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User Consultation Behaviour in Internet Dictionaries: An Eye-Tracking Study

Abstract

The purpose of this paper is to explore and discuss user consultation behaviour on the basis of eye-tracking data and interview data. To date the focus has been almost exclusively on the use of log files in Internet lexicography – an approach which is questioned in this article. The paper is based on empirical data from an exploratory eye-tracking study of the user consultation behaviour of six participants and on interview data from a follow-up post-study interview of the participants. The paper elucidates and discusses the consultation behaviour in Internet lexicography and shows not only at *what* the participants looked, but also *how* they accessed lexicographic data. The paper presents a suitable method for using eye-tracking studies in Internet lexicography and advocates an increased use of this method to produce empirical data upon which additional theoretical considerations on the information and data access process can be developed. Finally, the implications for further research in user consultation behaviour are briefly explored.

1. Internet Dictionary Usage and User Consultation Behaviour: Eye-tracking

Several theoretical contributions on the usage of Internet dictionaries rely on log file analysis. The user's behaviour (key strokes and mouse clicks) is logged and tabulated in automatic, server-generated log files, and this technology has no doubt contributed to theory development and user-prompted update and revision of the content of the dictionaries in question, cf. for example De Schryver/Joffe (2004), Bergenholtz/Johnsen (2005), De Schryver et al. (2006), Bergenholtz /Johnsen (2007), Hult (2008) and Almind (2008), who all make a strong case for the use of log files in internet lexicography.

However, log files only show *what* characters the users have typed on the keyboard and log files do not show *where* users of an internet dictionary have looked.

The eye-tracking method proposed in this article is suitable for the study of the user consultation behaviour in connection with the use of an internet dictionary, and it can be used to learn more about what the user looks at, and how his eyes move and fixate during for example search operations and processing operations. Systematically collected data, which include data on eye fixations and eye movements, can be converted into valuable knowledge about Internet dictionary usage, and can be used in the pre-design, design and redesign phases of a dictionary project and in controlled dictionary reviews.

Finally, it is argued that eye-tracking studies in Internet lexicography are important in the ongoing development of theoretical considerations on information and data access in lexicography, because eye-tracking data may help us gain insight into what users are looking for, how they access data in specific situations and to what extent the user profile plays a role in user consultation behaviour.

This article has three overall objectives.

First, it introduces and discusses a new type of usage study designed for Internet dictionaries. Second, it demonstrates and discusses how a user of an Internet dictionary locates lexicographic data in specific situations and discusses the user consultation behaviour on the basis of eye-track-

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ing data and interview data. Third, it discusses the possible implications of this study for lexicographical data processing, Internet dictionary design and offers a number of theoretical considerations on search paths and search sequences.

The theoretical and practical relevance of this type of user survey in Internet lexicography is apparent, because eye-tracking data may help us learn more about the user, who was once characterized as the "bekannten Unbekannten" by Wiegand (1977: 59). User survey research is admittedly faced with a number of challenges and inherent weaknesses, some of which are raised by Tarp (2006), who questions whether user surveys can uncover the needs of the user. Despite the fact that Tarp (2006) to some extent has a point, when it comes to an entirely objective identification of user needs, it is argued that a study of the type presented in this article does produce useful data of relevance for lexicographers, lexicographic web editors and publishers, especially today where focus is on needs-adapted information and data access. Desktop research alone does not suffice, a view which is shared by Farø/Gottlieb (2007: 195), who criticize Tarp (2006) for his "intuitions and desktop research" (my translation).

2. Definitions and Delimitation

For the purpose of this discussion, we first need to define the term internet dictionary. A useful definition is offered by De Schryver et al. (2003: 4), who describe an internet dictionary as an "online dictionary for which the data are stored in databases, no matter where these databases are located, and which can be consulted from a search screen by anyone from anywhere through the Internet".

The important eye-mind assumption proposed by Just/Carpenter (1980) also needs to be defined. The eye-mind assumption is based on the widely recognized assumption that there is a high correlation between long fixation durations and effortful processing in the user's brain. Just/Carpenter's assumption has later been confirmed by Rayner (1998), who also demonstrates that eye fixation and gaze time data reflect cognitive processes in the user's brain. In this study it is also hypothesized that user consultation behaviour and especially effortful cognitive data processing can be measured and analysed by means of eye fixation data.

Furthermore, a number of eye-tracking-specific concepts need to be defined. The term eye movement refers to the situation when a participant's eyes move from one location of the screen to another and eye movements are typically shown by means of saccades, that is, the scanning path of the participant's eyes across the screen. The term eye fixation is the moment when the eyes are near-stationary and are encoding information, and a commonly recognized technical definition is offered by Duchowski (2007: 46) who defines fixations as "...eye movements that stabilize the retina over a stationary object of interest". Also the threshold (minimum time for a fixation) is relevant here as interpretations of fixation frequency depend on the selected time threshold of the eye-tracking system. A fixation duration may range from 80 ms to 600 ms, and eye fixations are typically seen as an indicator of attention, cf. also Duchowski (2007) for a detailed discussion of eye-tracking methodology. For the purpose of this eye-tracking study, the minimum threshold was set at 100 ms within a 40 pixel radius, because this study focused on a combination of user consultation processes (search, reading and processing tasks). The 100 ms fixation filter setting, which is low in comparison to the setting used in for example translation and reading studies, was preferred because of the somewhat sporadic nature of the user consultation process in Internet lexicography.

Typically, eye fixations are shown by means of blue or red circles on the screen depending on the software used. The Tobii eye-tracking equipment used in this survey shows fixations by means of blue circles as is shown in e.g. Appendix D. Transitions are when a participant's eyes move from one area of interest to another area of interest on the screen and are used to describe shifts between AOIs. Finally, area of interest (AOI) refers to a specific, designated area of the screen where fixations and user behaviour are recorded for subsequent data analysis, cf. also Poole/Ball

(2004) for useful definitions of eye-tracking metrics. ClearView 2.6.3 shows all AOI transitions (both cross-AOI and AOI-internal transitions) as will appear from the discussion below by means of a transition matrix, which shows cross-AOI and AOI-internal transitions. Finally, according to Duchowski (2007: 47) saccades are considered manifestations of the desire to voluntarily change the focus of attention and can be both voluntary and reflexive. A more technical definition is that "saccades are rapid eye movements used in repositioning the fovea to a new location in the visual environment", cf. Duchowski (2007: 42). The duration of saccades is typically very short, usually from 10 ms to 100 ms.

Finally, it is relevant to stress that this article discusses the results and theoretical implications of a delimited, exploratory survey, which was designed to demonstrate how six users use a specially selected Internet dictionary. The article focuses on Internet dictionary usage and on user consultation behaviour on the basis of data on the user's eye movements, eye fixations, saccades and transitions while performing a number of search and processing operations in connection with a translation task. The article only focuses on the lexicographic part of the translation task and is delimited to the actual look-up and processing process.

3. Existing Research in Dictionary Usage and Dictionary Users

This section of the article will focus on existing user survey research and outline a number of useful conclusions and findings from this research. As already noted above Wiegand (1977: 59) once described the user as the "bekannten Unbekannten", and since then much research has been carried out to learn more about the known unknown. A number of user surveys were carried out by for example Béjoint (1981), Benbow et al. (1990), and Nesi (2002), but the problem with these user surveys, as pointed out by Bergenholtz/Johnsen (2007), was that they were primarily based on introspection, which is an argument also raised by Simonsen (2002: 94-99), who reports on an analysis of 25 lexicographic user surveys. The use of introspection as a method in dictionary usage is questionable, because self-observation and consequent reporting of own thoughts and observations, either verbally or in writing, are inherently very subjective and not suitable for studying dictionary usage.

Another type of user survey was proposed by Wiegand (1985), who outlines a protocol survey involving foreign students of German. This contribution introduced the use of user protocols, which was later refined and used by other researchers, for example Atkins/Varantola (1997), who used a combination of a questionnaire and a user protocol involving students, Bergenholtz (1988), who carried out a dictionary test involving students, Diab (1999), who discussed a case study of students at the University of Jordan with a combination of a questionnaire, interviews and a protocol, and Nesi (2002), who used a test involving students to mention just a few. The use of protocol surveys and especially dictionary tests constituted a big step forward, however the focus of these surveys was dictionary use and the target group was typically students. In addition Wiegand (1998) outlined a large number of studies of dictionary use, and Hartmann (1989) discussed the "sociology of the dictionary user" and called for further empirical studies of dictionary use. Hartmann's call for further user research resulted in a large number of studies, some of which are mentioned in Hartmann (2008), and Hartmann has played a major role in dictionary use research through the Dictionary Research Centre at the University of Exeter.

All these researchers have shed valuable light on the 'bekannten Unbekannten', however the dictionary users and their actions are to some extent still unknown, especially in Internet lexicography. The surveys briefly outlined above did not empirically measure what users looked at during the access process, because they were mainly based on partly introspective, subjective descriptions by the users. An eye-tracking survey objectively measures what the user really looks at and what he does – a user protocol subjectively includes what the user says he does, or believes he does.

The advent of log files and log file analysis, however, marked the beginning of a new era in Internet lexicography and they offered a new method of describing the 'bekannten Unbekannten'. The first, and probably most important, contribution on the use of log file data in Internet lexicography was published by De Schryver/Joffe (2004), who discuss how electronic dictionaries are used on the basis of log file data from the Sesotho Sa Leboa Dictionary (SeDiPro).

Another important contribution on the use of log files in Internet lexicography is Bergenholtz/Johnsen (2005) where the authors demonstrate that log files can indeed be used to improve Internet dictionaries. The two authors make a very strong case for log files in Internet lexicography and offer a long empirically substantiated discussion of how log files can be used to improve the lemma selection of an Internet dictionary, and they call for further research into stronger search systems. Bergenholtz/Johnsen (2005) criticize De Schryver/Joffe (2004) for using a limited number of visitors and number of lookups in their discussion, a criticism, which De Schryver et al. (2006) later elegantly address in their discussion of the value of corpus-based lexicography.

A similar discussion is offered by Bergenholtz/Johnsen (2007), who argue that the data from log files should be analysed on the basis of lexicographic functions and that data should be correlated with data on the user and the user situation. Other important contributions on log files include Johnsen (2005), who offers a discussion of the use of log files in the DANISH INTERNET DICTIONARY in relation to four other Internet dictionaries, and Hult (2008), who discusses log file analysis of the Swedish LEXIN Internet dictionary. Other relevant contributions on web log research include Ling et al. (2001) and Ling et al. (2002) which both discuss query patterns and web logs.

The research based on log files is a huge step forward, because it objectively measures the search operations of the dictionary users, but log files only show what the dictionary users searched for not how they searched for and accessed data.

One example of eye-tracking surveys in Internet lexicography is Simonsen (2009a), who reports on an eye-tracking survey, where five participants were asked to perform a number of operations in two versions of the same Internet dictionary; the only difference being that the first version of the Internet dictionary had a vertical data presentation and the second version a horizontal data presentation. On the basis of eye-tracking metrics and think-aloud protocol data, Simonsen (2009a) concludes that a horizontal data arrangement is recommended in connection with cognitive lexicographical functions, that is, when data are to be processed with a view to acquire knowledge whereas a vertical data arrangement is recommended in connection with communicative lexicographical functions, that is when data are to be used in for example L1-L2 translation as is the case in the present eye-tracking study. Furthermore, Simonsen (2009b) discusses another eye-tracking survey with special emphasis on the lexicographic functions. On the basis of eye-tracking metrics, Simonsen (2009b) argues that there is a correlation between the different lexicographic functions and the cognitive load measured as eye fixations and gaze times. Simonsen (2009b) found that cognitive lexicographic functions, such as L1 knowledge acquisition, incurred more cognitive load than communicative lexicographic functions, such as for example L1-L2 translation. In fact Ordbogen over Faste Vendinger cf. http://www.idiomordbogen.dk/ (Danish Dictionary of Fixed Phrases) uses such an approach as it allows users to search for Danish idioms and phrases on the basis of lexicographic functions. In conclusion, the two eye-tracking studies discussed above show that there is a link between *how* a user accesses data (search-related data) and *how* he uses data (function-related data), but they did not focus on the user consultation process, which is the focus of the eye-tracking survey discussed in this article.

The above brief literature review revealed that to date different aspects of the known unknown have been revealed, and recent developments on the use of log file data in conjunction with lexicographic functions bode well for the future. The different eye-tracking surveys within the field of Internet lexicography briefly outlined above are also relevant for this survey because they have revealed different aspects of the user's dictionary usage. However, we still need to learn more about the user consultation behaviour.

4. Methodology and Experimental Set-up

The methods used in this article include the collection, tabulation and interpretation of eye-tracking data and interview data.

Eye-tracking data may help lexicographers decide on the best design of an Internet dictionary and on where to locate search fields and how to order and present lexicographic data. A survey of the type discussed here may also supply a prospective subscriber with comparable and objective data on how a specific number of users have used the Internet dictionary in a specific number of situations. Finally, the research method proposed here could also be used by professional reviewers when reviewing an Internet dictionary in order to be able to review how the Internet dictionary in question allows users to access data.

A Tobii 1750 remote eye-tracker was used to register the eye movements of six participants, who were all professional translators with an MA degree in translation: for additional information on the occupation, company, experience, area of expertise and knowledge level of the Internet dictionary of the participants, see Appendix A. The six participants were invited to take part in the eye-tracking study and the interview on a specified date and time. On the day of the eye-tracking study, the participants were asked to use the Danish-English Accounting Dictionary at http://www.regnskabsordbogen.dk/regn/dkgb/dkgbregn.aspx, and the experiment was carried out in a special eye-tracking lab. The eye-tracking software used was ClearView, cf. also www.tobii.com for further information on the Tobii 1750 and ClearView.

Each participant was asked to look up at least five lemmata, which corresponds to a total of 30 lemmata (5 lemmata X 6 participants) during a translation task. The recordings totalled 3 GB, but unfortunately, as is often the case in eye-tracking studies, the quality of some of the data collected was not satisfactory, despite the fact that two successful pre-surveys were carried out and despite the fact that the eye-tracking equipment was calibrated for each participant. Unfortunately, the eye-tracking data from the six participants were not comparable, because the quality of some parts of the recordings was not good enough. To ensure comparability three participants with each three successful recordings of comparable lemmata were selected for further analysis by means of the ClearView Software, see also the discussion below and Appendix C, which includes a hot spot chart for each of the three selected participants. The remaining three participants were eliminated from the study because the eye-tracking data recorded for these three participants were not comparable with the data for the selected three participants.

One reason why the inclusion rate is only 50% may be that this eye-tracking survey focuses on the analysis of eye movements across large text units or entire screen texts and not eye movements from one word to another, which is typical in reading and translation studies. Another reason why data from only three out of six participants were included may be that the measuring accuracy of the eye-tracking equipment was not good enough because of the time threshold setting or because of Brownian motions. The lemmata selected for further analysis were the terms “direktion”, “gældende” and “retvisende”, which are all typical words used in a statement by the management on the annual report.

The participants were asked to translate a small text from Danish to English and in the process look up at least five Danish lemmata from the economic register during a L1-L2 translation situation. Some of the participants looked up fewer than five lemmata, other participants looked up more than five lemmata. Before the test the participant received a written instruction sheet and a number of oral instructions including information on the purpose of the experiment, the process of the experiment and the intended use of the data. The text used in the eye-tracking study is shown in Appendix B. The participants were all professional translators with different degrees of experience and different expertise areas. Anonymized participant profiles are shown in Appendix A, which lists relevant information about the participants, including occupation, company, experience, expertise area and knowledge level of the test object.

The test object, which today is managed by www.ordbogen.com, was the Danish-English Accounting Dictionary at http://www.regnskabsordbogen.dk/regn/dkgb/dkgbregn.aspx. The actual user interface, with labelling of the two AOIs, is shown in Figures 1 and 2.

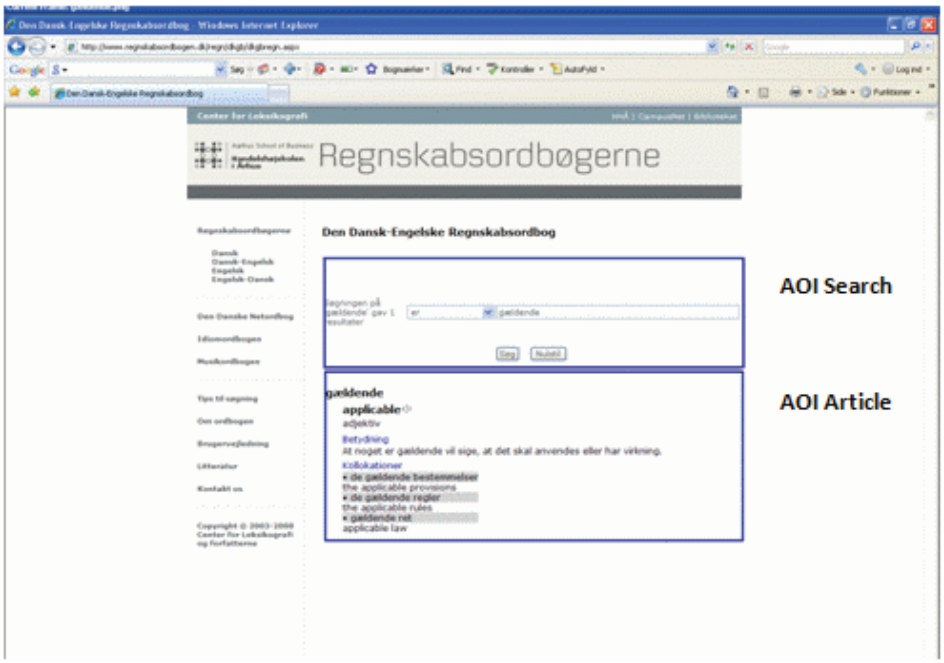

Figure 1. User interface of test object with the two AOIs X_search and X_article

In transition matrix experiment I, two overall AOIs were used as shown in Figure 1. The AOI Search was the search field of the internet dictionary and the AOI Article was the actual lexicographic article.

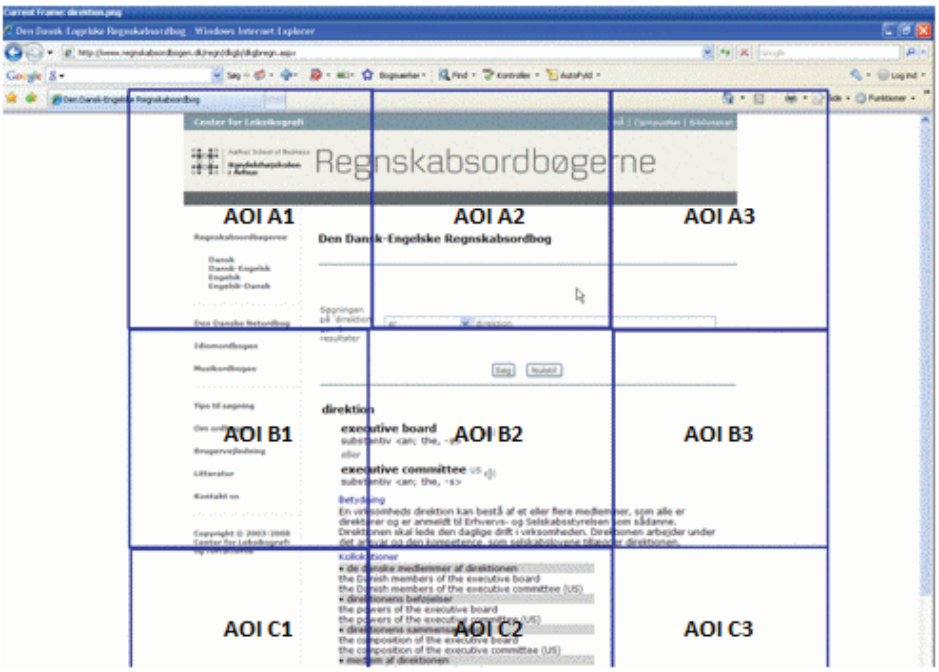

Figure 2. User interface of test object with the nine AOIs A1 to C3

In transition matrix experiment II, a somewhat more detailed AOI grid was used. The grid divided the user interface into nine AOIs with a view to analysing the information access of the user. The nine AOIs are named A1 to C3, respectively, as is shown in Figure 2.

The second type of data collected is interview data. The qualitative follow-up interviews with the participants were performed immediately after the eye-tracking experiment and a total of 78 minutes of interview data were recorded by means of a digital recorder. Selected questions asked and responses given by the interviewees are included in the discussion below. The questions asked were designed to encourage the interviewee to explain what he did and what he saw during the individual search operations and the subsequent information processing.

5. Findings and Analysis

The experiment aimed at examining how six Danish translators use a Danish-English Internet dictionary by tracking the eye movements and eye fixations during lexicographic search and processing operations. During the interview, the participants were asked a series of questions on their user consultation behavior.

For the purpose of this study, three measures are included in the analysis of the eye-tracking data: 1) the fixation count, which is the number of eye fixations in a given AOI, 2) the gaze time, which is the duration of eye fixations in a given AOI and 3) transition matrix data measuring transitions and measuring the scan path of the participant's eyes during consultation. The eye-tracking study is thus based on the measurement of the number of eye fixations, the number of milliseconds used on gazing, and finally, the number of transitions between and inside the AOIs. For the first two measures two AOIs were used: AOI_search, which consists of the top 1/3 of the screen and AOI_article, which consists of the remaining 2/3 of the screen. The motivation for defining two overall AOIs was to obtain data on two different operations: the search operation and the reading operation.

For the last measure, two experiments were conducted. Experiment I used the same two overall AOIs as used for the first two measures. In experiment II the screen was divided into nine AOIs forming a grid. The AOIs were named A1-A2-A3 (top area of the screen), B1-B2-B3 (middle area of the screen) and C1-C2-C3 (bottom area of the screen). Each of these AOIs measures approx. 7.5 X 7.5 cm, see also Figures 1 and 2 and Appendices D and E for further information on where the AOIs are placed on the actual user interface. To be able to study the scan path of the user nine small AOIs were defined. In the following discussion the following abbreviations Participant A, Participant D and Participant F are used for participants A, D and F, respectively.

5.1. Fixation Count

Fixation counts can be shown graphically by means of gaze plot charts, which plot the fixations of the participant. The bigger the blue circle the longer the fixation duration. The numbers in the blue circles refer to the fixation number and these unique numbers are used to identify the fixation count, and in the analysis of the transition matrix data, the fixation order of fixations.

Figure 3 below shows a ClearView gaze plot of participant D's fixations on the screen for the Danish lemma "retvisende".

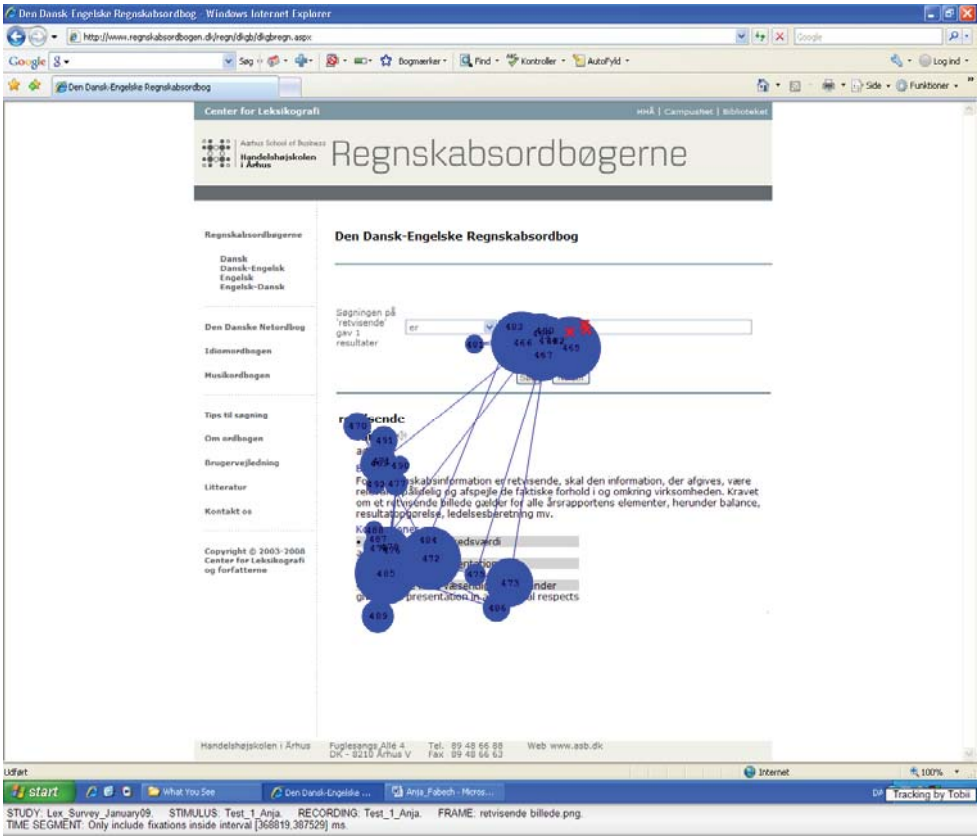

Figure 3. Gaze plot of participant D's screen fixations for the Danish lemma "retvisende"

Participant D had 31 fixations in and around the search field, which is referred to as AOI retvisende_search and 44 fixations in and around the article field, which is referred to as AOI retvisende_article. Participant D's fixation counts in the two AOIs appear in Table 1 below. As is shown, the participant had more eye fixations in the article field than in the search field.

	AOI retvisende_search	AOI retvisende_article
Number of Fixations	31	44

Table 1. AOI fixation count of participant D's screen fixations for the Danish lemma "retvisende"

A similar finding was made for participant A. Figure 4 below shows a ClearView gaze plot of Participant A's fixations on the screen for the Danish lemma "direktion".

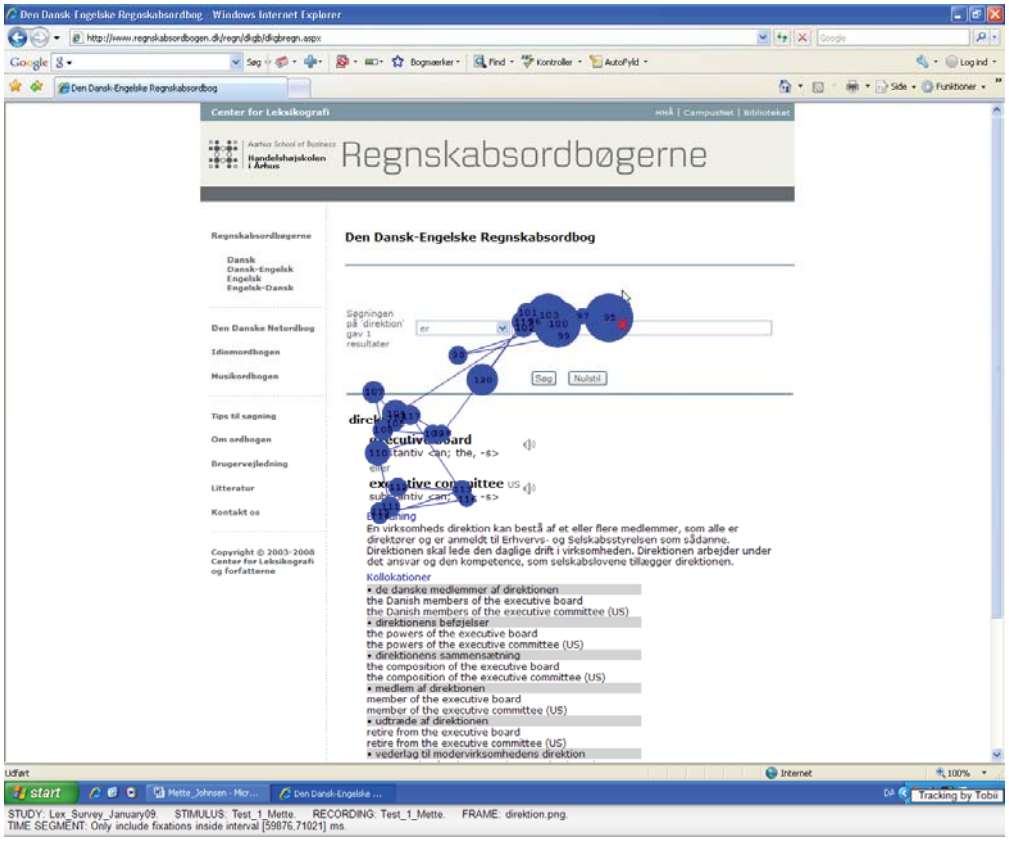

Figure 4. Gaze plot of participant A's screen fixations for the Danish lemma "direktion"

On the basis of the AOI analysis it was found that participant A had 12 fixations in AOI direktion_search and 14 fixations in AOI direktion_article, respectively, as is shown in Table 2 below.

	AOI direktion_search	AOI direktion_article
Number of Fixations	12	14

Table 2. AOI fixation count of participant A's screen fixations for the Danish lemma "direktion"

Participant A had almost just as many fixations in the AOI direktion_search as in the AOI direktion_article. The very small difference in the number of fixations may be explained by comments made by participant A during the interview; for this term she says " I just wanted to check a term".

Participant F's consultation behaviour in terms of eye fixations was somewhat different from participant D and participant A, see Figure 5 below.

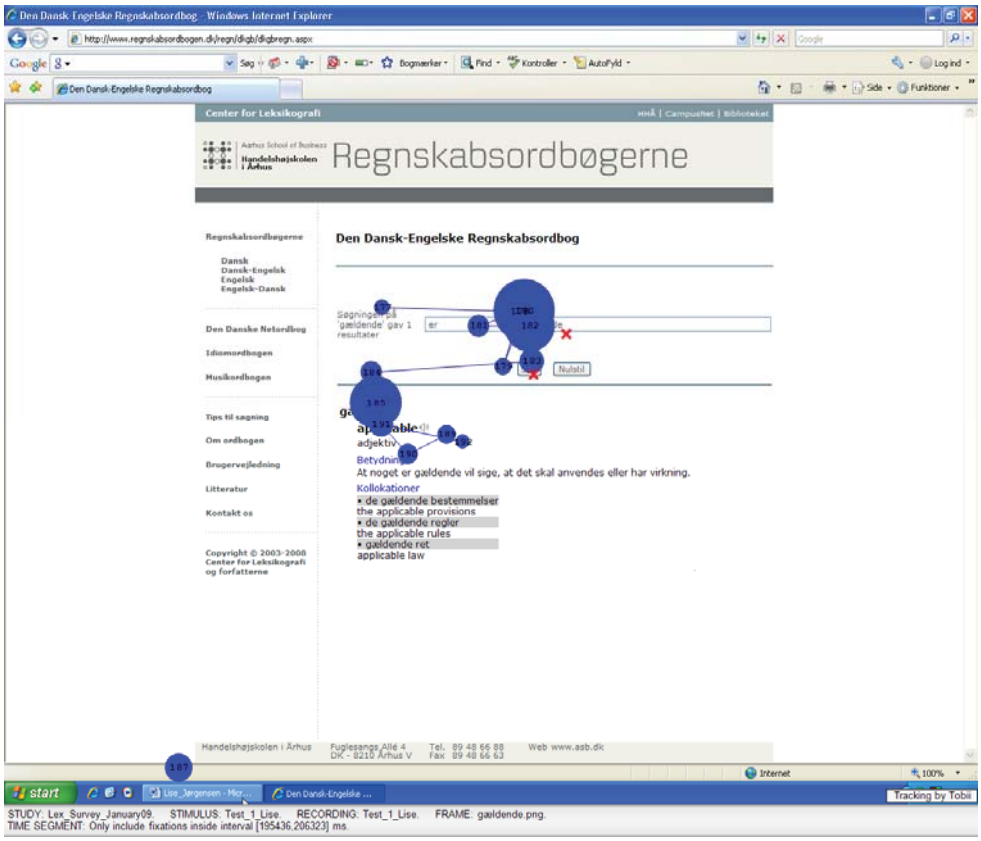

Figure 5. Gaze plot of participant F's screen fixations for the Danish lemma "gældende"

On the basis of the AOI analysis it was found that participant F had 8 fixations in AOI gældende_search and only 5 fixations in AOI gældende_article as is shown in Table 3. In other words, participant F had more fixations in the search field than in the article field.

	AOI gældende_search	AOI gældende_article
Number of Fixations	8	5

Table 3. AOI fixation count of participant F's screen fixations for the Danish lemma "gældende"

5.2. Gaze Time

The gaze times of the participants are shown in Tables 4, 5 and 6. The gaze times are shown graphically in the gaze plot charts above in Figures 3, 4 and 5 by means of blue circles and the bigger the blue circle the longer the gaze time. The duration of a participant's fixations inside an AOI may help us understand how long it takes a user of an Internet dictionary to execute a specific task measured in milliseconds. Furthermore, the gaze time reflects how much cognitive effort the participant puts into a specific task based on the ***eye-mind assumption*** by Just/Carpenter (1980).

On the basis of the gaze time analysis, it was found that participant D looked considerably longer at the AOI retvisende_article than at the AOI retvisende_search as shown in Table 4 below.

	AOI retvisende_search	AOI retvisende_article
Gaze time	13496 ms	17880 ms

Table 4. Gaze time data for participant D's screen gazes for the Danish lemma "retvisende"

A somewhat different result was found for participant A, as shown in the gaze data in Table 5. Participant A first of all looked more at AOI direktion_search than at AOI direktion_article, which seems to suggest that participant A did not need to scrutinize the lexicographic data, because she is an expert on translating economic and financial texts. Participant A spent 3927 ms looking at AOI direktion_search, but only 2531 ms at AOI direktion_article. Another plausible explanation could be that participant A being an expert in this field did not need to look up the term and thus only looked up the term to check her own translation.

	AOI direktion_search	AOI direktion_article
Gaze time	3927 ms	2531 ms

Table 5. Gaze time data for participant A's screen gazes for the Danish lemma "direktion"

A similar finding can be seen for participant F. Participant F also looked comparatively longer at AOI gældende_search than at AOI gældende_article, and again the participant spent more time gazing at the search field than at the lexicographic data. Again this is consistent with the interview data and her profile, which shows that she is an expert on accounting texts, which may be why she did not have to scrutinize the lexicographic data. The gaze data for participant F are shown in Table 6.

	AOI gældende_search	AOI gældende_article
Gaze time	4285 ms	1674 ms

Table 6. Gaze time data for partipant-F's screen gazes for the Danish lemma "gældende"

5.3. Transition Matrix Data

Transition matrix data are useful when measuring transitions between or inside AOIs. Two experiments were conducted, and the purpose of the two experiments was to analyse time-dependent, linear information access behaviour patterns of the participants. Information access path here refers to "the scanning path of the participant's eye fixations" and is in line with scanpath which is defined as …"usually a complete sequence of fixations and interconnecting saccades" by Poole/ Ball (2004). The sequence of fixations and interconnecting saccades is shown in Figures 6-8.

5.3.1. Transition Matrix Experiment I

In experiment I the two overall AOIs X_search and X_article were used again. These two AOIs were also used during the collection of the eye fixation and gaze time data and it was expected that there would be a high amount of cross-AOI transitions between the search field and the article field, but the opposite was found. As is shown in Tables 7, 8 and 9 below, almost all transitions were AOI-internal.

Participant D for example, had 24 transitions from AOI retvisende_search to AOI retvisende_ search (or 80.0%) and 38 transitions (or 86.4%) from AOI retvisende_article to AOI retvisende_ article. The AOI-external data will also appear from Table 7 below.

From / To	AOI ”retvisende_search”	AOI ”retvisende_article”
AOI ”retvisende_search”	80.0% (24)	13.6% (6)
AOI ”retvisende_article”	20.0% (6)	86.4% (38)

Table 7. Transition matrix data for participant D’s transitions for the Danish lemma “retvisende”

For participants A and F, see Tables 8 and 9 below, similar data were found. As is shown in Table 8, participant A had 7 transitions (or 87.5%) from AOI gældende_search to AOI gældende_search and 4 transitions (or 100 %) from AOI gældende_article to AOI gældende_article.

From / To	AOI ”gældende_search”	AOI ”gældende_article”
AOI ”gældende_search”	87.5% (7)	0.0% (0)
AOI ” gældende_article”	12.5% (1)	100.0% (4)

Table 8. Transition matrix data for participant A’s transitions for the Danish lemma “gældende”

The same overall picture was found for participant F as is shown in Table 9. Participant F had 9 transitions (or 81.8%) from AOI direktion_search to AOI direktion_search and 12 transitions (or 85.7 %) from AOI direktion_article to AOI direktion_article.

From / To	AOI ”direktion_search”	AOI ”direktion_article”
AOI ”direktion_search”	81.8% (9)	14.3% (2)
AOI ” direktion_article”	18.2% (2)	85.7% (12)

Table 9. Transition matrix data for participant F’s transitions for the Danish lemma “direktion”

The data show that a high amount of the transitions were AOI-internal, and additional analysis of the data by means of the Gaze Replay option in the ClearView software supports the contention that the participants were prone to looking within small, designated areas, that is, primarily inside the search-related AOI or the article-related AOI, which in essence is what users do when looking for lexicographic data. This contention is supported by research published by Jacobsen (2008), who on the basis of a survey of website readers concluded that short, compact segments or boxes of text were preferred.

However, with a view to analysing the details of user consultation behaviour, an additional experiment was needed. Consequently, a more fine-meshed grid of AOIs was designed to be able to analyse the participants’ information access paths more closely. The user interface and the fine-meshed grid of AOIs are shown in Figure 2 above.

5.3.2. Transition Matrix Experiment II

On the basis of the analysis of the data from experiment I, it was decided to design a more fine-meshed grid of AOIs, see also Figure 2 and Appendix E for further information on the AOI grid

used. As is shown in Appendix E, the screen was divided into nine quadrants named A1 to C3. In addition to analysing transitions between the nine AOIs, experiment II also looked at the participant's information access paths by plotting gaze plot data in the grid to be able to analyse the user consultation behaviour. The transition matrix data and the information access path data of three selected participants in connection with the Danish lemma "direktion" are shown in Figures 6-8 and Tables 10-16.

For the purpose of experiment II, the gaze plot data were exported to an Excel spread sheet with nine quadrants as shown in Figures 6-8. Three types of fixations were identified: search-related fixations which occurred in or around the search field (especially AOI A2), processing-related fixations, which occurred in or around the actual lexicographic article (especially AOIs B1, B2, B3, C2 and C3) and finally navigation-related fixations, which occur in or around menus.

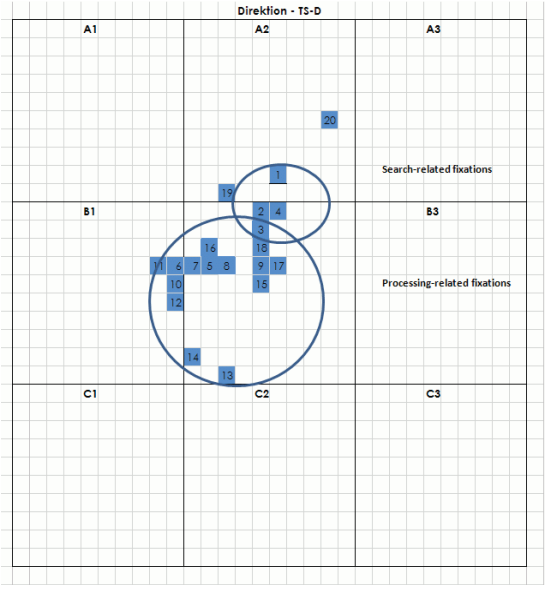

Figure 6. Participant D's transition matrix data for the Danish lemma "direktion"

Fix. No.	1	2	3	4
AOI	A2	B2	B2	B2

Table 10. Participant D's search-related fixations

Fix. No.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
AOI	B2	B1	B2	B2	B2	B1	B1	B1	B2	B2	B2	B2	B2	B2	A2	A2

Table 11. Participant D's processing-related fixations

The data shown in Figure 6 demonstrate that participant D's information focus is in the centre area of the screen, especially in quadrants A2 and B2. The information access path will also appear from Figure 6, where fixations seem to be in two groups: search-related fixations (fixations 1-4) and processing-related fixations (fixations 5-20). As expected, the information access path starts in or around the search field, see fixations 1-4, and after participant D typed the lemma in the search field, the information access path followed the lemma and the equivalent and continued along the structure of the lexicographic article, cf. fixations 5-19. The information access path ended in or around the search field in quadrant A2, cf. fixation 20.

The information access sequence is shown in the Tables 10-11 above. The first line of the table shows the sequence of the fixation numbers indicated in the nine quadrants and the second line of the table indicates the quadrant name. As is shown in Tables 10-11 participant D had 3 search-related fixations in the B2 quadrant and 10 processing-related fixations in the B2 quadrant, and the access sequence was chronological as participant D first had four fixations in or around the search field and then 15 fixations on the lexicographic article. The sequence of fixations is also shown in Tables 10-11.

When studying the data for participant A, similar observations can be made. Participant A's information access path is in fact quite similar to that of participant D.

Again two primary areas of information focus can be identified, see Figure 7 below. Participant A's information access path also begins in and around the search field in quadrant A2, continues to quadrant B2 and ends its journey in quadrant A2 as was the case for participant D. Fixations 1-9 are all roughly in the search-related cluster and fixations 10-26 are in the data processing zone, respectively. As will appear from participant F's fixations in the data processing zone, her information access behaviour seems to be both horizontal and vertical, which seems to suggest that she processes the lexicographic data line by line. In other words, participant A processes the equivalent, continues to the definition of the Danish lemma "direktion" and then reads the examples line by line, cf. fixation numbers 10-13, 14-16, 17-19 and 20-22.

The information access sequence and the names of the grids are listed in Tables 12-13.

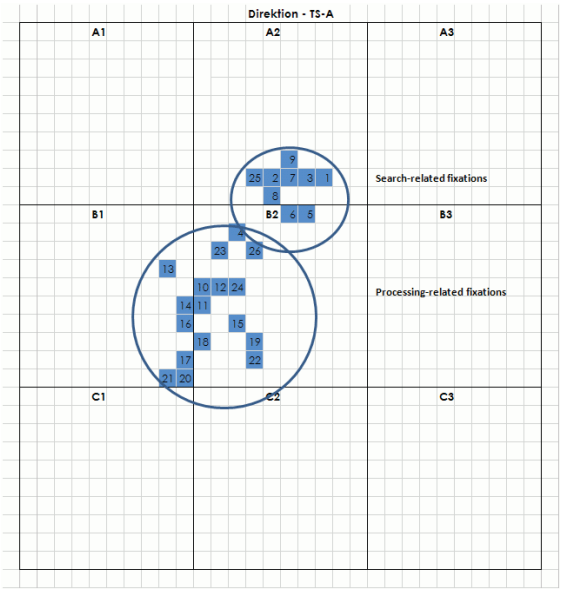

Figure 7. Participant A's transition matrix data for the Danish lemma "direktion"

Fix. No.	1	2	3	4	5	6	7	8	9
AOI	A2	A2	A2	B2	B2	B2	A2	A2	A2

Table 12. Participant A's search-related fixations

Fix. No.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
AOI	B2	B2	B2	B1	B1	B2	B1	B1	B2	B2	B1	B1	B2	B2	B2	A2	B2

Table 13. Participant A's processing-related fixations

Similar observations can be made for participant F, whose information focus is also in the centre area of the screen except for the four outlier fixations in quadrant C1, whose location is equivalent with the collapsed Microsoft Word document used in the experiment and fixation no. 22 which is a fixation on the menu of the Internet dictionary in question and thus a navigation-related fixation. Again the fixations can roughly be divided into search-related fixations (fixations 1-9), processing-related fixations (fixations 11-17 and 21) and navigation-related fixations (fixations 10, 18-20 and 22), see Figure 8 and Tables 14-16 below. Participant F's information access path starts in or around the search field in quadrant A2, cf. fixations 1-9 and ends with a number of fixations in quadrant B2. From B2 participant F's information access path seems to follow an almost straight horizontal line, cf. fixations 11-17 and 21. Finally, fixations 10, 18-20 and 22 are navigation-related as already explained above.

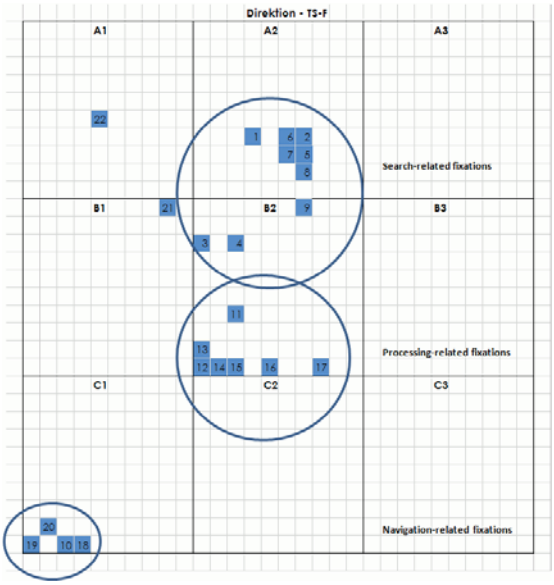

Figure 8. Participant F's transition matrix data for the Danish lemma "direktion"

Fix No.	1	2	3	4	5	6	7	8	9
AOI	A2	A2	B2	B2	A2	A2	A2	A2	B2

Table 14. Participant F's search-related fixations

Fix No.	11	12	13	14	15	16	17	18	19	20	21
AOI	B2	B2	B2	B2	B2	B2	B2	C1	C1	C1	B1

Table 15. Participant F's processing-related fixations

Fix No.	10	18	19	20	22
AOI	C1	C1	C1	C1	A1

Table 16. Participant F's navigation-related fixations

In summary, experiment II demonstrated the user consultation behaviour of the three participants and their information access paths and the sequence of their fixations.

Looking back at the eye-tracking survey, I believe that a number of learning points could be highlighted. First, the number of participants involved in the two experiments should have been considerably higher. This would have increased the total amount of eye-tracking data collected and would have made it easier to produce conclusive evidence for contending that there is a connection between the user profile and the user consultation behaviour. Second, additional pre-survey tests should have been performed to find the optimum time threshold setting for this type of eye-tracking experiment. I believe that the time threshold of the eye-tracking system perhaps should have been higher, for example 200-300 ms, because the user consultation behaviour of Internet dictionary users resembles the processes measured in reading and translation studies. A different setting might have improved the quality and comparability of the data acquired and thus improved the total data basis. Third, additional pre-survey tests should have been performed to identify the optimum way of measuring the different phases of the user consultation behaviour and it might be argued that the access process involves additional sub-steps such as navigation, writing, search, reading, processing and navigation.

However, despite the weaknesses of the eye-tracking study discussed in this article, the survey constitutes a new and empirically based method, which admittedly should be developed further, but which is suitable and relevant in Internet lexicography to gain additional insight into the user consultation behaviour. So despite the few participants involved and the somewhat tautological results, which merely seem to confirm what we already intuitively know about the user and the user consultation behaviour, it is argued that this eye-tracking study seems to indicate that the user consultation behaviour depends on several factors such as lexicographic function, user situation and user profile etc. This eye-tracking study thus adds valuable insight into user consultation behaviour and thus also into the development of more effective information tools. One line of research that I would like to pursue in continuation of the work presented in this article is to further test the connection between the lexicographic function, the user profile and the user consultation behaviour.

6. From Eye-tracking Metrics to Improved Design and Needs-adapted Information Access?

A number of general surveys have already established that the reading patterns and information access of readers of Internet pages are dramatically different from that of readers of paper-based texts, see for example Poynter Institute's Eyetrack III study from 2004 in Poynter (2004) and Jacobsen (2008), who offered some interesting conclusions in a study of website readers: that all types of readers had difficulties finding the information they needed, that short, compact segments or boxes of text were preferred by especially inexperienced readers, that most users preferred a centre column design and that most users did not like scrolling.

The data from this eye-tracking study, supported by the interview data, seem to suggest that the information access process is connected with the user profile and the user situation in question, and the data confirm some of the conclusions reached by Jacobsen (2008). Participant D, who has three years of experience within the technical register, performed meticulous horizontal processing of the lexicographic data and states during the interview that *"I think I spent most time reading or studying the data – or focusing on something to understand it."* when asked where her eyes fixated during the experiment, while participant A, who has more than ten years of experience within the economic register, performed more brief consultations and said during the interview that "*I am quite experienced in this field, so most of the times I used the dictionary to confirm my translation – I quickly looked down to confirm my approach"*.

6.1. Fixations

The fixation counts are shown graphically in Figures 3, 4 and 5 by means of the black numbers in the blue circles.

As is shown in Figures 3-5 and Tables 1-3 above, participant D and participant A had 31 and 12 fixations in the AOI search field and 44 and 14 fixations in the AOI article field, respectively. These data indicate that these participants had more fixations in the article field than in the search field. Participant F, however, had 8 fixations in the search field, but only 5 fixations in the article field. All this is supported by the interview data. When asked "where did your eyes fixate during the experiment?" Participant A for example said: *"I think my focus was after I looked up a word. I am quite experienced in this field, so most of the times I used the dictionary to confirm my translation – I quickly looked down to confirm my approach. If I did not know the translation I spent more time looking through the examples"* and participant D said *"I think I spent most time reading or studying the data – or focusing on something to understand it."*

6.2. Gaze times

The gaze time also appears from the gaze plot charts above in Figures 3, 4 and 5. As will appear from the data measured in milliseconds and tabulated in Tables 4-6 above, participant D looked longer at the AOI article field than at the AOI search field, while participant A and participant F spent considerably longer time looking at the AOI search field than at the lexicographic data in the AOI article field. Again these data are supported by the interview data, where both participant A and participant F stated that they spent most time scrutinizing data. Participant A states: *"I think I spent most time reading or studying the data – or focusing on something to understand it"*.

6.3. Transition matrix data – experiment I

As is shown in Tables 7, 8 and 9, almost all transitions were AOI internal. It was expected that the participants would have had considerably more cross-AOI transitions, because participants were expected to go back and forth between the two AOIs, but that was not the case. As explained above, transition matrix data show the transitions of a participant's eyes and together with the Gaze replay functionality in the ClearView software these data indicate potential information access paths and scanning sequences. The fact that there were relatively few transitions between the two overall AOIs seems to indicate that the user behavior can be divided into three overall operations: a search-related operation, a data-processing operation and a navigation-related operation, which transition matrix experiment II also showed.

The transition matrix data from experiment I showed that participant D for example had 24 AOI internal transitions from AOI search field to AOI search field and 38 AOI internal transitions from AOI article field to AOI article field, and very few AOI external transitions. In fact participant D only had 6 AOI external transitions from AOI search field to AOI article field and 6 AOI external transitions from AOI article field to AOI search field.

These data seem to indicate that the scanning paths of the participants are relatively fixed and focused on the operation in question, that is, whether or not the user is performing a search operation or processing data. In other words, the users' scanning paths were relatively fixed and restricted to a small area of interest. Similar conclusions were reached by Morrison et al. (1997), who found that eye-tracking data can be used to evaluate the design of decision support systems and to evaluate the presentation of information in Human-Computer Interaction displays in military combat information centres.

The very few cross-AOI transitions furthermore seem to suggest that Internet dictionary design should take into account the preference of Internet dictionary users for fixating within relatively small areas of interest and the scanning paths and scanning patterns of the participants also support this interpretation.

6.4. Transition matrix data – experiment II

As already described above, the purpose of transition matrix experiment II was to analyse the participant's information access path and sequence of fixations. The research design used in experiment II was much more fine-meshed as it was based on nine AOIs, cf. Appendix E.

The data from transition matrix experiment II support the conclusions from experiment I, but they also give a detailed overview of the entire access process of the participants.

As is shown in Figures 6-8 the majority of transitions were AOI internal. The transition matrix data show that the participants were prone to looking within small, designated areas especially in AOIs A1 and B2, see Figures 7-8 above. The transition matrix data also seem to show that the two primary information access processes: the search-related operation and the data processing-related operation are separated in time and location. Not surprisingly, participants use less time and fewer fixations in the search-related AOIs in comparison with the data processing-related AOIs, cf. Figures 6-8.

The search operation and the data processing operation are thus two separate operations. The search operation can be described as a writing process during which the participant focuses on entering the search string in the search field and the processing operation is to a larger degree an exploratory process during which users explore the various types of data. This is a natural process, and the theoretical implication of this is to further develop the integrated web page in Internet dictionaries to facilitate the two different processes: the writing/searching process, which is a very focused consultation behaviour and the reading/processing process, which is exploratory, cf. Figures 6-8. This indicates that there is a relation between the actual operation performed (searching or processing) and the information access structure needed.

In this study the participants had one objective with two sub-steps: to find the lexicographic data and to read, understand and extract the lexicographical information needed to translate a text from Danish into English. These two different needs result in two different access processes: a very focused search-operation where the user fixates in or around the relatively restricted area of the search field and a more unfocused data processing operation, where the user either scans the lexicographical article with a view to finding, reading, understanding and extracting the English equivalent needed or meticulously reads the lexicographical article line by line following the usual direction of reading, cf. Figures 4-6 above from which it appears that participant A follows a horizontal and vertical information access path and participant F follows a predominantly horizontal information access path.

Finally, even though the data are far from conclusive, it is interesting, but not surprising, to find that the user profile and degree of experience also play a large role for not only the time consumption in connection with search and data-processing operations (fixations and gaze times), but also the user consultation behaviour (information access paths). The purpose of this survey was not solely to study the relationship between the user profile and the user consultation behaviour, but a number of interesting trends were nevertheless found. Participant A for example, is a very experienced translator with more than 10 years of experience with translation of texts from the financial and economic register. Her consultation behaviour is both horizontal and vertical as described above, which seems to indicate that she quickly identifies the equivalent, reads a few words and scans the lexicographic article, because she only needs to check what she already knew or become reassured of her own translation proposal.

A similar trend can be observed by analysing participant F's user profile and user consultation behaviour. According to Appendix A, which outlines the participant profiles, participant F is also a certified translator, but with only two years of experience from the technical register. As is shown in Appendix A, both participant A and participant F report that their knowledge level of Den Dansk-Engelske Regnskabsordbog, cf. www.regnskabsordbogen.dk (Danish-English Accounting Dictionary) is high on a low-medium-high scale. Participant F's user consultation be-

haviour is characterized as being primarily horizontal, which suggests that she meticulously reads line by line, because she feels she needs to be completely sure which equivalent to choose.

7. Conclusion

This paper outlined and discussed an eye-tracking study specially designed for Internet lexicography. The method developed and discussed is based on data from an eye-tracking study of six participants and post-survey interview data, and it is argued that empirical data on the user consultation behaviour are useful in the ongoing development of more effective information tools, especially because different users with different user profiles seem to have different user consultation behaviours. Consequently, additional knowledge of this behavior may help us develop and design more effective information tools, whose data to a higher extent are specially adapted to the user and in sync with the user need, user situation and user profile.

The paper demonstrated how six users of an Internet dictionary located and processed lexicographic data in an L1-L2 translation situation and demonstrated not only at *what* the participants looked, but also *how* they accessed the lexicographic data to be able to translate. The eye-tracking study used a total of three measures to harvest data on the user consultation behavior: the number of fixations, the length of gaze times and the number of transitions. Two transition matrix experiments were also carried out to further analyse the scan path and scan sequence of the participants. The first transition matrix experiment was based on two AOIs to measure the overall consultation behaviour in search-related operations (search and writing) and article-related operations (reading and processing) and the second transition matrix experiment was based on nine AOIs to get more detailed data on the information access path or scan path of the participants.

The article discussed the analysis of two fundamental processes in lexicography: to locate the lexicographic data and to read, understand and extract the lexicographical information needed to translate a text from Danish into English. This results in two access processes: a very focused search-operation where the user fixates in or around a relatively small area of the search field and a more exploring data processing operation, where the user either scans the lexicographical article with a view to find, read, understand and extract the English equivalent needed or where the user meticulously reads the lexicographical article line by line following the usual direction of reading.

The analysis of the gaze time data showed that two of the three participants spent more time gazing at the search field than at the lexicographic article. The analysis of the eye-tracking data combined with the analysis of the interview data and the user profile characteristics indicate a correlation between the user profile (experience and area of expertise) and the user consultation behaviour and how the user accesses and processes data. Participants A and F for example are both experienced translators of accounting texts and they actually had more fixations and spent more time on the search process than on the data processing process, which was consistent with the interview data where they both stated that they just wanted to check a term and did not have to scrutinize data. Only participant D spent more time fixating on the lexicographic data which again is consistent with her user profile as she is an expert on translating technical texts. The gaze time data thus indicate a correlation between user profile characteristics and the user consultation behaviour.

The analysis of the transition matrix data support the above findings but also show a more detailed picture of how the participants accessed the lexicographical data and in which sequence. The data showed that most transitions were in fact AOI-internal, and additional analysis of the data by means of the Gaze Replay option showed that the participants were prone to looking within small, designated areas, that is, inside the search-related AOI or the article-related AOI.

The analysis of the transition matrix data also showed the scan paths and scan sequences of the participants and showed that there were three types of fixations: search-related fixations, which occurred in or around the search field, processing-related fixations, which occurred in or around the actual lexicographic article and navigation-related fixations, which occur in or around menus.

The data indicated that the scanning paths of the participants were relatively fixed and focused on the actual operation, that is, whether or not the user is performing a search operation or processing data.

The data indicated that users of Internet dictionaries process lexicographical data in accordance with not only the lexicographical function, but also in accordance with their user profile. Obviously, a much more extensive study is needed to provide conclusive evidence for this contention, but the theoretical implications of this study are to realize that the individual user profile, the lexicographic function and the specific user situation play a crucial role for the development of the data access structure of Internet dictionaries.

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9. Appendix

Appendix A. Participant Data

Name	Occupation	Company	Experience	Expertise Area	Knowledge Level
Participant A	Certified translator, MA	Bech Bruun www.bechbruun.com	10 years experience	Economic	High
Participant B	Certified translator, MA	Dialog Translatørservice http://www.dialog-ts.dk/	3 years experience	Legal	High
Participant C	Certified translator, MA	Godt Sprog	12 years experience	Literature	Medium
Participant D	Certified translator, MA	COWI www.cowi.com	3 years experience	Technical	High
Participant E	Certified translator, MA	Semler Sprog www.semler-sprog.com	8 years experience	Technical	Medium
Participant F	Certified translator, MA	Dantranslation www.dantranslation.com	2 years experience	Technical and Economic	High

Appendix B. Source Text and Lemmata

Ledelsespåtegning

Movias **direktion** har behandlet og godkendt årsregnskabet for **regnskabsåret** 1. januar – 31. december 2007.

Årsregnskabet er **aflagt** i henhold til **gældende** lovgivning og efter de retningslinjer, der er fastlagt af Velfærdsministeriet i Budget- og Regnskabssystem for kommuner. Vi anser den valgte **regnskabspraksis** for hensigtsmæssig således, at årsregnskabet giver et **retvisende billede** af aktiver og passiver samt den finansielle stilling.

Movias årsregnskab er godkendt på bestyrelsesmødet den 22. maj 2008.

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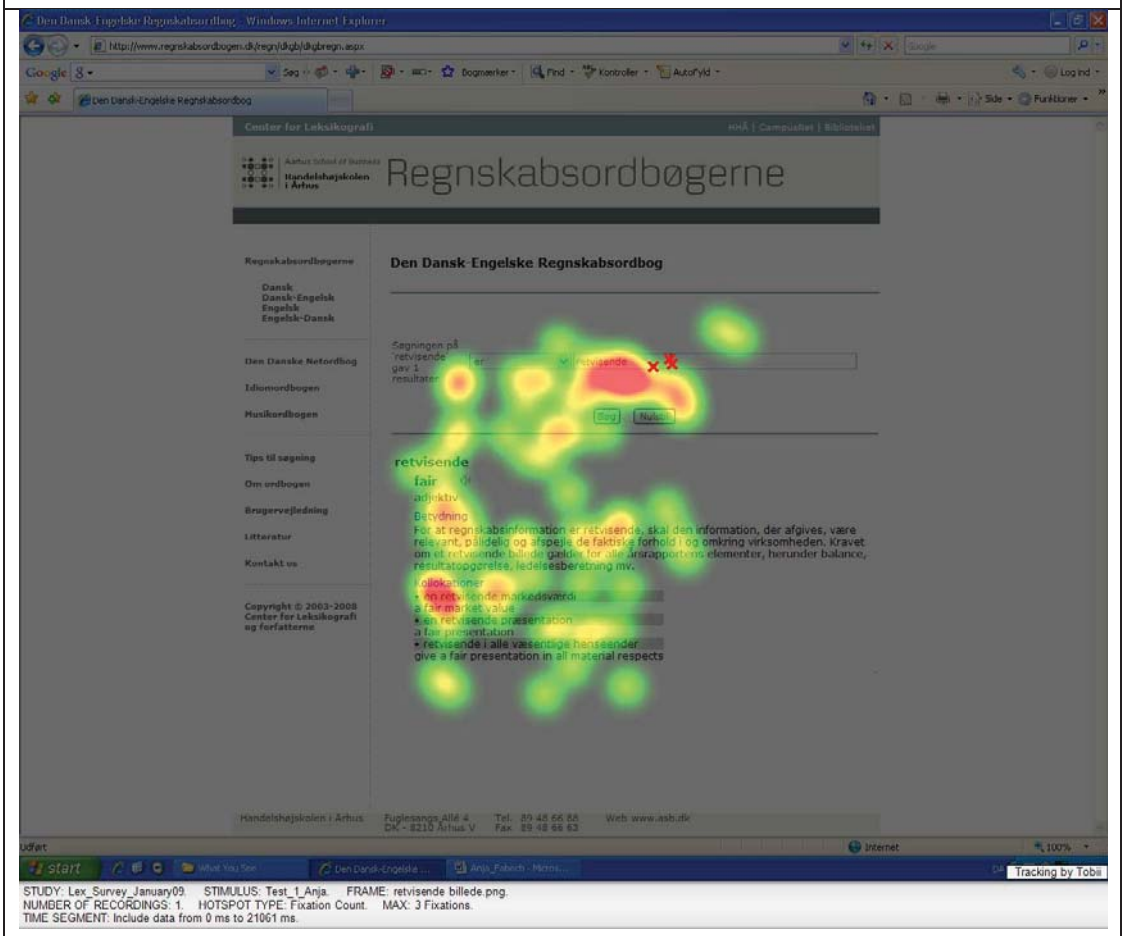
Johannes Sloth
Administrerende direktør

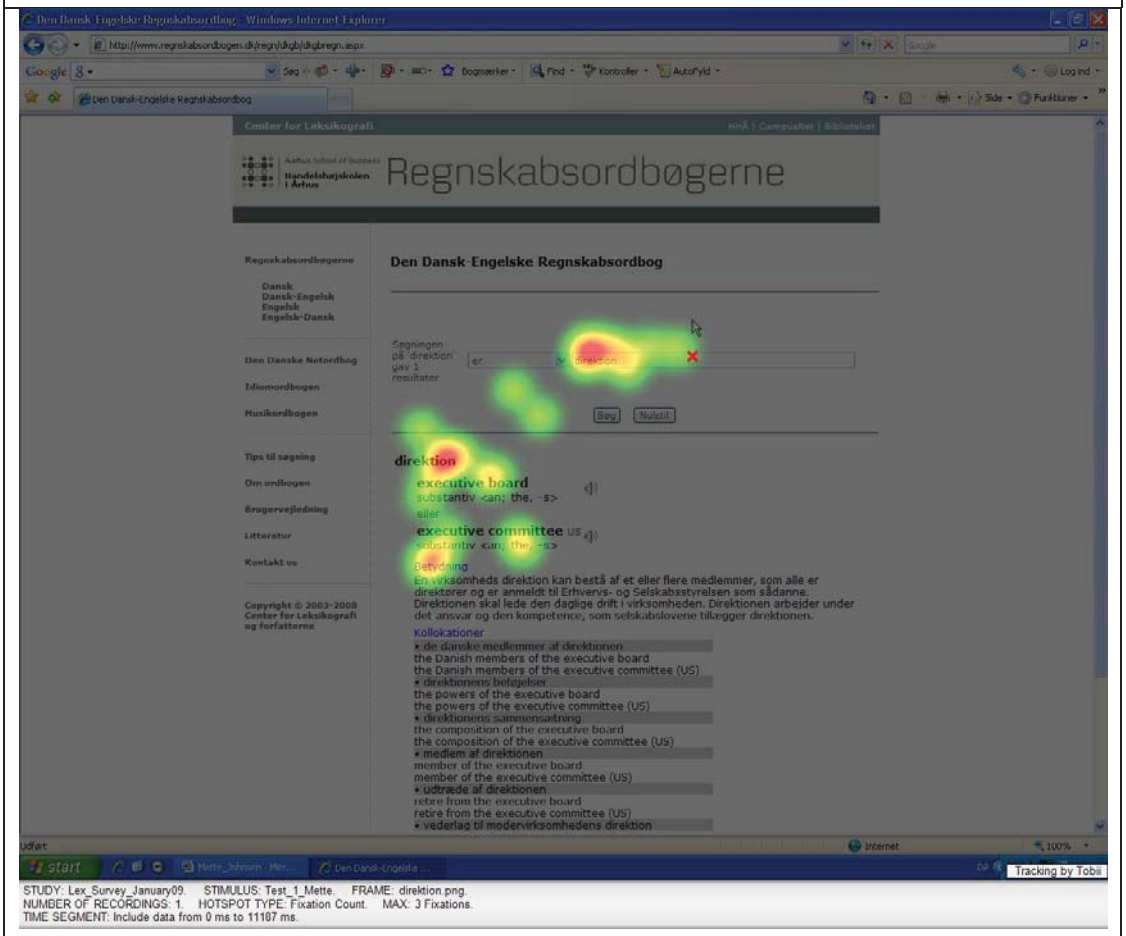
Appendix C. Hot Spot Charts

Hot spot chart of lemma ”retvisende billede” (participant D)

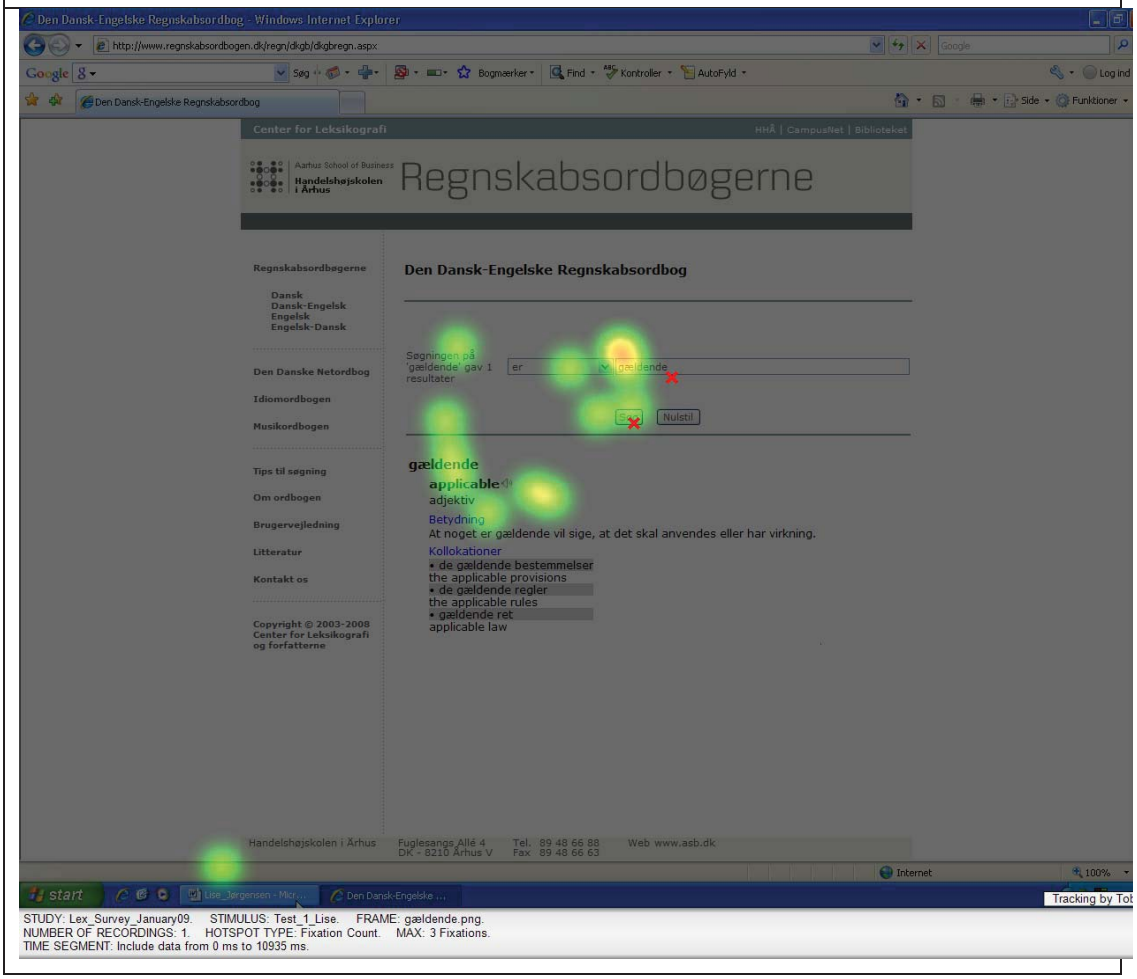


A hot spot chart offers a quick overview of user activity on a page. By means of colours it displays areas where users have had many and long fixations (red), areas where users have scanned briefly (green) and areas which users have completely ignored (grey).

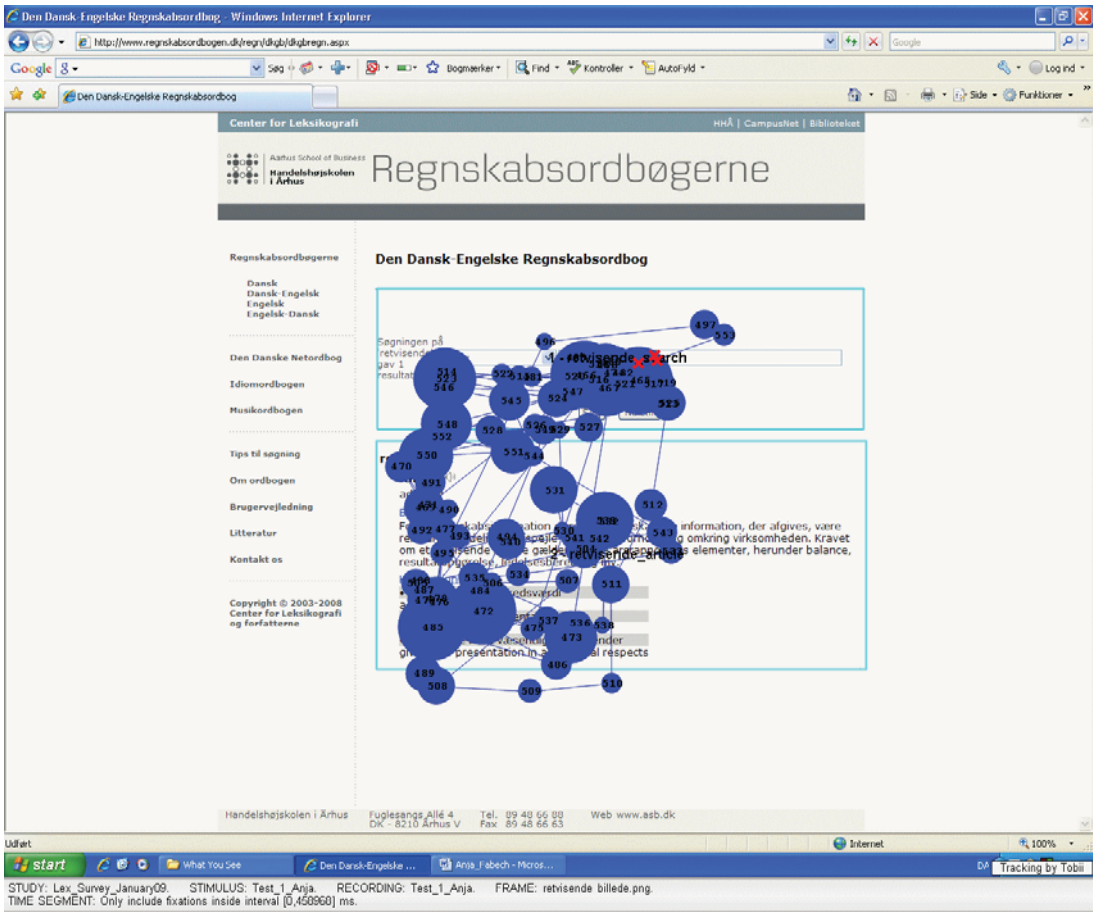
Hot spot chart of lemma ”direktion” (participant A)



Hot spot chart of lemma ”gældende” (participant F)

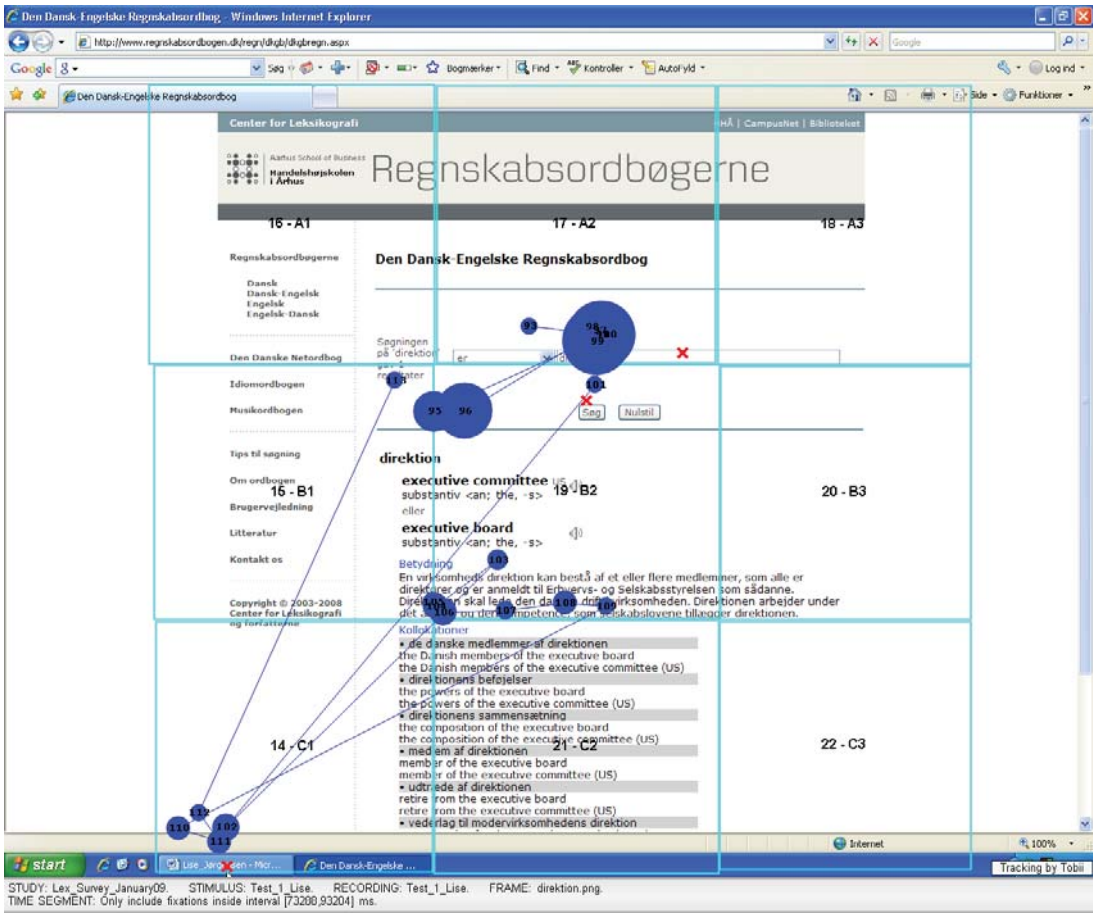


Appendix D. AOIs for Transition Matrix Experiment I



This screen dump from ClearView shows the two AOIs used in Experiment I. The screen dump also shows participant D's fixations and fixation numbers in connection with the lemma "retvisende billede".

Appendix E. AOIs for Transition Matrix Experiment II



This screen dump from ClearView shows the nine AOIs used in Experiment II. The screen dump also shows participant F's fixations and fixation numbers in connection with the lemma "direktion".