied by a test facilitator on their way through the inner city of Graz. Participants were asked to follow a specific route (to reference GPS data tracks). Overall time of data capture per test person was about 15 minutes. Then the technical equipment of the participants was demounted and the data was saved. Participants were asked to fill out a final post-questionnaire and the financial allowance was paid.

Data Analysis. The main focus of this study is the relationship between eye tracking and motion tracking data. Therefore the synchronized data was investigated according to correlations between eye and body movement metrics. But also the general visual attention while walking through the shopping street was analyzed by considering how many fixations participants had in different areas of their visual field and on commercial logos.

4.2 Results

Visual attention and orientation while walking through a shopping street. The first part of the data analysis focused on the attention on different areas of the visual field based on the eye tracking data. Without considering the body orientation this – of course - doesn't tell anything about the concrete direction of visual attention. As can be seen in Fig. 5 most times the gaze of participants falls in the horizontal middle in a somewhat lowered position. This result indicates that participants direct their eyes most of the time towards this default position so to say.

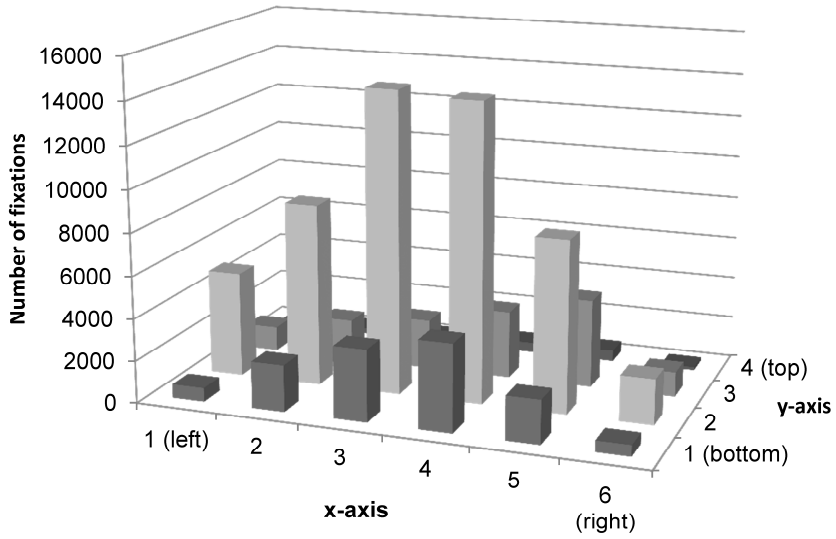

Fig. 5 Number of fixations over all participants at different areas of the visual field from left to right and bottom to top (752x480 pixels)

Also the horizontal head orientation of the alongside the shopping street moving participants is mostly aligned centered (see Fig. 6 a and b), with a stronger orientation towards the right side (where the shops of the street in our test scenario were located). For this analysis the orientation of the street was taken into account. Regarding the vertical alignment of the head of pedestrian users (see Fig. 7 a and b) the average orientation is directed towards a slightly elevated position (mean = 4,10 degrees), and there is more orientation towards the upper sphere than the lower sphere.

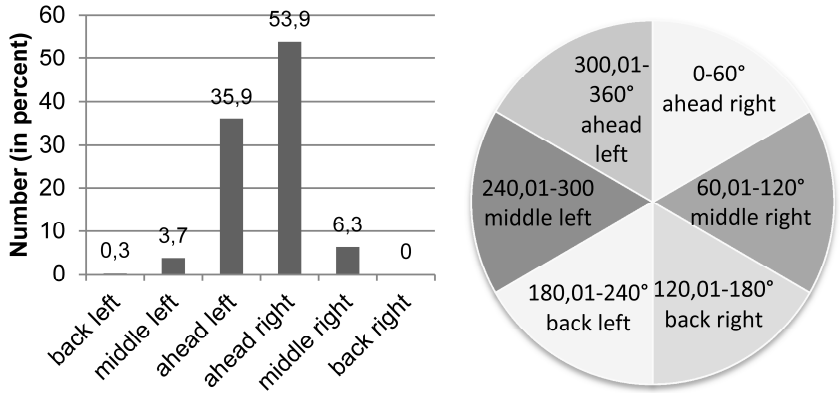

Fig. 6 a) Horizontal head orientation in relation to orientation of the Herrengasse in percent from back left to back right b) Categorization of the horizontal orientation data

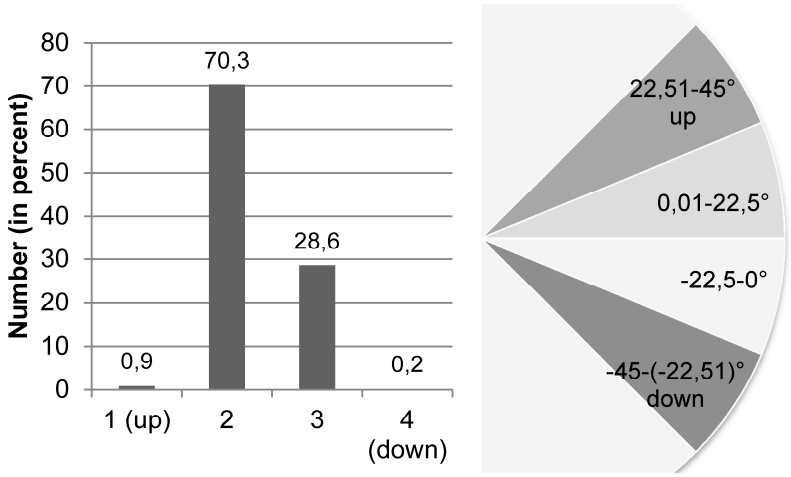

Fig. 7 a) Number of vertical head orientations in percent from up to down b) Categorization of the vertical orientation data

Relationships between head and body orientation data. The relationship between head and body orientation was analyzed with the data of the two motion sensors. The results show a distribution of orientation as might be expected: In the majority of cases the head orientation is aligned with the body orientation, with decreasing numbers for relative orientations to the sides (see Fig. 8).

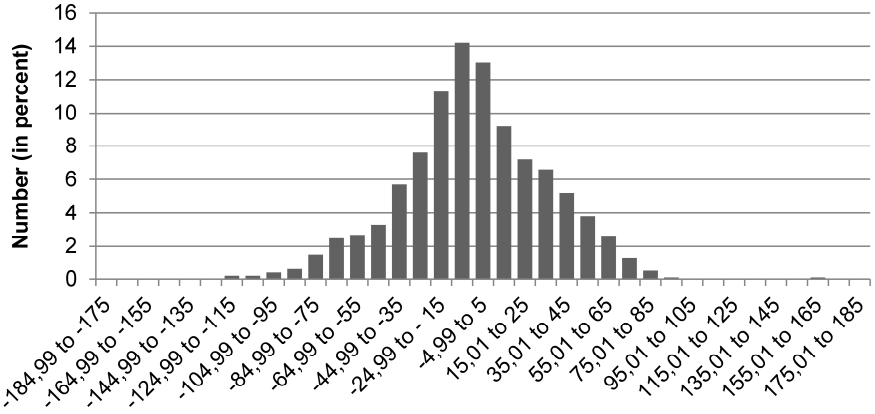

Fig. 8 Relative horizontal head orientation (difference between head and body orientation) expressed in degrees across all test participants

Relationships between situational factor, visual attention, and motion. The relationship between the number of people on the shopping street (categorized into "few" and "many"), the motion speed of participants', the number of fixations on commercial logos and the horizontal centrality of the head orientation was calculated. The results (see Table 1) show an interesting correlation between motion speed and horizontal deviation: higher speed is associated with a smaller deviation from the centered orientation ($r = -0,26$, $p < 0.01$). The other correlations (although also statistically significant) are rather small, but indicate e.g. that a lower motion speed is related to the fixations of logos and a higher number of people on the street. A subsequent comparison of means shows a significant difference in motion speed while fixating a logo and fixating something else than a logo (0,92 compared to 0,99 m/s) and between few and many people on the street (1,00 compared to 0,97 m/s).

Table 1 Pearson correlations between the situational factor "number of people on the street", the attentional factor "fixation on logos" and the motion factors "motion speed" and "horizontal deviation of the head"

	Motion speed	Horizontal deviation of the head	Number of people on the street	Fixation on logos
Motion speed	1	-0,26	-0,05	-0,05
Horizontal deviation of the head	-	1	-0,02	-0,03
Number of people on the street	-	-	1	-0,02

Attention to logos. Besides its relationship to other variables (see previous section), the attention on advertising media in the shopping street was investigated also in general. The fixations on logos were annotated by means of the scene videos, and it was coded for each frame if the participants fixated a logo or something else. The results show that big size logos in the shopping street received a considerable amount of attention, because about four percent of the fixations are on them (89,5 percent are on something else, than logos and 6,5 percent couldn't be assessed in the videos). In 60,4 percent of the logo fixations the head orientation of participants was ahead right, which means that they looked at logos on the same street side in front of them and didn't turn their heads too much to look at logos (see Fig. 9). 29,7 percent of the logo fixations were on the other side of the street.

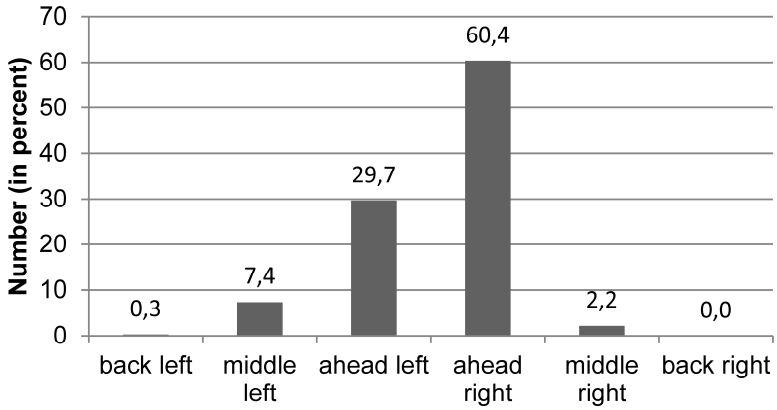

Fig. 9 Head orientation over all participants while they fixated on logos

4.3 Discussion

The investigation of pedestrians' attention and motion with the aid of mobile eye tracking delivers initial results relevant for advertisement strategies in a shopping street. The eye, head, and body orientation of the participants may indicate how advertisement should be placed. The eye gaze of participants were in average on a slightly lowered position, whereas the head was a bit elevated from straight ahead (4,10 degrees). This can easily be explained by the needs of pedestrians to navigate between other pedestrians, the usage and consultation of personal devices (e.g. looking on the watch, consulting written materials, using electronic devices, etc.) and watching objects of interest in shopping windows, for which the head orientation doesn't need to be necessarily lowered. Interestingly four percent of fixations are directed to logos, and these fixations tend to relate slightly with the lower motion speed of participants', which is again related to the number of peo-

ple on the street. Furthermore people tend to show less variation in their horizontal head orientation when they move faster. Since participants' fixated mainly logos which were straight ahead of them, and didn't look at logos beside of them, it may be advantageous to place logos so that they can be seen from more distance.

5 Attention on the Move - Summary of Findings

The two presented studies investigated the attention on advertising media in two different situations: within a digital display in public transport and towards logos in a pedestrian shopping street. The results show that the attention towards advertising media is in both situations not negligible. 61 percent of the participants fixated the info-screen at least once, and 3,64 percent of the time the participants' attention was on the display, although they could only see at the displays at certain positions in the tram. Similarly four percent of the visual attention of pedestrians in a shopping street was targeted on advertisement logos. The results also indicate that daytime and crowdedness (which are probably related to each other) may have an impact on the visual attention on advertisement, but for clear results this has to be investigated in a more systematic way. Interesting are the main orientations of attention of participants walking through a shopping street, which lies in position horizontally centered, and vertically lowered for eye gaze and respectively elevated for head orientation. While walking along shops, participants mainly looked at advertisement logos which were distant in front of them, so that they didn't turn the head to the side much. Furthermore logo fixation has been found related to a slower motion speed.

6 Implications for Pervasive Advertising

Initial implications for pervasive advertising in public spaces can be drawn from the presented studies. Digital displays installed in the public transportation systems evoke a decent amount of visual attention; regardless of the actual content (news, entertainment, advertisements etc.) they are transmitting (study 1). This result is even more interesting considering the fact that participants were not instructed to stand near by the displays to have the possibility to look at them. For plain advertisement logos the location and placement seems to be of high relevance, since people fixate logos located in front of them (study 2). Therefore logos which are mounted at right angle to the house walls might be seen better from their perspective (see Fig. 10) than those mounted parallel. The results of study 2 also indicate small relations between the logo fixation, motion speed, and number of fixations. A slower motion speed as well as fewer people on the street, slightly relates to logo fixations. This instance seems reasonable, since on the one side pe-

destrians with a higher motion speed have to be concentrated more on where they are walking and on the other side viewing logos could decelerate them. Furthermore people on the street could block the view on logos. However, because of the field design of the study, with many uncontrolled variables, the correlations are (although significant) very small. To clarify causality the relation between speed and logo fixation has to be investigated more systematically, within an experimental setting. The eye tracking and motion data of the pedestrians' reveals the ideal placement of logos at medium height, since most eye gazes and vertical head orientations are at this level. For future research it would be interesting to analyze the relationship between eye and head/body movements.

Fig. 10 Shopping street "Herrengasse" with logos mounted at right angle to the house walls

7 Discussion of Research Methods for Analyzing Attention

The used method of mobile eye tracking to investigate the concrete visual focus of participants in public situations has a great potential for researching perception and attention processes. Only by tracking the participants' eye gaze and motion valuable data about the actual attention and orientation towards advertisement can be assessed. However, the procedure needs a further development of tools for automatic processing, because so far the data handling is quite laborious. Also less obtrusive technology would be very much desirable to minimize possible influences of the tracking equipment on the users' behavior.

Even though these are two serious methodological issues, we still think eye tracking provides very valuable research data as they have the chance to also provide situational and not only out-of-context and summative data (as recall and recognition rates), therefore this method allows studying the involved perception processes in much more detail.

In future work we plan to develop formal models of the users' attention behavior to be able to quickly and cheaply estimate attention distributions in virtual

models of the environment, thereby allowing considering these data already in the design phase of buildings and public spaces.

8 Limitations of the Studies

As for all research, for understanding the results the limitations of our two studies should be considered. Whereas the number of user was very high in the first study the results of the second study need to be interpreted more carefully as the number of users was much smaller. However, with regard to mobile eye tracking studies the number of users is still on the top of available research.

Another limitation that should be considered is possible effects of the used tracking technology on the movement pattern of the users. As the equipment is very well visible people might have behaved differently compared to casual situations. Users were asked after the tests whether the technology had an influence on their behavior or not, and a majority of users replied with minimal to no effect.

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