Eye tracking and its application in usability and media research

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1. Introduction

Over the last ten years the Internet has become an incredibly important media in everyday life of ordinary people. By now the World Wide Web is not a foreign concept anymore; millions of people make use of the internet in terms of e-mail, online banking, online shops, etc. Companies have realised the necessity of user friendly interfaces and software which even an inexperienced user is able to handle. Since the interaction with the Internet becomes ubiquitous, assessing usability of interfaces is a fundamental and necessary part of HCI development. Observing the overt behaviour of users, (which button does a user click on, how is the mouse used), retrospective self report, questionnaires and thinking aloud methods are just examples of traditional and quite successful strategies in order to investigate usability problems.

So, why should there be a need for a new method when conventional methods seem sufficient in optimising usability and what is it's contribution in the evaluation of how usable a particular design is?

We will give a short introduction of the eye tracking method in applied marketing research and its benefits. Reporting two of our studies we will discuss the limits of traditional usability testing and will show how tracking the eye gaze can fill this gap.

2. Eye tracking, visual attention and the limits of conventional usability methods

Eye tracking has been used for nearly one hundred years in psychology, focusing on recording eye movements while reading. When personal computers started to flourish in the 1980's, researchers began to incorporate the field of eye tracking into

issues of human-computer-interaction. As technological advances such as the Internet, e-mail, and videoconferencing evolved into viable means of information sharing during the 1990's and beyond, researchers tried to apply eye tracking in order to answer question about usability (e.g. Benel, Ottens & Horst, 1991; Ellis et al., 1998; Cowen, 2001). In these terms Goldberg and Wichansky distinguish between two groups of readers: eye tracking scientists who apply their work to usability evaluations and usability engineers who try to implement eye tracking into their studies.

Facing an increasing information overflow on web sites, many providers compete in the so called "war for eye balls" for the limited attentional resources of Internet users. Providers need to know the attentional strength of an advertisement, e.g. where to place a logo etc.
Assessing the allocation of visual attention with conventional methods like click analysis, questionnaires or simply asking subjects where they have paid attention to, are limited to those processes which are part of conscious reflection and conscious control. Relying exclusively on such methods will lead to a major validity problem, because, attentional processes do not solely depend on conscious control. They are often controlled beyond subjects' awareness, are therefore not reportable or are simply too fast to be analysed by mouse movements.
In order to test the attentional strength of marketing interventions or to find out where on the screen visual attention is deployed to, it is necessary to apply specific and valid psychological methods.
Going along with technological advances in the recent years, eye tracking has become a promising tool in order to answer such questions. The main target of the eye tracking method is to assess the allocation of visual attention on the screen. There is overall no doubt that eye tracking data are a necessary precondition for the focus of visual attention.

2.1 Eye tracking reveals higher validity in data compared to conventional methods – a dissociation between self reported data and eye tracking data

Another well known major validity problem using conventional usability methods arises when testing subjects in an artificial environment, such as a usability lab. Subjects are aware of the test situation. The description and verbalisation of their own behaviour might be biased in terms of social expectations, political correctness or simply to give a good impression. This is especially the case when it comes to target group analysis.
In this part of the article we will argue that eye tracking can be a helpful and, moreover, a necessary method in usability testing for the proper assessment of the relevant psychological processes which can not be assessed by self report measures. Self report measurements, like thinking aloud protocols or questionnaires, produce biased or even wrong data which are not predictive for behaviour.
We will now present data from four eye tracking studies including 270 subjects to support our argumentation. In those studies we could demonstrate sex differences in the attentional focus of subjects perceiving a web site, which were not detectable with conventional usability measurements. Moreover, comparison of eye tracking

data between men and women showed the reverse results than data assessed with thinking aloud protocols and questionnaires.

2.1.1 Method

In our lab we use a non-invasive (remote) eye tracking system, which registers the eye gaze with infrared technique and pattern detection. The most evident advantage of non-invasive eye tracking methods is that subjects do not need to wear a helmet. This leads to a quite natural reception-situation. Because, the reference frame stays stable, data can be analysed automatically and can be visualised with the "Eye Square – Visualiser" software. Options of analysis are individual or aggregated path analysis, density distributions, fixation duration's or definition of hotspots. For a more detailed description of methodological issues of the eye tracking method, it's advantages and disadvantages see (Jacob & Karn; Aaltonen).

Subjects were asked to go on the web site of a major German bank and find an interesting link within 30 seconds. 120 subjects took part in this study (60 man and 60 womem). With presentation of the web site, eye tracking was recorded. Figure 1 shows the density distribution between men and women when looking at the web site for the fist ten seconds.

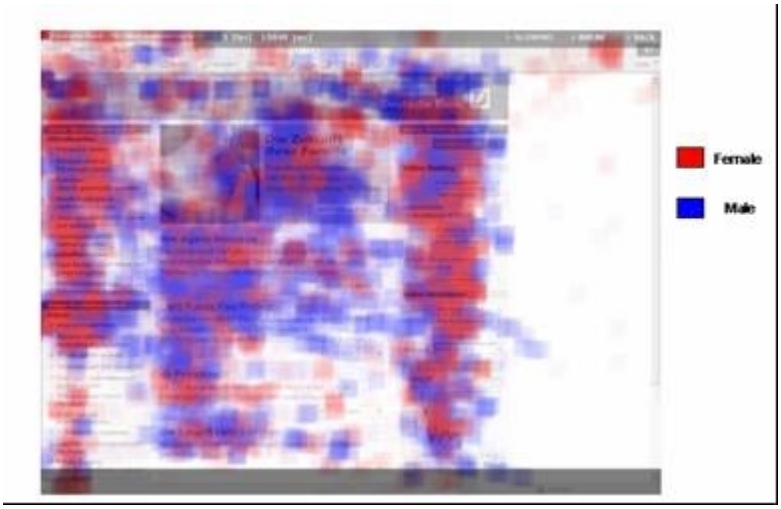

Figure 1: Sex differences of the attentional focus when looking at a web site.

Results are shown in figure 2. We coded attention on textural stimuli and on pictorial stimuli, such as photos, icons or logos. A conducted t-test analysis revealed significant differences in attentional behaviour between the genders, textural information $p<0,01$ and pictorial stimuli $p<0,05$.

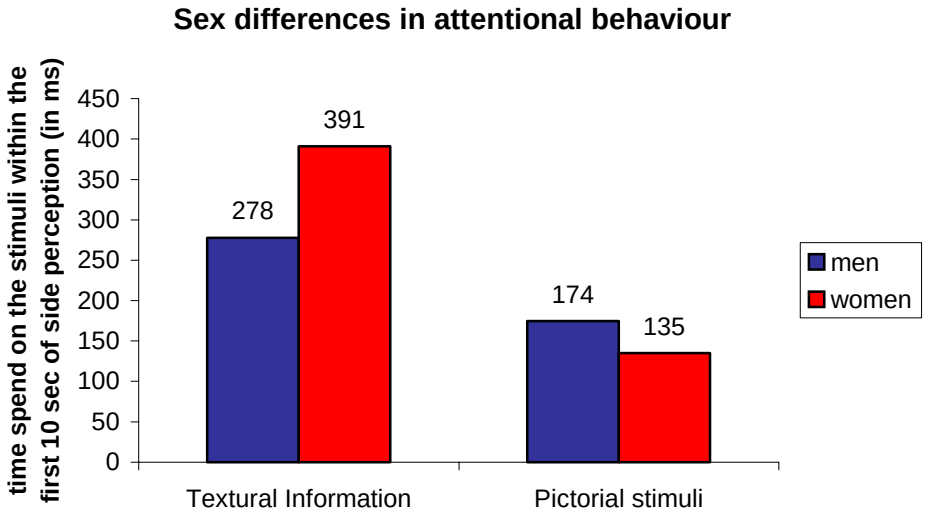

Figure 2. Time of recorded eye position, indicating the attentional focus of men and women when perceiving textural or pictorial information.

After recording the eye tracking data subjects had to fill out a questionnaire. A main dissociation between the eye tracking data and the self reported data is shown in figure 3. Here, subjects were asked to rate how important they find either, pictures or text on the web site.

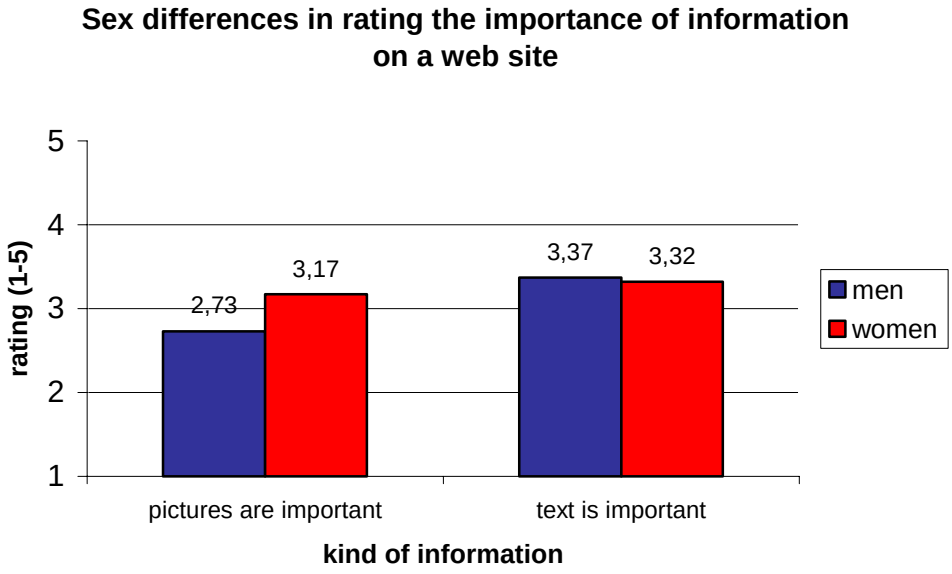

Figure 3. Self reported data of the questionnaire. The bars show the rating of how important women and men find pictorial and textural information on a web site (1= not important at all up to 5= very important).

2.1.2 Discussion

The empirical findings indicate that there is a big difference in the attentional behaviour between women and men (see figure 1). Whereas women tend to receive textual information very carefully, men start their orientation on a web site at photos and generally, read less text. Concluding from the empirical data, we therefore, describe women as being text orientated and accurate, and men as icon orientated and loose.
Data from introspective methods (thinking aloud protocols and questionnaire) revealed a quite different conclusion: We often heard men saying statements like: “I do not need pictures on a web site”.
A naive interpretation of the findings using conventional methods might have led to misleading guidelines. Only in combination with the eye tracking method, the whole story comes to the surface and can be summarised in: Women read and men do not.
Our speculation is that this might be connected with the higher verbal intelligence of women. Our results are in accordance to studies from “MediaAnalyser”, although their interpretation of the data is based on women’s higher need for orientation on a web site (Vogt, 2002).

One might object that the described sex difference in attentional behavior between man and women might be caused by a difference in internet experience between man and woman. We conducted analyses and found no significant difference between the internet experience of man (mean = 3,76) and woman (mean = 3,73). The internet experience was assesed by ratings on a five point scale with 1 = very little internet experience to 5 = very high internet experience.

We also found the described effect in studies where we asses visual attention on print adverstisments. We therefore conclude that the difference in the likelihood to read is indeed caused by sex differences.

The presented study is a good example how the application of the eye tracking method provides a more valid tool in usability testing and demonstrates the advantages compared to conventional usability methods when it comes to behavioural biases of users in terms of social expectations.

2.2 The problem is, finding the origin of a problem

An often occurring question in usability research is whether a link has not been noticed or whether a link was not understood. Testing usability with conventional methods, such as click analysis, will only provide a descriptive view of the clicking behaviour of subjects. In this case, respondents did not make use of the button. Using conventional methods alone, it is not possible to locate the origin of the problem. Why did they not use the button?
A strong benefit of eye tracking in combination with click analysis is that the psychological stages underlying the antecedents of clicking decisions will be better understood. Such a combined strategy would allow a clear distinction between the constructs of perception, comprehension and action.
Furthermore, the eye tracking method reveals the possibility to analyse pathways of attentional distribution on the screen. It can be asked how long does a user focus on

particular items, what screen parts consume time, are confusing or difficult and where does a user expect certain information on the screen. Gaze data reveal information, whether a user is paying enough attention to some specific area in a problematic situation. It will be possible to discover insecurities and hesitations of the users' behaviour, which will not be reliably measurable with other methods. This is in accordance with results of the "Poynter Study" in which the authors concluded that eye movement analysis produced highly relevant data, otherwise not collectable, such as: reading behaviour, cognitive workload, level of attention, viewers' entry point and level of frustration. The most often eye tracking metrics are: fixation, gaze duration, area of interest and scan path (for a detailed overview see Jacob & Karn).
For example, analysing the gaze pattern can be very helpful in understanding how a user structures information, which provides a useful basis to create better layouts. Figure 2 shows the analysis of gaze patterns of print media. The numbers demonstrate the order of the gaze path. As can be seen, the subtitle is read before the actual headline, which in this case resulted in a failure of the fast comprehension of the advertisement.

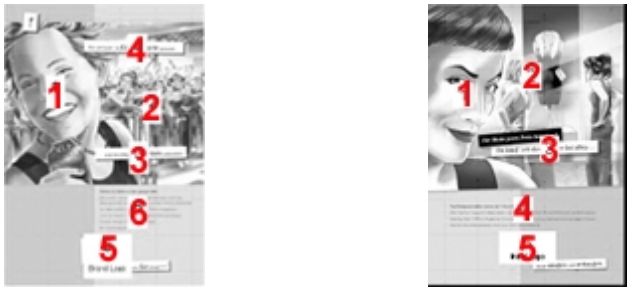

Figure 2: Example of analysed gaze patterns of print media with split headline and with the second version of the prind ad with a single headline(N = 30 each ad .

Taken together, from an applied perspective eye tracking has a clear benefit in terms of practicability.

We will now present data from three a web site usability studies of a major German bank, in which 90 subjects took part. The eye tracking method was combined with click analysis, which enabled us to identify the exact antecedents of subject's clicking behaviour. With the combination of both methods we gained a detailed look at the origins of task failures.

2.2.1 Method

Before the actual usability test took place (data are not being reported here) subjects were asked to look at the website and find a certain button within 30 seconds. Eye tracking was recorded for the first 10 seconds. In combination with the eye tracking method a click analysis was applied. Based on the click analysis method we separated cases in which subjects did not make use of the task relevant link and analysed the according eye tracking data.

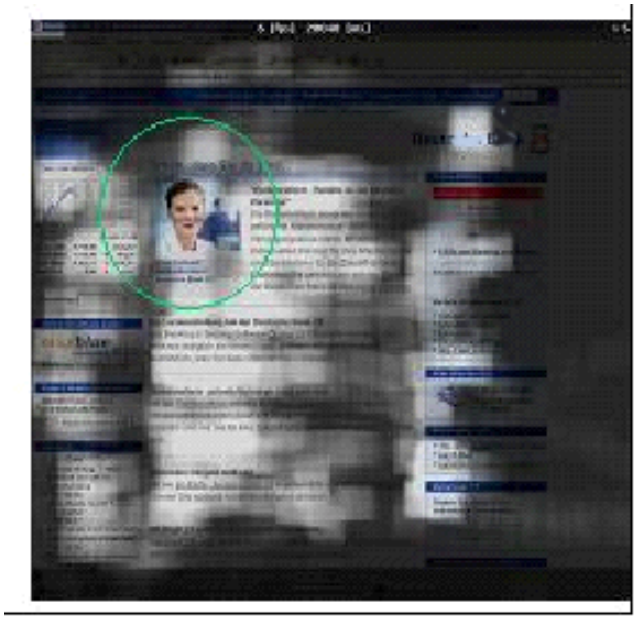

Figure 5: No Attention – No Action.
Inverted Density distributions of subjects looking at the web site of a major German bank. Eye tracking data clearly show that visual attention is barely allocated to the task relevant links which are the entry points to the main services (located at the top of the site) and the entry point to the online account.

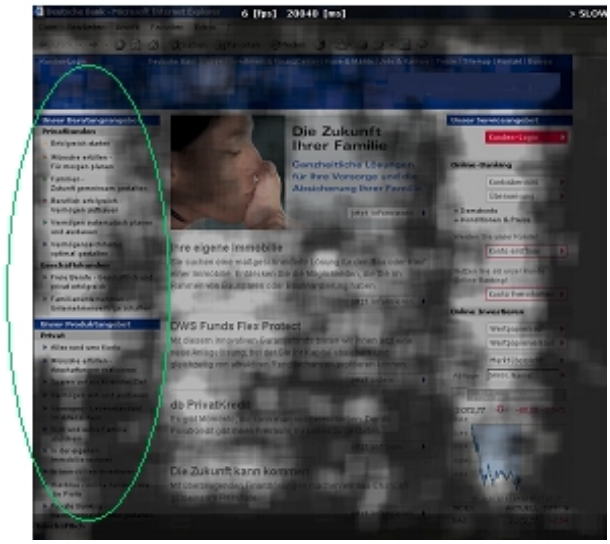

Figure 6: Attention but missing Comprehension.
Inverted density distributions of subjects looking at the web site of a major German bank. Eye tracking data show, that visual attention is indeed allocated to the task relevant link like Product links and the entry to the online account but those links are not used therefore indicating a problem of comprehension.

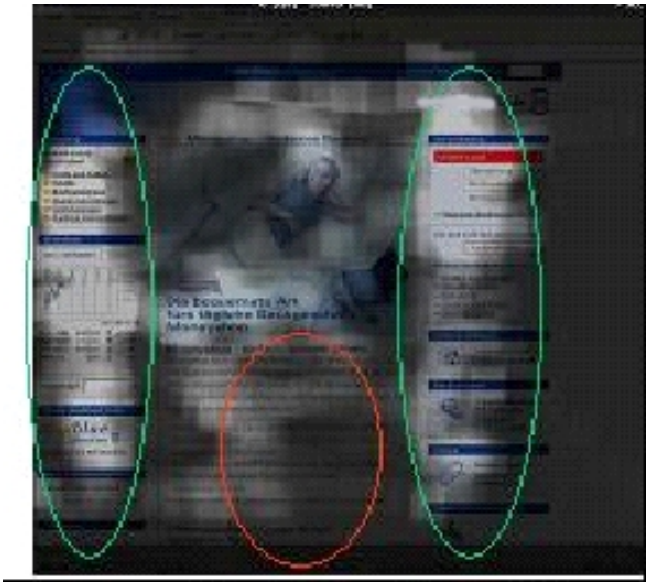

Figure 7: Attention and Comprehension cause Action.
Inverted Density distributions of subjects looking at the web site of a major German bank. Eye tracking data show that visual attention is indeed allocated to the task relevant links as e.g. product links and the entry to the online account.

2.2.2 Discussion

The results of our studies are straight forward. Implementing exclusively conventional methods in usability testing will not permit an interpretation of results beyond a descriptive level. As indicated by our results, click analysis alone is insufficient to explain why users did not make use of a certain button. On the other hand, the additional eye tracking method in these studies gave insight into otherwise not reportable behaviour right before the actual mouse click, or even more important, when lacking a mouse click.
Only the combination of both, conventional methods and eye tracking analysis, allowed differentiating the origins of the problem when subjects did not make use of a task relevant link. In study 1 eye tracking data reveal, that the relevant link was simply not perceived by the majority of subjects (see figure 5).
Even though, the click analysis of study 2 shows the identical results (subjects did not use the link), only the eye tracking data give a clue about the origins of the problem. Here, subjects did indeed allocate visual attention towards the task relevant link, as seen in the density distribution (see figure 6), but the fact of still not using it indicates a problem on the level of comprehension, rather than perception, which is solved in stdy 3 (see figure 7).

Therefore, we can state that the assessment of visual attention with the eye tracking method helped us to provide deeper evaluations and led to important conclusions, which would not have been taken into account, if we would have only used conventional methods of usability testing.

2.3 Conclusion

The aim of this article was to ensure the general understanding that eye tracking provides additional value in usability testing.
In our studies we tried to demonstrate the implications when using conventional usability methods alone. We showed that such a strategy can lead to validity problems of the received data, or on the other hand, will lead to biased or even wrong data. Eye tracking data can unveil response biases of subjects due to an artificial testing environment, which would be undetected in conventional usability testing and therefore, results in a higher validity of usability data. Another major benefit of using eye tracking in usability testing lies in its practicability. Whereas conventional usability methods reveal data only on a descriptive level, the additional application of eye tracking provides insight in the origins of a problem. It allows detailed analysis of the stages on which a problem occurs, such as perception or comprehension.

Although, we have focused exclusively on the advantages of the eye tracking method in this article, we are quite aware of the eye tracking method being a fairly new tool in its application in usability research. However, there are drawbacks, which we think should not be neglected (for a detailed overview see Jacob & Karn). One of the disadvantages of eye tracking in usability research was based on its high financial impact. Also, the immense analysis time of the data made eye tracking in the past a rather exclusive method.

We solved this problem with the development of our own software tool “Visualizer” which allows for an easy setup of an usability test and for automatic and cost–efficient analyses of eye tracking data. We have conducted studies in the fields of Usability, Print Advertisements, TV Commercials and Point of Sale Analyses with more than 2000 subjects in the past year. We see a big demand for tools like eye tracking which allow to asses less biased data in consumer research than pureley introspective methods.

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