WHAT'S GOING ON

AN EXPLORATIVE STUDY ON THE INFORMATION PROCESSING OF DIGITAL ILLITERATES

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ABSTRACT

This research project encompassed the information processing of digital illiterates when they interacted with technology. First, the problem definition was stated, based on assumptions and experiences from both people with a high sense of technical skills, as those with no skills whatsoever. From here, a methodological framework was formed to tackle the stated issues and investigate how digital illiterates process the information on a screen. As there were no previous researches similar enough to form a control group, this study stated that each person should be able to perform a certain set of operations to function properly within the digital society. The study aimed to lower the total actual cognitive load users' experiences whilst interacting with the technology – that is, performing the defined set of operations. A website was custom-built based on standard HCI principles and feedback received in the preliminary stages of the study, and a series of exercises were set up. Participants' performances were monitored through self-report (questionnaires before and after the practical test), time measurements (Keystroke-Level Model) and visual observations (think-aloud principle). Results indicated that there indeed is a correlation between self-reported skill level and performance; a larger sample size would supposedly show a stronger correlation. Coherently, a self-reported low investment of cognitive load correlated with a good KLM score. The evaluations were presumably troubled, as the design of the website's interface did not take into consideration enough the implicit needs of participants. This explorative study wants to welcome other researchers to follow up on these findings.

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1 INTRODUCTION

The availability of online services has increased significantly in the last years and continues to expand. This development is not merely limited to commercial and informative services; rather, the steepest growth can be acknowledged in the digitalisation of governmental and municipal services. The shift from old-fashioned paperwork to efficient digital environments implies that people need to become accustomed to new skills – that is, digital skills. This learning curve is different for everyone, and, inevitably, some cannot keep up with the speed of change. According to the Dutch Central Bureau for Statistics (CBS), overall, digital skills of the Dutch population are improving, meaning a decreasing part falls under 'no skills whatsoever', and an increasing part under 'basic skills' or 'more than basic skills'. However, there seems to be a divergence between the rate of growth in skills of the population, and the speed with which new services emerge digitally. As the analogue variant of services becomes redundant and disappears, this divergence is ever more so important to address.

This thesis presents an explorative study, which emphasises the information processing of the individuals who struggle with digital environments and will further be referred to as digital illiterates. Furthermore, the starting point of this research project is some form of friction between the way of offering the services and the receiver – i.e. the population. Erroneous receiving of information and instructions leads to subsequently erroneous learning the required skills, which applies to digital illiterates in particular. Naturally, a wide variance of educational methods is developed and currently in development to aid the digital illiterates, which have shown their purpose and usefulness. However, when regarding the statistics from the CBS, something is still missing. Therefore, this research project will not assess existing methods and software, but rather makes assumptions based on performances of digital illiterates and people with a high level of digital skills. In this sense, possible biases towards the existing methods are eliminated, as well are avoided their possible pitfalls. The assumptions are used to design a testable, usable digital interface, with, naturally, digital illiterates to try out the interface. The research question (*RQ*) for this study is as follows:

How can we achieve a higher level of accessibility for digital illiterates?

This explorative research aims for gaining insight on the different methodologies used in this study, i.e. if they are useful for future research in this area, rather than focusing on finding a sound solution for the issue at hand. During this thesis, the possibilities and existing pitfalls will be acknowledged and further examined, accompanied by appropriate suggestions for future research. The goal is, by conducting the experiment in a qualitative manner, to indicate how, in the future, quantitative research with these methods and similar questions can be properly conducted.

Some notes have to be made. First, because of the individual, personal nature of this research project, evaluations will be done qualitatively, and later quantified for comparative purposes. Secondly, it is the general assumption that digital illiteracy occurs significantly more often with seniors, from the age of 65. Although this is undeniably true, it is also true that non-seniors can have serious issues with digital environments. Therefore, for this research, people of all ages are of interest. Thirdly, regarding the nature of this research project, it is quite probable that the group of participants will consist of predominantly people over the age of 65, since they are easier to find and subsequently approach. However, for the strength of this research project, this should not be an issue. Fourthly, the methodology can turn out to be faulty in ways of assessing the issue at hand. To prevent the evaluations from being faulty altogether, different modes of assessment have been set up. And finally, it is possible that the participants are not willing to follow the instructions; in this case, the individual participant's results need to be omitted from the set of results.

This research paper is built up as follows; in section 2, a more elaborate outline of the problems at hand is provided, together with existing related research. Section 3 provides a set of preliminary interviews and forms prerequisites for proper design. Section 4 contains the methodology, in which the different modes of assessment will be explained. To come closer to an answer to *RQ*, a set of four sub-questions (*SQ*s) is stated. Furthermore, the participants and evaluations can be found in this section. Section 5 presents the results of the experiment for each subdomain. Section 6 gives the conclusions of the results and suggestions for future research for each problem area are made. In Section 7, the discussion regarding this research project is opened. Section 8 mentions possible future work in a more general, broad sense.

2 STATING THE ISSUE

Shneiderman et al. (2018) mentions eight principles, "Golden Rules"[1], and they apply to interface design. One of the principles states that the short-memory load should be reduced, as people have a limited capacity of working memory, making it prone to cognitive overload. As will mentioned later on in this paper, we can measure cognitive load and estimate when an overload is about to occur. Thus, a change in information processing can be quantified. The problems described below presumably all cause discrepancies in the information processing of digital illiterates.

2.1 PROBLEM AREAS

The invisible barrier between a digital illiterate and their digital environment is founded in four areas: way of addressing, layout, credibility and technical familiarity. By this distinction, the issue's origins can become clear, after which they can be overcome. For this study, possible issues with hardware and operating software are not discussed, since the sole purpose is to determine information processing. First, each area is addressed together with their assumed issue. Hereafter, existing related work on this topic is mentioned.

2.1.1 WAY OF ADDRESSING

The way of addressing in an interface roughly consists of two elements: the actual text and the form of address. The first determines how much text there is used, if the information is extensive or concise, and if the use of vocabulary is high or low. The form of address comprises either a personal or an impersonal approach, and a patronising or a deferential approach. Social cues have a certain momentum, and, together with the appropriate verbalisation, can work fantastically. For instance, if a user is supposed to fill out personal information on a website, and the headline says, "please fill out your personal information", this should be clear. However, if the headline says, "try to fill out your name, if you can", some form of bias is implemented, leading to a discrepancy between message and supposed action.

All these elements are heavily depending on the target group. With the way of addressing, from my previous experience, digital illiterates often feel patronised; they find the form of address demeaning, which dovetails with an abundance of social cues — which will be discussed below. Furthermore, it is assumed that the use of

[1] The complete list can be found here. Last accessed on 26 July 2019.

vocabulary is unfitting in general for the target audience; it is either too complex or too simplistic - the latter resulting in a patronising experience for the digital illiterates.

2.1.2 LAYOUT

The next area covers the layout of an interface, which is the result of decisions in visual design and social cues. Being an attractive interface has its advantages: "[when] physically attractive computing products are potentially more persuasive than unattractive products […] users may assume the product is also intelligent, capable, reliable, and credible" (Fogg, 2003). Thus, correct visual design is indispensable. Alternatively, bad visual design will lead directly to frustration, and indirectly to a lowering in total credibility — which will be discussed below. In order to achieve good design, designers should carefully monitor their target audience before making design choices. In this way, establishing a visual design that appeals to the target audience is most likely, and the interface will be as persuasive as possible (Shneiderman, 2018). The layout principles for this study will be following the standard principles of Human-Computer Interaction. In the following section, these principles will be defined more precisely, after the first set of interviews have been conducted.

Social cues are meant to let users know that the interface they are interacting with has a psychology of its own. In this sense, the concept of similarity is of great concern; we as people tend to be more easily persuaded by people who are similar to us (Fogg, 2003). For interfaces, this means that an interface can be designed in a way to express empathy, or encouragement, for instance - in essence, humanising a lifeless piece of technology. When an interface designer is successful in creating an interface with its own psychology, the user's experience will be more fulfilling on the whole (Shneiderman, 2018). As mentioned above, assumptions regarding social cues overlap with assumptions regarding the way of addressing; pointing the user too much in a certain direction, i.e. an excess of social cues, breaks with the similarity principle and causes the experience of being patronised.

2.1.3 CREDIBILITY

The total amount of credibility arises from the first two areas. The area of credibility is of importance when it comes to determining "whether or not the technology has the potential to persuade" (Fogg, 2003). In the context of governmental and municipal services, the interface should be able to persuade the user to take certain steps, fill out certain forms, look up particular information, and last but not least,

actually using their services. As credibility in itself is a broad concept, a distinction is made, as can be seen in Table 2.1. These different types of credibility assume that actually perceiving an interface as credible is influenced by both first-hand and third-party experiences. For example, high reputed credibility leads to higher overall credibility. Naturally, this works the other way around as well. If the third-party endorsements are predominantly negative, the overall credibility will decline, leading to perceiving the interface as deceptive.

Ideally, people come up with an objective total credibility, given the four subdomains. However, as we all are humans, erroneous assessments are currently made. So is the case in assigning credibility to a particular interface as well. The

Type of credibility	**Basis for believability**
Presumed	General assumptions in the mind of the perceiver
Surface	Simple inspection
Reputed	Third-party endorsements, or referrals
Earned	First-hand experience that extends over time

TABLE 2.1. CREDIBILITY OF COMPUTING PRODUCTS. SOURCE: FOGG, 2003.

erroneous assessments come in two forms: incredulity error and gullibility error. When an incredulity error occurs, the user perceives something as not credible, while this something is perfectly credible. A gullibility error happens the other way around; when something is perceived as credible, but in fact, is actually not. The latter is often the case with clickbait and other online advertisements.

The assumption here is that an interface is assessed inaccurate, leading to a faulty perception of credibility - incredulity and gullibility errors supposedly occur often with digital illiterates. The goal is to find out in which element of credibility the discrepancy between actual credibility and perceived credibility emerges. The other assumption regarding credibility is that digital illiterates tend to rely more on third-party's experiences than on their own.

2.1.4 TECHNICAL SKILLS

In this context, technical skills refer to the set of skills one needs in order to operate a computer, as well as the know-how regarding specific tasks on a computer. Following the norm set by the CBS (2016), technical skills are measured through four subdivisions, and each division comprises of its own set of activities. The CBS assigns

a cumulative skill level to a participant if one of the subtasks[2] is performed. If none of the subtasks is performed in the last three months, a 'no skills whatsoever' is noted; a 'basic skills' is granted to those who performed one of the subtasks in the last three months, and 'more than basic skills' when more than one of the subtasks is performed in the last three months. Even though the overall distinction is quite clear, this way of 'testing' fails horribly on the following grounds: firstly, the participants are not asked whether they had difficulty with completing the task. Secondly, there is no control over whether they actually performed the task successfully. Thirdly, if a participant performed one task a hundred times in the last three months, while another participant performed two tasks, but both only once, the latter will receive a higher skill grade than the former, while it can be safely assumed that the former's skills are more adequate. Lastly, since the participants do not fill out a questionnaire on their experiences, it cannot be assessed why they do or do not use particular services, or why they avoid certain tasks. As this mode of assessing is clearly rejected for this research project, a set of different modes will be discussed in SECTION 4.

The technical affiliations of the interviewees are determined through the technical familiarity, set up by Lawry et al. (2019), and comprises the following factors;

(i) forward planning and anticipation;
(ii) relative speed;
(iii) verbalisation; and
(iv) situational awareness.

Forward planning and anticipation can be defined as "actions that make the following step easier and faster" and can for instance be seen when a user hovers their fingers towards certain buttons needed for the next task. Relative speed measures each task individually, and is "particularly useful if the participant shows a lot of variance in the speed with which they perform actions". Verbalisation can help to define the level of technical familiarity; however, this requires individual assessment. A high level of verbalisation can indicate both a low and a high level of technical familiarity, which is the same for a low level of verbalisation. In this sense, it depends on *how* the individual verbalises. For instance, if someone has a low level of verbalisation, but that *what* they say is adequate, they are likely to have a higher level of technical familiarity than someone who verbalises continuously without

[2] A full list of the subtasks can be found on this web page of the CBS.

stating specific details. The last criterion, situational awareness, indicates how acquainted an individual is with the technical device. Low-level situational awareness predominantly leads to not recognising important information presented by the device used, while familiar individuals "would know exactly what a button did without more than a glance".

The main assumption here is that developing technical skills per se is blocked by the discrepancies in credibility, layout and way of addressing. Learning something new, stepping out of your comfort zone, will inevitably lead to more frustration and agitation when you already experience similar emotions. Although possessing technical skills in general is an important factor in solving the problem at hand, the expected low level of technical familiarity is a result of the problems stated in the other areas rather than a self-contained element.

2.2 RELATED WORK

As discussed before, the CBS tries to measure the digital skills of the Dutch population. Besides measuring, governmental policy is to include more and more people into the digital society. In "Digitale Inclusie: Iedereen moet kunnen meedoen" (2018), the Dutch government's digital agenda is presented. This includes the general notion of how digitalisation affects society, as well as different approaches on how to achieve a higher degree of digital literacy within the population. There appears to be one clear message, and that is that the Dutch government actively aspires a digital society. However, there are some serious issues with this publication. Although the approaches at first glance seem quite reasonable, no explicit information on the practical implementation whatsoever has been provided. A torrent of collaborations with third parties is mentioned, for different elements and different target audiences, regrettably also without explicit information on practical effectuation. Leaving room for own interpretation for the third parties can be both positive and negative, as they can diverge from the government's original goals. It is expected that a publication issued by the government should comprise extensive and thorough information, as well as strategies on how to achieve their proposed goals. However, this publication gives the semblance of an ideal instead of a practical informative publication, and, without any actual examples of digitalising society, the publication loses its informative strength altogether.

The next research emphasises inclusive design in ticket vending machines (Hurtienne et al, 2013). With inclusive design, they intend to "minimise the number

of people who have difficulty with or are excluded from [the] use [of products], or to control such exclusion by manipulation of product features". In other words, instead of providing educational ground for learners, this approach aims for products that are in itself comprehensible for a larger group of people, and desire a smoother learning curve. To establish how design can be inclusive, firstly prior experience with technology is determined. Hurtienne et al. (2013) makes a distinction between exposure, competence and subjective feeling. Exposure relates to how much an individual has interacted or had the opportunity to interact with a certain product. Competence with technology refers to the skills and knowledge one requires for interacting with a certain product. Subjective feeling "considers [..] the users' private feelings and thoughts when interacting with technology". These three components serve as a foundation from where their inclusive design can grow. To give substance to this foundation, participants were called for in various places — multiple locations mean multiple angles, which gives a broader stream of information. These participants were provided with two designs of a ticket vending machine; the first design was the original design, the second the 'inclusive redesign'. Their skills were determined beforehand by self-reported questionnaires, and the design was tested on its usability within the focus group. However, as is predominant with digital literacy researches, this study indeed focuses on elders only. This immediately excludes possible digital illiterates from younger age groups. Furthermore, since ticket vending machines are used by people from all ages and digital backgrounds, it could be of interest to investigate how younger people, or people with a higher level of prior experience, would interact with them.

Another study is done by Blackler et al. (2015) and explores the field of what intuitivity in interaction actually is. Intuitive interaction is defined as "fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction." The measure of any intuitivity in interaction is determined by prior experience — dovetailing with Hurtienne et al. (2013) — and technical familiarity — Blackler et al. (2015) uses the term 'technological familiarity', which is interchangeable with the previously explained field of technical familiarity. In this explorative study, cognitive processing is measured whilst performing tasks. Afterwards, self-reported questionnaires are taken. The various measures of cognitive processing, together with the various measures of technical familiarity, are allocated to measures of intuitivity. Unfortunately, this study does not provide insight on the actual evaluations, on how the experiment was set up, and on the focus group —

even for an explorative study, this should be mentioned, as it now cannot lead to possibly logical future work.

The last related study by Terry et al. (2019) does not focus on digital illiterates per se, but on nursing and midwifery students and improving their digital skills. As they state, "the development of digital literacy not only facilitates engagement with effective decision-making, problem solving and research, but also enables nurses to take responsibility for continued learning in areas of personal or professional interest." Additionally, Terry et al. (2019) acknowledges that digital literacy skills are continuously developing and that an individual thus should continuously develop their digital skills. For this study "a digital literacy training scheme was developed", with certain competences regarding digital skills. The study acknowledges the friction between online information and its perceived credibility. As previously discussed, information found online is often subject to both incredulity and gullibility errors. High-familiar participants could be named 'champions', where after they served as tutors for their low-familiar peers, giving ground for peer-based education. Results showed that the champions predominantly benefited from the peer-education method, whilst the learners did not show significant results. That leads to the main issue with this study; naming champions in the first place. The term 'champion' suggests that they are the best in their field, and their level of skills cannot be equalled, or even aimed for. Furthermore, the perfection of existing skills costs less effort than learning new skills. In this respect, the high-familiars became even higher-familiars, while the low-familiars stayed low-familiars, and the proposed goal for this study is not achieved.

3 RESEARCH DESIGN

The following section will investigate the principles of this research project. First, the technical specs and software used in this research project are mentioned, Secondly, to pinpoint the exact issues occurring in the areas mentioned in SECTION 2, a set of four interviews was conducted. Two of the interviewees are considered high-familiars, the other two are low-familiars. The interviews were accompanied by a practical test beforehand and both were conducted in an informal setting. The practical part served to determine each interviewee's level of skill and gain insight on the bottlenecks both groups experience when they interact with technology. Hereafter, the highlights of the interviews are mentioned, which will guide this research project into forming the problem definition.

3.1 TECHNICAL SPECS AND SOFTWARE

A MacBook Pro 15″ and an external Logitech 3-click mouse were used. The motivation for choosing a laptop over a desktop computer stems from statistics from the CBS (2018); according to them, 78% of the households in 2017 have access to a laptop, whereas only 55% had access to a desktop computer. The external mouse was added to bypass possible issues the interviewees – i.e. the low-familiars – could experience with the trackpad.

To diminish possible friction between the participants and the operating system, as much redundant information as possible was omitted from the interface, leaving only a desktop icon with Google Chrome visible. Google Chrome has been used for this study, as this browser had the largest market share between June 2018 and June 2019 in The Netherlands[3]. A website was custom-built for the evaluations with Wix, a website builder tool. See Appendix I for a visual portrayal of the interface. This website was following a set of five guidelines of organisational display in Shneiderman et al. (2018). The guidelines are as follows:

(i) consistency of data display;
(ii) efficient information assimilation by the user;
(iii) minimal memory load on the user;
(iv) compatibility of data display with data entry;
(v) flexibility for user control of data display.

[3] Browser Market Share Netherlands - Global Stats. Last accessed on 26 July 2019.

The first comprises a consistent choice in font, text size, capitalisation, et cetera. The second guideline comprises the format of the interface, for instance, if the language is correct. The third guideline revolves around the total cognitive load, which also appears in the aforementioned eight Golden Rules, and will be discussed in SECTION 4 as well. The fourth guideline applies to more editable, interactive interfaces than the website used for this study, and is thus not relevant here. The fifth and final guideline is applicable to this experiment when participants need to upload a file, and might want to check which file or folder is added last.

3.2 INTERVIEWS

During the tests, the think-aloud principle was applied. By verbalisation, hopefully, interesting insights could emerge. The tests and interviews were voice-recorded and transcribed. Interviewees were encouraged to stray from the original questions if they felt the urge to do so. Based on the results from the think-aloud, the test performance and the interviews, design principles for this research project are stated. The list of exercises and questions can be found in Appendix II, the time performances of the interviewees – i.e. the time they needed to perform al exercises of the practical test – are listed in Table 3.1. The interviewees were expected to finish the test between 5 and 10 minutes. With an average of 7 minutes and 53 seconds, this lies well within the prospected range.

Interviewee	**Time (mm:ss)**
Interviewee 1	10:36
Interviewee 2	03:23
Interviewee 3	06:29
Interviewee 4	11:07
Average Time	07:53

TABLE 3.1. INTERVIEWEES' SCORES, BASED ON ONE TEST.

3.2.1 HIGHLIGHTS

INTERVIEWEE 1

Interviewee 1 stated that they have a certain sense of ease when it comes to interacting with interfaces. They look for specific objects in specific places, for instance, they stated that the login button can always be found on the top right of the screen and that contact details can be found on the bottom of the page. When looking in general online, they would leave their original search query open, and instead of

clicking on results, opening results in new tabs, after which they would use CTRL+F[4] to search for keywords. They believed that information should be presented through a collaboration of icons and text. There were no specific topics that could be improved for better accessibility in general, because, as they stated, frequent exposure has led to a high level of familiarity.

The extra question was answered with predominantly that the overall design of the posed website is extremely poor, and subsequently, information presentation is blurry, sometimes obsolete, and sometimes absent. And, concluding, that the website did not carry any link to the mobile application, even though it is currently being promoted.

INTERVIEWEE 2

Regarding the first and second question of the next part, Interviewee 2's answer was very similar to that of Interviewee 1, stating that, because of the multiplicity of being exposed to websites, they feel a natural way of looking for the login on the top right, the language settings on the top right as well, and that clicking on the company logo will lead to the homepage of the website. For Interviewee 2, it felt intuitive to do. When they look something up online, they act similar to Interviewee 1, opening multiple new tabs, and using CTRL+F to overcome poor design if the need is there. When asked if they preferred either icons or written text, Interviewee 2 answered that for them, it is depending on the type of information, but that it should feel as if it makes sense.

Interviewee 2 answered the sixth question by predominantly stating design issues, both in the Dutch and English versions of the website, but also named that an effort had been made to actually create something user-friendly - however, the website builders did not (yet) achieve their goal.

INTERVIEWEE 3

Even though the questions were asked in general, the answers of Interviewee 3 nearly only revolved around the website used for the test, making the answers very specific, and once again clarifying that Interviewee 3 does not interact often with digital environments. However, they did mention that keywords like 'home' state the homepage of a website or company. When Interviewee 3 would want to look for company-specific information, they would look for it under 'home'. However, when

[4] the command that lets the user search for words within a document or webpage.

pointed to the actual embedded contact details in the footer of the page, Interviewee 3 did not understand that these details could be found on any page. On the other hand, Interviewee 3 felt confident in using Google. When presented an alternative search engine, Qwant, Interviewee 3 acquainted themselves with it quite fast. Regarding icons and text, they found that, dovetailing with the opinion of Interviewee 1, the two should be in collaboration. Lastly, Interviewee 3 referred to the test website, stating that information can be presented more clearly, such as pointing out to the user where they can log in.

INTERVIEWEE 4

Although Interviewee 4 stated various times that digital interactions do not apply to them, in fact, they do. Interviewee 4 stated that they use Wikipedia and online banking, because these two aspects were of interest to them. Furthermore, Interviewee 4 stated that over the years, "the fun has been taken out the Internet", aiming at the numerous advertising banners and gamification overall. They prefer written text, such as Wikipedia, to indulge themselves with information. However, even though Interviewee 4 strongly declared that they feel patronised when a website uses icons to display information, they do not seem to care when it comes to online banking. Another interesting finding is that on the one hand, Interviewee 4 expressed their discontent with websites asking for personal information, such as location access, but on the other hand, they spoke very fondly of the accessibility of Google's interface and the ease of getting results, for instance when one is looking up holiday destinations. Concluding, Interviewee 4 described that they appreciate it when a website puts a line of welcoming words on their home page, as actually navigating to the designated page is considered for them to take up a serious amount of effort - which also became apparent from the test.

3.2.2 OBSERVATIONS: WAY OF ADDRESSING

The website's textual information was perceived to be presented clearly. However, as experienced by the digital illiterates, there was too few textual and visual information on how to upload a file — the information was given in the FAQ, but for the digital illiterates, this did not appear to be a logical place to search for information at all, since they did not open the page. Thus, more explanation of difficult tasks is needed. The main issue the interviewees had with the way of addressing was the lack of a welcoming message once they opened the web page, and the ambiguity regarding logging in, which will be discussed below. In general, the lack of addressing and informing the user textually was the main issue here.

3.2.3 Observations: Layout

The location and size of some basic buttons, such as language selection, logging in, and the website's logo were perceived as clear. The font size and the colour scheme caused no bother as well. Even though overall, the visual layout of the interface was perceived as clear, there are some functional bottlenecks. Firstly, it was unclear whether the user was logged in or not. Secondly, even though all redundant information was eliminated for this test, there seemed to be still some misunderstanding regarding pages, such as the FAQ. This means that the FAQ should either be eliminated or placed in a less obvious spot – or it should have been clearer that the page provides extra explanation. Thirdly, the banner at the top of the page - which is a promotion for the website itself, and not part of the study - seemed to distract, just as any other ad would distract. Thirdly, re-entering a password after logging in seemed to arouse annoyance with all interviewees. Lastly, the most complicated for the digital illiterates was the uploading of a file — this was within the line of expectations. It appears that, due to not understanding the goal of the task, it is extremely hard to perform the task.

3.2.4 Observations: Credibility

As expected, the incredulity error has been detected. In the areas of presumed and earned credibility, the digital illiterates expect the interface to have a faulty performance, which turns into a self-fulfilling prophecy; by not assessing the credibility on a surface level anymore, it naturally will be more cumbersome to interact with the interface. Furthermore, the reputed credibility is extremely powerful. In practice, this means that negative sentiments rather than positive sentiments towards a similar existing interface will be stored in people's memory, just as negative thoughts and emotions are easier to store than positive. The conclusion is that, due to previous negative experiences, a strong credibility bias has grown within digital illiterates, in this case leading to incredulity errors. According to Fogg (2003), it may be possible to regain some of the credibility with the user by either "providing accurate information over an extended period of time" and "to make the same error repeatedly (if it is not a critical error)". As both of this is true, but not feasible for this research project, it is essential to perform the evaluations in a quiet, peaceful setting, with as few distractions as possible.

3.2.5 OBSERVATIONS: TECHNICAL SKILLS

FORWARD PLANNING AND ANTICIPATION

It became apparent quite quickly that both Interviewee 1 and Interviewee 2 can be considered high-familiars in this field. Both through observing their gestures and listening to their verbalisations, they each stated that their anticipatory movements come intuitively and caused no problems whatsoever. For Interviewee 3 and Interviewee 4, forward planning and anticipation were not so evident. Both of them needed to search for everything on-screen, and, in the case of Interviewee 4, they needed to search the keyboard for each key individually. However, after they were done typing, both Interviewee 3 and Interviewee 4 would immediately move their preferred hand towards the touchpad of the laptop, knowing that the machine desired mouse control instead of keyboard control now — an operation called 'homing', which will be further discussed in SECTION 4. So, it can be stated that there was some sense of anticipation, but to a very low degree compared to Interviewee 1 and Interviewee 2.

RELATIVE SPEED

Since these tests were conducted just to gain insight on the differences between high and low levels of technical familiarity, the tasks were not individually measured, but rather the total time only. Interviewee 2 finished the test quickly and without any errors. However, as can be seen in Table 3.1, some explanation is needed regarding the amount of time it took Interviewee 1 to complete the test. One clarification for Interviewee 1's time; they anticipated so quickly and effortless, that typos occurred each time they needed to enter something. Furthermore, because of the quick, natural way of clicking buttons and links, they erroneously clicked quite often. The other explanation revolves around verbalisation and will be discussed below. As for Interviewee 3's time, they followed the instructions very clearly and visibly focused on the test in general. Interviewee 4, on the other hand, was visibly and audibly frustrated by the laptop and the tasks. Because of this, Interviewee 4 did not seem to have the required amount of focus, which led to slow task completion with a fair number of typos.

VERBALISATION

As stated above, the participants were asked explicitly beforehand to voice their thoughts throughout performing the tasks. Interviewee 2 and Interviewee 3 limited

their thoughts on completing the tasks and the digital environment, which gave a clear overview of their respective mindsets. Interviewee 2 stated some elements which she found to be ambiguous, such as the login button not showing when one is logged in or not — which was actually claimed by all participants. Where Interviewee 2 expressed their annoyance, Interviewee 3 rather expressed their confusion, which states a difference in the number of times they have been exposed to similar digital environments. Interviewee 1 had strong thoughts on all topics, drifted a lot, but in that sense, gave multiple possible solutions for one particular task. As well as with Interviewee 2's annoyance, this advocates for their high-level of technical familiarity. Interviewee 4 had strong thoughts as well on all topics, however, practically none of them seemed to be constructive for performing the tasks. Because of their lack of focus, nearly every task needed to be done twice to complete them. Subsequently, Interviewee 4 expressed their ambivalence towards computers in general, stating that they all do not work properly, while, it is more plausible that they experienced an overload of the total cognitive work memory, which led to not being able to focus anymore on the task at hand.

SITUATIONAL AWARENESS

This study not quite focuses on situational awareness, but some words can be said about them. Interviewee 1 was annoyed by using the laptop, because of the brand – which is an interesting, although different discussion altogether, and will thus not be addressed further in this study. However, they did know where to find the buttons and controls needed for the tasks. Interviewee 2 and Interviewee 3 did not state any problems and started using the device without further problems. Interviewee 4 had, apart from searching for specific keys which would occur on their own device as well, some difficulties with the trackpad, since they were familiar with using a regular mouse.

As expected, the digital illiterates showed blockage of their skills. As stated in the interviews, they both have low technical familiarity, but they do show forward planning and anticipation, meaning that they are acquainted with the product itself — just not with the particular actions. For digital illiterates, the trackpad instead of a regular mouse can pose problems. The combination of low technical familiarity, lack of focus and an overload of the memory load causes the digital illiterates to stay low-familiars.

3.3 PREREQUISITES

This research project will focus on the information processing of digital illiterates. Participants are assumed to be low-familiar, without any prerequisites regarding age. Furthermore, this research project assumes a digital society, where people should be able to take care of governmental and municipal issues online. The technical skills, performance, and cognitive load will be measured, in order to determine where the pitfalls lay in current design principles. Finally, this study will provide suggestions for proper design, which is inclusive for digital illiterates from all ages, but prioritises successfully applying the methodology over results.

4 METHODS

This section consists of the following elements. Firstly, the different modes of assessing participants' skills, performances and experiences are outlined. Following, sub-questions will be posed. After this, the evaluations will be illustrated.

4.1 MODES OF ASSESSMENT

By defining the various modes of assessment, it will become clear how this research project measures various aspects. An overview of all modes can be seen in Table 4.1, and they will be discussed below. Apart from focusing on what the individual cannot actually do, or has troubles with, this study takes an interest in existing skills as well, as emphasis can be laid on those aspects that urgently require adjustments.

When	Method	Goal
Before evaluations	Prior Experience vs. Prior Knowledge	- Justify difference between experience and knowledge
	Primed Task Recall	- Apply prior experience and prior knowledge on unknown product
During evaluations	Think-aloud	- Determine level of skill - Determine technical familiarity - Determine amount of intrinsic and extraneous cognitive load
	Skill Acquisition Model	- Determine different stages of skill acquisition - Determine amount of intrinsic and extraneous cognitive load
	Technical Familiarity	- Determine different elements of familiarity with digital product - Determine amount of total cognitive load
	Keystroke-Level Model	- Estimate and calculate amount of time executing actions - Determine amount of extraneous cognitive load
After evaluations	Questionnaire on mental effort	- Determine amount of intrinsic cognitive load
	Questionnaire on stress level	- Determine amount of total cognitive load
	Questionnaire on difficulty	- Determine amount of intrinsic cognitive load

TABLE 4.1 MODES OF ASSESSMENT.

4.1.1 PRIOR EXPERIENCE VS. PRIOR KNOWLEDGE

Commonly, it is assumed that an individual becomes more proficient in using a particular (digital) product by just using it frequently over time. However, as Lawry et al. (2019) states, there is a distinction to be made between prior experience and prior knowledge. The former indicates the collection of experiences the individual has from the first use up until today, whereas the latter encompasses the knowledge

the individual has gathered as a result of this collection of experiences. Subsequently, this knowledge can be applied and further expanded in future use of the product, or similar products. This is of interest to mention considering digital illiterates often not lack the actual collection of experiences, but do lack the required prior knowledge to draw from. To measure this, the primed task recall will be applied.

4.1.2 Primed Task Recall

This brief, but effective method can provide insight into how individuals think they should use a particular product. When they have not used the product before, they get a brief time of spectating the product, after which they are asked how they think they would perform specific tasks. This method, 'priming', "works on the assumption that items in memory are activated (or primed) by related cues in the environment" (Lawry et al., 2019). Concerning digital illiterates, this mode is of the utmost importance to find out their mindset - which elements claim the most attention, which elements are slightly overseen, and so on. This method is also effective in determining an individual's prior experience and prior knowledge, as priming not only reveals what the individual already knows, but also should give insight on what the individual can actually do.

After this stage of assessing, the participant will interact with an actual interface. The following set of methods measures their skill level and performance.

4.1.3 Skill Acquisition Model

In general, acquiring a certain (set of) skill(s) is a transition from "error-prone, slow interaction to fast, non-conscious interaction", following Lawry et al. (2019). This transition is established through practice and experience, and can be divided into roughly three subsequential stages, which overlap and therefore are not interchangeable;

(i) the 'cognitive' stage;
(ii) the 'associative' stage; and
(iii) the 'autonomous' stage.

This set of stages, developed by psychologist J. R. Anderson, is appropriately called the Skill Acquisition Model. In the first stage, the individual's main goal is problem-solving. In general, a certain base level knowledge is required for a particular skill, which the individual is accustoming themselves too. They only learn about the action, but not yet about the cognitive processes involved in performing this action.

Slow behaviour generation and failures in memory when executing tasks are characteristic for individuals interacting at a cognitive stage. In the second stage, the associative stage, the individual shows an increase in performance speed, a reduction of errors, and improvement to the efficiency, presumably resulting from prior experience. The individual "moves from the declarative representation" of the first stage, to a "procedural or more process-based representation". Furthermore, the goals in this second stage are to correct the previously made errors (i.e. the errors in the domain knowledge of the individual), and to actually acquire experiential knowledge - thus, the associative stage can be defined as the stage where prior experience is translated into prior knowledge, moreover since there is a shift from "general problem solving methods to domain specific methods". The improvements made in this stage revolve around the speed of executing tasks and reducing the effort needed for each task. The final stage, or autonomous stage, shows a proceduralisation of actions, which likewise lose their conscious character; the individual executes the actions "fast and effortless", which makes them more difficult to interrupt. At this stage, the individual has mastered the action, which means that a further increase in experience will not any longer improve the behavioural performance. The skill acquisition model is of interest for this research project as it can be juxtaposed to the participant's performances, and in this sense, the study can investigate which specific actions require more and which require less effort - in other words, how an individual's behaviour can directly show in which stage they find themselves, regarding a particular product.

This concludes skill acquisition in general. Following, some insight on the proficiency in technical skills will be given.

4.1.4 TECHNICAL FAMILIARITY

As discussed in SECTION 2, an individual's technical familiarity can be determined by distinguishing four main criteria;

(i) forward planning and anticipation;
(ii) relative speed;
(iii) verbalisation; and
(iv) situational awareness.

Technical familiarity will be measured through two methods: the Keystroke-Level Model (see below), and by applying the think-aloud principle during the evaluations.

4.1.5 KEYSTROKE-LEVEL MODEL

The Keystroke-Level Model (KLM) allows the researcher to quantify qualitative data. Being a part of the GOMS[5] model for measuring human-computer interaction, KLM "allows [the researcher] to predict how long an experienced worker will take to perform a particular operation when using a given interface", following Raskin (2000). However, as this research emphasises on inexperienced users, NGOMS was brought into life, which "takes into account non-expert behaviour, such as learning time". Originally published in *The Psychology of Human-Computer Interaction* in 1983, KLM sets typical times to actions, rather than that the researcher has to measure it all by themselves (Table 4.2). The first, Keying (*K*), indicates the time to press keys and clicking the mouse button. The time for *K* varies from 0.08 seconds for a very high-skilled typist to 1.2 seconds for a completely inexperienced typist - the latter will be used for calculating performance times in this research project. Furthermore, the time for *K* includes the time it takes the user to make corrections that they have caught immediately, such as typos. 'Shift' is counted as a separate keystroke. Pointing (*P*) refers to pointing with the mouse to certain aspects on the screen. Homing (*H*) refers to moving the hand from the Graphical Input Device (GID), such as a mouse, to a keyboard, and vice versa. Mentally preparing (*M*) stands for the time the user needs to think about the action they are about to perform. The last, responding (*R*), indicates the time the system needs to respond, so this last factor cannot be influenced by the user itself, and therefore does not have a fixed time, but depends on the type of computer and other external factors, such as Internet connection speed. The responding time can have an unexpected effect on user actions. If the system appears to 'do nothing' for approximately 0,25 seconds, the user is likely to try again or begins to wonder whether the system is failing.

Furthermore, KLM comes with a set of heuristics regarding *M*, which can be seen in Table 4.3. In the context of KLM, 'arguments' refer to the information the user supplies to a command, for instance, the exact time the user wants an alarm to go off. 'Operators' refer to the factors *K*, *P*, and *H*. A 'string' represents a sequence of characters, whereas 'delimiter' signifies the character that marks the beginning or the end of a meaningful string of text, such as a natural-language word or a telephone

[5] Goals, Operations, Methods, Selection. (*The Psychology of Human-Computer Interaction*, 1983).

number. For illustration, a period is the most common delimiter at the end of sentences. Applying KLM to this research project, an estimated amount of time will be made based on the data in Table 4.2 for each action, together with an average Responding time (*R*).

Symbol	Time (s)
Keying (*K*)	1,2
Pointing (*P*)	1,1
Homing (*H*)	0,4
Mentally preparing (*M*)	1,35
Responding (*R*)	tba

TABLE 4.2. KLM SYMBOLS AND CORRESPONDING TIMES.

Rule 0. Initial insertion of candidate *M*s
Insert *M*s in front of all *K*s. Place *M*s in front of all *P*s that select commands, but do not place *M*s in front of any *P*s that point to arguments of those commands.
Rule 1. Deletion of anticipated *M*s
If an operator following an *M* is fully anticipated in an operator just previous to that *M*, then delete that *M*. For example, if you move the GID with the intent of tapping the GID button when you reach the target of your GID move, then you delete, by this rule, the *M* you inserted as a consequence of Rule 0. Thus: *P M K* becomes *P K*.
Rule 2. Deletion of *M*s within cognitive units
If a string of *M K*s belongs to a cognitive unit, then delete all the *Ms* but the first. A cognitive unit is a contiguous sequence of typed characters that form a command name, or that is required as an argument to a command. Examples of cognitive units are: "Y", "move", "Helen of Troy", "3.900".
Rule 3. Deletion of *M*s before consecutive terminators
If a *K* is a redundant delimiter at the end of a cognitive unit, such as the delimiter of a command immediately following the delimiter of its argument, then delete the *M* in front of it.
Rule 4. Deletion of *M*s that are terminators of commands
If a *K* is a delimiter that follows a constant string for example, a command name or any typed entity that is the same every time that you use it then delete the *M* in front of it (adding the delimiter will have become habitual, and thus the delimiter will have become part of the string and not require a separate *M*). But if the *K* is a delimiter for an argument string or any string that can vary, then keep the *M* in front of it.
Rule 5. Deletion of overlapped *M*s
Do not count any portion of an *M* that overlaps an *R* delay, with the user waiting for a response from the computer.

TABLE 4.3. HEURISTICS FOR PLACING MENTAL OPERATORS. SOURCE: RASKIN, 2000.

4.1.6 MEASURING COGNITIVE LOAD

Cognitive load can be divided into and measured in various ways. This research project will adhere to the definitions and distinctions made in *Managing Cognitive Load in Adaptive Multimedia Learning* (Kalyuga, 2009). They state that cognitive load

is “generally defined as the demand for working memory resources required for achieving goals of specific cognitive activities in certain situations”. In this respect, it has to be noted that there is a distinction between cognitive resources (the actual cognitive load) and the ideally required resources (the cognitive load required to perform a certain task). If the actual cognitive load exceeds the amount of required cognitive load, we speak of cognitive overload. Presumably, this is often the case with digital illiterates. Therefore, this research project will seek to prevent such an overload.

The total amount of actual cognitive load is the sum of three components: intrinsic, extraneous and germane cognitive load. The first, intrinsic load, refers to the mental effort we exert when learning complex materials, and establish key connections between these materials. This intrinsic load is caused by “internal intellectual complexity of the task or material”. The amount of extraneous load depends on design choices and is irrelevant to the learning curve of the user. Therefore, the general aim is to keep the extraneous load as low as possible - as is what will be aspired in this research project. The last, germane load can give insight on the “useful, learning-relevant demands on working memory”. The germane load is difficult to recognise and extract and is often assessed erroneously. Furthermore, through iteration, the germane load can be observed best. Since this experiment will be conducted once, only the intrinsic and extraneous cognitive load will be regarded. For future work, however, the germane load can be of significant interest, if this study would be iterated.

The various modes of assessment utilised in this research project serve the purpose of determining the total amount of cognitive load. While some modes favour the intrinsic load, others serve to determine the extraneous load or the cognitive load on the whole. Table 4.1 shows which component of the total cognitive load can be surveyed in each particular mode.

Since quantifying cognitive load, which relates to specific, individual processes and characteristics of a person can be troublesome, Brünken et al. (2003) designed a two-dimensional classification of quantifiable measurements. In Table 4.4, an overview of the full set of possibilities can be seen. For this research project, the following set of possibilities will be used; the self-reported mental effort, stress level and difficulty (all through questionnaires after the evaluations), learning outcome measures (through KLM), and dual-task performance (think-aloud during the evaluations). Measuring physiologically and measuring through brain activity would both be too

invasive for the nature of this study, as the intended users are likely to experience stress already when performing the tasks only, which will have the counter-effect of increasing the extraneous load too much, leading to an overload (Kalyuga, 2009). To quantify the data retrieved from both the skill acquisition model and the determined technical familiarity, sample keywords mentioned during the evaluations will be counted. In this sense, a comparable dataset can be acquired.

	Causal Relationship	
Objectivity	Indirect	Direct
Subjective	- Self-reported invested mental effort	- Self-reported stress level - Self-reported difficulty of materials
Objective	- Physiological measures - Behavioural measures Learning outcome measures	- Brain activity measures (e.g. fMRI) - Dual task performance

TABLE 4.4. ASSESSING COGNITIVE LOAD. SOURCE: BRÜNKEN ET AL., 2003.

4.2 SUB-QUESTIONS

Different sub-questions are set up, which subsequently will lead to an answer to *RQ*. By resolving the sub-questions, an answer to *RQ* can eventually be formulated. The sub-questions are inextricably connected, and are as follows:

- *SQ1*: Will providing only essential information lead to a lowered intrinsic cognitive load?
- *SQ2*: Will only providing essential information lead to a lowered extraneous cognitive load?
- *SQ3*: Will a lowered required total cognitive load lead to a lowered actual total cognitive load?
- *SQ4*: Will a lowered actual total cognitive load lead to better performance?

4.3 EVALUATIONS

4.3.1 PARTICIPANTS

Participants were recruited through Stichting Vobis[6], which provides computer lessons free of charge in The Hague. Assumed is that all participants interact with computers on a cognitive stage, thus are low-familiars, but that they do have taken an interest in learning – contrary to Interviewee 4 (see SECTION 3), who showed resistance to the technology and learning. The evaluations were done individually,

[6] The website of Stichting Vobis can be found here.

with as few distractions — i.e. other people — as possible during the tests. A total of eight participants were tested, of which four were female. Figure 4.1 shows the age distribution of the participants.

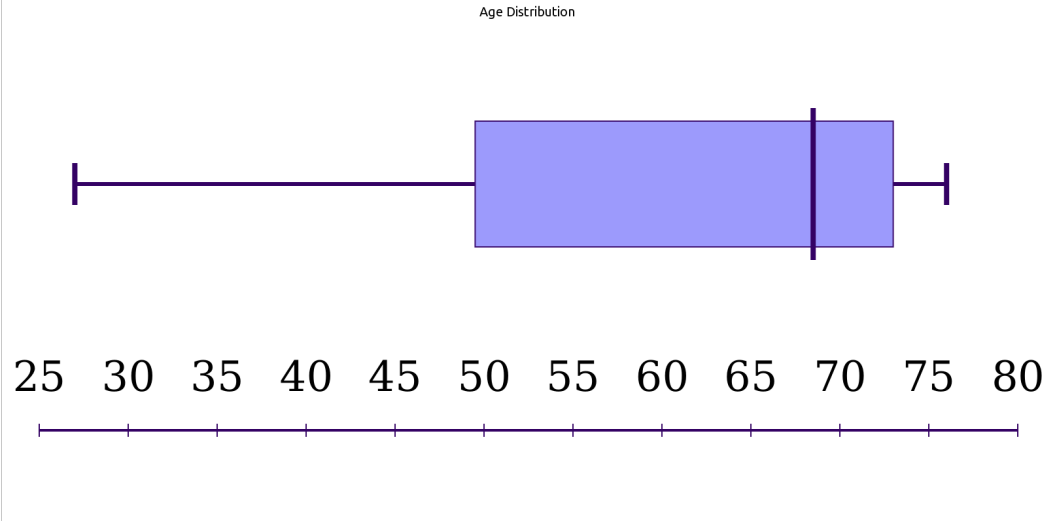

FIGURE 4.1. PARTICIPANTS' AGE DISTRIBUTION.

4.3.3 TESTING

Firstly, participants were asked to fill out a questionnaire, determining the difference between their prior experience and prior knowledge, as well as performing the primed task recall. The statements in the questionnaire could vary from 1 ('completely disagree') to 5 ('completely agree').

Secondly, participants were asked to take place behind the laptop and perform some tasks, whilst voicing their thoughts. The tasks were all performed on a second custom-built website, which is, in essence, an enhanced version of the one used for the interviews. The interface is an adjusted version of the website used for the interviews in SECTION 3; taking the interviewees' feedback into consideration, and again following the five guidelines stated in Shneiderman et al. (2018. A visual display of this interface can be seen in Appendix III. This second part of the experiment was voice and video recorded, and later analysed. The skill acquisition model was applied to determine if there were elements the participants understood better than others — i.e. if they interacted with the technology differently. Through the technical familiarity criteria, their overall technical familiarity was determined. By verbalisation, this would become aware even more compelling. The think-aloud principle would also lead to the participants voicing their level of cognitive load, by measuring the number of keywords. The keywords would be selected afterwards, as they are subjective. Through KLM, the participants' performance was measured.

Table 4.5 shows an overview of the tasks the participants needed to fulfil, with adjacent the purpose of each action.

After the practical test, the participants were again asked to fill out a questionnaire. This time, the statements revolved around their required mental effort, the experienced stress and experienced difficulty. Appendix IV shows a full overview of the questionnaires.

	Action	**Purpose**
1.	Open browser	Determine if they can find the browser
2.	Type in web address	Determine if they know how to type in an address
3.	Navigate to a page within the website	Determine if they know how to look for information within a certain website
4.	Navigate back to homepage	Determine if they understand that they are still on the same website
5.	Logging in	Determine if they can log in to a personal environment
6.	Navigate to a page for uploading a file within the website	Same as 3.
7.	Upload file	Determine if they can provide personal documents when prompted[7]
8.	Logging out	Determine if they understand that the personal environment should not be accessed by thirds

TABLE 4.5. EXERCISES.

[7] For governmental and municipal issues, often the user is asked to upload personal documents, such as a copy of their ID, a copy of their labour contract, a copy of their rental lease, and so on.

5 RESULTS

The overall results will be discussed below by method and chronological appearance during the evaluations.

5.1 PRIOR EXPERIENCE & PRIOR KNOWLEDGE, PRIMED TASK RECALL

The first questionnaire, before the practical test, comprised a set of seven statements, with each two different answers: "I think I know how to do this", stating prior knowledge, and "I can/will successfully carry this out", stating if they can perform the tasks based on prior experiences. This dovetails with the primed task recall. Since all participants verbalised quite thorough whilst filling out the first questionnaire, it became apparent that there were four main sentiments towards the statements (and subsequently, their supposed skills);

- "I am certain I cannot do this";
- "I think I cannot do this, since I have never done it before";
- "I think I would be able to do this, even though I have never done it before";
- "I have no clue if I can do this or not".

Overall, participants pronounced a rather low self-esteem, while the average outcome shows differently (Table 5.1), as all scores lean more towards positive outcomes than negative. Figure 5.1 shows a negative correlation; if the self-reported average skill decreases, the time required to finish the KLM test increases.

Questionnaire beforehand	
	Average score (1 = worst, 5 = best)
Prior knowledge	3,7 (± 1,10)
Prior experience	3,4 (± 1,26)
Overall	3,6 (± 1,17)

TABLE 5.1. RESULTS OF THE FIRST QUESTIONNAIRE. TOTAL AMOUNT OF PARTICIPANTS *N* = 8.

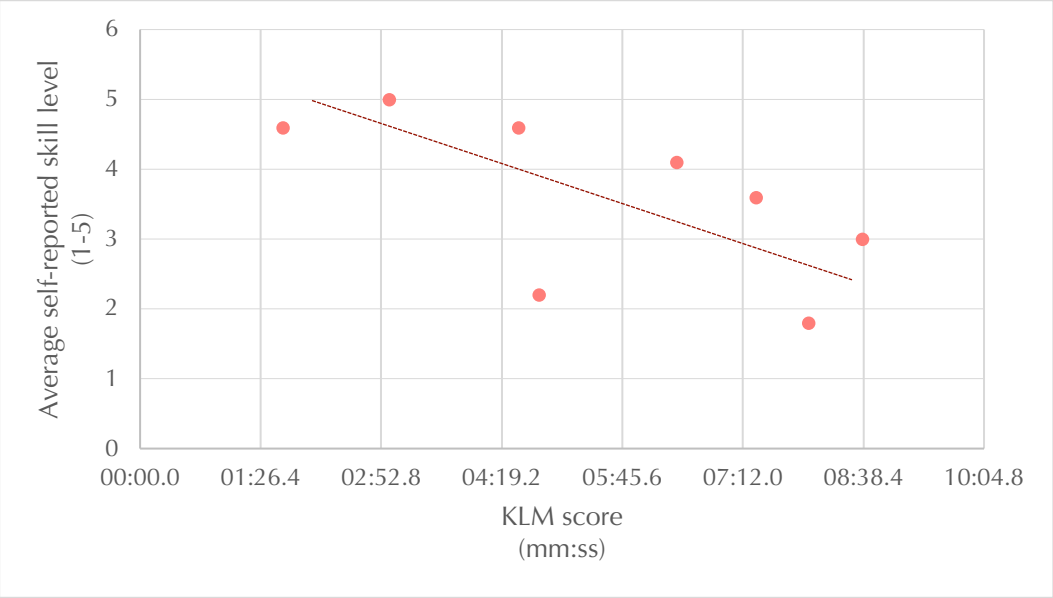

FIGURE 5.1. KLM SCORES VERSUS THE AVERAGE SELF-REPORTED SKILL LEVELS FROM THE FIRST QUESTIONNAIRE. SCORES ARE SORTED FROM BEST PERFORMANCE TO WORST PERFORMANCE, AND NOT CORRESPOND WITH THE CHRONOLOGICAL ORDER THE PARTICIPANTS TOOK THE TEST. A TRENDLINE IS ADDED FOR CLARIFICATION.

5.2 OBSERVATIONAL REGISTRATIONS

The think-aloud principle seemed too difficult for all participants, meaning they needed their full attention to executing the tasks. However, this dovetails with Lawry's vision on verbalisation, i.e. that a low level or absence of verbalisation can indicate a low level of familiarity. So, instead of focusing on verbalisation, the emphasis was laid on their body language. Additionally, a lot of questions were asked during the tests — as was stated by the researcher that this was possible at all times. These questions revolved predominantly around how to execute the tasks, and after instructions, they could perform the tasks. The 'why' of tasks was massively misunderstood, as illustrated by a verdict of one participant: "I have typed in something, but I do not know what I have done". The following findings are bulleted below:

- special characters, such as the forward slash (/) and the at sign (@), cause difficulties;
- the advertisement banner of the website sought the most attention, instead of the interface of the website itself;
- when they needed to log in, the button 'Log in' could be clicked, after which they could enter their credentials. Once logged in, the button changed to a welcome message: "Hi, [username]". For the participants, the difference between logged in and not logged in was unclear. Additionally, they all did

not understand that, for logging out, they needed to click their username and select the logging out option from the drop-down menu;

- practically for all the exercises, participants needed to be pointed to the particular page they needed to navigate to. Due to the colour scheme and font size, the interface could not direct the participants well enough;
- rather surprisingly, participants had trouble with the external mouse;
    - 2 participants (25%) did not know at all how to position their hand on the mouse;
    - 4 participants (50%) had trouble with double-clicking;
    - 2 participants (25%) did not know the difference between the left and right mouse button;
- when placing a specific task in a well-known context, participants usually came to a higher sense of understanding of the 'why' of the task. For instance, during the login exercise, when the researcher compared this action to login to a Facebook or Gmail account, the participant's face would clear up and the exercise was done with visibly less frustration;
- one participant stated, "these exercises make me sweaty", indicating that due to a large amount of effort and concentration, they would feel hot;
- practically all participants needed to be told that after they typed in the web address, they should press 'enter' for the page to load, and when prompted, no one showed a sign of recognition to this specific action;
- typos were massively unnoticed, and the researcher mentioned them, so that the participants could correct them before executing a task faulty;
- the colour scheme did not achieve enough contrast, leading elements of the interface to go unnoticed. The small font size also led to issues, partly because of the age of the participants, but also because different fonts, such as the website builder's banner and the browser's font, were larger and therefore attracted more attention;
- 6 participants (75%) typed with one finger of one hand.

5.3 Skill Acquisition Model

As mentioned before, all participants are assumed to interact with technology on a cognitive level. With exception from the two younger participants, all participants did interact within this first stage of the model. There were no significant differences

that could lead to parts of the interaction taking place in the second stage, the associative stage. However, there were some outliers:

- 1 participant (13%) opened the website from the browser history;
- 1 participant (13%) found another way of opening the browser without effort;
- 1 participant (13%) clicked accidentally on the right mouse button, but did manage to open the browser from the appeared drop-down menu;
- half of the participants recognised the logging in task, by verbalising, taking a steadier seated position, and by rubbing their hands together.

5.4 TECHNICAL FAMILIARITY

Indicating value to various levels of technical familiarity is done in the following manner. The existence of an individual criterion with a participant is roughly scaled from 1 (no) to 3 (yes). For relative speed, the starting point is also 1, meaning that a higher relative speed — i.e. if a participant performs certain tasks faster than average — will contribute to a higher total technical familiarity. The average level of these criteria will determine the total average level of technical familiarity. As there was no accurate method of measuring, an estimation will suffice.

As mentioned before, the think-aloud did not provide enough information to come up with a concise conclusion for the average technical familiarity. Nonetheless, some interesting insights were gained:

- overall, there were no signs of forward planning;
- overall, there were no signs of situational planning. For each task, each visual element and each part of information needed to be assessed anew, and recurring questions were asked;
- overall, there were no tasks in which the participants performed significantly faster than others, keeping their relative speed low altogether.

5.5 KEYSTROKE-LEVEL MODEL

As expected, the presumed results — i.e. the results calculated by the standards of KLM — and the actual results differed greatly. Table 5.2 shows the expected performance versus the actual average performance of each task. For this evaluation, response *R* was not calculated, as it showed to be similar for each individual task. The most significant bottleneck was the mentally preparing (*M*), seemingly longer than the proposed 1,35 seconds. Participants needed a moment of *M* after each subtask, and not just at the beginning of the task as the method describes.

Additionally, participants needed more time for Keying (*K*) than previously assumed by KLM, especially for special characters. Because of the uneasiness with technology, participants needed more time for Homing (*H*) than the presumed 0,4 seconds. Pointing (*P*) seemed to fall in the line of expectations, although it was often unclear for the participants where they should indeed point at — which falls under *M*. The time in between tasks, when participants were either processing the explanation of a task or processing the information of the last task, were not accounted for in the KLM, as they do not fall directly under the performance requirements stated by the model. Because of the long web address and the login credentials, those two tasks took up the most amount of time. It was expected that the upload task would take seemingly more time as well, but as the participants were even lower-familiars than presumed, help was provided immediately.

	Action	**Expected performance (mm:ss)**	**Actual average performance (mm:ss)**
1.	Open browser	00:03,8	00:12,6 (± 00:06,2)
2.	Type in web address	00:45,8	01:58,9 (± 00:51,7)
3.	Navigate to a page within the website	00:03,7	00:12,2 (± 00:06,0)
4.	Navigate back to homepage	00:03,7	00:06,3 (± 00:01,8)
5.	Logging in	01:05,1	02:25,3 (± 00:56,7)
6.	Navigate to a page for uploading a file within the website	00:03,7	00:05,7 (± 00:01,4)
7.	Upload file	00:18,6	00:25,1 (± 00:04,6)
8.	Logging out	00:02,1	00:06,6 (± 00:03,2)
	Total	02:26,4	05:32,6 (± 02:11,7)

TABLE 5.2. KLM SCORES; EXPECTED VERSUS ACTUAL, WITH THE STANDARD DEVIATION. TOTAL AMOUNT OF PARTICIPANTS $N = 8$.

5.6 COGNITIVE LOAD

First of all, it has to be noted that, regarding the required cognitive load, an estimate will be given, since the evaluation methods at hand only can indicate the required cognitive load. The actual cognitive load is measured more accurately. Table 5.3 shows the average results of the questionnaire after the evaluations, and, surprisingly, results are predominantly lower than expected — overall, it was assumed that the average would be on the higher half of the spectrum 1 to 5. In this sense, it is presumed that the middle of the spectrum indicates 'average effort'. Although the required mental effort exceeded this average, the other two elements were below the

average. Especially the level of stress was assumed to be higher. Figure 5.2 shows an increase on all three levels as performance decreases — i.e. when the time needed to complete the set of tasks rises. This correlation implies that the lowest-familiars need to do a larger amount of effort to operate technology, thus requiring a larger portion of their total cognitive load for undertaking the same actions than a slightly-less-low-familiar.

As discussed, both the levels of mental effort and difficulty indicate the amount of intrinsic cognitive load, and the amount of stress the total cognitive load. These results suggest that both intrinsic and extraneous load rise when skills lower (see Figure 5.2). Drawing correlation lines illustrate that the self-reported difficulty showed the steepest rise, after that the stress level, and self-reported mental effort last. From here, it can be concluded that intrinsic and extraneous load both are subject to change once the skill level changes.

Questionnaire afterwards	
	Average score (1 = worst, 5 = best)
Mental effort	3,6 (± 0,89)
Stress Level	1,9 (± 1,29)
Difficulty	2,8 (± 1,48)
Overall	2,8 (± 5,06)

TABLE 5.3. RESULTS OF THE SECOND QUESTIONNAIRE. TOTAL AMOUNT OF PARTICIPANTS $N = 8$.

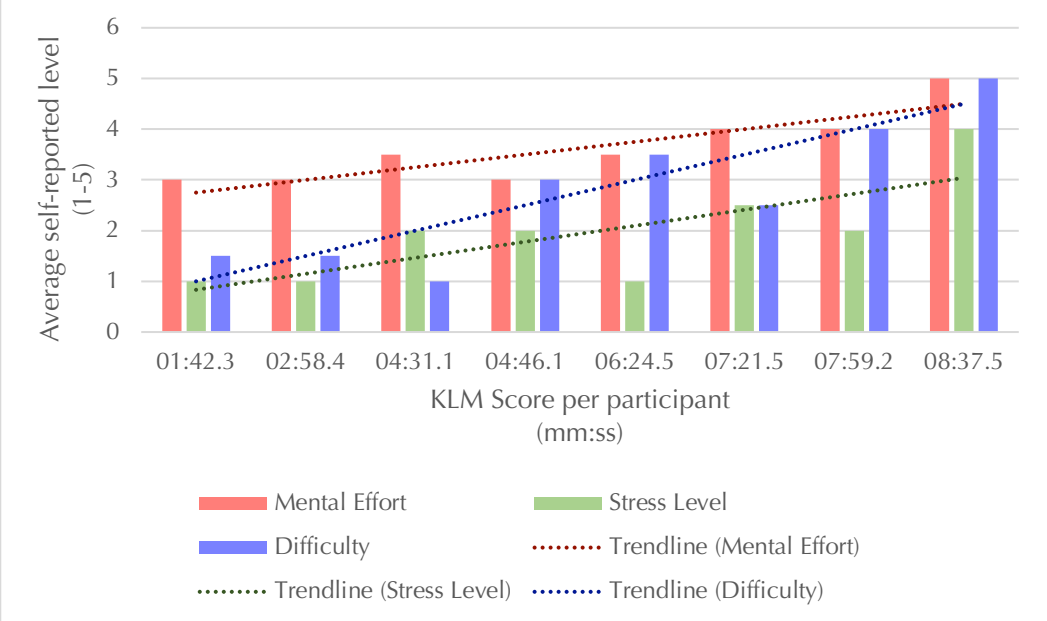

FIGURE 5.2. KLM SCORES VERSUS THE AVERAGE SELF-REPORTED LEVELS FROM THE SECOND QUESTIONNAIRE. SCORES ARE SORTED FROM BEST PERFORMANCE TO WORST PERFORMANCE, AND NOT CORRESPOND WITH THE CHRONOLOGICAL ORDER THE PARTICIPANTS TOOK THE TEST. TRENDLINES ARE ADDED FOR CLARIFICATION. TOTAL AMOUNT OF PARTICIPANTS $N = 8$.

6 CONCLUSIONS AND SUGGESTIONS

Resolving the sub-questions, will, as said before, lead to an answer to *RQ*. For clarification, the questions are once again shown below:

- *SQ1*: Will providing only essential information lead to a lowered intrinsic cognitive load?
- *SQ2*: Will only providing essential information lead to a lowered extraneous cognitive load?
- *SQ3*: Will a lowered required total cognitive load lead to a lowered actual total cognitive load?
- *SQ4*: Will a lowered actual total cognitive load lead to better performance?

As this explorative study has no appropriate comparison, due to the aforementioned reasons, 'lowered' in this sense means that there is no quantified 'overload' within each of the individual elements.

6.1 ANSWERS

SQ1

Omitting redundant information, that is, only providing information which is directly necessary for completing the tasks at hand, will lead to a lower level of required intrinsic cognitive load. In this sense, the required mental effort of an individual is reduced, opening up space in the total amount of cognitive load. Results seem to indicate that only providing essential information can lead to a lowered intrinsic cognitive load, but that this lowering depends heavily on different factors too. Thus, *SQ1* can be answered positively, with a note that this answer should be part of a larger whole.

SQ2

Regarding what is mentioned earlier, due to the absence of verbalisation overall, it is difficult to answer *SQ2* definitively. What can however be assumed is that the total cognitive load suffered an overload, showing in the poor performances of the KLM and the insecure verbalisations whilst filling out the first questionnaires. Together with the results from the self-reported questionnaires afterwards, an increment in extraneous cognitive load is inevitable. Additionally, poor design choices caused incomprehension overall. Alternatively, it is assumed that the total cognitive load will lower as the design and hardware are improved — i.e. more adjusted to its user —, thus affirming *SQ2*.

SQ3

As mentioned at the beginning of this study, its goal was to lower the required total cognitive load. Although a proper start has been made, it became clear that there should be done more research and prototyping to adjust an interface to the wishes and needs of a low-familiar. The actual cognitive load seemed to be congested in many of the participant's cases, and if they dovetailed with the required cognitive load, it would have not. Ergo, *SQ3* appears to be very likely, but cannot be answered with an indisputable 'yes' from only this study.

SQ4

As *SQ3* remains somewhat inconclusive, it's tricky to fully resolve *SQ4*. Yet, assuming that the actual cognitive load is indeed lowered according to *SQ3*, it can be stated as well that if someone feels more confident regarding their skills, their performance indeed increases, following Figure 5.2. Besides, a higher performance is inherent to a lower self-reported investment. Concluding, it can be stated that a lower actual cognitive load indeed leads to better performance, hence positively answering *SQ4*.

Answer to *RQ*

How can we achieve a higher level of accessibility for digital illiterates?

After taking the answers of the various sub-questions into consideration, the answer to *RQ* can be approached in the following manner. Leaving out redundant information also creates less room for distraction, but only following the design principles stated in the literary framework is not enough; practical prototyping has to be done beforehand as well. Due to the absence of this practical prototyping beforehand, the interface used in the experiment did not seem to create a high level of accessibility for the digital illiterates. The high-familiars did not have troubles with the design. As *SQ2* is answered positively, but only under the conditions that the interface is adjusted to the user, *SQ3* cannot be answered conclusively either. Thus, it cannot be said definitely that only the design is dependent on the level of accessibility. Besides, participants showed visible difficulty with the technology itself. Apart from all the things that cannot be answered indisputably, there are strong tendencies in the results that creating possibilities for lowering cognitive load will in reality lead to a lowered total cognitive load. Therefore, *RQ* will be answered with that by both lowering the intrinsic and the extraneous cognitive load will lead to a higher level of accessibility for digital illiterates.

6.2 SUGGESTIONS FOR FUTURE RESEARCH

Returning to the pillars mentioned in SECTION 2 and the prerequisites in SECTION 3, suggestions for future research will be given for each one. For each suggestion applies that it should be tested a couple of times, with both lower-familiars and high-familiars, before actually testing it on digital illiterates — the absence of iteration appeared to be the main pitfall of this study.

6.2.1 WAYS OF ADDRESSING

The first round of interviews, conducted in SECTION 3, concluded that there was a huge abundance of textual information and that there was a lack of personal approach. Therefore, all assumed surplus information was eliminated and the design used for this study came out. A personal welcome message was implemented. During the evaluations, it became apparent that the latter was not noticed at all, and that there in essence was so few textual information left, that a form of address was absent entirely. The suggestion here is that pieces of textual information should first be written on paper and to be read by low-familiars from paper, before putting them on a screen. In this sense, the barricade from technology is omitted momentarily, and the focus is purely on the text; both the information and the form of address can be assessed.

6.2.2 LAYOUT

It has been discussed that the layout used here showed some errors. As a result, the design did not function decently and did not persuade its users — i.e. the participants — enough to make them understand and subsequently act on the intended persuasion. Particular design choices should be researched, such as the contrast between colours and a larger font for readability – following the standard HCI principles, together with heuristics mentioned earlier in this thesis. Social cues were not recognised by the participants; unfortunately, only the advertisement banner was acknowledged. This means that, in order to win the battle against ads and clickbait, an interface's social cues should be large (or at least, larger than most banners), in the centre of the screen and textual explain what the cue is about — if it encourages action, or if it is there solemnly to provide information.

6.2.3 CREDIBILITY

Although the preliminary interviews showed that both the high-familiars and the low-familiars seemed to have issues regarding credibility, none of the participants addressed the matter as such. However, the four subdomains of credibility

(presumed, surface, reputed and earned) discussed in SECTION 2 should be taken into consideration when designing an interface. Together with the aforementioned suggestions, a sweet spot should be found to balance all evens out, precluding possible incredulity and gullibility errors. As it is assumed before that digital illiterates tend to rely heavily on third-party experiences, it is of importance to properly educate and guide them into the digital world.

6.2.4 TECHNICAL SKILLS

Following on the previous paragraph's last sentence, education is key. Both peer-education and teacher-education work. Exposure to technology in a decent way will definitely lead to a higher overall level of technical skills, and through the third-party experiences from either peers or proper teachers, credibility will rise, which is accompanied by a better understanding of an interface itself. As is mentioned in the introduction, various organisations already work on this. However, nowhere is stated that these organisations provide feedback and give insights from their experiences, so to indeed successfully educate society, some sort of platform for feedback should be provided. In addition, educational platforms and software should be adjustable to the specific group of learners — for instance, a larger font size for elders, a higher contrast in the colour scheme for people who are colour blind, et cetera. In this sense, every learner can really learn; each small success in the process of learning contributes to larger successes, eventually leading to the accomplishment of making a digital illiterate a (semi-)high-familiar.

7 DISCUSSION

This study aimed to understand the information processing of digital illiterates when they interact with technology. Although various similar studies exist on this topic, none of them searched for the discrepancy between information processing and an interface, and the boundaries of one's total cognitive load in this relation. Thus, this study provided a comprehensive methodological framework. This extensive framework combined often used and more uncommon methods. It could determine one's technical skills, through experience and trough knowledge, and measure both cognitive load and performance, thus providing the opportunity for new insights. The pitfall with this extensive framework was that the qualitative analysis proved to be very time consuming and therefore prone to erroneous findings. The components discussed below inevitably influenced the suggestions mentioned in the previous section.

7.1. INFORMATION PROCESSING

With iterating the experiment with a larger sample size of wider variance in age, results would have been more conclusive. Results have shown that information processing was not depicted clearly enough with the used methods. As the think-aloud principle was either not encouraged enough, or just downright too much for the participants at the time, potentially valuable information was not retrievable. The KLM scores are used as the main thread of the results, to which other measurements are correlated. This indicates that there is a shortcoming regarding measuring the information processing in the framework; it draws too much on performance, involuntary shoving information processing to the background. Additionally, the established times of KLM did not correspond in the slightest with the participants' scores. If the model would be slightly adjusted, namely by increasing the proposed time for digital illiterates, together with adding moments of mental preparation within each task — as this happened during the evaluations — results could be more in line with actual performances. In this sense, the sole existing of time needed for information processing is acknowledged and can be further investigated.

The primed task recall, which was originally meant to indicate an individuals' information processing, turned out to be redundant, as it essentially was the same as determining prior knowledge – for which the questionnaire before the evaluation was filled out.

7.2 Cognitive Load

The framework proved to not dive deeply enough into the difference between intrinsic and extraneous cognitive load, which leaves a speculative area yet to explore. As of now, only theoretical answers can be formed, but it is still unclear if the cognitive overload stems from predominantly the intrinsic or rather the extraneous cognitive load. This led to partially guessing and estimating of the amount of total cognitive load, and a clear perspective on 'how much' cognitive load was either required or experienced could not be given. Additionally, for this study, a preliminary way of quantifying the cognitive load was proposed. This proved to remain too vague; again, it was unclear 'how much' cognitive load was perceived, either intrinsic or extraneous.

7.3 Limitations

Due to limitations in resources and time, the evaluations were conducted only once, and the study consisted of only eight participants. Operating the recording equipment, guiding the participants whilst filling out the questionnaires, and guiding the participants through the practical test proved to be too many simultaneous acts for one person. This led to a smaller sample size than initially intended, as the intention was to gather data from as much as twenty participants. Moreover, finding participants proved to be quite cumbersome. Additionally, six of the eight participants were over the age of 65, while this study explicitly did not want to emphasise the elderly part of society only — again, if time and resources would have allowed it, a larger number of younger low-familiars may have been approached and invited.

Even though the small group of participants showed some significant results, there were still some disputable outcomes. All participants were members of the same organisation where they took computer lessons. Apart from age discrimination originating from the organisation offering the lessons from people aged 50 and up, having all participants from under one roof also meant that they were likely to make similar mistakes. This on its turn could lead to biased results. As mentioned in the previous section, it would be resourceful to take results from different locations, as they could establish new insights on information processing. Apart from a larger sample size and inviting participants from different places, iterating the study over a larger time period could provide more significant outcomes. The results of this study

relied on one evaluation moment without any iteration, which has proven to be shaky on some grounds.

As for the exercises during the practical test, it appeared that they were too difficult for the participants. The lack of visualised goal caused them to practically try different things based on trial and error, or just stare blankly at the screen. Only after providing verbal, very clear instructions, they were able to perform the tasks. This led to a distortion in the performances, and supposedly to an alteration of the self-reported elements in the second questionnaire. However, due to the lack of contrast and the small font size, together with the large other distractions from the website builder's banner and the browser's functionalities, it appeared to be the only suitable solution at the time. If the participants were not guided carefully through the exercises, they would not be able to finish them at all.

8 FUTURE WORK

Rather than come to a conclusive answer, this study was meant to open the road to further investigations. The proposed methodological framework can, therefore, be further explored by iterating the existing study over a longer amount of time, as possible design errors could be altered for the next round of participants. Inviting participants from a wider range of backgrounds, as well as a wider age range, could lead to results which are more representative of Dutch society. People from all different layers of society should be able to interact with the technology; this should also be taken into consideration when inviting the participants.

In respect to the framework itself, individual methods could be tested even more thoroughly. Adding a questionnaire beforehand were participants can fill out where they encounter issues with an interface would accompany the existing questionnaires. This will lead to a higher degree of comprehension of common bottlenecks, which can be focus points for the next iteration. During the practical test, participants could be encouraged more to verbalise their thoughts. As proven in the preliminary stages of this study, verbalisation gives great insight on the issue at hand, since a participant is not bound to answering in one possible way — i.e. with either 'yes' or 'no', or filling in a Likert scale questionnaire. As was initially assumed for this study, measuring the occurrence of keywords could prove to be useful. For the practical test itself, it could be expanded by cutting up exercises into smaller parts. For instance, uploading a file could be split in determining the kind of file, the purpose of uploading the file, and uploading the file itself. Furthermore, adding exercises, such as turning on a computer, or closing the browser after use, could again deepen results. Regarding the used hardware and software, as for the sake of not adding an abundance of variables, it would be advised to use a proper desktop computer — or a laptop with an external keyboard and mouse — and gain insight on participants' preferred web browser. This goes for the operating system as well.

If these adjustments and alterations are addressed, it will be possible to tackle the issues acknowledged in this study to a further extent, eventually leading to a more digital society.

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I would like to thank my supervisor Fons for approaching my research subject with the same enthusiasm as me, providing me with insightful tips and tricks, and coming up with creative suggestions.

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-- Sophie

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11 Appendices

Appendix I

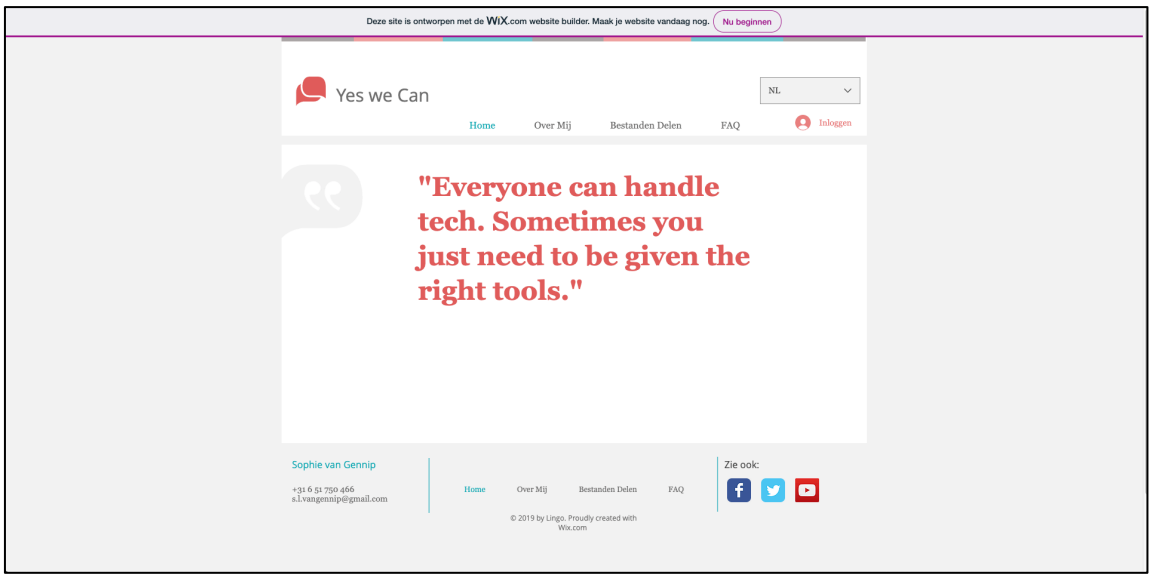

Figure AI.1. Home page of the first website. Built with Wix.com, April 2019.

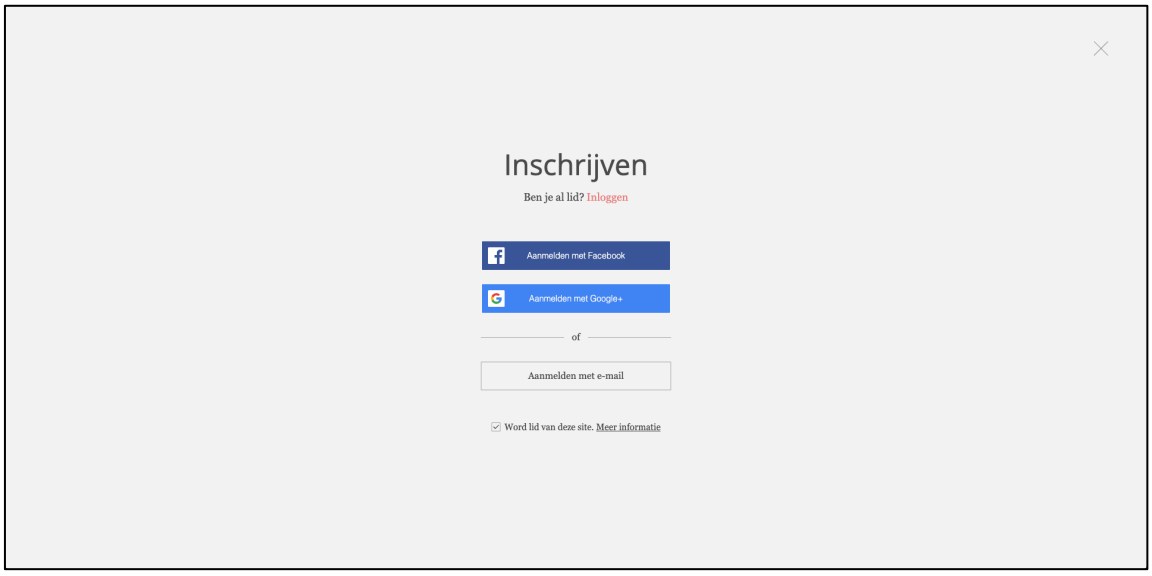

Figure AI.2. The user would see this after clicking the Logging In button. The first prompt is to subscribe to the website, instead of logging in directly, creating an ambiguous message. Built with Wix.com, April 2019.

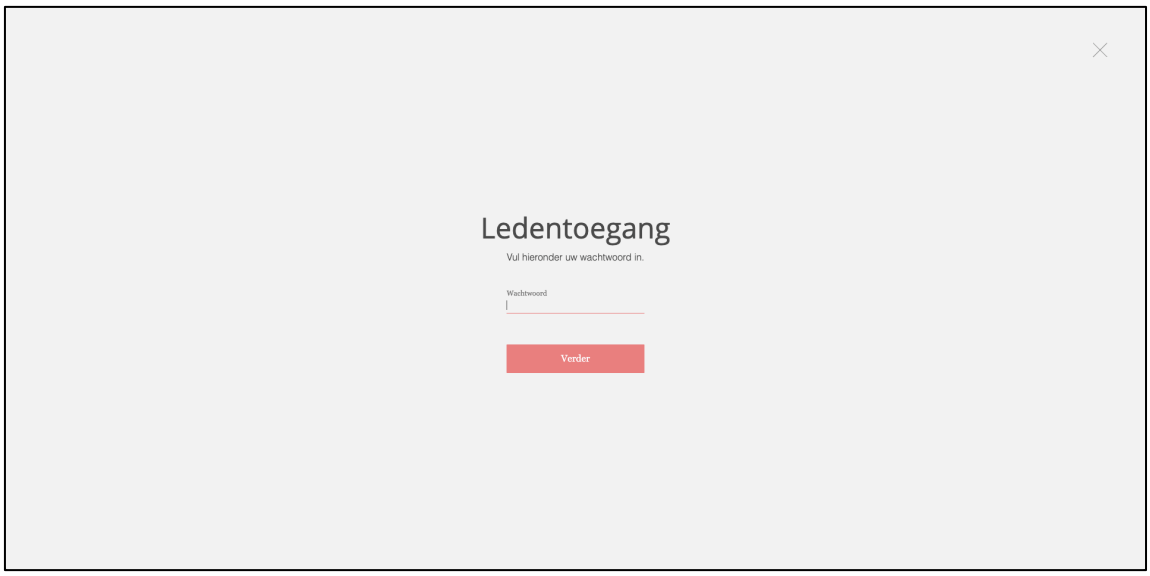

FIGURE AI.3. PASSWORD PROMPT WHEN THE USER TRIES TO OPEN THE PAGE 'OVER MIJ'. BUILT WITH WIX.COM, APRIL 2019.

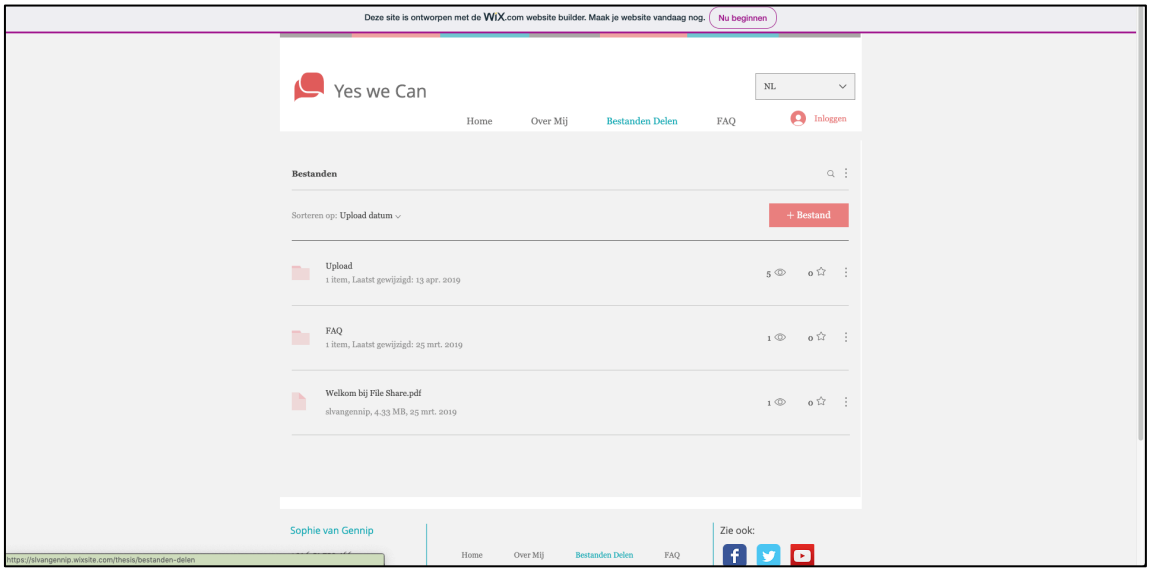

FIGURE AI.4. ONCE LOGGED IN, THE USER CAN ACCESS THE FILE SHARING PAGE AND UPLOAD A FILE. BUILT WITH WIX.COM, APRIL 2019.

APPENDIX II

Test		
	Action	**Purpose**
1.	Go to a given web page [details provided].	Can they navigate to a web page?
2.	If needed, set to the right language (English or Dutch).	Can they choose their preferred language?
3.	Log in using email address [details provided].	Can they log in without problems?
4.	Navigate to a certain page, which gives a password prompt [details provided].	Are they able to enter password without problems?
5.	Navigate to a certain page and upload a file [details provided].	Can they upload a file without problems?
6.	When you're done, log out.	Can they log out without problems?
Questions		
1.	When you look at a digital interface for the first time, how do you look at it?	
2.	When you look for something on a web page, do you know how to look for it?	
3.	When you look something up in general online, do you feel like you know which aspects on the screen are of more importance than others?	
4.	When presented information digitally, do you prefer this to be presented through icons or written text, and why?	
5.	Do you believe that there is a way in which it would be easier for you to interact with a digital interface?	
	Extra question for high-familiars	
6.	What does need to be changed in this interface [details provided] in order to make it more accessible to you?	

TABLE AII.1. LIST OF EXERCISES AND QUESTION FOR THE INITIAL INTERVIEWS.

Appendix III

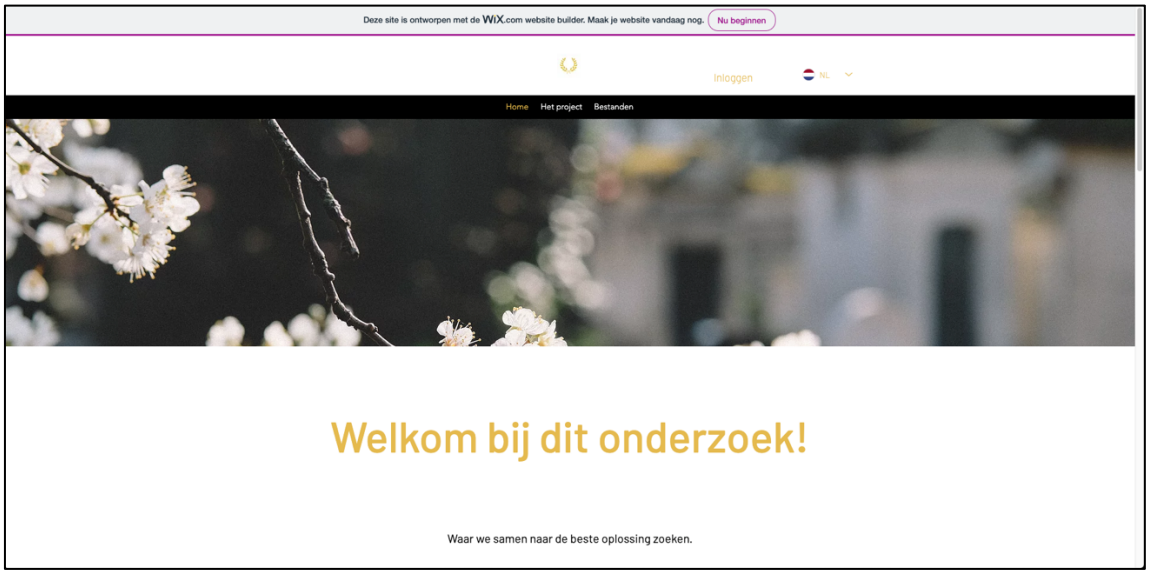

Figure AIII.1. Home page of the website. Built with Wix.com, June 2019.

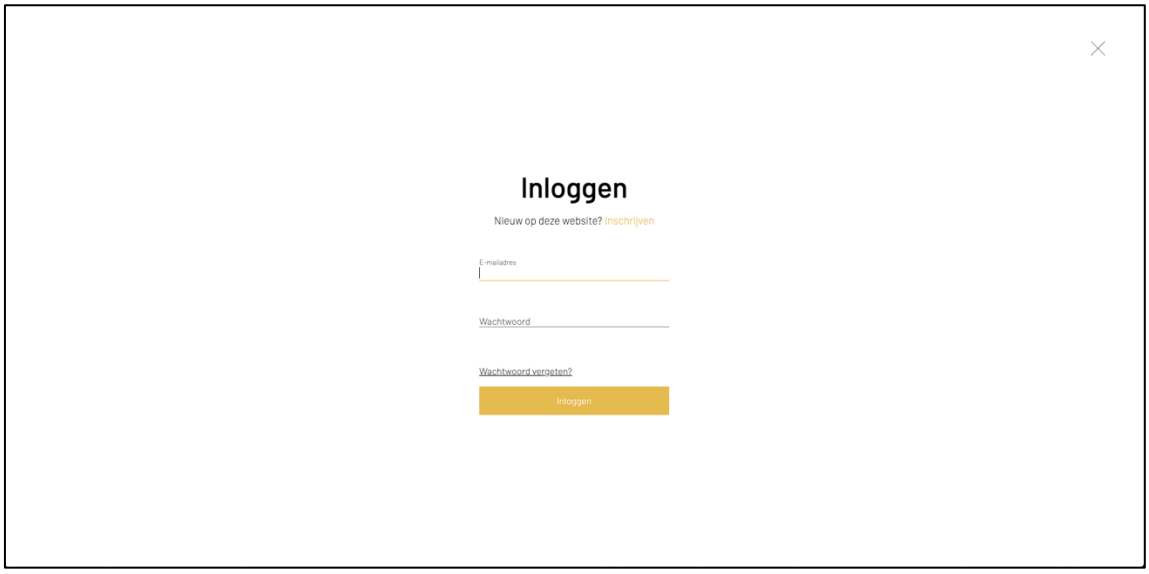

Figure AIII.2. Logging in. Built with Wix.com, June 2019.

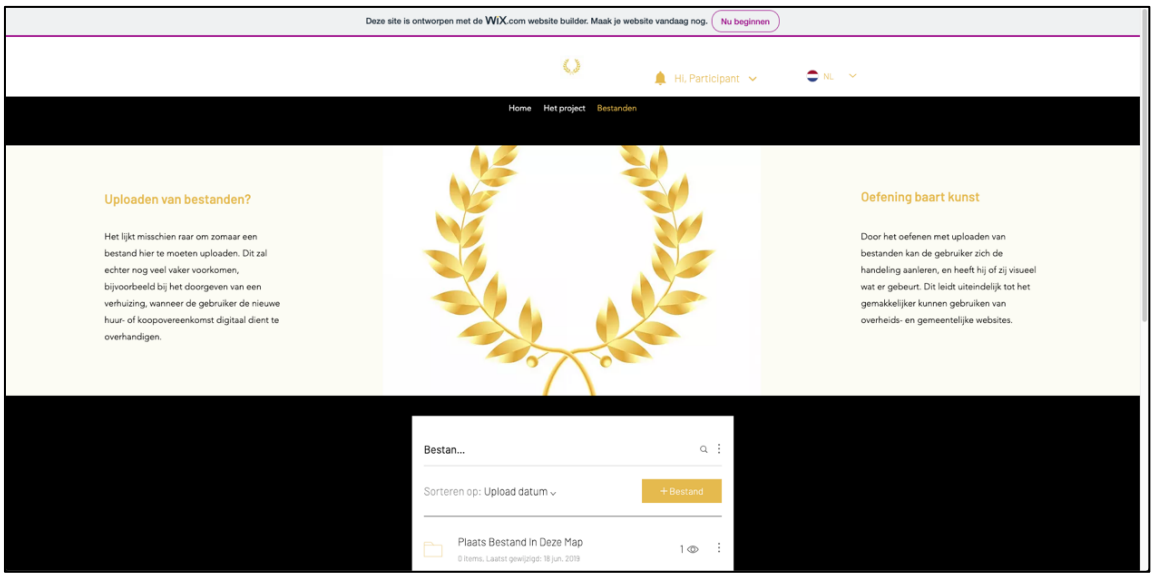

FIGURE AIII.3. ONCE LOGGED IN, THE USER CAN ACCESS THE FILE SHARING PAGE AND UPLOAD A FILE. BUILT WITH WIX.COM, JUNE 2019.

APPENDIX IV

Number participant: .....
Date: .....

Below you can find several operations and statements about these operations.

Circle the numbers which correspond to you (1 answer per statement).

1 = completely disagree
2 = mostly disagree
3 = some
4 = mostly agree
5 = completely agree

Opening the browser.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Navigate to a certain web address.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Choosing a website's language.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Logging in on a website.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Navigating to different pages within a website.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Uploading a file.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5
Logging out on a website.					
I think I know how to do this.	1	2	3	4	5
I can successfully carry this out.	1	2	3	4	5

FIGURE AIV.1. QUESTIONNAIRE BEFOREHAND, DETERMINING THE DIFFERENCE BETWEEN PRIOR EXPERIENCE AND PRIOR KNOWLEDGE.

Number participant: ……..
Date: ……..

Below, some statements are given regarding the tasks you just completed.

Circle the answers corresponding to your opinion (1 answer per statement).

It took a great deal of mental effort to complete the tasks.

completely disagree | mostly disagree | some | mostly agree | completely agree

I needed to focus with all my attention to complete the tasks.

completely disagree | mostly disagree | some | mostly agree | completely agree

I was frustrated whilst completing the tasks.

completely disagree | mostly disagree | some | mostly agree | completely agree

Completing the tasks gave me stress.

completely disagree | mostly disagree | some | mostly agree | completely agree

The tasks were difficult to complete.

completely disagree | mostly disagree | some | mostly agree | completely agree

I can make up various possible solutions for completing the tasks.

completely disagree | mostly disagree | some | mostly agree | completely agree

FIGURE AIV.2. QUESTIONNAIRE AFTERWARDS, DETERMINING THE MENTAL EFFORT (FIRST AND SECOND STATEMENT), STRESS LEVEL (THIRD AND FOURTH STATEMENT) AND DIFFICULTY (FIFTH AND SIXTH STATEMENT) PERCEIVED.