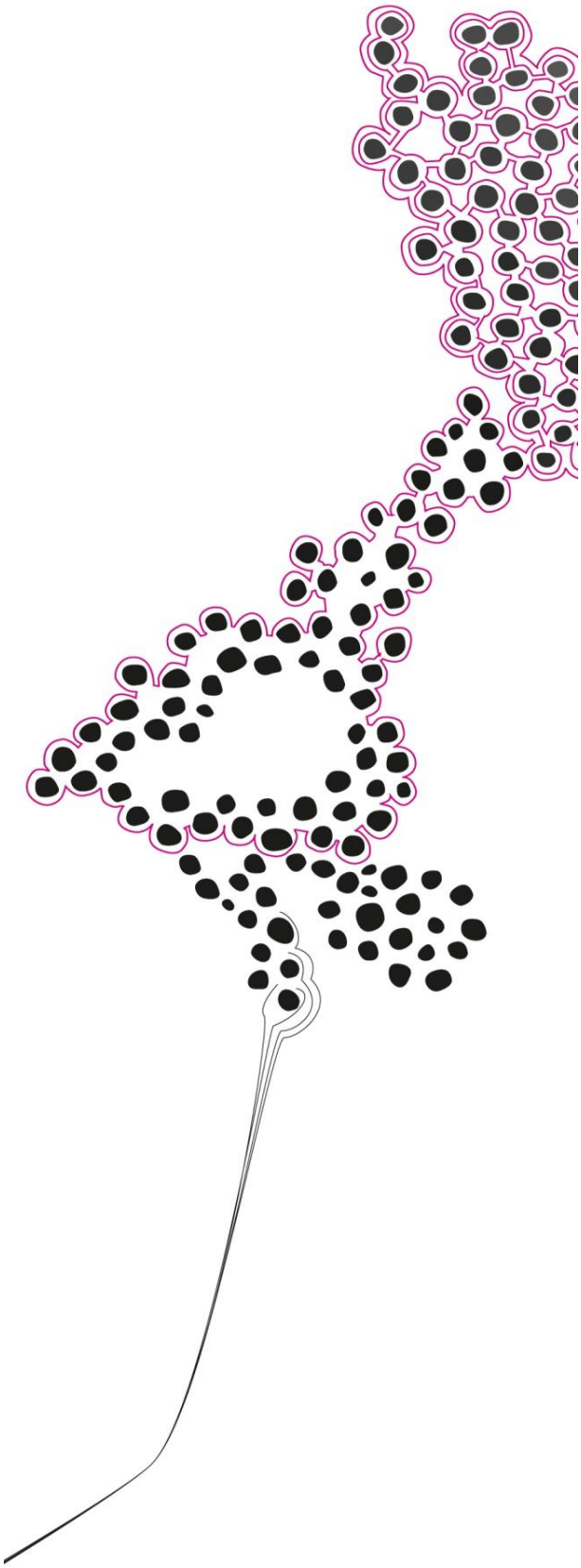

Beyond the first encounter: A longitudinal study about website navigation.

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Abstract

In Human Computer Interaction studies the usability of software or websites, in terms of efficiency, effectiveness and user satisfaction is rated. Participants are asked to perform specific tasks using the particular software or website and their performance is rated. In most cases these studies have cross sectional designs, measuring the performance of a number of participants at one particular moment in time. The power law of practice states that performance on tasks increases in terms of speed and accuracy with practice. In studies with a longitudinal design, thus rating the performance of participants over multiple sessions and therefore including the practice variable, this process of increasing performance can be mapped.

One of the main problems that occur when users of the World Wide Web perform information seeking tasks is dealing with the navigational structure of a website. User experiences often can be negative because of feeling lost or needing to much time to complete the task. Users make navigational choices based on their mental model of specific website structures. With time and experience these mental models are adjusted. The performance of a user on a navigational task is based on the fit between the mental model of the structure and the actual navigation structure of a website. Just as the power law of practice implies, the performance of users when navigating a website increases with practice, when their mental model is adjusted and fits more with the actual structure.

Website developers try to create structures that not only fit the mental model of users but also facilitate the learning process in order to reach a high level of maximum performance in the least amount of practice. In this longitudinal study is tried to get an idea to what extend navigation path length, a key factor in the concept of navigation path complexity, influences the learning process of users when it comes to navigational tasks on municipal websites.

Inhoudsopgave

1 Introduction

The World Wide Web, or in other words: the internet has without doubt been one of the greatest developments of the 20th century. At this moment one is able to access the internet almost anywhere in the world. Providing information, news, services and entertainment all over the globe, the World Wide Web proves to be of great use to over 2 billion people (Internet World Stats, 2012).

In order to assess the quality of software and websites, enabling to search and find information usability evaluations are applied. Those evaluations measure three aspects: Efficiency, effectiveness and user satisfaction (Kjeldskov, Skov, & Stage, 2005). According to Palmer (2002) navigation is one of the most important concepts influencing these aspects. He defines the concept of navigability as: *"The sequencing of pages, well organised layout, and concistency of navigation protocols"* and claims that navigation is an important design element which enables users to easily find the desired information on a website, without having to backtrack or getting lost in the structure. In his research Conklin (1987) claims that when a navigation structure increases in size, in terms of internal links between pages, it will become harder for users to keep track of their current position within the navigational structure and find out how to get from where they are at a certain point to where they want to be. This increases the possibility of feeling lost and disoriented. He calls this the *Disorientation Problem.* Feeling lost or having other difficulties when navigating is one of the main reasons for users to abandon websites (Ryu & Chen, 2013). Furthermore Katz and Byrne (2003) found that users tend to choose whether to browse (navigate through the menu structure) a website or not, based on an assessment of expected time and effort needed to do so. In most cases this assessment is made by just looking at the structure of the homepage. Laberge and Scialfa (2005) also confirm that nowadays difficulty in navigation, which mainly shows in having difficulties trying to find the desired information or getting lost on a websites is one of the main problems of users of the World Wide Web.

Therefore it's needless to say that improving the navigability of a website is one of the main challenges for website developers. Melguizo, Vidya and Van Oostendorp (2012) mention three key factors influencing the retrieval of information and feeling of disorientation on the web:

1. *The layout and menu structure of the website:*

   This focusses mainly on the type of menu structure used. The characteristics of a website are claimed to have a large influence in making the right navigational choices. Different menu structures create a difference in *breadth and depth* of the navigational structure, influencing the chance of getting lost or the time needed to find specific information (Katz & Byrne, 2003)

2. *User characteristics*

   Specific characteristics such as special ability are believed to influence the ability of users to deal with complex navigational tasks

3. *The complexity of the information finding task itself*

   Information seeking task can have specific characteristics which make them harder or easier to complete. Fang (2007) says users are expected to generate more errors and spend more time when executing difficult tasks in comparison to executing easier tasks.

Website developers cannot influence the characteristics of its users. However by taking observed information seeking behavior and expected user characteristics into account they can improve their website layout and structure in order to make the navigational tasks as easy and efficient as possible.

2 Navigation path complexity

Navigation tasks can be defined as *"sequences of actions performed by the searcher in the process of looking for information to satisfy a current information need"* (Melguizo, Vidya, & van Oostendorp, 2012). A website's structure can be visualized as an amount of nodes which are all linked together in a certain way, as shown in the figure below (fig 1). The different nodes represent different pages within the website. One node represents the actual homepage where a different node represents the page with the desired information. By using the menu structure and provided links on the different pages, users are able to navigate from the home page (or any other page) to the desired page. A user is assumed to follow the *path* that appears most likely to lead him to the specified target (Ryu & Chen, 2013).

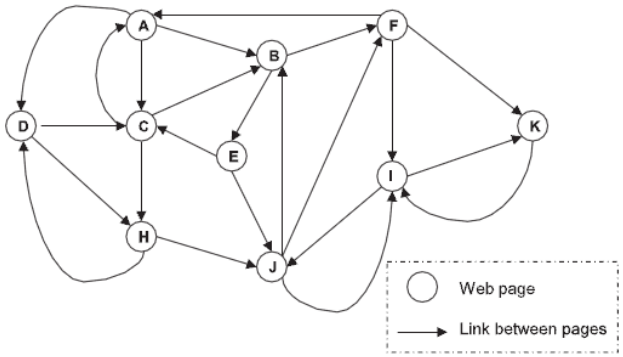

Figure 1 (Chen & Ryu, 2013): Navigation Structure example of a website with 10 pages.

Melguizo Vidya and Van Oostendorp (2012) define three aspects that influence the complexity of this navigation task or in other words: *Navigation Path Complexity*:

1. *Page complexity*

   Page complexity is about the complexity of locating and assessing the different navigation choices on each website. This for example is influenced by factors such as the visual design (Katz & Byrne, 2003) or de amount of outward links on a page (Ryu & Chen, 2013)

2. *Page information assessment*

   The difficulty users have to assess to which degree the information provided the page they are viewing is relevant in relation to their goal.

3. *Navigation path length*

   Navigation path length refers to the length of the path leading to the desired information. Obviously, with a longer path, a user will have to make more choices. This automatically means the user will have to deal with *page complexity* and *page information assessment* more often.

This research will mainly focus on the effect of navigation path length on the *performance* of users when executing information seeking tasks on a particular website. In this context when referring to path length, the smallest possible sequence of actions needed to reach the information goal is meant, rather than the actual length of the path the user takes. While developers aim to maximize users' performance, it is important to investigate to which degree certain factors, in this case path length, influence this performance. Furthermore, in this research the terms *information seeking task* and *navigation task* are used for the same concept and therefore can be equally substituted.

3 The process of learning.

In a cross-sectional study, where participants' performance is measured at a certain point in time, path length could be manipulated to rate its influence on user performance, perhaps contributing to the menu-depth vs. menu-breadth debate (Zaphiris, 1997). While cross sectional studies can be used for evaluating the usability of a certain website at a certain point in time or to compare the usability of one website with another, it neglects the fact that becoming familiar with a certain task or structure through practice may improve users' performance over time. However, while longitudinal studies are common in other fields of science, this is not yet the case in Human Computer Interaction studies. Even though evidence exists that to some extend users that are considered experts perform better at certain tasks than novice users do on the same tasks (Kjeldskov, Skov, & Stage, 2005). Therefore it could be interesting to assess the influence of path length in the long run. Research about practice states that *learning rate* is an important variable when modeling a learning process as a parameter indicating the rate at which one improves his performance between two separate trials (Cousineau & Lacroix, 2006) (Rosenbloom, 2006). A question that rises is if, and if so, to which extend, the path length involved in specific information searching tasks influences this learning rate. Will users actually improve their performance at a different rate when different path lengths are involved? Also, the asymptotic nature of *learning curves*, which will be discussed later, suggests that after a certain amount of trials a maximum performance is reached. Therefore another interesting question is whether the path length involved influences the maximum performance and the process of reaching it.

3.1 Mental models and schema theory

In order to understand how people learn and understand why getting familiar with software potentially increases performance, it is important to get some insight into *mental models* and *schema theory*.

A users' mental model of a website represents the patterns in which users structure and group information (Spencer & Warfel, 2004). In a more abstract sense Palmquist et. al.(2005) define mental models as a group or network of interrelated concepts that reflect conscious or subconscious perception of reality. This construction can be formed through experience, training and instruction. An example to illustrate the concept of mental models in practice: When you walk into a supermarket you have never been before in order to buy a specific product you often already have an idea of where to look for it, or perhaps where not to look

for it. Even though you have never been into this supermarket before, based on your experience with other supermarkets you formed a network of information based on which you make your decisions how to navigate through the store. When you see shelves with canned food, you know you will probably not find toilet paper in the same pathway. Assuming you are there to actually buy toilet paper you will pass this specific pathway without paying much attention. After finding your desired product you will probably look for the shortest way to get back to the front of the store because you assume that is where the cash registers are located. Primarily based on experience and logical reasoning you have a mental model of the general layout of supermarkets and you use it to navigate your way through this specific one. The same goes with websites. When people are looking for specific information a user follows the path he thinks is most likely to lead him to the target page, based on his current mental model of the way information is structured on particular websites. Therefore the performance of users is the highest on websites that have little discrepancy between its actual structure and the users' mental model (Ryu & Chen, 2013).

Schema theory is based on the same idea of people having mental *schemas* of reality and can be used to explain the way people develop these mental models over time. Rousseau (2001) states a so called *schema* is a cognitive organization of conceptually related elements and represents a prototypical abstraction of a complex concept. Schemas gradually develop from past experience and guide the way new information is *organized*. So while it can be a useful challenge to try to make reality meet the mental model of people as good as possible, people also tend to change their mental models over time when discrepancy occurs or keeps occurring or new information is presented. According to schema theory *learning* either involves *accretion, turning* or *restructuring.* Accretion is the process of adding bits of information to existing schemas while turning and restructuring describe the processes of respectively making minor or major structural changes to those existing schemas. In some cases old schemas are replaced by totally new schemas as a whole (Fang & Holsapple, 2007). Restructuring or even obtaining new schema's take significantly more effort in the learning process than accretion or turning, but might be necessary when a certain amount of new information is presented. This hints to the fact that path length might influence the process of developing schemas, since longer path length means more information to process and thus could result in a higher level of discrepancy. Which, in turn, might cause the need for more elaborate modifications to the existing mental model. Also, presumably a more sophisticated navigational structure of a website requires a more sophisticated mental model from the user.

3.2 Learning Curves

The power law of practice implies that the process of learning through practice can be described by a function. This function has the shape of a curve and is called a *learning curve*. These learning curves are used in different fields of psychology in order to depict how the accuracy and speed of performing a specific task improves with practice. An example of such a curve is shown in figure 2. While curves for each task vary, they all have the same tendency of showing dramatically increased performance initially and then after continued practice, this effect slowly diminishes when the performance increase between trials lowers (Speelman & Kirsner, 2006). When the different values of the rated performance for a specific task are put together in a diagram, using statistical procedures the parameters of the best fitting curve can be estimated and the curve can be plotted. (Cousineau & Lacroix, 2006). Using these parameters the plotted function can be extrapolated over more practice sessions and variables like future performance, the rate at which the performance will increase or the level of maximum performance (suggested by the asymptotic nature of the learning curves) can be predicted.

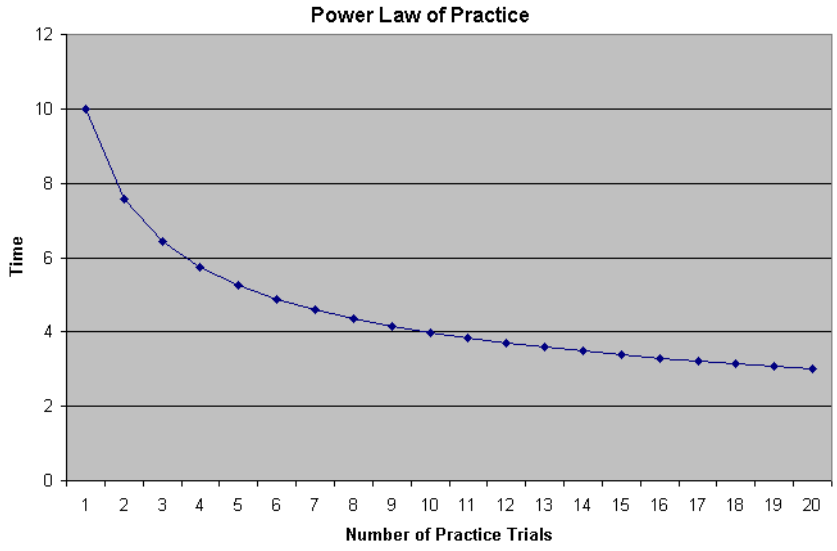

Figure 2: an example of a learning curve

4 Hypotheses

In this research navigation performance of website users on information seeking tasks with varying path length are measured and compared over time. This is done in order to get an insight in the effect of this variable in the learning process of users, assuming there exists a difference between novice and expert users, thus performance increases with the number of tasks executed. Therefore the main hypothesis to test is:

There exists a difference between initial performance and performance after a certain amount of trials.

As will be discussed later on in the method section, two metrics will be used to rate performance: The time it takes a user to execute the task completely (*Time on Task*) *and* the amount of errors (*Amount of paths taken minus the ideal path length)* made while executing the task. The above hypotheses suggest that both variables will decrease significantly while the user executes more tasks or repeats the same task.

Assuming a learning effect is found, the question remains if this learning effect is different for different path lengths. Therefore there are two sub-hypothesis. The first being:

SH1: Maximum performance is reached significantly faster with low path length tasks than with high path length tasks.

Assuming it takes more effort from a user to form or adjust a more elaborate and fitting mental model, maximum performance, both in terms of Time on Task and amount of errors, will be reached in fewer trials with easier tasks. Also this implies that there is a smaller difference between initial performance and maximum performance on less difficult tasks, or even between two trials.

In order to assess the influence of path length on navigational performance over time it is interesting to compare maximum performance on low path length tasks with maximum performance on high path length tasks:

SH2: Maximum performance reached varies significantly with different path lengths.

Logical reasoning suggests that a navigation task with a longer path length requires more time in total and leaves more room for errors that navigation tasks with a short path length, since more actions need to be executed to complete the task. However, assuming that maximum performance on a task only involving 1 path (action) means that the specific users exactly

knows where to find the information, the time it will take the user to find this information would be the same as the time it takes for the user to physically perform the required actions. Assuming maximum performance does *not* vary with path length, a task with a longer path can be seen of a sequence of tasks involving only 1 path. Therefore, defining the time needed by the user to perform a task (in case of maximum performance) with just 1 action as *T seconds*, the time it takes for the same user to perform a task with *N* actions, given maximum performance does *not* vary with path length, could be estimated as *NT* seconds. A significant difference between this estimate and the actual time on task would suggest a difference in maximum performance.

5 Method Section

This section contains information about the actual testing phase. The website used for the research, the participants, the navigational tasks and the variables measured will be explained.

5.1 The website

This research is conducted using the following website: www.Hengelo.nl. This is the municipal website of the town of Hengelo (The Netherlands). It provides all kinds of information about this town and its government for people living in Hengelo, potential visitors like tourists or anyone else that could be looking for information about Hengelo. The main benefit for using a municipal website is that most of its content, and therefore also the way the website is structured, is not likely to change often. Also, since it needs to be accessible for anyone interested, the navigational structure should be easy to use for first time visitors. A card-sorting study done by Selina Baumann (2012) confirms the fact that this particular municipal website can be considered well-structured and easy to navigate. Therefore can be assumed that navigating this website is most likely based on logical reasoning instead of plain guessing.

5.1.1 Ways to navigate the website

The website has several different ways to navigate the website. On the homepage a 'search'-option can be found. Also there is a bar with some navigational options found at the top of the website (figure 3) containing a link to the so called sitemap. This sitemap gives a quick and accessible overview of all pages that can be accessed on the website.

Figure 3: the search box (red) and the navigation bar (blue) found on the homepage

Besides this navigation bar and search box, a hierarchical menu and a menu with several direct links to common topics can be found. Both are shown below in figure 4. When options provided by the hierarchical menu are accessed, the menu with the direct links disappears.

Instead, a ‘quick-to’-menu appears at the bottom of each page appears (figure 5). For practical reasons the participants are asked *only* to make use of the hierarchical menu and any links provided on opened pages. However, the submenu “Gemeentebalie” provides access to all information by a path length of 3. In order to create different tasks with varying path lengths, participants are told not to use this sub menu. At last, also the submenu “Actueel” is not used, since this submenu contains information that is likely to change a lot. So in short, participants were instructed only to use the hierarchical menu excluding the submenus: “Gemeentebalie” and “Actueel”. When the participant assumes it’s needed in order to find the desired information, any clickable links that appear on the pages that are accessed by using the hierarchical menu can also be used.

Figure 4: The hierarchical menu (red, left) and the direct links (blue, right)

Figure 5: the 'quick-to'-box found on the bottom of most pages

In the navigational structure of www.Hengelo.nl almost all information can be found by traversing 3 paths maximum. Most of the links that suggest a 4th path lead to the homepages of new websites or open pfd-documents. Since browsing a new website or PDF-document in order to find information involves starting a completely new navigation task, these are not included in the research.

Most pages that are accessible by traversing 1 path contain a short introduction to a particular topic. Specific information on these particular topics can then be found by traversing 1 or 2 more paths.

5.2 Tasks and Instructions

5.2.1 Instructions

Each participant is tested in 3 sessions with a break of 2 hours between the sessions. At the beginning of the first session each participant is instructed verbally by the researcher. The researcher makes use of some quick examples on the website of Hengelo to aid in this instruction process. Also the participant is provided with written instructions. An example of these written instructions can be found in the appendix. After the participant has fully understood all the instructions, the session begins. At the beginning of the 2nd and 3th session the participant is provided with the written instructions again and is also again asked if he fully understands all of it.

5.2.3 Material used

Each session each participant is provided with an instruction form and a form with 6 questions about different topics about Hengelo. The instructions for each session are the same, but the questions differ. So the participant is provided with 18 different questions in total. Also a laptop is used. On the screen (desktop) of the laptop two shortcuts can be found: one to access www.Hengelo.nl and one to access Morae Recorder, the program used by the researcher to record each session. See figure 6 below. Because each session is recorded, the researcher does not need to be present during the testing and is therefore unlikely to interfere with the process.

Figure 6: shortcuts found on the laptop-screen (desktop)

5.2.4 tasks

In each session the participant is asked to answer 6 different questions about different topics concerning Hengelo. Each session contains 6 new questions. In total the participant needs to answer 18 questions. All 18 questions are the same for each participant, also the questions provided in each session are the same for each participant. All information can be found on the website. Therefore the participants were told in advance that whenever a new website or PDF-document opens, they are looking in the wrong place.

The participant is asked to perform the following sequence of actions in order to answer each question:

1. Read the question
2. Use the provided shortcut to open the website of Hengelo
3. Navigate the website in order to find the desired information
4. When the desired information is found, note the specific page number (found in the URL of the page, see figure 7) in the space provided below the question
5. Close the page using the "x-button" on the top right of the screen

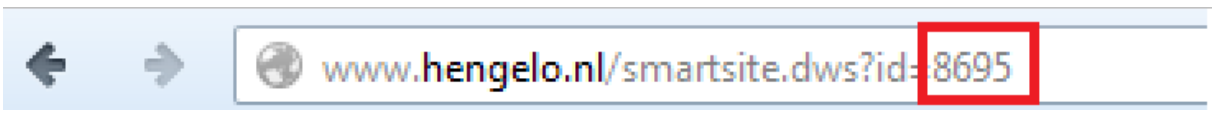

Figure 7: part of the address-bar of the internet browser. The page number is marked by the red square.

In this way, when examining the recordings after each session, the researcher can see when the participant starts a specific navigation-task and when the participant finishes it. A

navigation task in this case means the process that *begins when assessing the homepage, deciding the first navigational choice to make and ends after assessing the last page in the navigations sequence and the participant has found the desired information*. The time it takes for each participant to note the page number may slightly differ, but is not considered significant.

The reasons only the page number needs to be noted, instead of a full answer are: 1) Some people write larger answers than others. Therefore the time between *having found the desired information* and *closing the website, signaling the end of the task* may differ significantly for each participant and therefore might cause errors in the results. And 2) the research is not about *answering the questions correctly* but about *navigating the website and determining the desired information is found*. Therefore, for practical reasons, the participant is only asked to give the page-number instead of writing an elaborate answer.

5.2.5 The Questions

Each session contains 6 questions: 2 for witch a navigation task with a path length of 1 is needed (PL1-questions), 2 PL2-questions and 2 PL3 questions. Respectively considered as tasks with a short, normal and long path length. The reason that is chosen to use these specific lengths is that fact that most pages can be assessed within a maximum path length of 3 paths. The specific questions used in each session can be found in the appendix. For each session the different questions are grouped randomly in terms of PL. This is to ensure participants do not recognize a pattern, which might interfere with the learning process in an unwanted way.

PL1-questions

These questions mainly involve assessing the homepage of www.Hengelo.nl

PL2-questions

The total of 6 PL2 questions are divided into 2 categories, based on the corresponding submenus of the hierarchical menu: *"Ondernemen in Hengelo"* and *"Bestuur en Organisatie"*. Each session contains 1 question of each category. The reason why there is chosen to use categories is to try to make the tasks in some way similar, while still using different questions. Because each page varies in terms of the difficulty of the page assessment task, one PL2-task can be more difficult than another PL-task which involves 2 completely different pages. This could interfere with the results and cause a bias. By grouping the tasks in

two categories, at least the first page is the same and therefore the tasks somewhat similar. Of course, this will result in a separate learning-curve for each category.

PL3-questions

The same goes for the PL3-questions as described above for the PL2-questions. The categories used for these questions are: *"Wonen in Hengelo"* and *"Bezoek Hengelo"*.

All questions are chosen in this way that the answers are either found on the first part of the page, easily found under specific headers or are easily noticed because of reasons like color or text size. In this way is tried to minimize the difference in individual page assessment difficulty. This is done in order to try to make the tasks even more similar and make *path length* the main variable discriminating between the tasks and therefore deciding the difficulty.

5.3 Measuring Performance

From all participants their performance on every individual navigation task was measured. In order to do so without interfering with the test, each session of every user was recorded using special software. This software records everything that happens on screen during the session, so it is possible for the researcher to see every performed action by the participant, after the test is finished. In order to rate the individual performance, two measurements were taken: *Amount of navigational errors (ANE)* and *Time on Task (ToT).*

Amount of errors (task accuracy)

Every task selected has a specific *ideal path length*, being the shortest route from the home page to the page were the desired information can be found (the *target page*). In case the answer to the question could be found on multiple pages, the one that can be accessed through the shortest path length is selected. The *amount of navigational errors* made by the participants during the task is measured by taking the difference between the actual amount of navigational actions (navigating from one page to another) taken by the participant and the least amount of actions required (ideal path length) for the specific task.

Time on Task (task speed)

For every individual task the time it takes for the participant to successfully complete this specific task is measured. To make sure the same process is measured in the same way each time a participant performs a task, timing starts when the website of Hengelo is opened by the

participant, using the provided shortcut and ends when the participant closes the internet-browser again.

With these measurements can be tested if the participants increase their performance on these navigational tasks either in terms of accuracy or speed, or both. Based on these measurements fitting learning curves could possibly be created by using statistical software. These learning curves can then be compared in order to look for differences in the learning processes for tasks with different path length.

5.4 Participants

The research was conducted over 10 participants. A few more details are explained below.

Novice versus Expert

The term *expert* suggests that, in contrast to people that are rated *novice*, the person in order is already familiar with the concept, meaning he or she has already been through a potential learning process. This does not necessarily mean this person has already reached his or her maximum performance level and is not still learning. However, as the shape of learning curves suggest, the effect of learning between trials becomes smaller over time and the expert could be close to his maximum level of performance.
Therefore, to be able to accurately notice a potential learning effect, is chosen to work with novice users. Since in modern society everyone grows up using the internet it would be difficult, if not impossible, to find participants that are not familiar browsing websites. Therefore, in this research *novice* means that the participants never browsed the website used in this research (www.Hengelo.nl) before and never browsed a website of this particular kind (municipal websites) before or at least have no active memory of doing so in the past.

Language

To make sure the familiarity of the participants with the language used on the website would not be an interfering variable during the research, only participants speaking Dutch as their first language were selected.

Education

Since intelligence and learning capabilities may be likely to be interfering variables in this research all participants selected are currently following higher education.

Age and sex

All participants selected are in the age group of 20-25. Most of them (9) are male and 1 of them is female.

6. Data-analysis

In this section, all data derived from the testing will be analyzed and discussed. A summary of all findings and plausible explanations and meanings for these findings will be discussed in the results section. In this section the 6 different tasks will be referred to as *PLX(y)*, *PL* being the abbreviation for *Path Length*, *X* being the specific path length and *y* being either category 1 or 2 from the specific task. A more detailed description is given in table 1.

Table 1: Description of the different task abbreviations used. The questions referred to can be found in the appendix.

Task	Description	Questions involved
PL1(1)	All navigation tasks with path length 1 that are asked first in each session	Session 1: Question 1 Session 2: Question 1 Session 3: Question 3
PL1(2)	All navigation tasks with path length 1 that are asked second in each session	Session 1: Question 2 Session 2: Question 4 Session 3: Question 6
PL2(1)	All navigation tasks with path length 2 belonging to the theme: *Ondernemen in Hengelo*	Session 1: Question 3 Session 2: Question 2 Session 3: Question 2
PL2 (2)	All navigation tasks that with path length 2 belonging to the theme: *Bestuur en Organisatie*	Session 1: Question 4 Session 2: Question 5 Session 3: Question 5
PL3 (1)	All navigation tasks with path length 3 belonging to the theme: *Wonen in Hengelo*	Session 1: Question 5 Session 2: Question 6 Session 3: Question 1
PL3 (2)	All navigation tasks with path length 3 belonging to the theme: *Bezoek Hengelo*	Session 1: Question 6 Session 2: Question 3 Session 3: Question 4

6.1 Amount of Navigational Errors (task accuracy)

The first of the two variables measured is the amount of navigational errors (ANE) made in the navigation process. This metric was derived by taking the difference between the smallest possible (or: ideal) path length for a specific navigation task and the actual path length of the complete navigation action performed by the participant completing the same task. Looking at the data, two main types of navigational errors were made:

Type 1 Errors: target-page assessment errors

In these cases the participant did reach the target page during the navigation session, but failed to locate the required information to answer the question or did not assess the

information as relevant. Therefore, the participant continued the navigation task until he did find the required information, either by returning to the target page or assessing information on different pages as relevant for answering the specific question asked.

Type 2 Errors: Route errors

In these cases the target page was visited only at the end of each navigation session and was also identified as such by the participant. However, the participant did differ from the ideal path length during the process. Where Type 1 errors are primarily based on failing to assess a specific page or maybe not even assessing it at all, these errors tend to be mainly based on not knowing which menu option to use. Or in other words: When these navigation errors occurred during the process the participant did not seem to know where he could find the information and/or what route to take to the target page.

In some cases type 1 and type 2 errors were combined in the same navigation task. In those cases the participant did reach the target page during the process, but not with the smallest amount of navigational steps possible *and* also did not identify the target page when visiting it the first time in the process. In 42% of all cases where navigational errors were present, only type 1-errors were involved, meaning that in those cases the participant did find the right page taking the shortest route possible. Figure 8 shows the total amount of errors made in each session, grouped by PL-task.

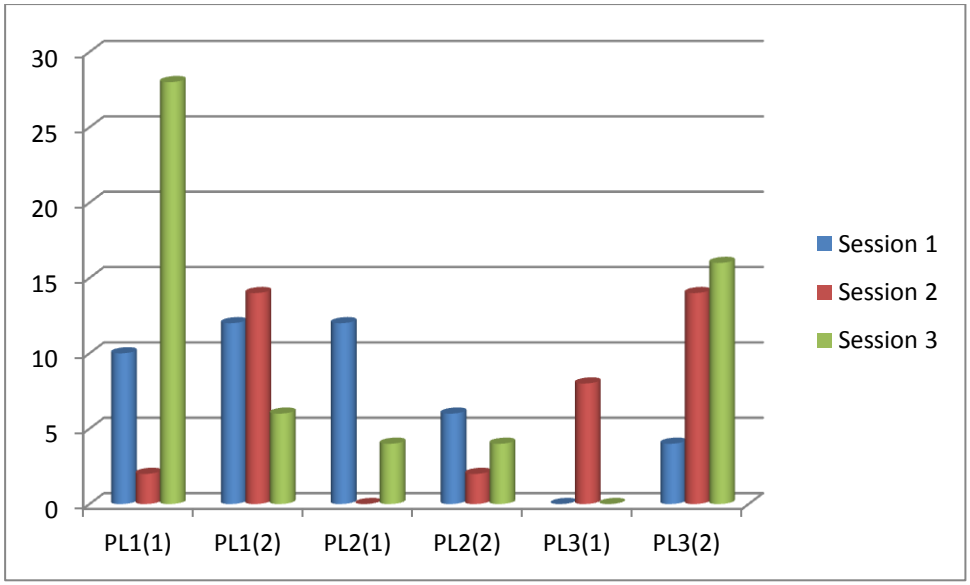

Figure 8: Total ANE for each session, grouped by PL-task

The figure only shows a downward trend in the amount of errors for the PL3(1)-task. But, in contrast, an upward trend is visible for the second PL3-task. The high amount of errors in some cases could be caused by individual participants making a relatively high amount of navigational mistakes. However, when the amount of errors is averaged by the amount of participants (figure 9) responsible for the mistakes nothing special can be found regarding possible learning effect.

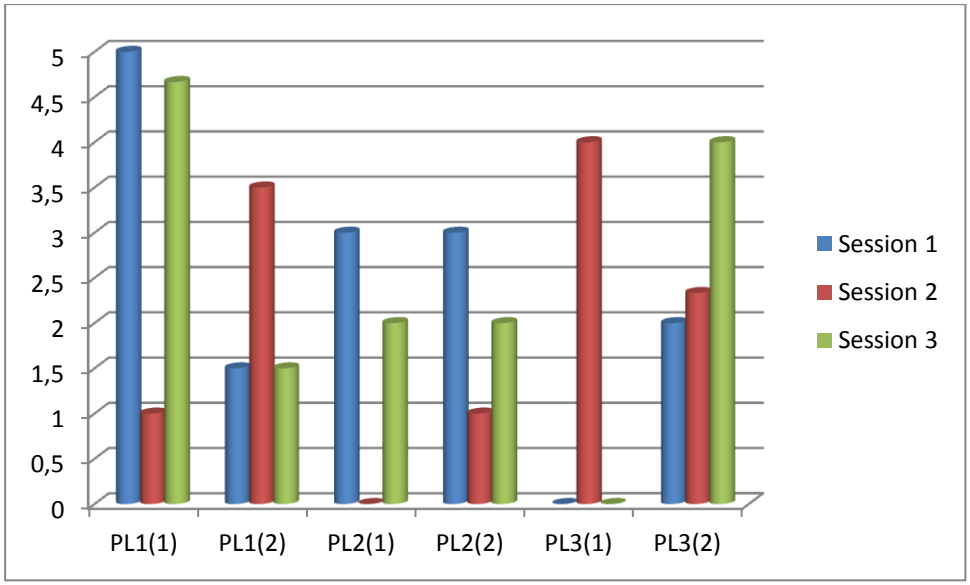

Figure 9: Amount of errors each session averaged by the amount of participants responsible for the errors

6.2 Time on task (task speed)

6.2.1 Increasing Performance Overall

When looking at the specific Time on Task (ToT) for all tasks in each session, an increase of performance can be seen to different extends. There are 4 main kinds of increased performance:

- A decrease of ToT between session 1 and session 3. (S1>S2)
- A decrease of ToT between session 2 and session 3. (S2>S3)
- A decrease of ToT between session 1 and session 3. (S1>S3)
- A decrease of ToT between all sessions. (S1>S2>S3)

The table below (table 2) shows in how many cases which kind of decrease in ToT was noticed in the data. Keep in mind that some cases fit in several categories. For example: A case where the last variant of ToT-decrease is present also fits in all other categories. In the

same way, a case where a decrease of ToT is noted between S1 and S3 may also show a decrease in ToT between S2 and S3, but not between S1 and S2. So, for example, the bolded 80% in table 1 states that in 80% of the participants shows *at least* a decreased ToT for the PL1(2)-task between session 2 and session 3.

Table 2: Cases of ToT-decrease for each Path Length(PL)- task

Task	**S1>S2**	**S2>S3**	**S1>S3**	**S1>S2>S3**
PL1(1)	80%	0%	20%	0%
PL1(2)	60%	**80%**	10%	40%
PL2(1)	60%	40%	60%	20%
PL2(2)	100%	40%	100%	40%
PL3(1)	40%	60%	20%	20%
PL3(2)	20%	60%	60%	20%

While for each PL-task at least some kind of ToT-decrease is visible, very few cases actually show a decrease in ToT for each session. However in 52% of the cases that do not fit in the S1>S2>S3-category navigation errors are involved in either the second or thirds session, or even in both. As discussed above navigation errors can be divided in two categories:

1) *The goal page is visited during the process, but is not assessed as such at that moment* and 2) *All errors are made before eventually reaching the goal page*. The cases where type 1-errors are present can be filtered out by measuring the time between opening the website and leaving the target page for the first time. By doing so, the part of the ToT caused by failing to identify the target page as such, rather than making wrong choices in the navigation route, is not taken into account. After all cases involving navigation errors from the first category are corrected, the results become like shown in table 3. Although for every kind of task several changes in individual ToT are made because of this correction, changes regarding decrease of ToT between sessions only occur for the PL1-tasks.

Table 3: cases of ToT-decrease for each Path Length(PL)- task after correction

Task	S1>S2	S2>S3	S1>S3	S1>S2>S3
PL1(1)	100%	40%	80%	40%
PL1(2)	80%	60%	60%	40%
PL2(1)	60%	40%	60%	20%
PL2(2)	100%	40%	100%	40%
PL3(1)	40%	60%	20%	20%
PL3(2)	20%	60%	60%	20%

To get a better view of where most cases of decreasing ToT between sessions occur, the main categories can be divided into more specific categories. This will also filter out all cases that are now part of multiple categories.

1. *A decrease of ToT between S1 and S2, but not between S2 and S3*
   (S1>S2 AND S3>S2)
2. *A decrease of ToT between S2 and S3, but not between S1 and S2*
   (S2>S3 AND S2>S1)
3. *A decrease of ToT between S1 and S3, but not between S1 and S2*
   (S2>S1>S3)
4. *A decrease of ToT between S1 and S3, but not between S2 and S3*
   (S1>S3>S2)

Figure 10 shows the percentage of cases of decreasing ToT between sessions when the more specific categories are used and therefore gives a more detailed view between which sessions performance increased. All data used is from after the correction mentioned earlier. For example, the first bar on the left shows that, after correction of the data based on type 1 navigation errors, 60% of the participants shows a decreased ToT for the PL1(1)-task between session 1 and 2 *but not* between session 2 and 3.. There are no participants that show a decreased ToT on this task between session 2 and 3 *but not* between session 1 and 2 and also no participants that show a decreased ToT between session 1 and 3 *but not* between session 1 and 2. Furthermore 40% of the participants show a decreased ToT between sessions 1 and 3, but not between sessions 2 and 3. Stating that all participants that showed a decreased ToT between sessions 2 and 3 and/or a decreased ToT between sessions 1 and 3 *also* had a decreased ToT between sessions 1 and 2. Since all categories mutually exclude each other,

from the graph can be derived that for 4 of the 6 tasks 100% of the participants shows some decrease in ToT at least somewhere in the process. For the PL1(2)-task and the PL3(1) –task these percentages are respectively 80% and 60%.

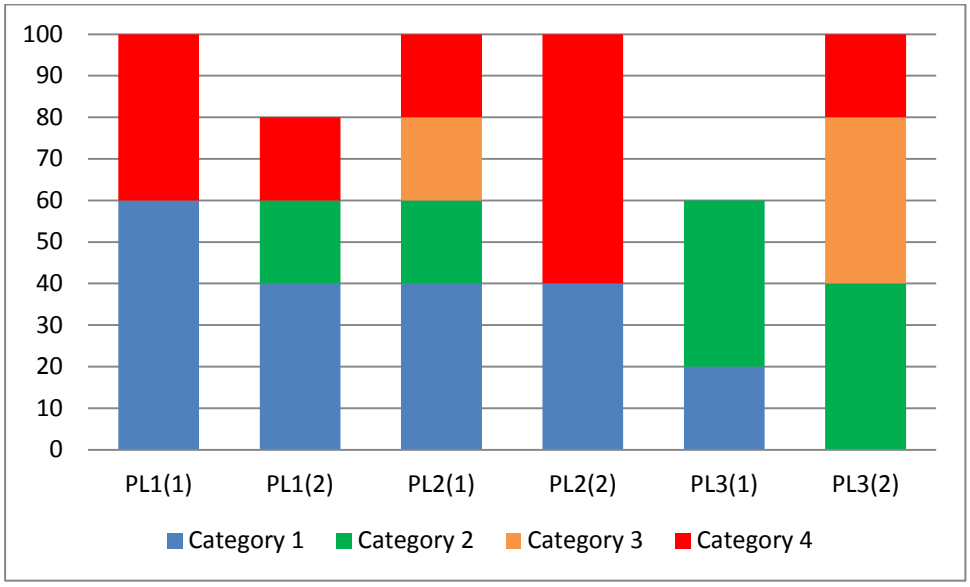

Figure 10: cases ToT-decrease between sessions as a percentage of the total amount of cases for each kind of task. The different categories are: 1: (S1>S2 AND S3>S2), 2: (S2>S3 AND S2>S1), 3: (S2>S1>S3), 4: (S1>S3>S2).

Based on these results can be stated that for all 3 path lengths task speed increases at some point during the process. However there are very few cases where performance increases between each session, suggesting a significant learning effect over time. There can be several reasons for the lack of results indicating a steady learning process, which will be discussed in the results section.

6.2.2 Increasing task speed on individual tasks

Even though there is not enough evidence to be found in the data for a significant learning effect, there might be a visible difference in task speed between the different tasks. Figure 11 shows the average ToT for each session grouped by task. Then for each PL the two graphs are averaged again and shown together in figure 12. Again, the data retrieved after the correction for type-1 navigation errors is used.

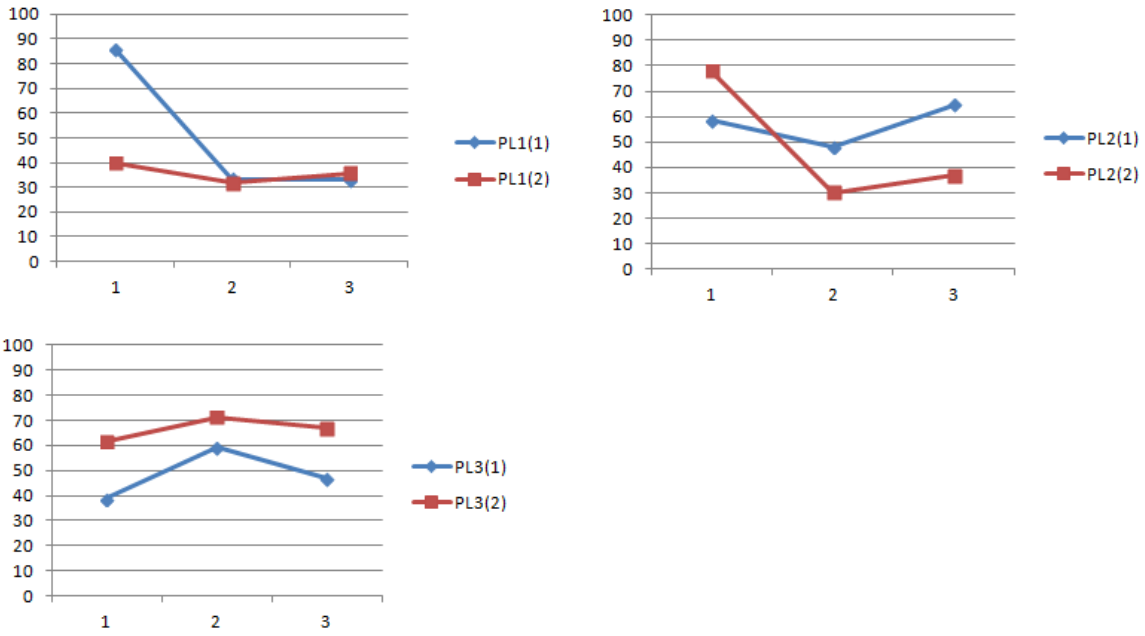

Figure 11: Average ToT in seconds for each session grouped by PL-task

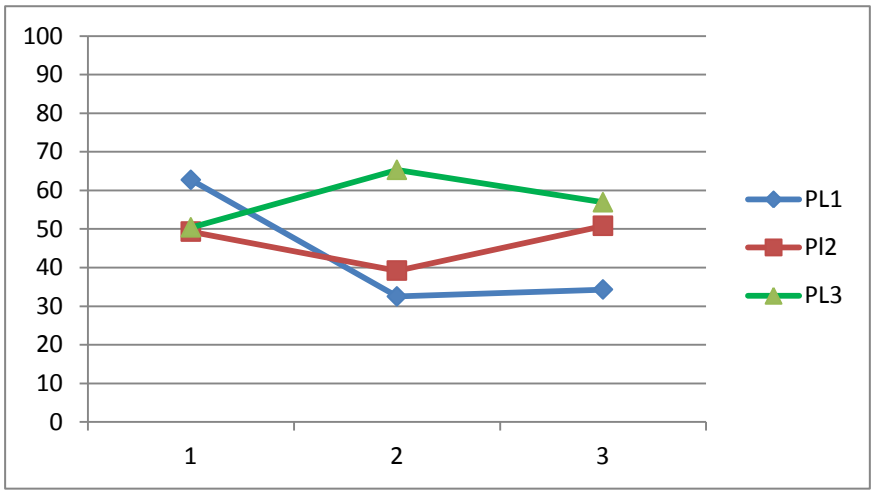

Figure 12: Average ToT in seconds for each PL-task after averaging both variants of each PL-task

As expected, these graphs also do not show any continuous learning. Therefore not much can be said about the individual learning processes and rates for the different path lengths.

6.2.3 Predicting the learning process

Since the data does not show any continuous learning no plausible learning curves can be constructed. Therefore nothing relevant can be said about the predicted learning process over more than 3 sessions, nor can the maximum performance in terms of Time on Task be predicted for any given path length.

6.3 Differences between the Path Lengths

Even though the results do not show a continuous learning effect, a difference in both terms of task accuracy as task speed can be detected. Table 4 shows the different ToT all sessions and grouped by path length. The Average ToT is also averaged over the amount of paths for each task.

Table 4: Average ToT for each PL task, with both categories for each task taken together.

	PL1	**PL2**	**PL3**
Average ToT	43 seconds	55 seconds	58 seconds
Average ToT/PL	43 seconds	27,5 seconds	19,33 seconds

The first row suggests the ToT increases with path length. This is not surprising since tasks involving a longer path length require more navigation actions. However, with SPSS no significant difference between the average ToT for each task is found: *F=1.794, P=1.72*. This means the data derived from the testing does not provide sufficient evidence stating that there is *any* difference in average ToT between the three kinds of tasks. In other words: There is no evidence that the total time a random user needs to complete a task varies with path length involved.

The second row suggests that the time needed for traversing 1 path decreases when the total amount of paths involved increases. Considering the time it takes for a user to traverse 1 path is based on the *time it takes for the user to assess the current page* and *the time it takes to decide which menu option to choose after deciding the current page is not the target page*, the data suggests that the time needed for either one or both of these variables decreases. The 95% confidence intervals in figure 13 show that, with 95% certainty, it can be stated that:

- The time spend per path on PL1-tasks is between 3 and 29 seconds *longer* than the time spend per path on PL2-tasks
- The time spend per path on PL1-tasks is between 11 and 37 seconds longer than the time spend per path on PL3 tasks
- There is no significant evidence that time spend per path on PL2-tasks is longer or shorter than the time spend per path on PL3-taks

Multiple Comparisons

Dependent Variable: pathmean

Bonferroni

(I) task	(J) task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	15.81667*	5.31328	.011	2.8461	28.7872
	3.00	24.02222*	5.31328	.000	11.0517	36.9927
2.00	1.00	-15.81667*	5.31328	.011	-28.7872	-2.8461
	3.00	8.20556	5.31328	.378	-4.7650	21.1761
3.00	1.00	-24.02222*	5.31328	.000	-36.9927	-11.0517
	2.00	-8.20556	5.31328	.378	-21.1761	4.7650

*. The mean difference is significant at the 0.05 level.

Figure 13: 95% confidence intervals for the differences in time spend per path for each PL-task.

7. Conclusions and Discussion

Whilst there is some discussion on the exact way to model the law of practice (e.g. Rosenbloom (2006), Heathcote et. al. (2000), Lacroix & Cousineau (2006)), this law states that performance increases with practice and thus *Time on Task* decreases while the user gets familiar with the system. Therefore, given the test participants had only few or even no prior experience using a website or software, the data received from a longitudinal study on user performance should fit with a so called *learning curve* (Cousineau & Lacroix, 2006) with, in case *Time on Task* is used as a performance metric, a downward slope that gets less steep when the amount of trials increases and eventually reaches a horizontal asymptote, suggesting a level of maximum performance (Speelman & Kirsner, 2006). When looking at the data for each individual path length task (PL1(1),…. PL3(2)) most cases do show a decreased ToT between at least two sessions and except for the PL3(1)-task at least 60% shows a decreased ToT between session 1 and 3, suggesting this downward slope. Only in a few cases performance decreased between all three sessions. The exact percentages can be found in table 3, located in the Data Analysis section. However, where in at least 60% of the cases a downward sloped learning curve is suggested when looking at individual test results, only three out of the six tasks actually result in such a curve when data is averaged over all participants: The PL1(1)-task, PL1(2) task and the PL2(2) task. The R^2- values for the PL1(1)-task and the PL2(2)-task are respectively 0,871 and 0,766, being the only two tasks were more than 75% of the total variance is accounted for. All R^2-values are below in table 4

Table 4: The R^2-values corresponding to each task

Task	**R^2**
PL1(1)	0,781
PL1(2)	0,403
PL2(1)	0,048
PL2(2)	0,766
PL3(1)	0,277
PL3(2)	0,413

Based on this can be said that although most cases do show decreased ToT somewhere in the process, no significant increase in performance was found *in the first 3 sessions* and no learning curves could be constructed that fitted the data. Therefore, in this study, not enough evidence is found to support the main hypothesis: *There exists a difference between initial performance and performance after a certain amount of trials.*

In the literature several claims can be found that would explain the lack of noticeable increased performance within the first few trials. Mendoza and Novick (2005) report the possible existence of "*entry barriers"* for novice users, implying that novice users may encounter some difficulties while getting familiar with a certain system before the actual learning process starts. Since in this study not all tasks were exactly similar within each path length (i.e. different target pages were required, even within the same PL-tasks) these so called entry barriers could possibly turn up in all sessions before the website is at least explored in total once, actually leading to a higher ToT in sessions 2 and/or 3 and therefore ruling out a visible learning effect within a few sessions only. Because of this reason, for further research, more sessions are suggested after all required target pages are reached and assessed at least once by the participants.
In a longitudinal study done by MacKenzie and Zhang they as well found fairly low R^2 – values when trying to similarly predict the learning process of users using a standard QWERTY-keyboard and comparing it with to the learning process when using a different layout . They claim that the model was by no means predicting the users' learning behavior from their initial exposure and that the users were actually "fairly well along the learning curve" because they could be considered experts with this layout before taking part in the research. The characteristic shape of learning curves suggest that the further along the curve a user gets (i.e. becomes an expert) the less present and therefore visible a potential learning effect becomes (Speelman & Kirsner, 2006). Taking into consideration that the website structure of www.Hengelo.nl fits the general mental map users have of municipal websites to a high extend (Baumann, 2012), one could argue that all potential users could be considered experts already and would therefore be situated well along the learning curve, at a point where close to no learning effect would be visible anymore. More evidence for this claim could be found in the theory about mental models and schemas, claiming that users adjust these mental maps based on experience and repeated practice and by doing so learn to use a particular navigation structure (Fang & Holsapple, 2007). Since users are not required to drastically change their general mental model of municipal websites in order to successfully find their

way around the website of Hengelo, not much learning is involved in this case. To actually test this assumption more sessions would be required in further research.

Besides the low amount of sessions causing a lack of data showing a potential learning effect or fully supporting any explanation for the non-existence of such an effect in this particular study, this lack of data could also be caused by the relatively low amount of participants (10). Hedeker et. al. (1999) claim that in every study researchers should carefully choose their sample size in order to maximize sensitivity. However, where longitudinal designs are fairly common in other fields of research, they are fairly new in the field Human-Computer Interaction and therefore no leading theoretical framework, including recommendations regarding sample size, exists in the literature so far (Gerken, Bak, & Reitener, 2007). In contrast to cross-sectional studies, in longitudinal studies fewer participants are usually engaged prolonged period of time (MacKenzie & Zhang, 1999) and several studies are known making use of approximately 10 or even less participants, that do find the expected results such as increased performance over time (e.g.: McQueen et. al. (1995), Bellman & McKenzie (1998), MacKenzie & Zhang (1999), Hertzum et. al. (2009)). However, it could be assumed that increasing the amount of participants could increase the chances of a visible learning effect, assuming that the current sample size does not sufficiently enough represent the population.

Since no plausible learning curves could be constructed, no predictions for future performance could be made. Therefore no significant conclusions could be drawn regarding the first sub hypothesis: *Maximum performance is reached significantly faster with low path length tasks than with high path length tasks.* Like described above, this is either because the participants already reached a level of maximum performance or because too few sessions were involved in the research in order to have enough data to accurately fit a learning curve.

Assuming all participants in fact could be considered expert users, based on the statements regarding the fit between the general mental model of users and the actual structure of www.Hengelo.nl as found by Baumann (2012), and therefore already reached or are close to their level of maximum performance a few things may be concluded with regard to the second sub hypothesis. This sub hypothesis said that *maximum performance reached varies significantly with different path lengths*. However, as stated earlier in this section, further research would be recommended to fully support this assumption.
Complexity is one of the key factors leading to poor usability, and therefore users'

performance on tasks (Baecker et. al., 2000). This suggests that when a navigation path becomes more complex overall performance decreases. According to Melguizo et. al. (2012) the three main factors influencing navigation path complexity are: *Page complexity, Page information assessment* and *Path length*. Manipulating one of these factors would change the complexity and therefore likely also the users' performance . Logically navigation tasks involving longer path lengths may be considered more complex since more pages need to be assessed and more actions need to be performed. However, there is no significant difference between peformance on different path length tasks found in the data. The only significant difference is found is between PL1-tasks and tasks involving longer routes when the total ToT is devided by path length involved, i.e: The ToT/path-ratio is actually smaller with longer routes. One of the reasons could be that the navigation options provided in the hierarchical menu become more specific rather than general, when getting into deeper levels of the website. Based on the information foraging theory the allocation of attention is an important factor when navigating and looking for information (Pirolli & Card, 1999). *Information scent*, a concept derived from this information foraging theory, describes the amount of remote information a user can derive regarding the location of information based on the design or labeling of the information structure (Katz & Byrne, 2003). Therefore, when the labeling of the menu options gets more specific it will become easier for the user to allocate their attention and chose the right option. This influences the page complexity, decreasing the time needed for the descion making process and therefore actually making part of the task less difficult. The fact that, since the homepage contains no specific information, PL1-tasks mainly involve deciding which menu option to choose from the homepage and the menu options on the hompage are fairly general, leading to a lower information scent compared to menu options provided on deeper levels, supports the statement that page complexity becomes less with a higher path length.

Another finding was that participants only tend to assess the information provided on the page that they assume to be the target page and not the information provided on pages that they assume to be 'intermediate' in the total navigation route. It is probable that users allready have an expected target page, and the route to this page, in mind based on their mental model. This is particularly shown in the high amount of navigation errors involving actually passing the target page in the process, but failing to identify this page as such by making a proper page information assessment the first time. This would mean that, unregarding path length, for any task only one page information assessment is made. Unless the presumed target page does not provide the desired information and the user therefore needs to continue his search.

This would mean that the claim that tasks involving longer routes are more complex based on te fact more page information asessments need to be made, could not be justified based on the data of this particular research. Based on all the above, the only claim that could be made regarding to the influence of path length on task complexity and therefore users' performance is that menu structure and labeling decides whether navigation tasks involving a longer path length are actually performed faster or slower than navigation tasks involving shorter path lengths (i.e: respectively have a lower or higher ToT/path-ratio). This statement partly matches with the findings of Melguizo et. al. (2012), saying that the inluence of path length on users' performance varies with different menu-styles. However, Zaphiris (1997) found that users actually prefere less deep structures. Just as in this research, in his research the amount and type (navigational) errors made during the information seeking proccess was one of the key metrics. The data from this research does not show a significant difference in amount of errors made for each path length. However, when the broad-ness of the menu provided on the homepage of www.Hengelo.nl would increase like Zaphiris suggests, the menu options could become more specific rather than general. This would make the page assessment of the homepage less dificult and might deminish the difference in ToT/path that is found in the current data.

Summerizing the findings it can be said that, because of several plausible reasons, the data does not provide enough evidence showing a actual learning process. Therefore no predictions about future performance or amount of sessions leading to a certain rate of performance could be made. By increasing the amount of participants, the amount of sessions and/or the similarity of the tasks different results might be found, when not assuming that potential users of the website Hengelo could allready be considered experts from the first time visiting. Regarding the influence of path length on task performance can be said that, for this particular website the ToT/path ratio lowers when the navigation task involves multiple paths. This presumably is based on the fact that, unregarding path length, only one page information asessment is made and information scent becomes higher on deeper levels of the website, making page assessment (i.e: choosing the right navigation options) less difficult for the individual steps.

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Appendix

Appendix 1: Instruction form

Onderzoek Website Navigatie www.Hengelo.nl

Beste participant,

Hartelijk dank voor uw deelname aan dit onderzoek. Het doel van dit onderzoek is om een beter beeld te krijgen van de manier waarop mensen hun weg vinden binnen de structuur van websites. De website die hiervoor gebruikt wordt is de website van de gemeente Hengelo (www.hengelo.nl). In drie verschillende rondes zult u gevraagd worden om specifieke informatie op te zoeken op deze website. Om bruikbare resultaten te verkrijgen is het van belang dat u de volgende instructies zorgvuldig doorleest en volgt durende het gehele onderzoek nauwlettend volgt. Mocht u vragen hebben, raadpleeg dan de onderzoeker. Dezelfde instructies zullen u ook mondeling worden verstrekt voorafgaande aan het onderzoek.

- Hieronder vind u enkele specifieke vraagstellingen. De antwoorden zijn op verschillende plekken van de website van de gemeente Hengelo te vinden. U wordt gevraagd om *elke* vraag te beantwoorden. **Belangrijk:** Dit doet u *niet* door daadwerkelijk het juiste antwoord te geven, u hoeft slechts het speciale nummer te noteren dat te vinden is in de url van de specifieke pagina. De onderzoeker zal u uitleggen hoe dit werkt.

- Uw sessies zullen door middel van speciale software worden opgenomen, zodat de onderzoeker deze later terug kan kijken. Om dit zo goed en duidelijk mogelijk te laten verlopen is het nodig dat u bij elke vraag het volgende stappenplan volgt:

    1. Lees de vraag goed door en zorg dat u deze begrijpt
    2. Minimaliseer dit scherm
    3. Gebruik de snelkoppeling op het bureaublad om de website van de gemeente Hengelo te openen.
    4. Zoek op de website het antwoord op de vraag. Wanneer u zeker weet dat u het antwoord gevonden heeft noteert u het bijbehorende nummer, te vinden in de URL van de specifieke pagina, in het lege vak onder de vraag.
    5. Sluit de browser doormiddel van het kruisje rechtsboven.

    Voor de volgende vraag, begin opnieuw bij stap 1.

- Om de juiste resultaten te kunnen verkrijgen is het van belang dat u *alleen gebruik maakt van het navigatie menu dat links op de pagina te vinden is*. Dit menu bestaat uit de volgende kopjes: *Actueel, Gemeentebalie, Bestuur&Organisatie, Wonen in Hengelo, Ondernemen in Hengelo, Bezoek aan Hengelo* en *Projecten en Plannen.* Geen van de antwoorden is rechtstreeks te vinden via het menukopje *gemeentebalie*Daarnaast mag u gebruik maken van links op de geopende pagina's, indien nodig.
  U wordt vriendelijk verzocht geen gebruik te maken van de navigatieopties bovenaan de pagina (*mijnloket, home, contact, lees voor, sitemap* en *proclaimer)* en/of het "snel naar"-menu te vinden in het gele vak onderaan de pagina.

Appendix 2: Lists of questions

Eerste sessie

Vraag 1
Welke 3 bestuursorganen zijn gerechtigd om belangrijke beslissingen te nemen betreffende alles inzake Hengelo?

Vraag 2
Met wie kan je contact opnemen voor aanvullende informatie, wanneer je in Hengelo je eigen bedrijfje wilt starten?

Vraag 3
Welk telefoonnummer kan je bellen wanneer je meer informatie wilt over een geschikte vestigingslocatie voor je bedrijf?

Vraag 4
Uit wat voor soort personen bestaan de verschillende adviesorganen binnen Hengelo?

Vraag 5
Hoeveel parkeerplekken en parkeergarages zijn er te vinden in Hengelo?

Vraag 6
Noem 5 musea die te vinden zijn in Hengelo?

Tweede sessie

Vraag1
Hoeveel inwoners wonen er grof geschat in Hengelo

Vraag 2
Welke twee externe instanties kunnen u, volgens de website, nog verder helpen bij het starten van een eigen bedrijf?

Vraag 3
Welke zaken behoren er volgens de site tot het archeologisch erfgoed van Hengelo?

Vraag 4
Welke van de drie organisatorische organen staat bovenaan in de 'hiërarchie'?

Vraag 5
Geef een korte (1 a 2 zinnen) taakomschrijving van de *rekenkamercomissie?*

Vraag 6
In welke periode is de wijk "Hasseler Es" gebouwd?

Derde sessie

Vraag1
Voor welke kinderopvangkosten kun je toeslagen aanvragen?

Vraag 2
Welke instanties zijn verantwoordelijk voor het uitvoeren van het door de gemeenteraad opgestelde beleid?

Vraag 3
De gemeenteraad stelt regels op die 'verordeningen ' worden genoemd. Waarvoor dienen deze verordeningen, volgens het inleidende stukje op de website

Vraag 4
Welk jaar en welke gebeurtenis is tekenend voor de start van Monumentenzorg Hengelo?

Vraag 5
Op welke drie winkelmotieven richt het Detailhandelsbeleid Hengelo zich?

Vraag 6
Sinds wanneer geldt de verplichting om alle gemeentelijke ruimtelijke plannen digitaal beschikbaar te stellen?