Eye tracking in Library and Information Science: a literature review

Introduction

Eye-tracking equipment has now reached a mature level as a technology and is in wide spread use within a number of disciplines i.e. human-computer interaction, usability research, psychology, marketing research etc. The field of library and information science has adopted research methodologies from the field of human computer interaction in the study of interaction between users and information systems, and information behaviour (Ingwersen & Järvelin, 2006). It is therefore relevant to investigate the use of eye tracking as a research tool and methodology in papers published within the field of Library and Information Science (LIS). In this paper, LIS research literature is defined from what can be identified in two research abstracts: Library and Information Science Abstracts (LISA) and Library, Information Science & Technology Abstract (LISTA). Both databases cover the area LIS extensively and therefore form the basis for identifying relevant research for this review.

Eye tracking

That eye-movements can tell us something about how we question the surrounding world is not a new discovery. The research on eye movements and its importance for our understanding of the world has been investigated since the 1880s with the foundation of modern eye tracking (Wade & Tatler, 2005). Since then the movements of our eyes has been studied to uncover the relation between eye-movement and cognitive processes and identify how visual stimuli affects us, and influences the decisions we make (Jacob & Karn, 2003).

It is possible to divide the application of eye-tracking into eye-tracking research and eye-tracking used for gaze interaction (i.e., as an input device) where the eye-tracker acts as a substitute for a mouse controlled by eye-movement. Eye tracking technology used in research has been applied to a number of scientific fields e.g. psychology and medicine etc. Examples is the study of eye-movements and cognition in psychology, and in medicine pathologies of specific medical condition that is manifested in eye-movements. The application of eye tracking has led to the formation of the eye-mind hypothesis where the assumption is that what we think and what our attention is about, is directing our eye movements i.e. eye movements are driven by top-down, high-level cognitive processes (Just & Carpenter, 1980). Other research, Land & Tatler (2009), claim a bottom-up explanation where eye-movements are driven by properties of the image exposed on the retina and do not involve high-level cognitive processing, the saliency of the image. (Land & Tatlet, 2009). These two approaches tend to be integrated into eye-movement control (ibid, 2009). The processes that guide our visual behaviour are influenced by a number of factors usually dived in top-down attention and bottom-up attention. Top-down attention includes voluntary eye-movement where the shifts in attention is controlled by the task we are involved in i.e.

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looking for a specific information on a web-page. Bottom-up attention includes involuntary eye-movement, where the visual system is guiding our gaze according to features intrinsic in the scene or objects we are looking at i.e. colour composition, dark and light objects etc. or the saliency of an object (Holmqvist et al. 2011)

Eye-movement is created because even though our visual field is approx. 180 degrees the actual area with the highest visual acuity, the fovea, is only allows for approx. 2 degrees of movement since the full colour and light spectrum is only available from the fovea. The surroundings are still visible but only as a blurred image meaning that repositioning of the eye is necessary for requiring an optimal image.

The repositioning of the eye occurs in general 3-4 times per second depending on change in visual attention. Eye movements can be categorized according to two main types: saccadic eye movement and fixation. The actual eye movement is the saccadic eye movement where the eye is repositioned because of shift in attention from one object to another object. The saccadic movements is a very fast ballistic movement usually in the range of 30 – 40 ms. It is generally accepted that the no visual intake is happening during saccades. Fixations are the time between saccades where the eye is fixated upon an object. The fixation time on an object will fluctuate depending on the activity viewer is participating in. Rayner & Pollatsek (1989) measured fixation duration in reading from 202 ms – 264 ms depending on the type of literature, in contrast Henderson & Hollingworth (1999) reported a mean of 330 ms when viewing pictures and natural scenes.

Eye tracking technology

The fundamental function of an eye-tracker is to record the eye-movement of a person when looking at any object in their surroundings (i.e. looking at a picture, reading a text, navigating a web site, or exploring signs in an airport), using an infrared(IR) light source and a video camera. The infrared light illuminates the eye and creates pupil and corneal reflections or glints. A video camera records an image of the eye with reflections and the distance between the pupil reflection and corneal reflection is calculated herby establishing the gaze position of the eye. The gaze position can then be superimposed or overlaid on an image of the artefacts that are being studied i.e. a web-page, movie, natural scene, etc. Eye-trackers are mainly available as remote eye-trackers (Fig. 1) or as head-mounted eye-trackers (Fig 2). The remote eye-tracker is either a standalone box, placed below the display on for example a laptop, or is integrated in a display unit. The advantage of a remote eye-tracker is the fixed position relative to the stimuli object which facilitate an easier calculation of the viewing pattern. On the other hand, the remote eye-tracker limits the study to stimuli that can be shown on the actual display. Current head mounted eye-trackers are in the form of a pair of glasses where the eye-tracker camera and IR-light is built into the frame of the glasses. Furthermore, the glasses are equipped with a forward pointing camera that records the exact scene that the viewer is viewing. The eye-tracking glasses provide the possibility of investigating objects in the 3D-space such as artefacts in a museum, use of mobile devices and library interiors, etc. A major disadvantage of this approach is a demanding data analysis, which is due to the fact that the eye-tracker is fixed relative to the person wearing the glasses and not to the scene being observed. (Holmqvist et al., 2011)

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<INSERT FIGURE 1>

Figure 1 : Remote eye tracker. Eye cameras are embedded between LED lights seen below screen image

<INSERT FIG 2>

Figure 2: Eye tracking glasses with eye cameras and LED lights embedded in lower part of frame.

Research traditions in eye tracking

In the research literature a number of major research traditions can be identified (Holmqvist et al., 2011) (Findlay & Gilchrist, 2003) (Land & Tatler, 2009) (Khan & Jacobs, 2009) (Pool & Ball, 2005). Traditions within eye tracking have a foundation in a large number of experiments in visual search, reading tasks, natural scene perception and usability studies. These all present well-documented experimental procedures and measurements.

Visual Search is probably the most researched tradition and study how we search for targets among distractors and how some targets seem to stand out against distractors. This has led to the identification of two search functions: 1) parallel search where the target is easy to identify even if the number of distractors is increased and 2) serial search where the target object is "hidden" among the distractors and therefore is sensitive to an increase in the number of distractors. Examples of visual search tasks are screening a car park for your car, screening an image in dermoscopy, and looking for a specific icon in a web page.

In the study of eye motion in Reading tasks, the focus is on text comprehension. This is a well-established research tradition with a defined research focus that has resulted in a number of established metrics. The developed metrics reflect the stringent structure of text. This approach includes study of saccadic regressions in reading, number of saccades and fixations, and fixation time.

Natural scene perception is the study on how we visually investigate a natural scene and what the mechanisms are that direct our attention to objects in the scene.
A common example is investigating visual orientation on a computer screen and the influence of colour, hue, and light levels as well as how a given task influences eye-movement. Scenes are often divided into Areas of interest (AOI) (Fig.3) where the different metrics are applied. Established metrics are time to first fixation, number of fixations / fixation time, returning fixations and the distribution of fixations/time among the AOIs.

A natural application of eye tracking is Eye tracking in usability studies where eye-tracking is used as one of several different data collection tools. Usability studies integrate the previous mentioned research traditions into a higher level of analysis and are by nature focused on actual real-world artefacts (Holmqvist et al., 2011, p. 70).

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This also means that most of the metrics defined previously are applied in usability. What characterises the use of eye tracking in usability studies, is the use of supplementary data collection methods i.e. post experiment cued retrospective verbalization, interviews etc.

<INSERT FIG 3>

Figur 3 : Web page with gaze path overlay. Size of dots indicate fixation time. Three AOIs are defined: left side menu, top menu icons and lower menu icons

Measurements

A large number of measurements has been defined in eye tracking and the most important will be mentioned here. For an in-debt presentation of eye tracking metrics see Holmqvist et al. (2011). When using research where eye tracking is applied, it is of course important to use an eye tracking metric that is relevant according to the activity studied. As mentioned in the previous section, a number of metrics have been defined according to task and cognitive activity. Eye movement metrics can be categorized in a number of ways (Pool & Ball , 2005, Jacob and Karn, 2003) but the important metrics are

1) Fixation derived metrics, where the number of overall fixation can be indicative of how efficient display elements is organized on a screen or web-site. Long fixation time overall (mean) is interpreted as an indication of how difficult the users find it to obtain information form a display and number of fixation on each target or AOI as an indication of importance. A large number of fixation on an AOI can be interpreted as an area of high interest.
2) Saccadic metrics, in reading studies for example the number of regressive saccades are often interpreted as an indication of how difficult the text is to decode.
3) Scan path or fixation sequence metrics which can be interpreted as a measure of interface efficiency.

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Eye trackers also record a number of other measures and besides the metrics mentioned above, pupil size and blink rate are often recorded and used as a measure of arousal and mental work load (pupil size) (Bojko, 2013) and cognitive load (blink rate) (Bentivoglio et al., 1997)

Analysis of eye tracking data

Sophisticated software packages for analysis of recorded eye tracking data is available either as manufacture specific commercial products or open source free ware. The software does integrate both the definition of a study, the collection of data and provide advanced tools for analysing the collected data. This includes tools for defining AOIs and running statistical calculations on AOIs. Furthermore, the visualization of eye tracking data as heat maps or gaze paths for qualitative inspection is provided. Some software package's does also support integration with other data collection hardware as EEG (Electroencephalography) for measuring brain activity thereby synchronising data from different sources. Examples of commercial available software for analysis is Tobii Pro Studio from Tobii AB and SMI Experiment Suite 360 from SensoMotoric Instruments GmbH. Both software suites is used for designing studies and analysing recorded data.

Methods

The method used in this systematic literature review follows the PRISMA guidelines (Moher et al., 2009). First the LISA and LISTA databases where searched. The search terms: eye AND (tracking or gaze or movement* or mark) where used in both databases and the search where limited to Peer-Reviewed journal papers. 204 hits were returned from initial search and reduced to 192 documents after removing duplicates. The remaining documents were then evaluated based on document metadata according to the following selection criteria's:

Inclusion criteria

1) Papers published between 2005 and 2015 both years included
2) Only papers in English
3) Only papers where eye-tracking is used as the main data collection tool
4) The research did describe an experiment where users were included
5) Paper included a description of the research methods applied including experimental setting

Exclusion criteria

1) Papers using eye tracking technology for gaze interaction
2) Papers with the main purpose of developing eye tracking technology

The full-text of the remaining 107 documents were retrieved for further assessment according to selection criteria's. The assessment resulted in the inclusion of 59 papers in the review. The literature searches and selection process where completed by the author. (see figure 1 for details)

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Figure 4 : PRISMA chart of search strategy

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<INSERT TABLE1>

Table 1 : Summary of included studies, results and participants. Values in right column refer to research paradigm, R = Reading, S = Natural scene perception , U = Usability and V = Visual search

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Analysis

The objectives of this literature review is to report on the use of eye-tracking technology within the field of Library and Information Science, the application to different areas of LIS and to suggest some future use of eye-tracking technology in LIS research.

The papers in the review has been analysed using a methods-description approach (Cooper, 2010) where a template has been defined capturing title, author, purpose and key finding. For each paper the following information were coded: category by research paradigm, type of evaluation apparatus, eye-tracking measurements, participants and supplementary data collection methods applied.

Eye tracking paradigms

The reviewed papers are categorized according to the research paradigms described previously. Some of the research papers in this review rely on more than one research paradigm and the following approach was implemented to categorize:

- 3 papers reporting fixation data, saccades often within predefined AOIs or movement between AOIs (number of transitions between AOIs) but not collecting other non-eye tracking based metrics are categorized as Natural Scene Perception.
- 11 papers reporting on reading of text either as fixed slides or web-pages and reporting measures as regression and reading speed are categorised as reading studies.
- 39 papers positioning themselves as a usability study and / or introducing other data collection methods than eye-tracking (i.e. RTA, CTA, questionnaires etc) besides reporting fixation data analysed on AOIs are categorized as Usability studies.
- 6 papers are reporting on the identification of objects among distractors and not introducing other measures than time to identify object. Such papers are regarded as belonging to the category Visual Search.

A summary of the included papers is found in Table 1.

Since 2005 the yearly number of publications has been increasing (Fig. 5) from 3 in 2005 to 8 in 2015.

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Figure 5 : number of annual publications 2005 – 2015.

Experiment apparatus, type of eye-trackers, number of participants and study duration

A number of different experimental apparatuses were used for evaluations. The most common interface for evaluation were web-sites, web applications and web prototypes in 39 of the studies (N=59). In 5 studies different types of simulators were used, examples are Ba et al. (2015) uses a driving simulators, Tseng et al. (2013) investigates a simulated battlefield control room, slides or screen shots are used in 12 studies (see Williams et al. (2005), Fleetwood & Bryne (2006) for examples), 2 video based systems and 1 study where product labels were studied.

Eye trackers from 13 different manufactures were used of which 49 studies applied a remote eye tracker and 10 studies a head-mounted eye tracker. Remote eye trackers from Tobii Technologies were used in 44% of the cases with eye trackers from SMI as the second most used (12%). Table 2 gives an overview of the applied eye-trackers. Of the 13 different brands of eye tracker used, 26 are from Tobii Technologies

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Table 2 : Type of eye trackers used and brand

The sampling rate used in studies varies from 50 – 500 hz with a majority of studies using a sampling rate of 60 or 120 hz. The sampling rate can have an influence on the outcome of a study since a higher sampling rate produces a higher number of measurements or data points recorded. It is though, generally accepted that a sampling rate of 60 – 120 hertz is sufficient for most studies. Higher sampling rates have usually an application in studies of micro-saccades or in medical applications.

The precision of the eye trackers is in most of the studies reported as a reference to the manufacturer's data, which is usually measured under optimal conditions. Thus a precision measure available only in a perfect setting. The precision of eye tracked data changes during a study and therefore has an influence on the quality of recorded data i.e. precision and accuracy which must be taken into consideration when defining a study and analysing data for example applying AOIs in very close proximity, analysing fixation patterns in reading etc. (Holmqvist et al., 2011)

In all studies the number of participants is reported with an average of 34.21 (Stdv 23.24) participants per study (min = 5, max = 96). The number of participants according to research paradigm is presented in Table 3.

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Table 3 : Number of participants according to research paradigm

It is generally known in the eye tracking community that not all participants in an eye tracking study can be eye-tracked. According to Bojko (2013), a failure rate of 5 – 10 % must be expected. The causes of this are multiple, but common reasons are the use of glasses and make-up, which create reflexes and thereby disturb the eye tracker. Other issues are age due to physiological change in the eye and for some people the physiology of the eye regardless of other factors. 15 papers (N=59) report problems with the eye tracking of participants. On average 17.01% of participants could not be eye tracked with a max. value in one study of 61.54% and a min. value in another study of 3.30%.

In 8 papers the session time for eye tracking is reported ($\overline{x}$ 9.02 mins.) while in 14 studies the total session time is found ($\overline{x}$ 38.93 mins.). Detailed numbers are found in Table 4

<INSERT TABLE4>

Table 4 : reported time in minutes used for eye tracking and over all session time

Eye Tracker Measures and method of data analysis
The eye tracking measurements identified in the selected papers are shown in Fig. 6. The measurements can be categorized in three main groups: fixation counts, fixation duration and saccades and includes the most common eye tracking metrics presented before in this paper. In 35 studies AOIs are used to denote areas of special interest when analysing eye-movements. Fixation counts include number of fixations, total numbers of fixations, fixations before and after a predefined AOI. Fixation duration do include measures as duration of first fixation and total fixation duration. Saccades include saccade duration and number of saccades. In 9 studies the number of forward saccades and number of saccade regressions is presented. In 13 studies, gaze path is inspected as a qualitative measure of eye-movements often as a heat map presentation. In 4 studies, calculation of gaze path length is used for comparing gaze paths or comparing with output from a model of predicted scan paths.

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Figure 6: eye-tracking measures applied in reviewed studies and use of AOI's

Supplementary data collection and methods to eye tracking
In nearly all studies, demographic participant information is collected before the actual experiment or post-experiment. In all, pre-study questionnaires are used in 25 studies and post-study questionnaires are used in 28 studies.

Verbal protocols are collected in 10 studies in the form of concurrent think-aloud (CTA) or retrospective think-aloud (RTA). In Miwa (2011) both CTA and RTA is collected. The use of RTA is predominately designed as cued with replay of eye-movements. In three studies instruments for measuring cognitive work-load is introduced: in Burke (2004) the NASA TASK load index (Hartr & Staveland, 1988) used, in Xu (2013) a non-standard tool for assessing work load is applied. Arapakis (2014) assess affective state using the Positive and Negative Affect Schedule (PANAS)(Watson et.al ,1988), whereas Bebko (2014) measures participants' pleasure and arousal using Self-Assessment Manikin, a non-verbal pictorial assessment technique (Bradley and Lang, 1994). In total 13 papers collected data from participants using self-assessment questionnaires.

Transaction log-data of participant interaction with a system is collect in three papers Lorigo (2006), Semeraro (2008) and Senduru (2015). In Yen (2011) a post-study comprehension test is administered.

Facial expressions are recorded in two studies Romero-Hall(2014), Goldberg(2014) and in Predinger (2007) biometric signals as skin conductance and heart rate are recorded.

In Berget (2015) a post-study interview is used for collecting information about participants search behaviour, and in Forsman (2013) both a System Usability Scale (SUS) – questionnaire and a post study interview are used. The interviews are performed as a debriefing interview to collect information about participant's opinion and expectations.

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Discussion

The scope of this review was to identify the use any type of eye tracking technology as research method in LIS. The purpose of the review is also to identify gaps in how eye tracking technology is used in LIS research and possible use of eye tracking in future research. The review was guided following the PRISMA recommendations and after applying selection criteria described in the methodology section, 59 papers from the databases LISA and LISTA were found relevant for this review. This presents an increase in the use of eye tracking technology during a 10-year period from 3 to 8 studies (Fig. 5). This might cater for a possible increase in future use of eye tracking as a method.

The results of the review were organized in 4 main groups 1) Eye tracking paradigms 2) Experiment apparatus, type of eye-trackers, number of participants and study duration 3) Eye Tracker Measures and method of data analysis 4) Supplementary data collections methods to eye tracking

Eye tracking technology has developed fast during the recent years resulting in cheaper and more precise hardware combined with developments in software suites for recording and analysing data. This has led to an increased use of eye tracking in usability studies (Holmqvist et al. 2011). A trend also apparent from the reviewed papers were 66% of the papers is categorized as belonging to usability research.

By applying eye tracking methods, we can only tell part of the story on how people interact with a system. This because our eye-movements only show where we have been looking but not why. To gain an understanding of what is actually driving our attention, eye tracking in usability studies must be supported by other data collection methods (Jacob & Karn, 2003). In the reviewed papers, all of the studies belonging to the category of usability, apply a combination of methods.

Integration with other methods

The use of think-aloud protocols (TA), which allow users to express their actions verbally (Dumas, 2009) are considered a classic part of a usability study. The most commonly used TA is concurrent think aloud but in combination with eye tracking retrospective think aloud is often applied. Both RTA (5 papers) and CTA (4 papers) are used, in 3 papers both methods are applied. It is generally accepted within the eye tracking community that CTA influence the eye movements of a person (Bojko, 2005). However, according to Hertzum et al. (2009) the type of CTA protocol applied, will determine the influence on eye movement. Hertzum et al. (2005) also emphases that it is important to distinguish between classic think aloud, where the test person reports what is the focus of attention without any interference from a test moderator and relaxed think aloud, where the participant is asked to verbalise their thoughts often cued by a test moderator. Hertzum et al. (2005) claims that the most common used in usability studies is relaxed CTA. In 4 of the reviewed papers, CTA is applied without any discussion, of the applied CTA and eventual influence on eye movements, Bergström et al. (2013), Forsmann et al. (2013), Jones et al. (2014) and Wolpin et al. (2015) .

The combination of eye tracking and RTA has been proven to provide important information about a participant's visual strategies even if applied after the actual eye tracking session (Hansen, 1991), thereby avoiding any influence on the actual eye movements. The RTA session is usually supported by a replay of the recorded eye

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movements to support or cue the participant's recall of events (Olsen et al., 2010). Five of the reviewed papers employ RTA or RTA-like methods during post-interviews: Miwa & Kando (2007), Miwa & Takahashi (2008), Cook (2008), Sutcliff & Narmun (2012) and Kules & Capra (2012) who also discuss the validity of RTA.

In 3 studies a hybrid of CTA and RTA is administered. Miwa (2011) includes a 5-minute training session before participants use CTA however any possible influence of CTA on eye-movements is not discussed. Balasoukas & Ruthven (2012) apply a classic think-aloud technique and consider the possible influence from CTA on eye-movements. In both papers replay of eye tacking recording were used. Mardell et al. (2014) asked participants to offer comments during eye tracking sessions and during post-interview. The study did not apply video cues in post-session interview / RTA session.

An interesting development is also the integration of eye tracking with other bio-metric measurements as blink rate, pupil dilation, blood pressure, heart rate, skin conduction and EEG (Electroencephalography) where brain activity is recorded. This could elevate our understanding on how users interact with information to a new level.

Mobile technologies

The fast development of mobile technologies i.e. smart phone, tablets, smart watches, has resulted in a change in how users interact with information and how they search for information. This development raises a number of new challenges in how to study the information behaviour of users and their interaction with information systems using mobile devices. Mobile technology has also driven the development of responsive user interfaces where the user interface changes according to type of mobile device. Eye tracking could be used as a means of studying the usability challenges of mobile devices and thereby also the information behaviour of users. Only one paper Kim et al. (2015) studies the impact of mobile devices by researching the impact of changes in screen size on the usability of a web search engine. Kim et al. (2015) uses a remote eye tracker and displays a mock-up of a mobile device on a standard computer screen. An alternative solution would be to use eye tracking glasses to study user interaction with mobile device but the challenges involved in using mobile eye tracking equipment has only just recently been solved.

Application of eye-tracking outside lab-environments

A number of studies investigates information behaviour and information seeking. All of the studies are conducted in a research lab setting. The studies are mostly task-based where the user task has been defined by the researcher. This approach provides a high level of control of the experimental setting and consequently supports a good level of validity and reliability of the study. Though, this might be seen as a restriction. If for example, the aim is to investigate information behaviour in a daily-life situation, a lab setting might be a poor choice. However, this review did not identify any studies that apply eye tracking outside a laboratory environment or otherwise controlled environment. Which is interesting as one could claim, that an ecological gap exists between the possibilities of lab-based experiment and of studies performed in a daily life situation outside a controlled setting. Which is explored further below.

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A recent development of eye tracking equipment is the miniaturization leading to integration in a pair of glasses. This makes mobile eye trackers much less intrusive compared to earlier and facilitates a use of eye tracking in field studies. An example is the use of eye tracking in a museum environment (Eghbal-Azar et al., 2015). Eghbal-Azar (2015) demonstrates the application of head-mounted eye-tracking equipment in the form of eye-tracking glasses, and exemplifies the considerations concerning the use eye-tracking glasses in the experimental setting outside a lab environment. Eghbal-Azar et al. (2015) present two studies and they find a number of distinctive scan patterns that is frequent in the way visitors experience exhibitions (ibid p 112).

Head mounted eye-tracking equipment has a long history of being used in natural settings i.e. study of car driving, investigation of interpretation of signs in airports, air-traffic control situations etc., although not without difficulties. Eghbal-Azar et al. (2015) further describe a number of issues that prevent a wider use of head mounted eye tracking equipment among others, equipment cost (20.000 euro and up). Ethical issues are also an issue, since the scene in front of the participant is recorded. The analysis of recorded data has likewise been a major obstacle in head mounted eye tracking but lately, software provided by major vendors facilitate faster and more automated data analysis. On the other hand, head mounted eye tracking equipment is highly mobile and provides researchers with the possibility of using eye tracking in settings where remote eye-tracking is not applicable. Apart from benefitting study of user interaction with mobile devices as discussed above, and head-mounted eye tracking equipment is directly beneficial in how users interact with a physical library space.

Further perspectives

Eye tracking technology is still being developed even though the technology has been available for a number of years. Only recently, the price tag on quality eye trackers has reach a level that allows for a wider use of the technology in research. This development is driven by new players in the market and the on-going technological development resulting in cheap components and a constant miniaturization of components, allowing for the integration of eye-tracking in portable devices etc. A Danish start-up[1] as an example, is providing a remote eye-tracker for the cost of 100 US$, with specification on-par with eye-trackers provided by renown manufactures in the area of eye tracking costing 5.000 US$ or more.

With low cost eye trackers more researchers can afford to acquire eye tracking equipment and it will probably also open up the possibility of providing participants with an eye-tracker when studying their daily routines in interaction with a computer in a work place or home environment. This development is also supported by the advance of calibration free eye trackers and free open-source software for analysing the recorded eye-tracking data (c.f. Ogama – OpenGazeAndMouseAnalyzer from www.ogama.net)

[1] The Eye Tribe (https://theeyetribe.com)

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Conclusion

In this paper research from the field of Library and information science utilizing eye tracking as data collection method is reviewed. The databases LISA and LISTA is searched systematically and following the PRISMA recommendations for systematic reviews 59 papers were select for review according to selection criteria's. An increase in studies during the last 10 years is found but papers including eye tracking as data collection method leaves room for an increase. The reviewed papers cover 4 important research paradigms in eye movement research with a majority of studies within usability studies. All of the reviewed studies is performed in a laboratory environment but the current technological development will offer researchers the possibility to use eye tracking as a method in a natural setting. This could provide new insights in uses information behaviour and interaction with information.

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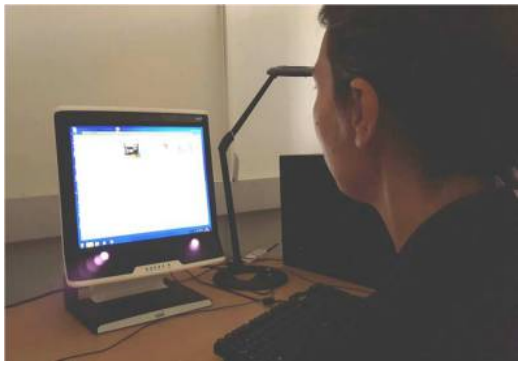

Figure 1 : Remote eye tracker. Eye cameras are embedded between LED lights seen below screen image

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Figure 2: Eye tracking glasses with eye cameras and LED lights embedded in lower part of frame

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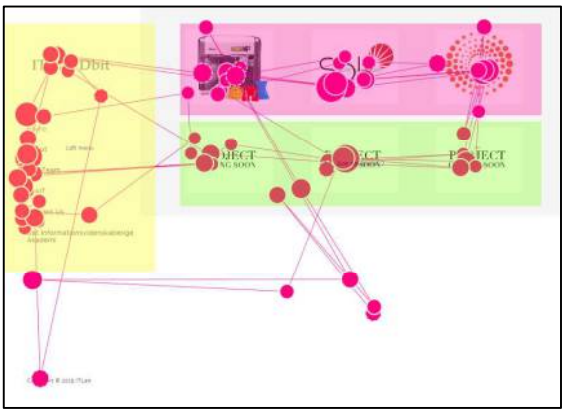

Figur 3 : Web page with gaze path overlay. Size of dots indicate fixation time. Three AOIs are defined: left side menu, top menu icons and lower menu icons

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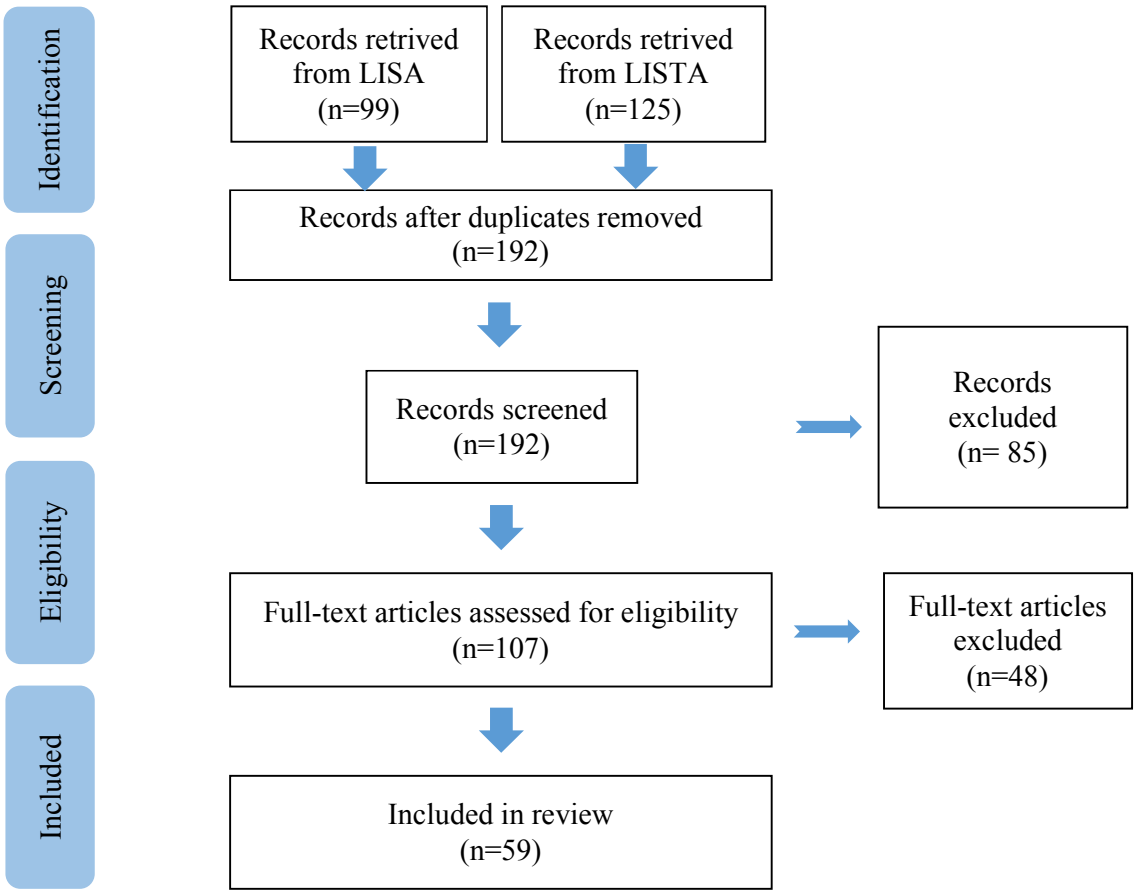

Figure 4 : PRISMA chart of search strategy

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Author	Year	Task	Result	Participants	Research paradigm
Acartürk et al.	2013	3 different stimuli with text and figures where used to investigate different signaling methods relating text to illustrations. Each participant was assigned one of three stimuli.	Signification difference in Gaze Shift was found between the tree conditions where participants in one condition preformed more gaze shifts compared to the other two. For total gaze time on stimuli a difference was found between the three condition. The same was reported for mean fixation duration.	Participants from a Technical University (91), mean age 21,5 years	R
Arapakis et al.	2014	To investigate the influence of sentiment and polarity in the content of news articles, user engagement was measured as user attention. Participants read two news articles, one interesting and the other uninteresting.	Participants had more gaze visit, frequent and prolonged fixations and spent significantly more time on browsing interesting articles. Titles with low sentimentality and positive polarity received longer and more frequent fixations and gaze seemed to correlate with positive affect.	Participants (57) from campus	R
Ba et al.	2015	To investigate participants' subjective appraisal and visual attention, participants were given 16 scenes in a driving simulator. Investigates the effect of signaling behaviour of other drivers on participants.	It was found in all scenarios that total fixation time and mean fixation duration was increased if signal was given. A significant increase in fixation frequency was found when other vehicles were present in rear-mirror. On- road mean-fixation was observed de-creasing when drivers were checking for signals in rear-mirror.	Male participants (20) mean age 24.1 from a university students population with active driving experience. Recruited (25).	S
Balatsoukas & Ruthven	2012	To investigate the relation between relevance criteria and visual behaviour in predictive relevance judgement, 281 relevance judgement made by users when searching the web for real information needs where collected.	The study shows a relation between ranking order and number and length of fixations. There also seems to be a link between surrogate components and fixations patterns depending on relevance criteria's.	Undergraduate and post graduate university students (24), 17 to 36 years old	U
Bebko et al.	2014	To identify if eye tracking metrics can determine which element of an advertisement influences the decision to donate to a non-profit organisation(NPO). Participants were presented with four NPO web-sites.	It was found that an increase in total visit duration, number of fixations on faces, and an increase in time to first fixation on text and logo indicated an increased willingness to donate.	University students (63) enrolled in business classes, convenience sample	U
Berget & Sandnes	2015	Each participant was asked to solve ten predefined search tasks in a library catalogue to identify the effect of dyslexia on database search.	It was reported that participants with diagnosed dyslexia used more time and formulated more queries than the control group. Dyslexic participants tend to use short queries, more misspelling and use external resources.	Diagnosed with dyslexia (20) and control group (20)	U
Bergstrom et al.	2013	Summaries of 5 previous usability studies by the authors. In 4 studies a number of information search tasks where conducted and one study was a link click study where the participant would click on links supposedly leading to the answer. All studies where related to investigation age-related usability performance.	Number of fixation on a specific AOI where related to age. Older people took longer time to first fixation at peripheral top AOI. Both accuracy and efficiency was higher for younger participants.	Older participants (15) and younger (22), older group > 50 years. Participant where either employed or residents	U
Brown et al.	2010	Task based interaction with elements containing dynamic content.	Study used to inform design of interface. Presence of Auto Suggests List (ASL) is used for correcting spelling or query formulation. Calendars where accessed as a table moving along row or moving down a column.	Volunteers (30)	U
Burke et al.	2005	Investigates search through news headlines at two levels of difficulty: exact matches and matches requiring semantic interpretation.	Results show both animated and static commercial banners decrease visual search speeds. Eye tracking data reveal people rarely look directly at banners.	Undergraduate students (24)	V
Cao & Nishihara	2012	Participant were watching an 11 minute intruction video followed by a posttest	The result showed a high consistence with corresponding learning style characteristics, which provides another way to verify the validity of learning style	32 graduate school students (32), recruited (38)	R

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Chae & Lee	2013	Participants were shown two different web page to investigate the relation between visual attention and decision quality in online shopping.	More visual attention was observed when a perceived higher decision quality was reported by participants.	University students (38) (40 recruited)	U
Chen et al.	2011	Judge topic similarity of two documents based on original text, snippet and terms.	Found that there is a difference in viewing behaviour between term presentation and original text / snippet resulting in more switches between the two documents.	Participants (15) majority of graduate students, recruited (21)	U
Chen & Pu	2014	2 different web shop interfaces were developed and participants were given the task of choosing a laptop to buy.	If recommendations were grouped in categories, participants tended to view more items.	Students and employees from a university (16)	U
Chu et al.	2009	3 different conditions with free inspection follow up with link activation.	Participant using "next" button in slide show viewed more slides than participants using other navigation, box format breaking news got most attention and fixations but recall of main story was lowest compared to other stimuli, all supplemental links were read but only 4 of 96 participants clicked on link.	Subjects 18 - 60 years (96)	U
Clark et al.	2010	Reading e-mail 4 manipulated version of each mail.	Purpose and form of genres can be determined by readers and form and content can be separable, as specific features result in fixations causing some readers to apply regressive saccades.	Majority with academic background (24) aged 20 - 48	R
Clark et al.	2014	Participants were given 64 e-mails and asked to identify e-mail genre.	A difference was found in scan path length with continuous reduction in length during the session.	Participants (24)	R
Cole et al.	2011	Two task based user studies to represent information needs of 1) journalism and 2) genomics. Task development based on simulated work task approach.	Relationships between task and reading behaviour was observed at task and page level. Shifts from scanning and reading behaviour in eye movement patterns combined with amount of text processed may be indicator of task type facets. Implications for modelling information search behaviour.	Study one: advanced undergraduate journalism students (30) (32 recruited). Second study, undergraduate and graduate students (36), recruited (40)	R
Cole et al.	2013	To identify the influence of user's domain knowledge, cognitive effort was investigated in reading using eye movement measures. Participants did 4 retrieval tasks each. Task were constructed as simulated work tasks and participants were asked to find and save documents answering the task question.	A correlation between cognitive effort in reading and domain knowledge was found.	Undergraduate and graduate students in biology related programs (40)	R
Cook	2008	6 search tasks on 6 web-pages (navigation).	2 pilot test conducted, 95% of first saccades where directed towards navigation menu no predominant preferred direction towards navigation menu is observed. Navigation menu position did not influence where participants first directed their search on home page. Audience organized navigations menu links tended to be chosen over topic organised menus. The right side of home-pages and images attracted little attention during task-directed search.	University students and staff (31), age 18 to 51	U
Doherty & O'Brien	2014	To investigate the effect of machine translated text participants were given machine translated text in their native language and asked to perform a number of similar task in a test system.	Less cognitive effort was observed for English text measured by fixation count, duration and task time. Only a minor difference was found between original text and translated text and on time spent on instruction windows and task window, less attention shifts were observed for English text.	Assigned to conditions based on participants native language (30)	U

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Fleetwood & Bryne	2006	Developing a detailed understanding of how people search for an icon in a typically crowded screen of other icons that vary in similarity to the target.	Participants rarely re-fixated icons that they had previously examined, and that participants used an efficient search strategy of examining distractor icons nearest to their current point of gaze. People had memory of where they had looked.	Undergraduate students (10)	V
Forsman et al.	2013	Task based usability evaluation with 15 navigation task and 8 clinical information finding tasks.	Task solving with data derived from tables were more used by specialist whereas residents were exploring the graphical user interface in general.	Pilot test (4) and usability test (8) with four specialist physicians and four resident physicians	U
Goldberg	2014	Participant did conduct 25 tasks on enterprise software pages to identify if font size, font type and gradient background effect completion time, investigate if eye-tracking can serve as a proxy for perceived web page clarity.	It was found that gradient background did influence task completion time. Larger Tahoma font on a non-gradient background performed best on time to first fixation. Pre-attentive measures cannot act as a proxy for web page clarity.	Professional managers and HR specialist/analysts (20)	U
Harris et al.	2009	Reading two page website half with positive credibility cues and half with negative credibility cues.	No difference in time spent or reading observed between positive cued and negative cued pages though some content irrelevant images and logos did influence participant behavioural response.	Psychology students (85)	U
Huang & Kuo	2011	Web shopping task.	Eye movements show that users of table presentation more likely adopt deliberate decision process than users of map presentations.	88 college students (88) average age 20.07 years. Recruited (91)	U
Jay et al.	2007	Searching for link on web-page and on text only web-pages.	more fixations on text-only page than standard web page ($p < 0.005$) longer fixations on standard web-page than on text-only.	Students and parents (18) between 18 and 50 years	U
Joachims et al.	2007	Google search task to capture relevance feedback on normal Search Engine Result Page (SERP) and manipulated SERP.	trust bias high ranked links on Google SERP is evaluted as relevanr even if abtracts is less relevant. Item 1 and 2 in SERP recives most clicks and fixations even when results are manipulated and presented in reverse order.	Study 1 : undergraduate student (29) , recruited (34); Study 2: undergraduate students (22), recruited (28)	U
Jones et al.	2014	A usability test of an OPAC, were participants responded to 13 prompts with 11 discrete tasks to test central parts of the OPAC	Eye tracking video showed that users were looking for a short period of time on thumbnails of items. Eye tracking reviled that users where looking at title information, even if image of book cover was available.	College students (18) and others (4)	U
Kammerer & Gerjets	2012	Task based web search users presented with two different SERP layouts.	Student select more internet pages containing objective information than pages more subjective or commercial information. The study also found that in tabular interfaces students payed less attention to commercials than in list based SERP interface.	University freshmen (58)	U
Katsanos et al.	2010	Task based navigation.	On high information scent web pages' users tend to be more focused, confident on choice, efficient and effective. InfoScent Evaluator is suggested as having potential for indicating potential problems in a web page information scent.	Two studies: students (23) mean age 23, students (34) mean age 22	U
Kim et al.	2015	Experimental study on the effect of task goals and Visual Information Perception Characteristics (VIPC) on driver eye movement where drivers in simulator were directed to stay in lane while performing a visual search task for relevant information on instruments.	It was found that oculomotor behaviour of participants were different according to their VIPS preforming the same task. In a classification model study it was found that based on a drivers VIPS it is possible to estimate behaviour and driving performance.	University students (9) selected from a group of 136	S

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Kim et al.	2015	Aim of experiment is to identifying differences in user search performance and behaviour on two differently sized display i.e. screen size 1280x1024 pixels and 320 x 480 pixels. Tasks were navigational and informational and each participant completed 20 tasks.	The study found that participants had difficulty in extracting information from search results on small screen. Regarding search performance no significant difference was found in time spent on result pages and accuracy of finding answers between screen size.	Participants (32) age 18 - 50 recruited on a university campus. Recruited (35).	U
Kules & Capra	2012	Each participant conducted a set of 6 exploratory web searches in a library catalogue to investigate how faceted search interfaces influence the search behaviour of the user.	The study shows that use of facets do not evolve during the search session and 10 - 30% of interface use is on facets. If users are shown a 60 - second introductory video on facets searching an increase in use of facets can be observed.	Undergraduate students (18)	U
Lehtimaki & Reilly	2005	Design and evaluate an oculomotor reading aid for beginning readers.	Training had a positive effect on gaze duration, on the mean and distribution of number of fixations per word, and on the percentage of words with re-fixations in the majority of subjects.	Children (5) 8 years old. Recruited (13)	R
Lentz & Maat	2007	Influence of reading aloud or silent and simultaneous commenting text.	Reading aloud required more time than silent reading ($p < .005$) for total reading time, comments resulted in more backwards action though no significant difference.	university students (26)	R
Lorigo et al.	2006	Analysing the sequences and patterns with which users evaluate query result returned to them when using Google.	Query result abstracts are viewed in the order of their ranking in only about one fifth of the cases, and only an average of about three abstracts per result page are viewed at all. discover that gender and task significantly influence different kinds of search behaviours.	Undergraduate students (23). Recruited (36)	U
Lorigo et al.	2008	Web search tasks in Google and Yahoo.	There is no significant difference between Google and Yahoo SERP in amount of time spend on reading abstracts, but more fixation and fixation is observed on reversed SERPs.	Undergraduate and graduate students (40)	U
Lucassen & Schraagen	2011	Reading Wikipedia article and assess trustworthiness with WkiTrust enabled.	Colouring of text in WikiTrust is hampering reading performance.	College students (14)	R
Mardell et al.	2014	Participants were presented with six different ground image sequence (moving image and serial still images combined with 3 different speed emulations) with the task to identify 18 different targets.	Moving mode resulted in gaze positioned on the left side of the screen, serial still images suggest that gaze moved to salient features in image. The results were independent of speed.	Students and research staff from university (18)	V
Miwa & Kando	2007	Web-search task.	Improved reliability by using eye-tracker for capturing search and learn processes and replaying eye-tracking during post session interview.	Third grade college students (7)	U
Miwa & Takahashi	2008	Exploratory information search task (web pages).	Modified taxonomy of knowledge modification. Video recording of eye-movements helped participants to stimulate recall of their search process.	Undergraduate and graduate students (14)	U
Miwa et al.	2011	Conduct two different web search tasks one defined as a informational task and second task a navigational task with the purpose to study exploratory search process.	Main finding that encountering unexpected interesting information may lead to temporary deviation of search goals, novel information can lead to modification of search goals. Cues from eye-tracking in RTA is helpful for researchers recall of thoughts and feeling during task solving.	Undergraduate and graduate students (16)	U
Plumlee & Ware	2006	Compares a zooming user interface with a multi-window interface for a multiscale pattern matching task.	Results suggest that only a single graphical object was held in visual working memory for comparisons mediated by eye movements, reducing errors by reducing the load on visual working memory.	Participants (10)	S

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Porta et al.	2013	Investigates the relation between banner subject and article content. Participant read 4 articles each. Two imposed articles and two free-choice articles.	There is no difference in number of fixation and total number of fixation neither for banners contextually related to article or for banners with no relation to article content.	Volunteers (30) aged 20 to 60 mean age 34, recruited (35)	U
Prendinger et al.	2007	Real-estate web site with life like interface agent.	Life-like agent captures users' attention and possess and certain degree of competence.	University student and staff (15)	U
Resnick & Albert	2014	The study investigated correlations of placement of banner ads on commercial web-sites and user tasks. Participants preformed a free-viewing task and a goal directed task.	Banner blindness was found to be prevalent when users are goal directed and can predict where the banner is likely to appear (side ad).	Participants (30) recruited from a university campus	U
Romero-Hall et al.	2014	To investigate if an emotionally-expressive animated pedagogical agent had an effect on the visual attention of learners. Participants were assigned to either a system with an emotionally-expressive agent, a system with a non-emotionally agent or a system without any agent. All participants were presented with 15 web pages of instructional content.	Eye-tracking data indicated that the presence of an emotionally-expressive pedagogical agent resulted in higher visual search activity in the image area than a learning environment without an agent. The presence of an emotionally-expressive animated agent and presence of a non-expressive agent resulted in more fixation in image area than in a system without any agent.	College students, undergraduates (51) and graduate (15). 13 participants were eliminated from part of the study.	U
Semeraro et al.	2008	Task based evaluation of web page with user agent.	Exploratory use of eye tracking to inform usability evaluation.	Skilled and unskilled internet users. Students and employed (15)	U
Senduru & Yildrim	2015	Investigation of seventh graders web search process using a web search helper tool. Participants performed three search tasks each.	The study showed that search patterns changes according to type of task. Exploration of scan path showed that time spent, scan type, number of keywords and reading styles differed for all tasks.	Seventh-grade students (11), 12-13 years old.	U
Shaffer et al.	2013	4 different versions of a web decision aid, 2 with videos and 2 with text with the purpose of investigating the effect narratives have on information search and the impact of the format of the narrative on decision making. In both the video version and the text version, one narrative included a dialog between patient and physician. The other version only included an interview with physician. Participants were provided with an instruction on diagnostic process and given access to one of the four web decision aids.	The presence of patient narratives increased search time by 4 minutes.	Women (56) mean age 48,7	U
Stone & Dennis	2011	Searching for target information on three different web sites.	Found that a semantic field model using both vector space and target corpus were best preforming model in estimating eye-movement.	University participants (49) age 16 - 57 mean 22 years	U
Sutcliffe & Namoun	2012	The paper objective where 1) to analyse visual attention and 2) develop a predictive model of visual attention. Participants viewed each website homepage in two conditions, exploratory and directed search task.	In evaluation the developed model for predicting visual attention resulted in a mean agreement of 66,2% in exploratory mode and mean agreement of 87,6% directed search mode. Animations and images dominated attention in exploratory mode and in search mode salient objects and information scent object leading to target text where predominant.	Postgraduate students and research staff (25) age 25-35 years	U
Tseng	2013	The participants searched for a designated target icon within 20 icons displayed on a simulated radar interface.	It was found that the best icon size was 70 - 80 min displayed and a 21 inch. computer screen resulted in the best support of visual search task. Highest accuracy was found on a TND map with less background clutter.	Undergraduate and graduate students (36), mean age=26,7 years	V

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Ulloa et al.	2015	The study examind visual behaviour of users reading online press posts received on Facebook wall. Three news formats were created: text only, text with large image and text with small image. Each participant was presented with three interfaces.	The study found that the presence and size of image positively influences the capacity to attract users sights.	Volunteers (24) average age 27,5 years and participating in academic activities	U
Williams et al.	2005	Impact of a visual element on its relative ability to track a user's attention when using a visual display unit (VDU).	Three measures of eye attraction related to the proportion of fixations, the proportion of time fixated, and the order of fixation. (Quotes from original text).	Undergraduate students (17)	V
Wolpin et al.	2015	Usability test of a web prototype of a patient self-report assessment system. Participants were asked to complete a series of structured tasks.	65 usability issues were identified from minor user confusion to critical errors preventing task completion.	Patients and caregivers (8)	U
Xu	2013	To investigate the influence of distance in collaboration, passive participants where observing an active user performing different tasks in a remote location.	The study show that passive users seemed link their trust in the active user with trust in technology. The eyetracking contributed as a manipulation check.	36 participants university students age 19 to 36 (38 recruited)	U
Yen et al.	2011	Reading Chinese on computer displays 8 different character size and font types were applied.	Found that 24 pixels and 1/8-character spacing KAI Chinese characters font had the shortest reading speed. Small-sized characters had longer fixation timer, fewer fixations and regressions. Character spacing should be considered in different character fonts to support efficient reading.	64 Native Chinese speakers (64) age 19 - 24 university students	R
Yoon et al.	2015	To provide insight into the perception of visual complexity by means of objective quantifiable measurements for automotive instrument cluster, participants were asked to find a star-shaped figure embedded in visual stimuli.	The study showed that not all of the objective measurement variables influencing subjective perception, had the same effect on visual search	Experienced drivers (41) average age 38,48 years. Recruited (45)	V

Table 1 : Summary of included studies, results and participants. Values in right column refer to research paradigm, R = Reading, S = Natural scene perception , U = Usability and V = Visual search

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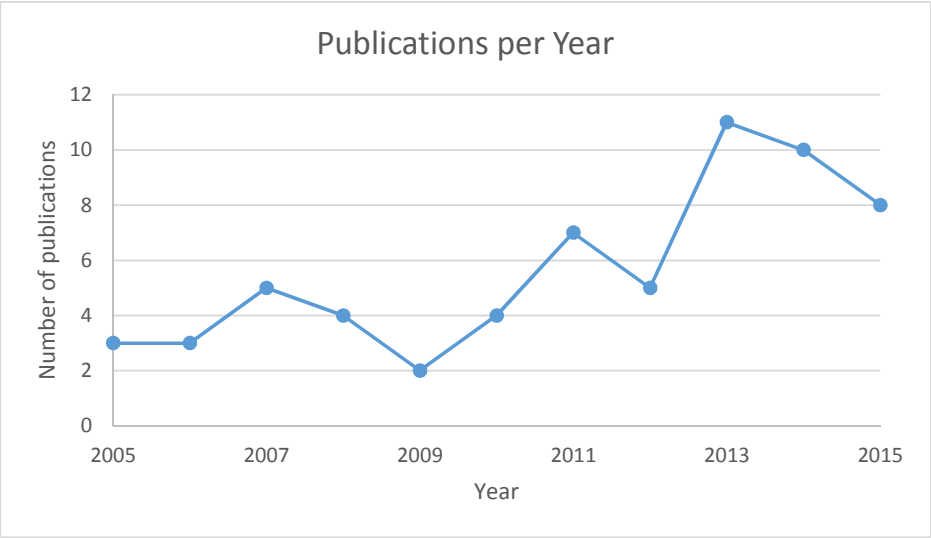

Figure 5 : number of annual publications 2005 – 2015.

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Remote eye trackers Eye tracker brand	Number
Arrington Research	3
ASL	4
Eye Response	2
FaceLab	2
LC Technologies	2
Motion Image Corporation	2
Smart Eye Pro	1
SMI	6
Tobii	26
Un-identified	1
Sum	**49**

Head mounted eye trackers Eye tracker brand	Number
ISCAN	1
Motion Image Corporation	3
Quick Glance	1
SMI	1
SR Research	2
Un-identified	2
Sum	**10**

Table 2 : Type of eye trackers used and brand

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Research Paradigm	Sum N	Avg N	Max N	Min N	Stdv
Natural scene	39	13	20	9	6.08
Reading	485	40.42	92	5	25.74
Usability	1373	35.21	96	7	24.06
Visual search	129	25.80	45	10	14.34
	2026	**34.34**	**96**	**5**	**23.63**

Table 3 : Number of participants according to research paradigm

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	Reported eye tracking time (N = 8)	Reported total session time (N = 14)
$\overline{x}$	9.02	38.93
Max.	25.00	60.00
Min.	0.50	20.00
Sum	**72.17**	**545.00**

Table 4: reported time in minutes used for eye tracking and over all session time

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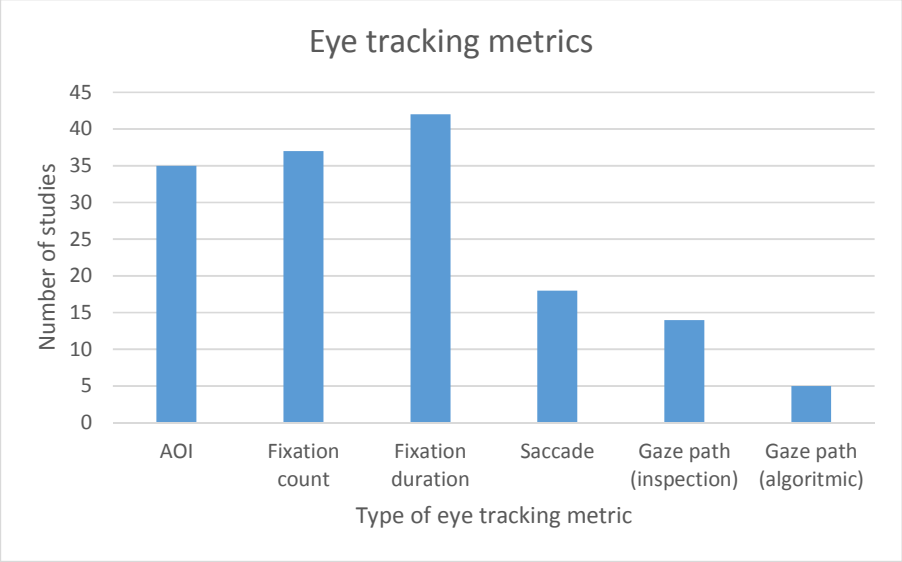

Figure 6: eye-tracking measures applied in reviewed studies and use of AOI's

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