UPPSALA
UNIVERSITET

IT 20 014
Examensarbete 30 hp
Mars 2020

Efficient Input Solutions for User Interfaces Primarily Intended for Information Presentations

Hassan Odimi

Institutionen för informationsteknologi
Department of Information Technology

This Page Intentionally Left Blank

UPPSALA
UNIVERSITET

Teknisk- naturvetenskaplig fakultet
UTH-enheten

Besöksadress:
Ångströmlaboratoriet
Lägerhyddsvägen 1
Hus 4, Plan 0

Postadress:
Box 536
751 21 Uppsala

Telefon:
018 – 471 30 03

Telefax:
018 – 471 30 00

Hemsida:
http://www.teknat.uu.se/student

Abstract

Efficient Input Solutions for User Interfaces Primarily Intended for Information Presentations

Hassan Odimi

The user interfaces of administrative information systems are typically based on screens serving both input and output functions. However, in numerous usage situations, such as healthcare, the primary purpose of these screens involves providing information to professionals. Therefore, these screens could be highly optimised using spatial and visual cues to support efficient search and reading. Accordingly, this thesis conducted a literature review to understand the drawbacks of the available interface solutions and how screens could potentially be optimised for information presentation. To delimit the thesis scope, reading and searching medical records constituted the main focus of the review.

The results indicated that the cognitive cost of visual clutter and scrolling could hinder the reading process. Moreover, related work and recommendations on designing support for finding and reading information were reviewed. However, a method to enter and update the data was perceived to be missing. Therefore, a general design hypothesis was suggested to enable input on screens optimised for reading.

The central theme of the input solution focussed on preserving the screen's original layout. This was accomplished using separated, yet fixed panels containing only the necessary instructions for each input task. Furthermore, the interface supports users by providing visual feedback on their actions and the system status.

Following this, the keystroke-level model (KLM) was used to evaluate the efficiency of the proposed solution for expert users. The results demonstrated that the solution could be as efficient as, or in some cases, better than the conventional interfaces.

Finally, an empirical study was conducted with 16 participants to evaluate the solution's efficiency for inexperienced users who briefly interact with the concept of reading screens. The results indicated that the reading screen scored significantly better than the standard option in terms of task times and mouse travel averages.

Handledare: Mats Lind
Ämnesgranskare: Mikael Laaksoharju
Examinator: Mats Daniels
IT 20 014
Tryckt av: Reprocentralen ITC

This Page Intentionally Left Blank

Acknowledgements

I wish to express my sincere appreciation and deepest gratitude to my supervisor Mats Lind, for his guidance and support through each stage of this thesis. His invaluable assistance and insightful feedback were essential to realise the goals of this work. Also, I would like to pay special regards to Mikael Laaksoharju for reviewing my thesis and providing me with encouragement, detailed and constructive feedback to improve the content.

I wish to extend my special thanks to Sita Vriend for helping with the recruitment for the experimental study, and for being my opponent. To my teachers, Lars Oestreicher and Mohammad Obaid for inspiring my interest in the field of human-computer interaction. Thanks to Anders Berglund for supporting me during the first year of the programme. Finally, I wish to acknowledge the love and support of my mother during the years of my study.

Contents

List of Figures

List of Tables

This Page Intentionally Left Blank

1 Introduction

Nowadays, people depend on information systems more than ever, as they have become an integral aspect of users' daily activities in almost every domain. As a result, the focus has substantially shifted in recent years towards what is called 'User-Centred Design'. Numerous authors have insisted on the importance of this design philosophy. For instance, Benyon (2019) argued that such an approach is so essential that it justifies being expensive and time-consuming. He explained that it concerns focussing on people's needs rather than technology, designing for diversity, and including users in the design process (Benyon, 2019, p. 12,22). However, according to Norman, this approach can become harmful when it is overused, since users are constantly changing. This makes the interfaces that users wanted less efficient as they gain proficiency in using the system. An alternative approach is to centre the design process on the activities that users perform instead (Norman, 2005).

Furthermore, prioritising user needs can sometimes lead designers to create comprehensive solutions that support all these demands equally. These types of solutions seek to balance several conflicting demands and make the system usable by everyone. For example, most systems are designed to combine input and output functionalities in one screen. However, these multi-purpose screens can hinder skilled users who are primarily interested in finding and reading information to support their decision-making process. Moreover, including instructions and elements that enable data input on the same screen will prevent users from conducting effective visual queries. Therefore, there is a need to create screens optimised for search and reading.

Visual search refers to the ability to locate particular items in a visual scene. However, since research has revealed that it is difficult to predict a consistent pattern in advance, some visual features can be used to drive visual attention towards the desired location (Benyon, 2019, p. 518). This ability to direct attention towards valuable information can be used to create the reading screens mentioned earlier. Such screens can prove beneficial for situations where physicians review medical records to diagnose a patient, for example.

Reading screens can be beneficial for numerous administrative systems, such as finance and banking, business, government digital services, and others. However, this work primarily focuses on reading the medical records and finding solutions to enable input on their reading screens. This was necessary to delimit the thesis scope and explore this area in some depth.

In order to identify the disadvantages of the current solutions and gain insights regarding how medical workers read the records, a literature review was conducted. The main findings of this review indicated that navigation, visual clutter, and scrolling played a vital role in hindering the reading process and imposing an extra cognitive load on users. Therefore, suggestions to improve the interfaces of similar systems included reducing the number of windows switching, eliminating the need for scrolling, and using fixed positions and visual encoding of screen elements (Borälv et al., 1994).

Overall, the reviewed suggestions and guidelines were found to emphasise enabling pattern recognition and reducing the cognitive cost imposed on users. However, the design of the reading screens' input methods was perceived to be less prominent in the literature. Therefore, to meet the first goal of this thesis—namely, developing a design hypothesis for an efficient input method that can be combined with reading screens—a design-thinking method was employed to produce a set of potential solutions. These solutions were later reviewed to select the most suitable option for further evaluation.

The second thesis goal was to evaluate the suggested solution's efficiency for expert users. To achieve this, the analysis has to be low-level, as this allows comparing the new design with the conventional input solution. Therefore, an estimation of both solutions' efficiency was calculated using the keystroke-level model (KLM), since this enables such comparison.

Finally, the third thesis goal was to evaluate the proposed design's efficiency for inexperienced users. Therefore, an empirical study was conducted with 16 participants with only a brief interaction with the interface. Insights from the literature review and the evaluations are presented in the upcoming sections in greater detail.

2 Purpose

The primary goal of this thesis is to propose a design hypothesis for an efficient input method for screens primarily optimised for finding and reading information.

2.1 Research Questions

This work aims to address these research questions to fulfil its primary purpose:

1. What would an efficient design solution look like to enable efficient data input for screens initially intended for information presentation?
2. How efficient is the proposed design for long-term usage by expert users?
3. How efficient would the proposed design be for users who have brief interactions with its interface?

2.2 Delimitations

The input method's proposed design hypothesis is initially optimised for efficiency, primarily using keyboards, and to a lesser extent using a mouse. Therefore, other entry modalities, such as voice recognition, handwriting, and gesture recognition, are not addressed by this solution. Furthermore, implementing a fully functional and interactive version of the input method so it can later be tested with its potential users remains beyond the scope of this project.

Moreover, the methods utilised to test the design exclusively focus on the cost of use in the long term and the cost of first-time use after a momentary interaction. This makes 'efficiency' the primary concern of the testing. Measuring other aspects of usability, such as satisfaction, would require different types of experiments that are not conducted here due to time constraints.

3 Theory and Background

Interacting with computer systems to read information, enter data, and make informed decisions has become an essential aspect of people's daily tasks in almost every work domain. This interaction is usually accomplished through a 'User Interface' (UI) functioning as the primary communication tunnel between the system and user.

In the early stages of information system development, designers typically designed the screen output and the end results first, followed by working on the necessary input to produce the desired output. This traditional approach worked with old systems that converted input data into a structured output. However, the continuous shift of focus toward users, and how they communicate with the system, led to user-centred systems in which the distinction between input and output became less transparent. This can be explained by the fact that users often work with a varied mix of input, screen output, and data queries as they conduct their routine tasks (Shelly and Rosenblatt, 2011, pp. 336–337).

Although the tasks performed by users became a complicated mixture of manipulating inputs and reading outputs, the design recommendations and user interface guidelines seem to treat those two aspects of the UI as separate components. For example, Shelly and Rosenblatt discussed some guidelines for designing data entry interfaces for users who spend most of their time entering data. These guidelines were based on general principles of interface design. Furthermore, they discussed separately the design of output screens and reports and how the layout of these forms should be designed to be attractive, balanced, and easy to read.

Balancing between the input and output functionalities can pose a significant challenge, since most of the administrative information systems are used to perform mixed tasks. As a result, designers tend to combine those two aspects in a comprehensive standardised solution. However, Goransson et al. argued that, as the complexity of the information system increases, the possibilities of developing standardised solutions to the interface problems becomes more limited. Therefore, the solutions must be application-specific to be effective. Moreover, the interfaces should not be treated as a separate part of the system, but should rather be specified from the expected use situations and evaluated within the same context (Goransson et al., 1986).

Typically, professionals in numerous situations often use computer screens as the primary source for finding and reading information, with an occasional need to enter or update the data. A typical example of such situations is when physicians are searching for information concerning a patient's medical history. Therefore, reading information from screens primarily designed to support data input is suboptimal for several reasons. First, a vast amount of screen space is allocated for the graphical symbols and instructions needed to make the input faster. Second, the visual means that would enhance the reading cannot be fully employed, since they would obstruct efficient input. Besides, using these visual means may contradict some principles of designing input interfaces.

3.1 Visual Search and Usability

The Electronic Health Records (EHR) systems offer an excellent example of use situations where doctors must find and read patient information efficiently to make the right decision regarding the appropriate treatments. However, the usability issues present with the interfaces of such systems can possess severe consequences and lead to medical accidents and errors. For example, if the screen layout makes it difficult for users to locate critical information, then it becomes more likely for such important information to be excluded from the decision-making process (Kushniruk et al., 2015).

3.1.1 Navigation and Scrolling

Another issue related to reading information was found in a study seeking to detect usability problems in structured data entry interfaces in dentistry. In order to link a diagnosis with a planned treatment, users need to navigate several tabs, and when it comes to the tab for selecting the treatment, the interface fails to indicate the previously selected diagnosis. This led to cognitive difficulty for users attempting to retrieve the necessary information from memory (Walji et al., 2013).

Similarly, a literature review conducted by Roman et al. (2017) identified several safety concerns that violated the usability heuristics related to EHR interface navigating, such as the following:

- Fragmented displays preventing a coherent view of patient condition.
- Disruption in the cognitive and clinical workflow.
- Showing irrelevant and non-applicable menu options as clickable.
- Scrolling back and forth through a large amount of information to locate information or data entry prompt or to correct an error.

Furthermore, Roman et al. listed some potential solutions to these problems that they identified in the literature they reviewed. Such solutions suggested grouping relevant information together on one page, minimising within- and between-page navigation using one of several methods, and integrating relevant data using fewer windows and screens (Roman et al., 2017). These suggestions indicate the necessity of having screens primarily optimised for locating and reading information efficiently.

As mentioned earlier, standardised solutions offer numerous disadvantages and can force users to find workarounds to overcome them. One particularly interesting issue was identified by Blijleven et al. (2017) among several workarounds. In a case study performed at one of the largest university hospitals in the Netherlands, Blijleven and his colleagues found that, despite the EHR under observation offering an extensive standardised template to enter the data, users still preferred copying data from previous progress notes and pasting it in new ones with the required modifications. The reasons given for not using the standardised templates were 'the excessive scrolling up and down' to follow the data fields that were misaligned with users' workflows. Furthermore, users found the template to contain too much irrelevant screen clutter, as well as inconsistency in placement for some of the interface elements.

The literature contains numerous studies concerning the usability issues related to various information systems. For instance, research discussing these issues in EHR systems in particular is abundant. However, since the primary focus of this thesis concerns developing and evaluating what could represent an efficient input solution for reading screens, the cost of navigation and scrolling is deemed the most relevant to reading information, since they affect the accuracy and speed of locating information. Moreover, visual clutter offers yet another factor that can affect readability and hinder user performance.

3.1.2 Display Clutter

Optimising screens to support finding and reading information requires a deep understanding of the information structure and the context in which those screens will be used. This understanding should precede other design strategies, such as using visual cues and spatial properties to support the reading process. Moreover, additional UI aspects, such as unnecessary scrolling and visual clutter, must be addressed. The reason is that these issues' consequences for performance were prominently identified when reviewing system usability literature.

Display clutter represents a widely recognised problem that negatively affects multiple aspects of user performance across various domains and applications. The detrimental effect of clutter can be found in fields ranging from performing non-crucial tasks, such as web surfing and video games, to critical tasks, such as aviation, security, military operations, and medical records (Moacdieh and Sarter, 2017, 2015, 2014).

However, there seems to be no unified definition of clutter that researchers refer to when discussing this topic. Furthermore, despite agreement on its detrimental effects in specific conditions, there remains no agreement concerning how to reliably measure and control this phenomenon (Moacdieh and Sarter, 2014; Shelly and Rosenblatt, 2011).

In a comprehensive review of the definitions and measurement methods visual clutter and its effects on visual search and performance, Moacdieh and Sarter (2014) cite multiple resources stating that, beyond delaying visual search, clutter can also increase memory load, cause confusion, degrade monitoring and change detection, and infuse confidence in the wrong judgment. Moreover, they found that clutter adversely affects situation awareness, object recognition, linguistic processing, and reading.

3.1.2.1 Types of Clutter

Since this thesis aims to design and evaluate efficient input methods to be used with screens optimised for data presentation, the aforementioned harmful effects of clutter for aspects such as reading and visual search are especially relevant in this context. Therefore, any design attempt should aim to reduce display clutter. However, it is better to first review clutter from different perspectives and then agree on a definition to choose the right criteria when evaluating any possible solution.

Moacdieh and Sarter (2014) sorted various definitions and perspectives of clutter into the following five main categories:

1. **Display Density:** Arguably the most accepted view on clutter, this primarily concerns the number and density of items displayed on the screen.
2. **Display Layout:** This aspect 'emphasises the arrangement, nature, and colour of display entities in addition to merely the number or density of entities present'. Therefore, poor visual design and structural organisation represent the primary causes of cluttering.
3. **Target-Background Similarity:** According to this view, the display is considered cluttered when the similarity between the search target and the background (or the surrounding distractors) prevents efficiently locating task-related data.
4. **Task-Irrelevance:** In this perspective, the main factor in assessing display clutter concerns the displayed information's relevance to the task at hand. Therefore, according to this view, clutter was defined, among similar definitions, as 'an abundance of irrelevant information' (Doyon-Poulin et al., as cited in Moacdieh and Sarter, 2014).
5. **Performance and Attentional Costs:** This view, unlike the previous ones, does not only consider the features and elements of the display as the sole source for clutter. Instead, it includes the effects that the screen induces on the user's attention and performance. Primarily, it considers the interaction between display-based and user-based factors, such as workload, user experience, and task difficulty.

The various aspects of clutter are interconnected, and one type can lead to another. Furthermore, several methods have been devised to measure the clutter of an interface. These methods vary depending on the properties they include in the evaluation, but they largely consist of the following: image processing methods, performance evaluation, subjective evaluation, and eye-tracking (Moacdieh and Sarter, 2014). However, the design and evaluation of the input method primarily focusses on the performance and attentional costs of clutter, as well as the task-irrelevance aspect. The other remaining aspects, such as display density, layout, and target-background similarity, relate more to the design of the reading screen itself.

3.1.2.2 Clutter in EHR Interfaces

As discussed earlier, EHR systems feature numerous usability issues due to their complex nature. Moacdieh and Sarter (2015) conducted an experiment to measure the performance and accuracy of a set of 15 medical practitioners performing tasks using a patient's medical history page. The researchers manipulated factors such as clutter level, stress level, and task difficulty. Furthermore, they employed methods such as performance and subjective evaluations in addition to using eye-tracking to measure the participants' attention allocation. Their results can be summarised as follows:

- Clutter significantly affected search times during the high-stress and difficult task condition.
- Screen time (i.e. the time spent extracting information related to the task from the interface) only counted for the low-stress condition. This was necessary, since the high-stress condition imposed a time constraint on participants. However, the clutter resulted in a significant increment of screen time despite the low-stress situation.
- In terms of the noticing accuracy, in all conditions, participants missed more crucial information with the highly cluttered screens.
- Search accuracy was not affected by the clutter. However, the authors argued that the search tasks employed in the experiment were not sufficiently challenging to influence the results. Another explanation was that the participants possibly compromised speed in favour of accuracy.
- Clutter's effects on search and performance were reflected in the location metrics of the eye-tracking data. This reflection suggests that participants were distracted by the irrelevant information in the display.
- Finally, the results from the subjective evaluation demonstrated a significant increase in rankings between low- and high-clutter screens. Moreover, during the high-stress condition, ratings exhibited a significant difference in the scales of performance, effort, frustration, and temporal and mental demands.

Interestingly, a qualitative study published two years later by Moacdieh et al. (2017) found that physicians were aware of clutter's effect on safety and efficiency. Moreover, they emphasised the 'extreme importance' of the information's visual design.

The findings from previous studies confirm that display clutter imposes cognitive costs on attention and performance, especially an excessive amount of information unrelated to tasks that the interface is optimised to support.

This negative relationship between irrelevant information and cognitive processes was further discussed by Colin Ware in his book *Visual Thinking for Design*. Here, Ware referred to the *theory of information foraging* developed by Pirolli and Card to justify the urgent need for optimising the cognitive process when designing visual interfaces. This theory explains how people, in their pursuit of information, strive to minimise the cost of time and energy by attempting to 'offload tasks onto the computer whenever possible' (Ware, 2008, pp. 174–177).

Ware further described details regarding the just-in-time visual queries process that the human brain exercises to perceive the surrounding world. He then argued that, after understanding this process, the goal of information design must be designing visual interfaces 'so that visual queries are processed both rapidly and correctly for every important cognitive task the display is intended to support' (Ware, 2008, p. 14). However, to be able to design an efficient input solution for the reading screens, it is essential to first understand how these screens can be designed to support the task of reading efficiently.

3.2 Reading Displays

People learn how to read from an early age. In the beginning, this comprises a slow, difficult, frustrating process requiring them to carefully think about each syllable and word they are attempting to comprehend. However, by practising this for a decent amount of time, reading becomes a skill that can be performed relatively easily.

Although people used to read exclusively from printed media such as books, newspapers, and documents, digitisation of these materials, and the nature of modern life, has changed this. Nowadays, people are required to read more from digital screens to complete their daily tasks. This shift of the reading medium has introduced numerous advantages, but it also features downsides, especially when compared to reading from papers.

A vast body of research has compared reading from papers versus reading from digital screens. The results of these studies are mixed and usually dependent on what the study attempted to measure (comprehension, speed, fatigue, recall). Moreover, it depends on the type of text (narrative or expository), the participants' age and level, text length, presentation, and various other factors. Furthermore, attempting to determine which method is better would be redundant, since it would be nearly impossible to replace the current systems with paper-based alternatives if papers won the comparison, for instance. However, interface design can still make use of the features that make reading from paper better in some circumstances.

Mangen et al. conducted an experiment with 72 10th-grade students in Norway to explore how reading from a digital interface affected comprehension. The students were asked to read two texts (1400–2000 words) and take a test afterwards. The main finding of the study was that students who read from papers scored significantly better in the reading comprehension test compared to those who used the computer screen. They considered this to possibly be due to the navigation differences between the mediums, as reading from a digital display includes scrolling, which could have caused 'spatial instability' and affected the mental representation of the document. Moreover, they argued that paper offers better access to information because of its fixed spatial cues. This aids in building and recalling a better mental representation when locating and retrieving pieces of information required to answer the test (Mangen et al., 2013).

One can argue that accessing information should not pose an issue, since today's advanced search functionalities can compensate for the disadvantage of reading from digital displays. However, examples from real-world applications demonstrate the opposite. For instance, in the study referred to earlier by Walji et al., the search feature of the evaluated EHR system was identified as a usability issue of medium priority to fix. The reason was that the search results did not match users' expectations (Walji et al., 2013). Moreover, after analysing the search logs of an EHR system, Natarajan et al. found that 14.5% of searches were navigational. For example, the reason behind queries that included medical record number (MRN) was to switch patients (Natarajan et al., 2010). Natarajan explained that users' ignorance of the limitations of the search functionality could be due to a lack of training. However, this percentage illustrates that users probably faced difficulties navigating and accessing information. Furthermore, when space traverse is regarded as a cognitive cost, an interface that enables information access via eye movements would be far more cognitively efficient than other methods such as mouse select, hover, or zooming (Ware, 2008, pp. 103–104).

Nygren et al. found that the process of reading familiar documents by skilled users can be divided into two components: The first is automatic, where users can gain knowledge via features embedded within the document itself. The second is conscious and non-automatic, requiring effortful cognitive processes to extract the necessary knowledge for the task at hand. Moreover, they argued that interface design can make use of features such as fixed spatial position, grouping, colour, typeface, orientation, and the absence of some information in order to enable users to gain knowledge concerning the presented information with little cognitive cost, leaving more attentional capacities available to solve essential tasks (Nygren et al., 1992b).

Furthermore, they explained that users could consciously access the knowledge gained at a low level from visual and spatial cues, which they could then use for task components 'like orientation, navigation, choice of search strategy, discovery of errors, choice of a proper reading level and coordination of values in time’. Moreover, ‘The knowledge is thus not gained by reading but by recognition of patterns and interpretation of the characteristics of the information media’ (Nygren et al., 1992b).

3.2.1 Reading the Medical Records

Nygren and Henriksson were interested in learning how physicians read paper-based patient medical records, as this understanding would enable insights regarding the design of computer interfaces for complicated work environments, such as healthcare systems.

They determined that the manner in which physicians read documents differs depending on the situation, including whether this involves examining a new patient for the first time or re-reading a document of a familiar patient. They also found that physicians could make a quick assessment of case complexity by glancing the document. This assessment was enabled by the visual cues of the printed paper, such as the distance between red stamps in one type of document. Moreover, it was found that, when examining a regular patient, physicians managed to retrieve their conscious memory of the patient’s situation—what they called ‘a memory-picture’—by simply glancing at the record (Nygren and Henriksson, 1992).

In other situations, Nygren and Henriksson found the medical record to be used as a dictionary to find specific facts and pieces of information, such as drug name for instance. However, if the physician had seen the information before, he or she would use the location as a clue and search the specific position to find it again. Searching for specific facts in many use situations indicated that the ‘reader uses knowledge about structure, sorting order and textural layout to limit the search space as far as possible’ (Nygren and Henriksson, 1992).

Physicians were also found to read medical records for problem-solving. In this situation, the primary goal of reading was ‘to test hypotheses, or evaluate strategies of action in the lights of the facts in the record’. Therefore, several new facts may call their attention and help them to develop a new strategy if those facts stand out from the pages (Nygren and Henriksson, 1992).

Nygren and Henriksson concluded with identifying three main types of text processing that occur during one of the previous reading situations:

- Reading – The reader carefully reads word by word.
- Skimming – The reader’s eyes wander along with the pages, reading only certain parts.
- Skipping – The reader skips certain sections of the page.

The previous reading strategies followed by physicians were found to comprise an interchange between reading, skimming, and skipping to find the right information that supports assessment and diagnosis. Therefore, Nygren and Henriksson developed design recommendations based on previous reading strategies. First, presenting a vast amount of information is encouraged, but the interface should feature a high degree of positional and textural structure that enables the information to grab the user’s attention. Second, orientation and navigation play an essential role in the design, and the visual and spatial cues should be used to enable searching and reading. Finally, the user should be able to view the entire record to develop an idea of what may be missing, as the absence of information can be helpful to derive new knowledge in some cases (Nygren and Henriksson, 1992).

As can be seen, a strong relationship exists between visual clutter and reading efficiency. For instance, designing an interface with fixed positions will not be possible when content leads to excessive scrolling and window switching. However, the amount of information is not the sole indicator of clutter, since skilled users are trained to deal with large volumes of data. Therefore, the quantity becomes a factor when the interface contains an abundance of unnecessary information, or when it imposes a cognitive cost on users.

Nygren et al. (1992a) designed an interface for reading medical records based on the recommendations of their previously mentioned work on reading paper records. The solution, for example, removed unnecessary information such as the headlines of some obvious information, such as name, date of birth, recent notes, and medications. In addition, the interface made all the essential reading occur on one level by reducing the number of windows. Furthermore, all objects possessed a fixed position, enabling users 'to build the pattern recognition of typical records' (Nygren et al., 1992a).

Their prototype possesses numerous features, such as dynamic interactions, visual coding of various components, page-turning by mouse clicks and gestures, a unique scrolling mechanism of indexes, and a visual manner of illustrating connections between the bundles of notes. Moreover, it offers dynamic feedback including animation and position shifting to provide the impression of direction when browsing pages.

In their argument defending the presentation and navigation method, they claimed that the position cues of fixed elements aid the user in searching the screen. Moreover, turning pages by clicking on one side of the page requires less attention compared to conventional scrolling. This is because, with standard scrolling, the user needs to regain orientation every time the text moves vertically (Nygren et al., 1992a).

Nygren and Allard also reported the advantages of fixed layout for searching and scanning web pages for intranet applications. They illustrated that, after training, skilled users developed effective scanning strategies on the fixed page layout. For instance, the scanning speed improved 25% with practice but became constant after 200 trials. Moreover, the rate was 83% faster when the search target was provided with a unique visual feature, such as colour, size, shade, space, and inclination (Nygren and Allard, 1996).

Tange et al. mentioned that some medical domains require a dynamic type of data entry due to the data's unpredictable nature in these domains. Thus, there is a need for accommodative entry forms that adapt to the screen's content. However, despite listing screen optimising using fixed positions cues as an effective approach to search and present data, they noted that this seems contradictory to the need for dynamic data entry (Tange et al., 1997).

The previous design concepts seem promising for developing screens optimised for reading. However, the literature does not suggest how such optimisation would be possible in the presence of various input elements. For instance, input elements possess numerous visual features pushing for users' attention. As a result, the recommended visual and positional cues will become less effective and may be perceived as clutter.

3.3 Related Work

Domańska (2018) offered a design hypothesis for a reading system for medical records after reviewing the relevant literature and conducting interviews and observations at Akademiska Sjukhuset hospital in Uppsala.

From these findings, her proposed design utilised navigational tools, layout, visual cues, and interactions to support users in dealing with the abundance of information typically needed in this field. Moreover, the final prototype was positively received when evaluated by a small group of physicians. Furthermore, it is believed that the design hypothesis 'would enable medical staff to read the data in a highly efficient way' (Domańska, 2018). However, the solution did not consider the challenge of inputting data with the same interface, since dealing with any additional windows or switching to a dedicated system for occasional input tasks would limit the design's efficiency and impose extra cognitive load on users.

4 Finding a Potentially Efficient Design

Creating an efficient interface design to enable input on reading screens can pose an intriguing challenge. Therefore, following a systematic approach to generate and refine ideas is essential. Design thinking was deemed the appropriate method for answering the first research question.

4.1 Design Thinking Method

Design thinking aims to generate a common starting point for designers and other entities involved in the design process. However, while there remains no commonly accepted definition for the term ‘design thinking’ (Schallmo et al., 2018), the following definition offers insight into what design thinking means:

> The Design Thinking approach is a systematic, user-oriented approach to solving real-life problems. Instead of focusing on how the problem can be technically solved, the main focus is addressing the user’s needs and requirements. (Plattner et al., 2009 as cited in Schallmo et al., 2018)

Ideo’s approach, introduced by Tim Brown, was considered reasonable when reviewing definitions and approaches of design thinking discussed by Schallmo and his colleagues. The approach mostly consists of recommendations rather than explicit rules and constraints. Ideo’s approach further considers the design thinking process to be ‘a system of overlapping spaces rather than a sequence of orderly steps’. Moreover, those spaces represent the three phases of its procedure model—namely, inspiration, ideation and implementation (Brown and Wyatt, 2010).

The following briefly discusses the three phases of Ideo’s approach, as explained by Brown and Wyatt (2010) and Schallmo et al. (2018), as well as how these phases correspond to the different stages of this project:

- The inspiration phase starts with defining the problems and opportunities after understanding the environment of the design challenge, taking restrictions into account. This was accomplished by constructing the specification of this thesis and reviewing the literature.
- Ideation consists of brainstorming, sketches sessions, developing, and iteratively testing initial prototypes. In the early stage of this project, brainstorming sought to generate numerous ideas for input solutions that could be applied to interfaces optimised for reading. Those ideas were then transformed into sketches and low-level prototypes for further examination.
- The implementation phase consists of creating and testing high-level prototypes, then converting the definitive one into the final design outcome. Furthermore, a communication strategy is developed to deliver the design to its stakeholders and potential users. In this project, a semi-functional prototype of the selected design was created, and one aspect of it (locating information on the screen) was tested during the evaluation stage.

The following sections primarily focus on the ideation phase and illustrate how the final design concept of the input method emerged and took its final form.

4.2 Ideas and Initial Sketches

Work on this stage was conducted during the first few weeks of this project. The sketches developed iteratively from general ideas drawn on paper to initial sketches produced using a desktop version of the cloud-based tool Figma[1]. The sketches were evaluated by an expert in several iterations, with each iteration benefitting from the prior feedback.

Proposing a solution for inputting data on an interface was intended to enhance the process of finding and reading information, which further required an adequate example of such an interface to start with. Therefore, the layout suggested by Domańska (2018) was approximately reproduced for use as the default interface, serving as the basis for further sketches of the input methods. As in the original, the layout mainly consisted of three panels—a general panel with patient information, problem list, and notes panels, as presented in *Figure 1*.

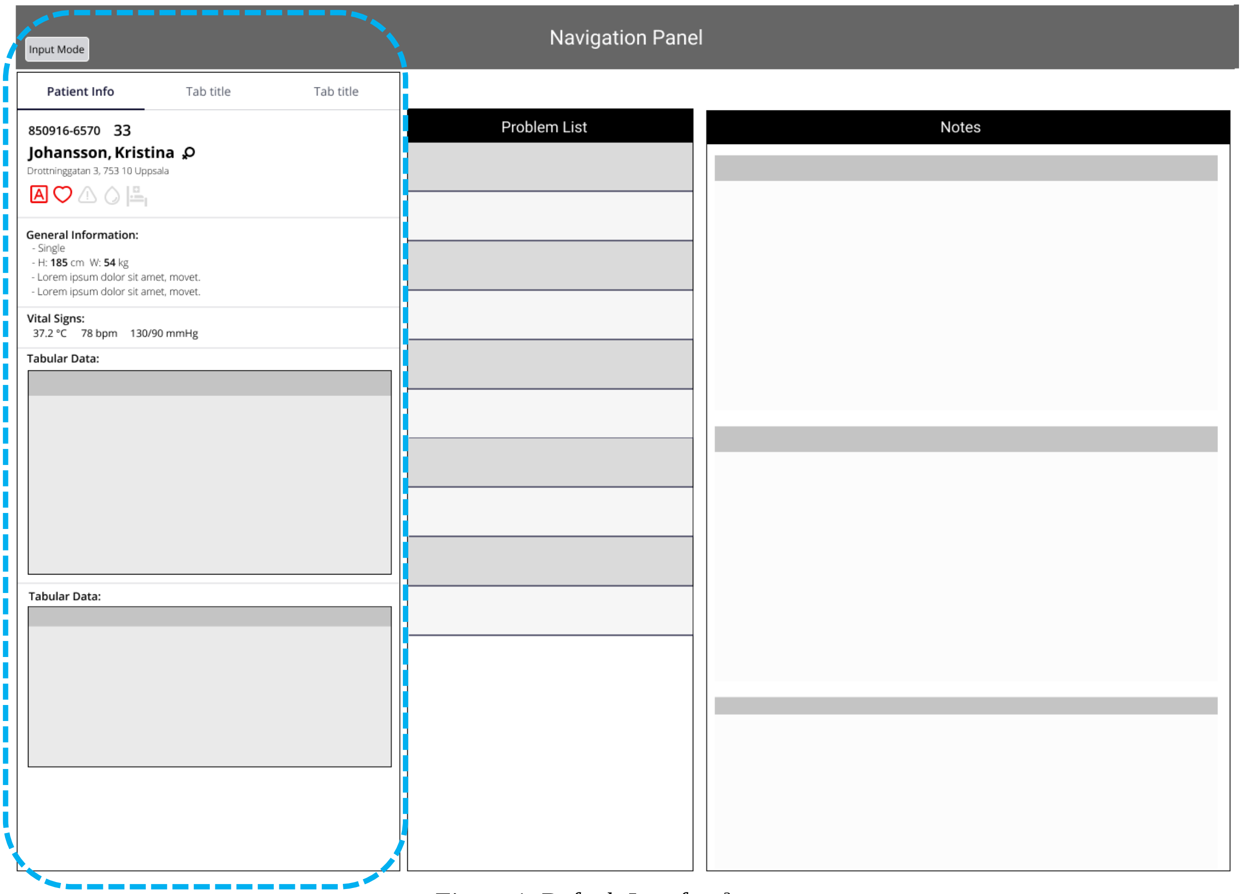


Figure 1. Default Interface[2]

In the early stage of the design process, brainstorming resulted in five ideas or approaches. These ideas were later sketched and evaluated. Moreover, characteristics that were considered appropriate were selected to develop the final solution. The blue dashed frame illustrated in *Figure 1* highlights the area in which these five ideas will be applied. Furthermore, all the design ideas presented below share the concept of having a 'switch mode button' to indicate the interface status, including whether it is active in reading or input mode.

1 Figma: collaborative interface design tool - https://figma.com/

2 Icons made by Vectors Market from www.flaticon.com, licensed by CC 3.0 BY.

4.2.1 Design Idea 1

Description:

This solution (presented in *Figure 2*) depends largely on revealing all the panels' input controls on its canvas once entering input mode. Therefore, screens in this design will look significantly different from one another when switching between modes.

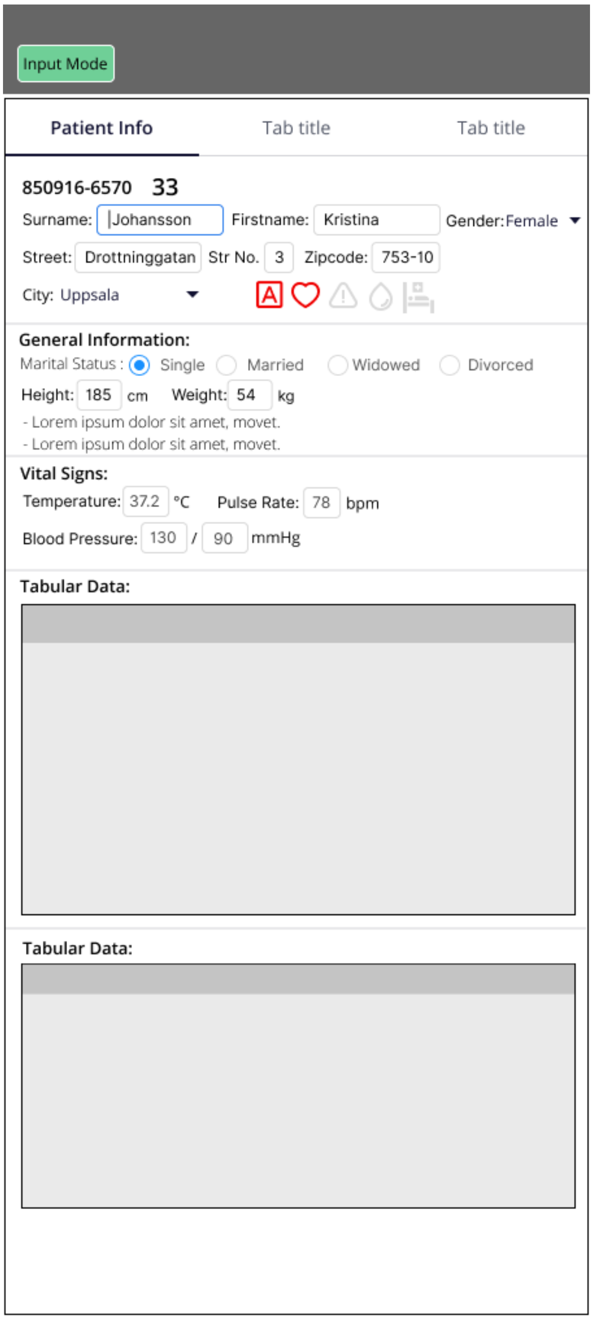


Figure 2. Design Idea 1

Discussion:

The main problem with this approach concerns the massive change in the panels' original layout and the extra scrolling caused by such change. Furthermore, this idea lacks creativity and does not differ entirely from switching windows, since the panel's structure will not look the same as the one in the reading screen. Therefore, situations that require users switching back and forth between modes while performing tasks will finally lead to frustration and extensive cognitive load (Borälv et al., 1994). As a result, this idea was entirely discarded.

4.2.2 Design Idea 2

Description:

This idea takes an entirely different approach from its predecessor, as presented in *Figure 3*. Once activating input mode, a checkbox appears next to each editable data region. At first, the user needs to check one or more fields to update; after clicking Select, the system generates a new panel containing the necessary input control elements to manipulate the information.

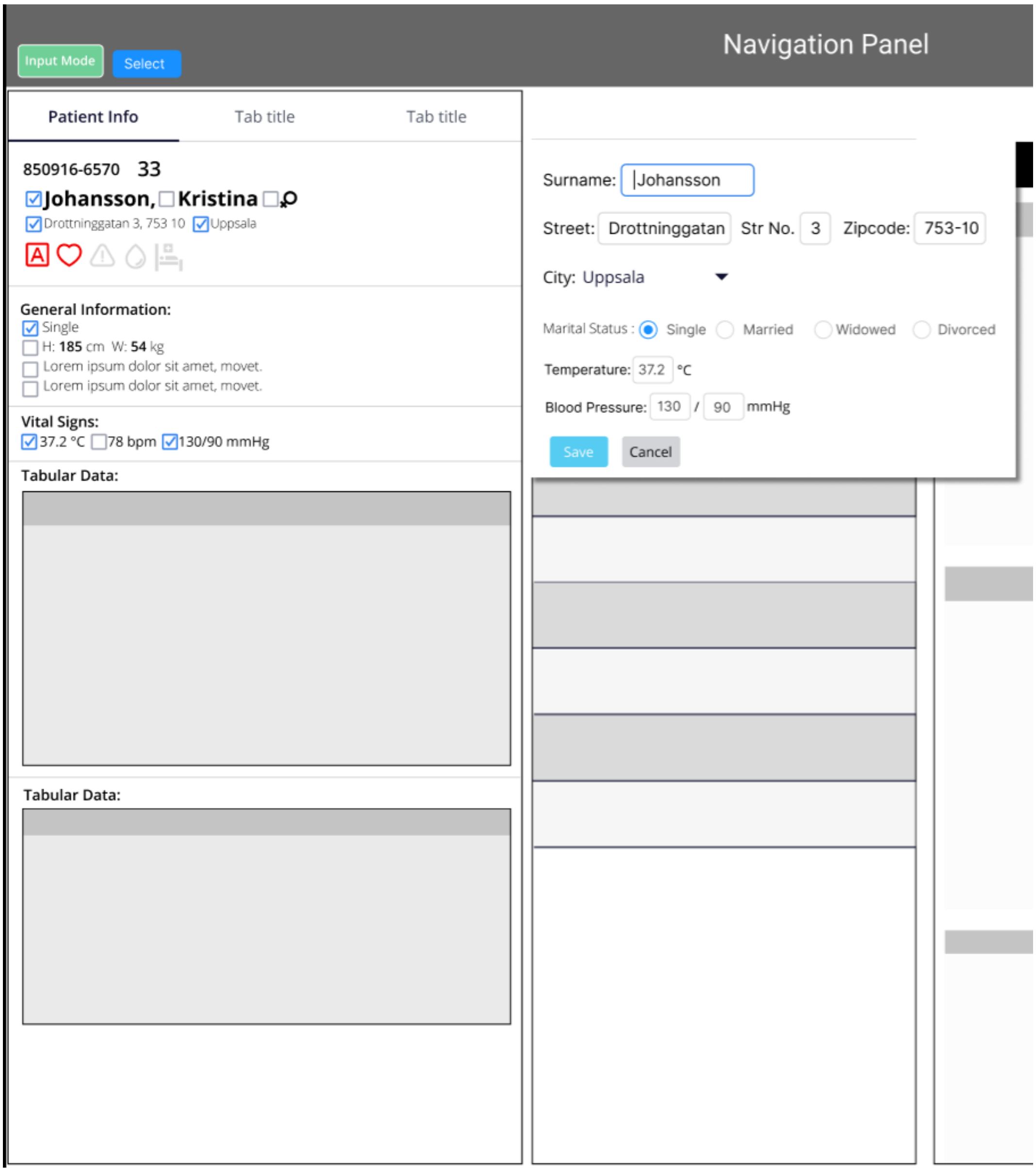


Figure 3. Design Idea 2

Discussion:

However, this solution will result in a unique layout for the input panel every time the user needs to edit some information. Moreover, it adds extra steps between selecting and editing the data. Furthermore, it forces the user to decide in advance which fields need editing, and this is usually not the typical use scenario. Therefore, it was decided to discard this design completely.

4.2.3 Design Idea 3

Description:

This solution (presented below in *Figure 4*) suggests having an additional input panel next to the one optimised for displaying information. Editing information on other panels requires hiding the currently active one. The useful aspect of this approach is that it enables saving or ignoring changes made to elements of the same panel. Although this design duplicates the panel being edited, it still makes it possible to read information related to the task from other visible panels of the interface.

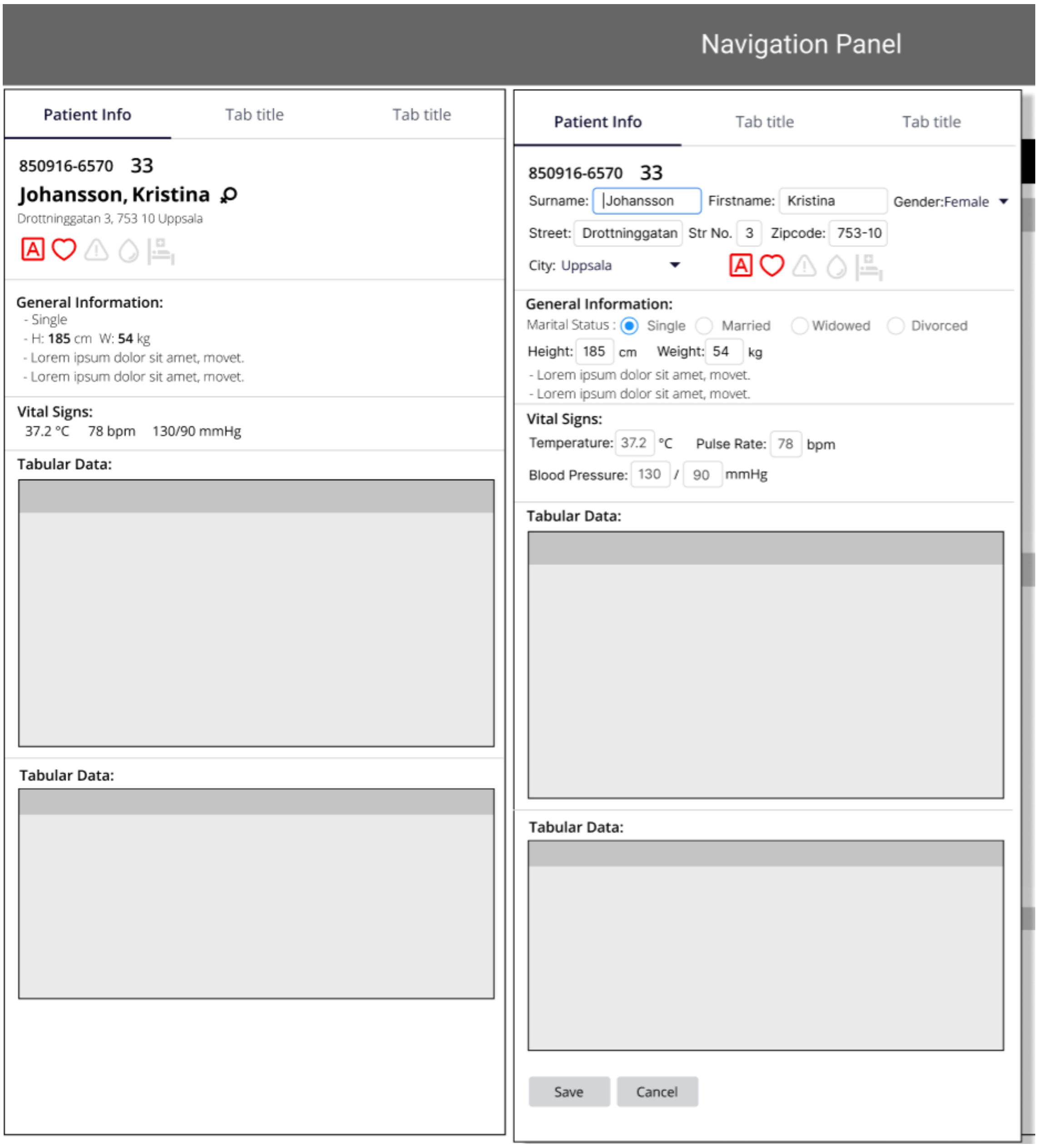


Figure 4. Design Idea 3

Discussion:

However, the issues with this idea are the same found in *Design Idea 1*; in addition, having an extra input-dedicated panel will cause wasted screen estate and hide the panel beneath. Such obstruction will make it harder to read the information necessary to perform some tasks.

Although this idea was discarded, having an option to cancel changes and revert to the original state of the reading panel was considered a useful feature. Therefore, adding a control panel with options such as revert (redo/undo) or ignore changes is considered in the final design solution.

4.2.4 Design Idea 4

Description:

The main idea behind this solution (illustrated in *Figure 5*) is that input controls such as text fields, drop-down menus, and others will appear on the same panel canvas when clicking over the relevant data region. For example, when the input mode is activated, clicking on 'Single', which indicates patients' marital status in *Figure 1*, will reveal the correspondent input control—in this case, the radio button group. Moreover, when finished updating or inputting the information of a particular field, moving to the next field can be achieved by either clicking on other data regions on the screen or by pressing the tab key on the keyboard.

However, when the input mode is activated, users may click on data regions that cannot be edited or modified. This data can include labels or information that they do not have permission to update, such as age and social number, for example. Therefore, all the data regions that can be interacted with or edited by the user can be highlighted in a different colour to avoid any confusion and play the role of a signifier.

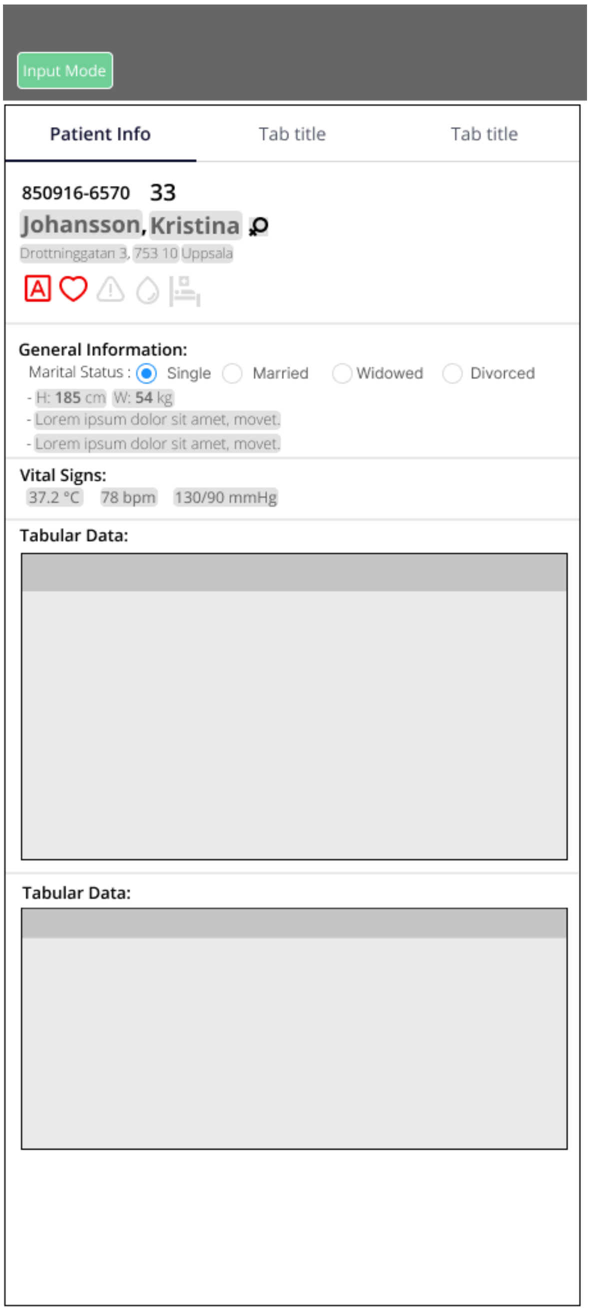


Figure 5. Design Idea 4

Discussion:

The primary critique of this idea is that the input controls will continuously change the original layout of the interface, which can make it challenging to find information on the screen and could lead to unnecessary extra scrolling in some cases.

Moreover, presenting input controls on the same panel will result in some data elements being moved and rearranged on the screen. Such movement may momentarily defer users' attention away from the field intended to be updated, since 'motion is extremely powerful in generating an orienting response' (Ware, 2008, p. 36).

Although this idea was discarded, since it creates motion and continuously alters the reading screen layout, having visual signifiers to illustrate what the user is allowed to edit was considered a useful element of the design, and so it is employed in the final solution.

4.2.5 Design Idea 5

Description:

The concept behind this design (illustrated in *Figure 6*) is relatively simple. Once a user clicks on the data region, a floating panel containing the associated input-control, labels, and instructions required for the task appears, along with options to save or ignore the changes. Moreover, moving to other fields can be accomplished by either tabbing or using the mouse.

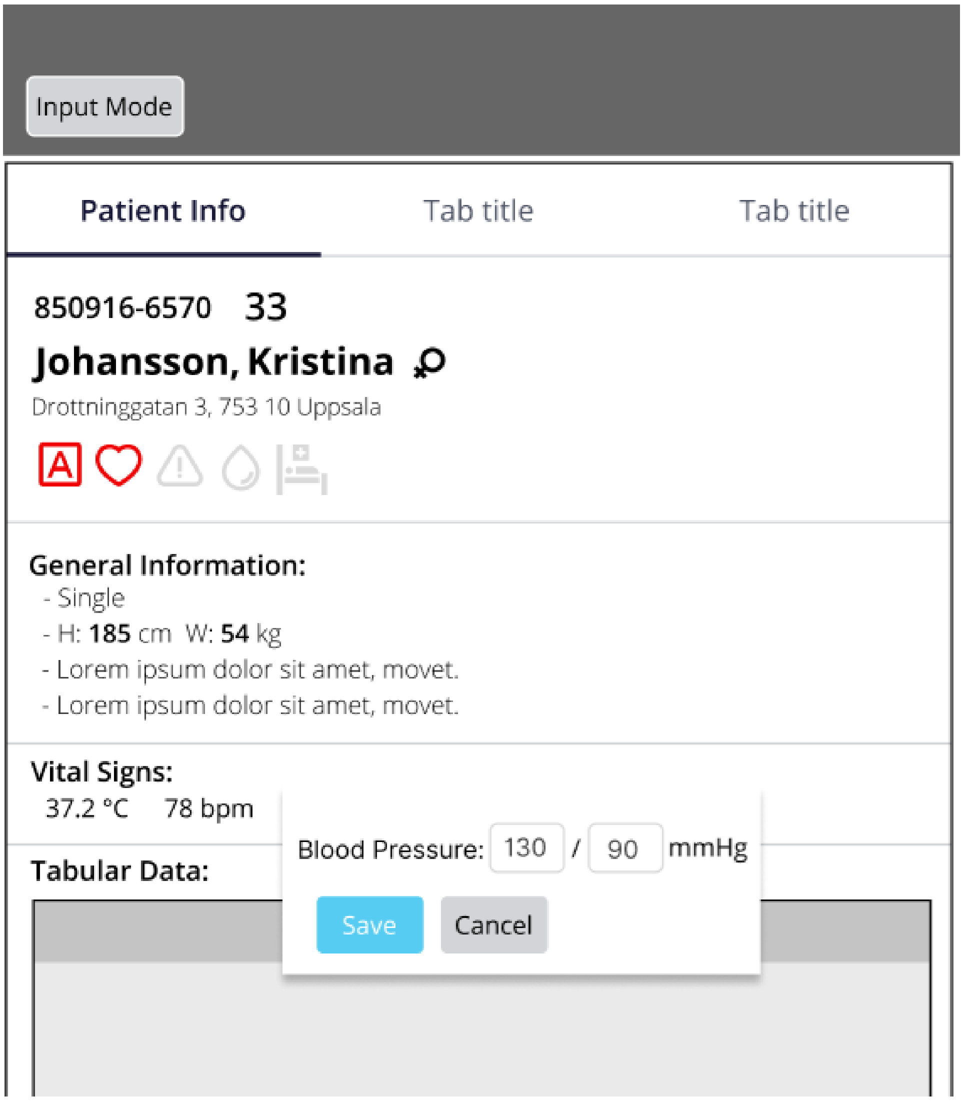


Figure 6. Design Idea 5

Discussion:

Although the need to save or ignore changes for every single (floating) input panel adds extra steps, this idea addresses the disadvantages of the other alternatives discussed earlier. Furthermore, it subtly separates the input controls from the interface's original layout. Additionally, it limits the floating input panel to one specific region at a time, reducing massive visual obstructions, and only elements that are particularly close to the updated field may be affected.

This solution preserves the essence of the reading screen as much as possible compared to the other designs. As such, it was decided to utilise its core concept of 'floating input panels' in the final solution.

4.3 Hybrid Design Solution

This design solution (presented below in *Figure 7*) employs the core idea of floating input panels of *Design Idea 5* and borrows the useful features mentioned in *Idea 3 and Idea 4*. In other words, it offers the ability to save or revert changes on the main level of the reading panel. Furthermore, it utilises visual signifiers to present elements that are allowed to be interacted with or edited.

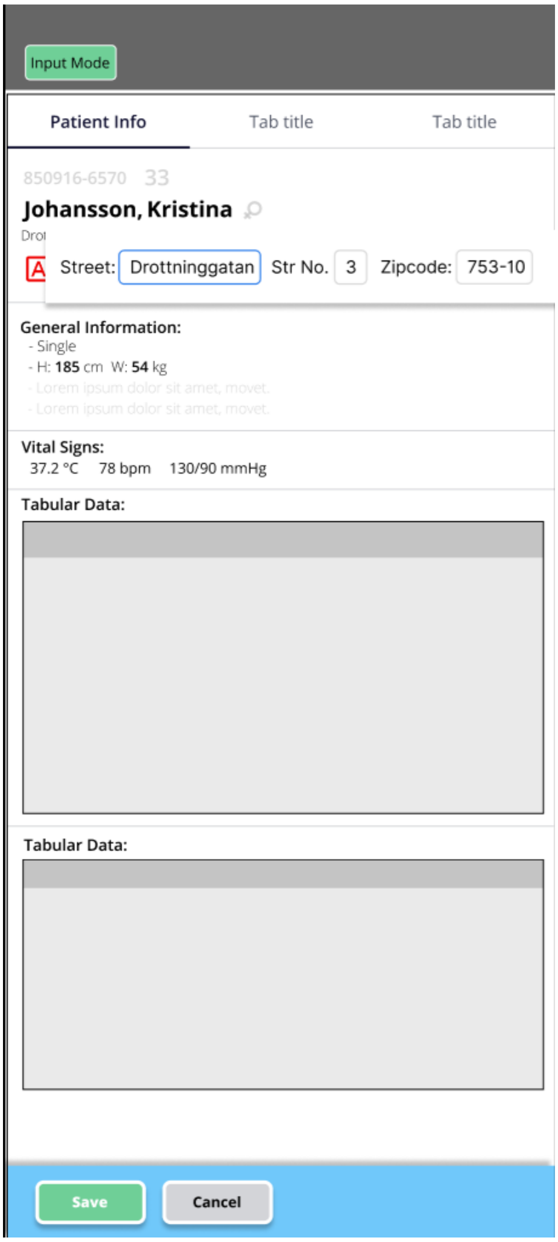


Figure 7. Hybrid Design Sketch

Furthermore, only elements that cannot be edited, such as locked fields, headers, or descriptive labels, will be highlighted in a different colour (light grey, for instance) rather than highlighting the editable fields. The justification for this decision is that there will be more dynamic information displayed on the reading screen compared to instructions and labels.

Finally, the name ‘Hybrid’ was inspired by the fact that this interface combines several design ideas into one. Additionally, it can be used for both reading and editing information in input mode with minimal effect on the reading screen’s original layout.

4.4 Prototyping

The prototyping phase required refinement, a variety of interactions, and some functionalities. However, Figma could not support such demands. Therefore, a premium version of the Justinmind[3] prototyping tool was employed. In the beginning, multiple versions of the hybrid solution were created and evaluated.

Figure 8 illustrates a prototype sharing the same layout with the previous sketches. The fields highlighted in green represent those updated during input mode. This feature was added to make the updated fields distinguishable so changes can be ignored or reversed.

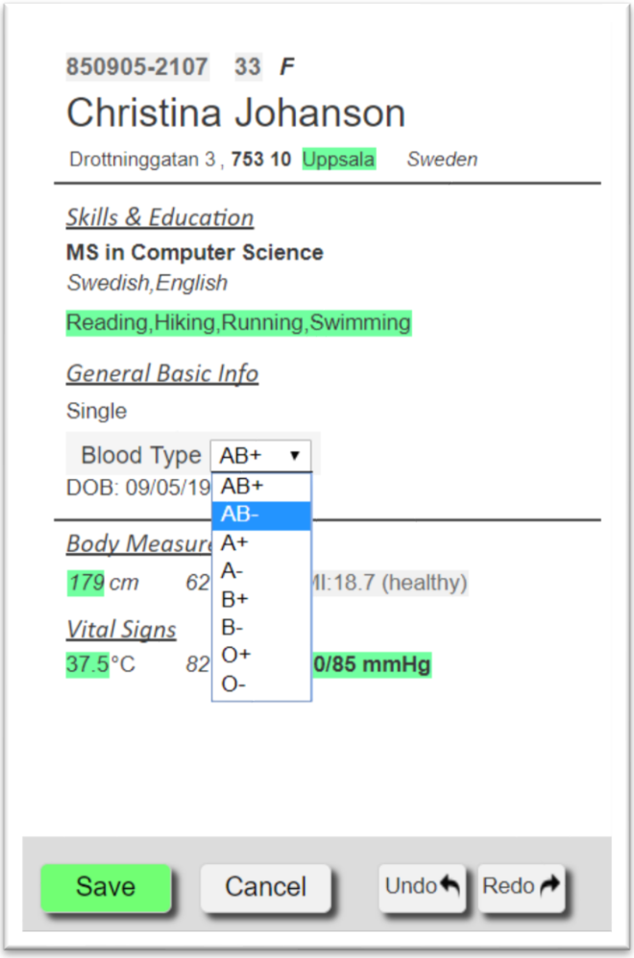


Figure 8. Hybrid Design Enhanced Prototype

In order to make the empirical study’s objective (later discussed in *Chapter 5*) comprehensible for participants, an interface with a general theme and several data fields to fill was necessary.

3 Justinmind: prototyping tool for web and mobile apps - https://www.justinmind.com/

Therefore, after reviewing a few medium-sized online forms, Application for Schengen Visa (*Appendix A*) was deemed suitable for the final prototype's inspiration.

The original layout of the Schengen Visa application was designed to combine both inputting and reading information. The form contains approximately 38 sections to be filled by the applicant and 11 sections in the margin used by officials. All this information was printed on two A4 pages, along with a header providing a place for applicants' photo and a consent form at the bottom containing approximately 585 words. In addition, the form seems to be designed to be filled traditionally by hand or by using a pdf editor, with a great deal of required information to be written in small areas in some sections.

Due to the abovementioned disadvantages of the original form, a major reconstruction was performed to create two versions of the form. The first was intended to combine both reading and inputting data in a manner similar to the standard forms that people encounter on the web while performing routine tasks, such as financial and governmental transactions. Some established heuristics were considered while designing the layout of the form. This version is referred to as the 'Standard Screen' for the rest of this report and illustrated in *Figure 11* (see *Appendix C* for a higher resolution).

The interface elements used in the standard screen consisted of six input-controls of those listed by the Assistant Secretary for Public Affairs (2013) in Usability.gov. Those controls include the following:

Text fields: Allow either single line or multiple lines of text entry.
Dropdown lists: Allow selecting one item at a time from a predefined list of items.
Checkboxes: Allow selecting one or more item from a set of options.
Radio buttons: Allow selecting only one item at a time from two or more sets of options.
List boxes: Allow selecting multiple items at a time from a list.
Date pickers: Allow selecting a date from a calendar.

Conversely, the second version of the form was primarily designed to support reading and finding information by removing all unnecessary labels and instructions usually intended to support inputting data. This version is referred to as 'Reading Screen', and it was designed by the supervisor of this thesis. Moreover, both screens were designed to convey the same information, and a list of fields, input-controls, and other specifications can be found in *Appendix B*.

The reading screen layout was intended to make visual query processing both rapid and accurate for every essential cognitive task the display is intended to support. This was accomplished using two primary visual channels (size and orientation of text) to easily read and find information, besides using the spatial layout to create different graphic patterns (Ware, 2008) to support readability.

The reading screen is presented on the next page in *Figure 9*, and a high-resolution version can be found in *Appendix D*. Moreover, the final prototype of the input method applied to the reading screen is illustrated in *Figure 10* (see *Appendix E* for a higher resolution).

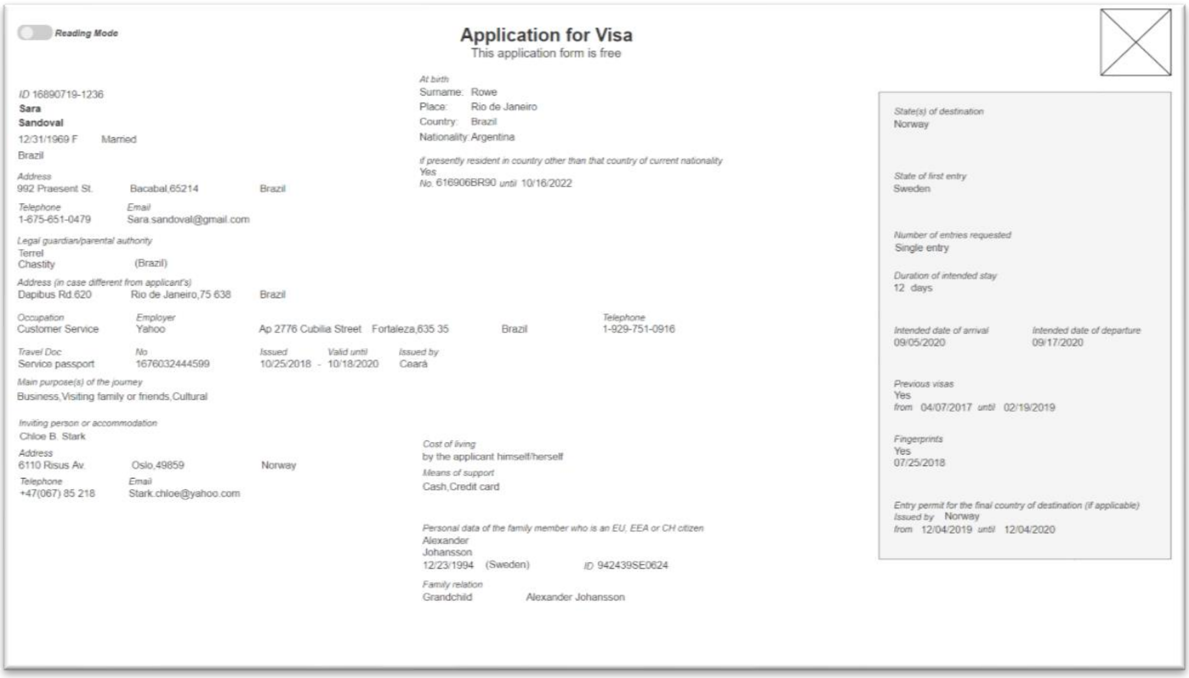


Figure 9. Reading Screen

4.5 Characteristics of Hybrid Input Solution

The final design of the input method (illustrated in *Figure 10*; a high-definition version in *Appendix E*) can be described in the following main points:

- The interface possesses two distinct modes (reading and input). The state of the system is always visible and indicated next to a slide button that enables mode switching with a clear transition.
- Tooltips are employed to provide a description when mouse-hovering on the information displayed on the reading screen. This is expected to help new users make sense of the elements on the screen.
- Labels and headers of the reading screen, alongside fields that cannot be edited by the user due to its nature or access privileges, are highlighted in a subdued colour. In the final prototype, light grey was selected to preserve the look of the original layout.
- A panel with options such as save, cancel, undo, and redo is presented in input mode. Beyond its functionality, this panel can be used as a visual cue of the current status.
- When clicking on regions that contain editable information, a floating panel appears fixed over that specific region. This panel includes the relevant input control(s) as well as all the descriptions and instructions required to perform the task.
- Only one floating input panel is presented at a time so as to prevent obstructing other fields and to preserve the reading screen's original layout.
- Moving to the next input panel can be accomplished using the tab key to hide the currently active panel and present the next one, or by using the mouse.
- Hiding the floating input panel can be performed by either pressing the Esc key or by clicking on the minimise symbol in the upper-right corner of each panel.
- Changes made using the input control(s) are simultaneously reflected on the reading screen, and the affected elements are highlighted in a different colour, such as light yellow. This visually reflects changes and makes reverting them easier.
- When an update to a particular field influences other elements on the screen, or when a specific input affects the path according to which the form will be filled, changes will be reflected on both the reading screen content and on the input panels that will consequently appear later.

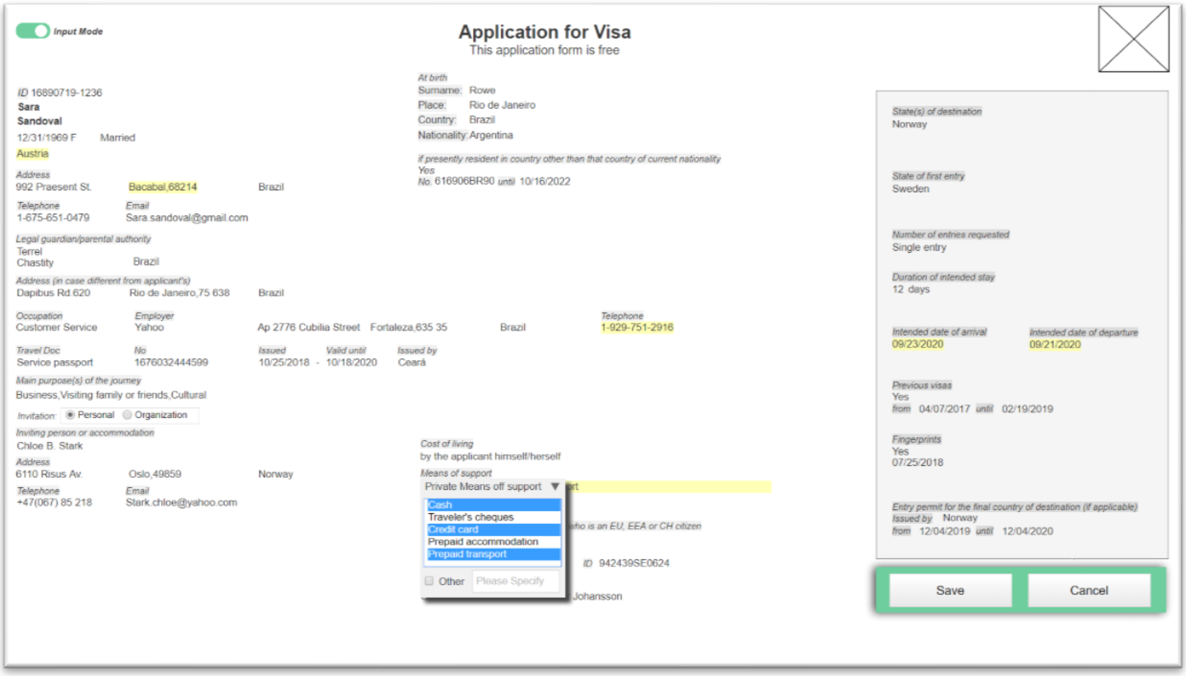


Figure 10. Reading Screen with the Hybrid Design Activated in Input Mode

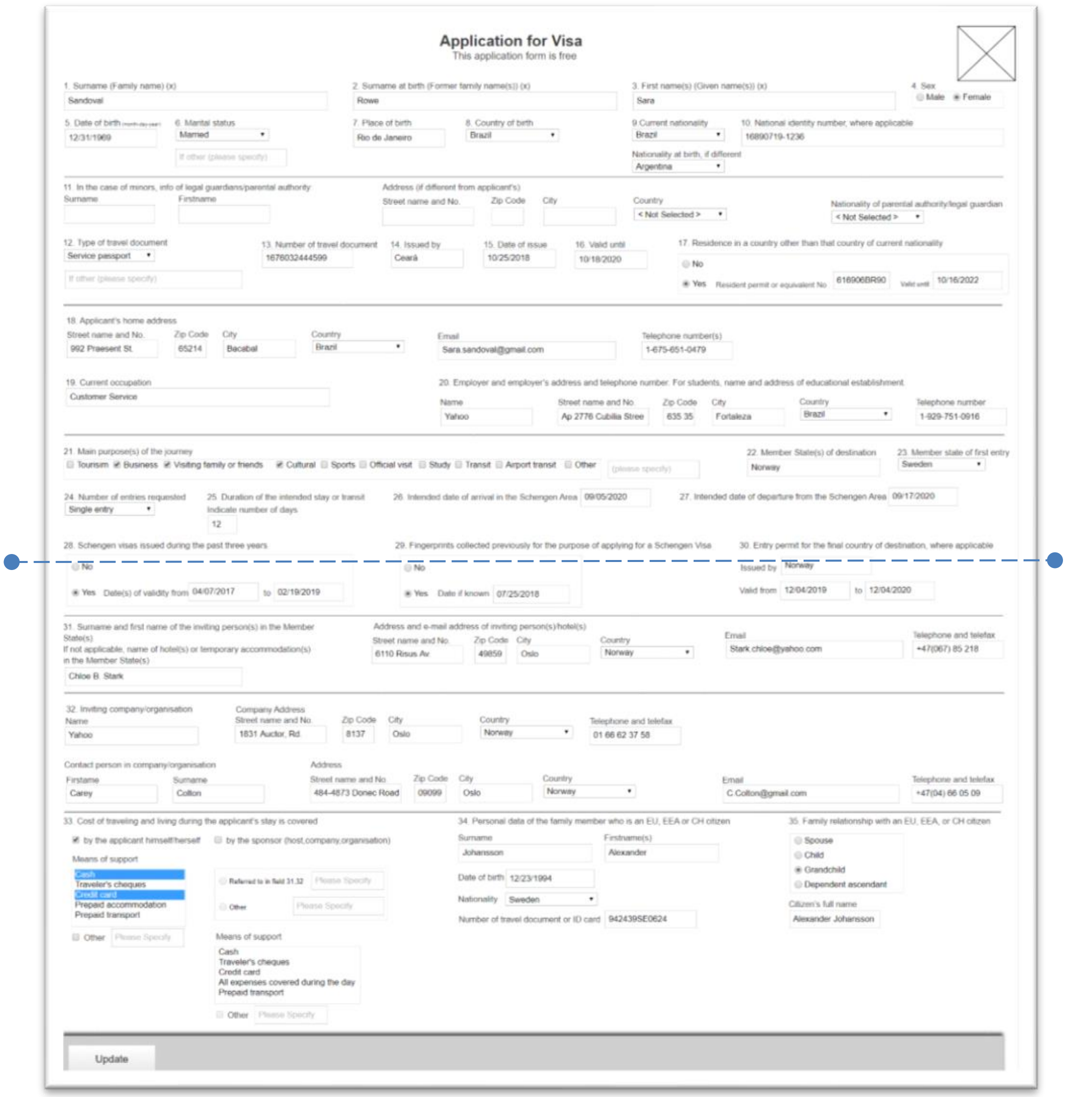


Figure 11. Standard Screen (Content below the blue dashed line require scrolling to show)

5 Evaluation

5.1 Inexperienced Users: Efficiency after a Brief Exposure

5.1.1 Method: Empirical Study

An empirical study was conducted to investigate the proposed input method's efficiency for inexperienced users interacting with its interface after a brief exposure.

The study's primary objective was to investigate the following statement:

'Is there a difference in the time it takes inexperienced users to locate specific information on a reading screen compared to using a standard screen?'

The primary reason for asking the previous questions is that, if the reading screen scores improve with finding information, the accompanying input method can benefit from such difference. This difference, if it exists, can alleviate any limitations in the proposed design that may occur during specific usage scenarios performed by non-expert users.

Moreover, finding the correct fields of information without further delay is more relevant in this case, as manipulating the input control is identical in both screens once clicked on the right element. Therefore, there was no need to test the input method itself with users at this stage of development.

Empirical Study Design

This study was conducted to test reading and standard screens using a between-subject design. Since these screens feature two fundamentally different layouts, switching between them to perform tasks requires constructing and recalling the relevant mental model of each. Therefore, using a within-subject design to test both screens with the same participant was avoided, since the sequence effects are expected to be strong and may confound the results (Graziano and Raulin, 2013, p. 345).

The screens employed during the study contained the same amount of information and used the layouts designed during the design thinking phase, with the visa application as the central theme.

After some consultations with the supervisor, the decision was made to divide the study into two stages:

1. A training session, where participants can familiarise themselves with the study's mechanics and gain some familiarity with the layout and the content. Moreover, this session enabled participants to request help or clarifications and become familiar with what is expected from them during the real study.
2. An empirical study session, where participants conducted the actual test without any help or feedback from the experimenter. This session consists of three trial blocks, with each block, in turn, containing six tasks that were then randomly ordered throughout the second and third block.

The tasks required users to accurately locate and click on a specific piece of information on the screen. Training and test session tasks are presented with their order on the next page in *Table 1*.

Confounding Variables' Control

Participants were randomly assigned to one of the screen types shortly before starting the experiment. In addition, tasks in both sessions were carefully selected to represent a fair distribution across different regions on both screens. This means that task answers were located at the top, middle, and bottom section of the standard screen, as well as the right, middle, and left section of the reading screen.

The content displayed on the screens (reading and standard) during the training session differs from the one used for the actual test. The data selected to populate both screens were mainly taken from a customised dataset, generated using an open-source tool[4], and the format was set to suit the fields of the visa application.

Table 1. Tasks Description and their Order throughout Blocks of Trials

Training Tasks	**ID**	**Task (*Find and click on*)**	
	A	The intended date of departure.	
	B	Applicant's marital status.	
	C	The first name of the family member who is EU, EEA or CH citizen.	
Experiment Tasks	**ID**	**Task (*Find and click on*)**	
	1	The surname (i.e. last name, family name) of the legal guardian.	
	2	The date of fingerprints collections.	
	3	The applicant's nationality at birth.	
	4	The applicant's means of support.	
	5	The email address of the inviting person.	
	6	The duration of the intended stay.	
	Task Order		
	Block 1	**Block 2**	**Block 3**
	T1	T4	T5
	T2	T3	T1
	T3	T5	T4
	T4	T6	T3
	T5	T2	T6
	T6	T1	T2

However, due to the reading screen's flexible design, some sections did not appear on the screen when a specific condition applies. This could provide reading screens with an advantage over the standard by increasing the content's intensity in the latter. Such design variation will lead to scenarios wherein two or more sections would still appear on the standard screen, but only the one that meets a particular condition will be filled with information. For example, the applicant can be invited by either an individual (i.e. personal invitation) or by an organisation. Those two sections contain an uneven amount of data (7 and 14 fields, respectively). Therefore, the screens used during the test were counterbalanced to display two versions of the form. The first version shows the personal invitation section filled in, while the other contains the organisational invitation information section.

Moreover, to restrict participants from accidentally peeking at the screen before starting tasks, black screens appeared before and after each task, with a button to show and hide the screen. This further made switching between the two versions of the form discussed earlier less prominent. Therefore, participants' attention should be primarily focused on tasks rather than dealing with unnecessary confusion. Besides that, all input controls on the standard screen were locked, and the mode-switching button was removed from the reading screen to avoid accidental clicks and changes.

Setup and Equipment

Screens required to solve the tasks, alongside the black transitional pages in between, were exported as HTML page to be used during the study. Moreover, all pilot tests and the actual study

4 https://www.generatedata.com

sessions were conducted using a Google Chrome browser on the Microsoft Windows 10 operating system. A Lenovo ThinkPad T580 laptop with a 15-inch FHD monitor at 1920x1080 resolution and 60Hz refresh rate was utilised, at 100% brightness level. The mouse was a Corsair Harpoon RGB, and a dedicated profile was created to disable all extra buttons and set the sensitivity at 500 DPI to avoid erroneous clicking and ensure consistency.

The screens used during the test were designed with Justinmind software to be displayed in a full-screen mode with an aspect ratio of 1.78 'HD 16:9' landscape orientation and a canvas size of 1536 x 864 pixels. The header and button on the transitional black screens were located at the same position on both screens. Screen and mouse clicks were recorded using the Morae[5] software suite.

The study took place in quiet study areas of the Department of Information Technology, Ekonomikum campus of Uppsala University, and the student dormitory. In an attempt to make the sessions similar to the natural environments, participants were given the freedom to choose the time and place.

Pilot Tests

Two pilot tests were conducted with two participants consecutively, and feedback from the tests was used to improve the experiment's overall design.

First Pilot Test:

During the first pilot test, the participant found the instructions on the transitional black screen more noticeable compared to the instructions presented in the panel of the testing software 'Morae'. Furthermore, the square buttons 'Go' and 'Stop' used to hide and show the screen drew participants' attention from the buttons used to start and end the task on the autopilot panel of the testing tool. This mainly occurred because the large 'Stop' and 'Go' buttons were coloured red and white in large font. On the other hand, the start and end task buttons of the autopilot panel were small and grey, with no option to change their look. Moreover, participants occasionally ignored clicking on the 'Stop' button after finishing a task and instead moved to the next one using the 'Morae' panel on the same screen.

Second Pilot Test:

Before conducting the second pilot test, instructions were removed from the transitional screens and only kept in the autopilot panel. Furthermore, the 'Stop' and 'Go' buttons were replaced with black-and-white square buttons without any text. Moreover, six extra meta-tasks were added to remind the participant of clicking on the black square when finished with the task in order to hide the screen.

The test instructions were found to be relatively easy to follow despite minor confusion at the beginning. That confusion led participants to slow down and be extra careful before interacting with the autopilot panel of the testing software.

Refining Study Format

The feedback from the two pilot tests revealed some confusion concerning the mechanism of starting and ending tasks. Furthermore, adding an extra 21 meta-tasks to remind participants when to click on the black square to hide the screen added additional complexity. As the primary purpose of the study was to accurately locate and click on the specified piece of information as quickly as possible, the confusion caused by the test's navigation mechanism could drive participants away from this purpose. Therefore, a decision was made to replace the autopilot functionality with classical task cards (*Appendix F*). The cards were printed on papers along with all the necessary instructions required to perform the test.

5 TechSmith Morae: User experience & Market Research Tool - https://www.techsmith.com/morae.html

Participant Recruitments and Demographics

It was believed that 16 participants would offer suitable statistical reliability for data analysis. Participants were recruited via online HCI group (2 respondents), personal recruitment (3 participants), and through sharing the experiment advertisement with a college acquaintance (11 participants).

Participants came from nine different nationalities. Twelve were from Non-EU countries where they were expected to possess some experience with the process of applying for a visa. The gender distribution was even at eight females and eight males.

Test Protocol

The setup was prepared before the participants' arrival at the location, and participants were randomly assigned to a type of screen (reading or standard). Participants were also asked to sign a copy of the consent form sent to them earlier by email. The form provided a brief description of the study, information about confidentiality, and the right to withdraw from participation without any consequences. All participants received a cinema ticket upon completion of the test as an incentive.

Test sessions lasted between 20 and 30 minutes, starting with participants reading the instructions that were explained briefly by the experimenter after signing the consent form. Following this, they received a printed copy of the assigned screen type to briefly examine so they could learn which type of interface they would be dealing with.

The training session began with participants placing the task cards upside-down on the table and withdrawing one at a time from the top. They then read the task description, followed by clicking on the white square at the upper right corner to show the screen. Once the participant found the required piece of information, they were asked to click on it, then end the task by clicking the black square at the upper right corner of the screen. Participants were reminded of the importance of locating the correct information as quickly as possible without sacrificing accuracy.

After the end of the training session, the experimenter informed the participants that they would no longer receive any help of feedback on their actions. Moreover, they were provided with a chance to ask questions in case they required any clarification before starting the real test.

Participants who were curious about the test's purpose or hypothesis were encouraged to finish the test first before offering them further detail. This was necessary to avoid imposing a subject effect on the participants. Additionally, during the real test, the experimenter sat at an angle that prevented direct observation, and only intervened to stop the recording and to replace task cards upon the end of each trial.

After completing the test session, participants answered The Single Ease Question (SEQ) to rate the level of task difficulty. The answers were on a scale of seven points, ranging from very difficult to very easy.

5.1.2 Results

All 16 participants completed the study. However, one participant missed a task during the third trial using the standard screen. Therefore, the participant was asked to retake the last trial when he finished, and only the time of the single missed task was taken from the retake to fill the gap in the data.

Tasks on both screens were perceived to be easy, since the averages of the Single Ease Question (SEQ) did not exhibit any significant difference between the reading and standard screen (6.5 and 6.25, respectively). This could be due to the tasks' nature and participant familiarity with similar visa forms.

Data Extraction

Data extraction and task scoring were manually performed using the Morae Manager tool after reviewing the study session recordings. Moreover, a set of criteria were followed to ensure accuracy:

- Tasks start the moment a participant clicks on the white square button at the upper-right corner to show the screen.
- Tasks end once a mouse click is fully observed on what is believed by the participant to be the correct answer.
- Tasks from both screens were marked using the same zoom level of 16x.
- Few adjacent fields on the screens were perceived as confusing by the participants. The reason is that those fields contained highly similar information related to the same entity, and they were positioned close to each other. Therefore, answers that met this condition were considered correct 'alternative' answers on both screens. *Table 2* presents the tasks listed next to the accepted alternative answers.
- Answers that were utterly irrelevant or erroneous were marked as incomplete tasks, and all mistakes or recoveries from previous wrong answers were logged using observation markers.

Table 2. Alternative Task Answers

Task #	**Correct answer**	**Confused with (alternative answer)**	**Frequency per trial block**			
			T1	**T2**	**T3**	**Total**
Standard Screen						
Task 3	Nationality at birth	Country of birth	2	1	1	**4**
Task 4	Means of support (covered by the applicant)	Means of support (covered by the sponsor)	2	2	0	**4**
Reading Screen						
Task 1	Surname of the legal guardian	First name of the legal guardian	1	2	2	**5**
Task 3	Nationality at birth	Country of birth	1	1	0	**2**
Task 4	Means of support (Cash, Credit card)	Cost of living (by the applicant him-self/herself)	1	1	1	**3**

All the raw data tables referred to in the following sections can be found in *Appendix G*

Standard Screen Task Times

First Block of Trials

Accuracy and Descriptive Statistics

As calculated from data in *Table 6*, the median of participants' average time on task equals 18.88 sec. The 25th and 75th percentiles are 14.13 and 27.88 seconds, respectively.

No wrong answers were made during the first block of trials. However, participants clicked on alternative answers on four occasions (as listed in *Table 2*).

Second Block of Trials

Accuracy and Descriptive Statistics

The median of participants' average time on task equals 6.01 sec, and the 25th and 75th percentiles are 5.05 and 9.96 seconds, respectively.

However, the percentage of correct answers equalled 95.83%, with two wrong answers highlighted in red in *Table 7.* Additionally, participants selected an alternative answer on three occasions.

Third Block of Trials

Accuracy and Descriptive Statistics

The median of participants' average time on task during the third block equals 5.28 sec, and the 25th and 75th percentiles are 4.96 and 7.13 seconds, respectively.

The wrong answers made during the second block were corrected by the participants during this block of trials. However, one participant was consistent during all rounds and selected an alternative answer for task three during this block as well (choosing applicants' country of birth rather than nationality at birth).

Mouse Travel Distances

Data concerning mouse movement (in pixels) during the tasks were generated for further analysis (presented in *Table 9* for the standard screen and *Table 13* for the reading screen, where wrong answers are highlighted in red). It was expected that such measurements might provide supplemental information and offer an estimation of scrolling's detrimental effect on the time for tasks, primarily for the tasks that required scrolling on the standard screen.

Reading Screen Task Times

First Block of Trials

Accuracy and Descriptive Statistics

The median of participants' average time on task during the first block using the reading screen equalled 9.48 sec, and the 25th and 75th percentiles are 7.55 and 16.99 seconds, respectively.

As *Table 10* highlights in red, five wrong answers were identified during this block, which made the percentage of overall correct answers 89.58%. Moreover, three alternative answers were selected (listed in *Table 2*).

Second Block of Trials

Accuracy and Descriptive Statistics

The median of participants' average time on task during the first block using the reading screen equalled 6.76 sec, and the 25th and 75th percentiles are 5.81 and 7.35 seconds, respectively.

Only one wrong answer continued to appear during the second trial block. This changed the percentage of correctness to 97.92%. However, four alternative answers were selected during this block.

Third Block of Trials

Accuracy and Descriptive Statistics

The median of participants' average time on task during the first block using the reading screen equalled 4.02 sec, and the 25th and 75th percentiles are 2.84 and 4.44 seconds, respectively.

The same wrong answer made by the same participant continued to appear during the final trial block. The percentage of correctness thus remained the same (97.92%). Moreover, three alternative answers were selected during this block.

5.1.3 Task Times Analysis

Examining the results from the first block of trials, it is clear that participants provided too many wrong answers on the reading screen compared to the standard (5 out of 48 versus none). Therefore, it cannot be assured that participants carefully followed the primary instruction of being accurate during this block. This inaccuracy makes the times recorded during the first block inappropriate for devising a meaningful analysis.

However, one possible explanation for the total number of unique errors during the three blocks being higher in the reading screen (5 out of 144 versus 2 out of 144) could be that the standard layout of presenting information might be more natural to read if the users are novel to the concept of reading screens.

Another explanation could be that participants felt pressured to be quick and clicked on the first answer that made sense to them on the reading screen. Doing so without verifying the answers using the tooltip to check the information labels could offer a reason for those errors.

The Mann-Whitney U test was deemed the appropriate statistical test for analysing the collected data. This test is referred to as the nonparametric version of the parametric Student's t-test, since it does not assume any specific data distribution (Mcknight and Najab, 2010).

The null hypothesis H_0 was formed as follows:

'There is no significant difference between the medians of the average times for standard screen tasks and those measured using the reading screen'.

And the alternative hypothesis H_1 was formed as follows:

'There is a significant difference between the medians of the average times for standard screen tasks and those measured using the reading screen'.

The test was performed using the statistics software Prism[6]. Moreover, all tests were two-tailed, and the significance level was set to α=.05. Since the results of the first block were considered overly inaccurate for providing any meaningful analysis, only data from the second and third blocks were considered.

Second Block of Trials

The Mann-Whitney U test indicated no significant difference between medians of the task times averages using the standard screen (*Md* =6.01 sec) and the times using the reading screen (*Md* =6.75 sec), p = .879, U =30.

Third Block of Trials

The Mann-Whitney U test revealed a significant difference between medians of task times averages using the standard screen (*Md* =5.28 sec) compared to the reading screen (*Md* =4.03 sec), p = .002, U =4 during the third block of trials.

Figure 12 on the next page illustrates the differences between average task times among screens during the second and third trial blocks.

6 GraphPad Prism8: statistical analysis and graphing solution - https://www.graphpad.com/scientific-software/prism/

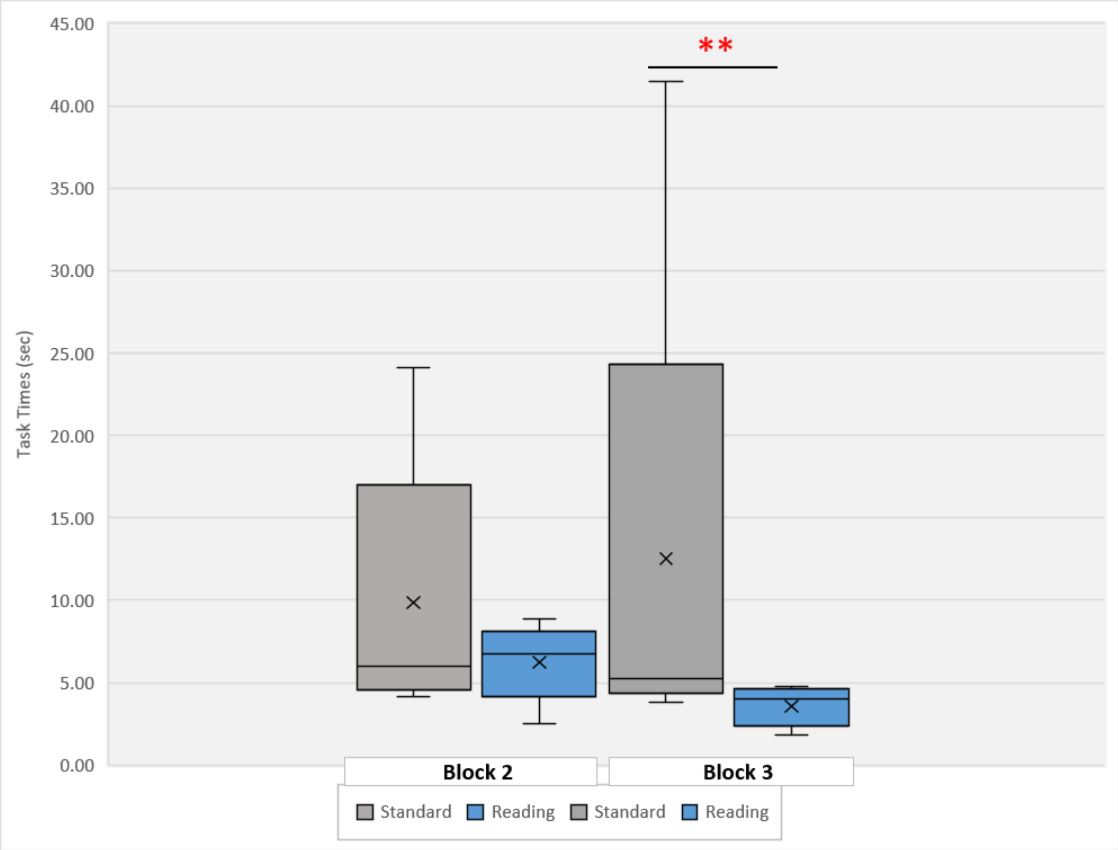


Figure 12. Average Task Times during the 2nd & 3rd Block of Trials

5.1.4 Mouse Travel Analysis

The mouse-travelling distances during tasks can be assumed to possess a normal distribution. Therefore, using the Student's t-test would constitute the appropriate statistical method to analyse the data.

In order to investigate screen type's effect on the mouse-travel distance, an unpaired two-tailed Student's t-test with a significance level of α=.05 was conducted to analyse the data collected during the second and third trial blocks.

Second Block of Trials

There was no significant difference between the means of the mouse-travelled distances during tasks per participant on the standard screen (M=2879 pixel) compared to the reading screen (M=2209), $t(14) = 1.62$, $p = .127$.

Third Block of Trials

There was a significant difference between the means of mouse-travelled distances during tasks per participant on the standard screen compared to the reading screen, $t(14) = 3.25$, $p = .006$, with the reading screens scoring lower (M=1842 pixel) than the standard (M=2868 pixel).

Figure 13 on the next page illustrates the differences between mouse distances between screens during the second and third trial blocks.

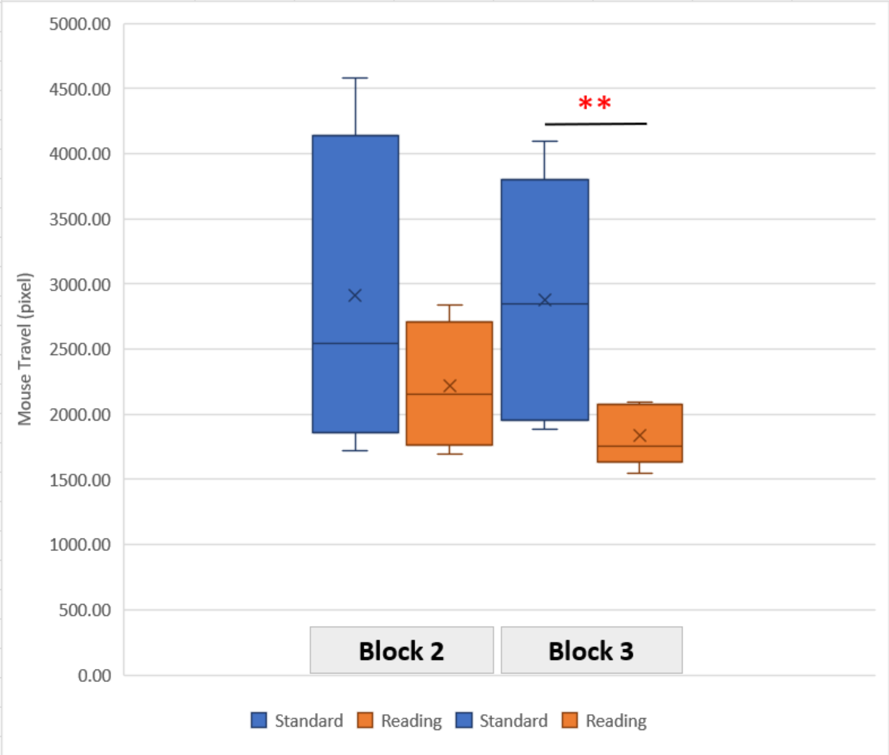


Figure 13. Mouse Travel Distances – Block 2 & 3

5.1.5 Scrolling vs Non-Scrolling Tasks

Although the Mann-Whitney U analysis of the average task times per participant indicated a significant difference between the two screens during the third block, it was decided to conduct further investigation. Therefore, the data were organised based on whether or not tasks required scrolling on the standard screen. This was intended to determine a possible reason for the difference in times. Moreover, this was also performed to estimate scrolling's detrimental effect on the participants' average task times on both screens.

Table 14 and *Table 15* in *Appendix G* provide measurements of task times during the second and third block of the trials, as divided into scrolling and non-scrolling tasks.

Scrolling vs Non-Scrolling: Task Times Analysis

Second Block of Trials

A Mann-Whitney U test indicated no significant difference between medians of the time averages for non-scrolling tasks using the standard screen (*Md* = 4.87sec) compared to using the reading screen (*Md* = 5.54 sec), *p* = .96, *U* =31.

Similarly, a Mann-Whitney U test identified no significant difference between medians of the time averages of scrolling tasks using the standard screen (*Md* =6.92 sec) compared to using the reading screen (*Md* =6.54 sec), *p* = .328, *U* =22.

Third Block of Trials

A Mann-Whitney U test indicated no significant difference between the medians of the time averages of non-scrolling tasks using the standard screen (*Md* = 4.68 sec) compared to using the reading screen (*Md* = 3.57 sec), *p* = .168, *U* =18.50.

However, the Mann-Whitney U test for the third block identified a significant difference between the medians of the time averages for the scrolling tasks. Specifically, the reading screen was faster (*Md* =3.10 sec) compared to the standard screen (*Md*=6.73 sec) and *p* =.005, *U* =6.

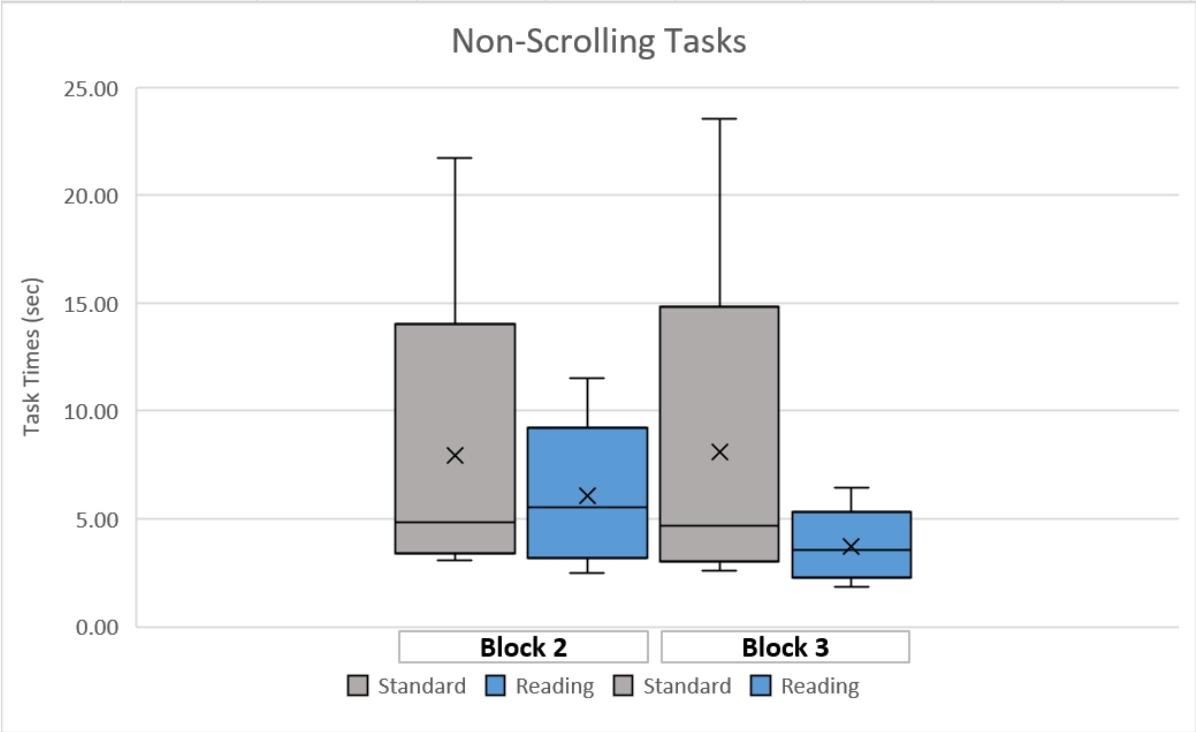


Figure 14. Box Plot of Non-Scrolling Tasks' Times

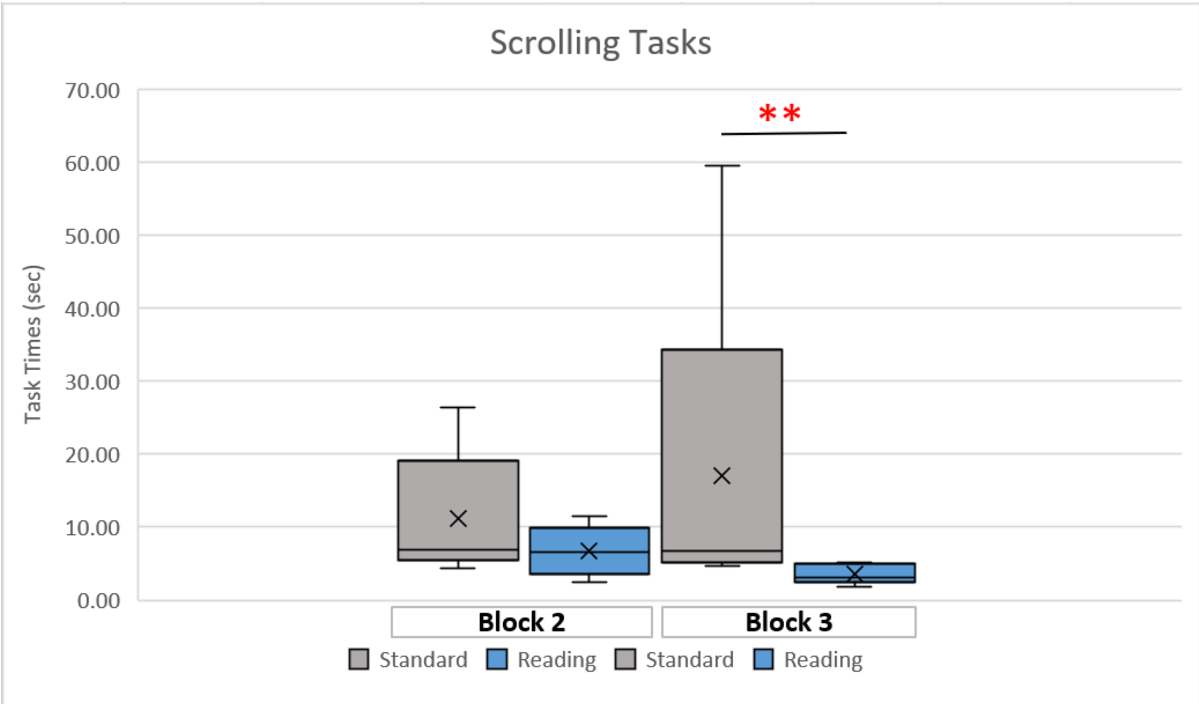


Figure 15. Box Plot of Scrolling Tasks' Times

Scrolling vs Non-Scrolling: Mouse Travel Analysis

The same division based on task types (Scrolling vs Non-Scrolling) was performed for both screens' mouse-travel distances. The data measurements of mouse travel distances for the second and third trial blocks can be found in *Table 16* and *Table 17*, *Appendix G*.

Similar to the general analysis of mouse movement performed earlier, an unpaired two-tailed Student's t-test with a significance level of α=.05 was conducted to compare the effect of task type (scrolling vs non-scrolling) on mouse-travel distances between the standard and reading screens.

Second Block of Trials

There was no significant difference between the means of the mouse-travelled distances during non-scrolling tasks per participant for the standard screen (*M*=2594 pixel) compared to the reading screen (*M*=1858), $t(14) = 1.99$, $p = .066$.

Similarly, there was no significant difference between the means of the mouse-travelled distances during scrolling tasks per participant on the standard screen (*M*=3164 pixel) compared to the reading screen (*M*=2560), $t(14) = 1.04$, $p = .317$.

Third Block of Trials

Unlike the results from the second trial block, there was a significant difference between the means of the mouse-travelled distances during non-scrolling tasks per participant. Specifically, the reading screen had shorter travel distance (*M*=1664 pixel) compared to the standard screen (*M*=2527 pixel), $t(14) = 3.66$, $p = .003$.

Moreover, there was also a significant difference between the means of the mouse-travelled distances during scrolling tasks per participant on the reading screen (*M*=2020 pixel) compared to the standard screen (*M*=3210), $t(14) = 2.51$, $p = .03$.

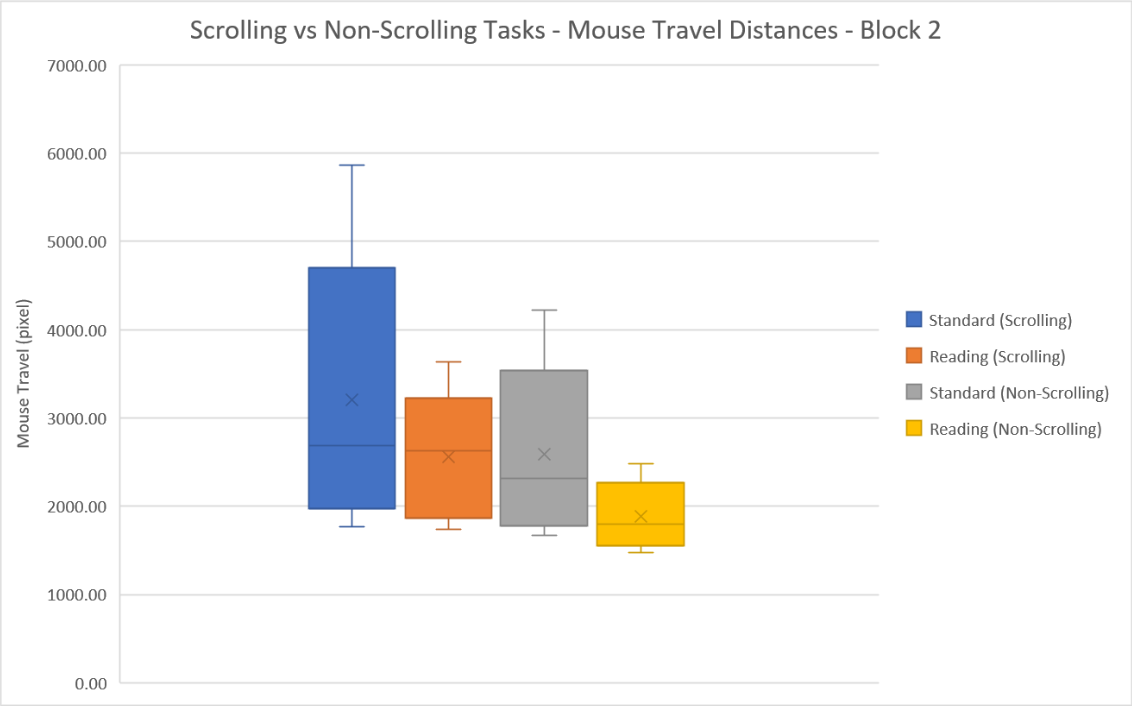


Figure 16. Scrolling vs Non-Scrolling Tasks – Mouse Travel – Block 2

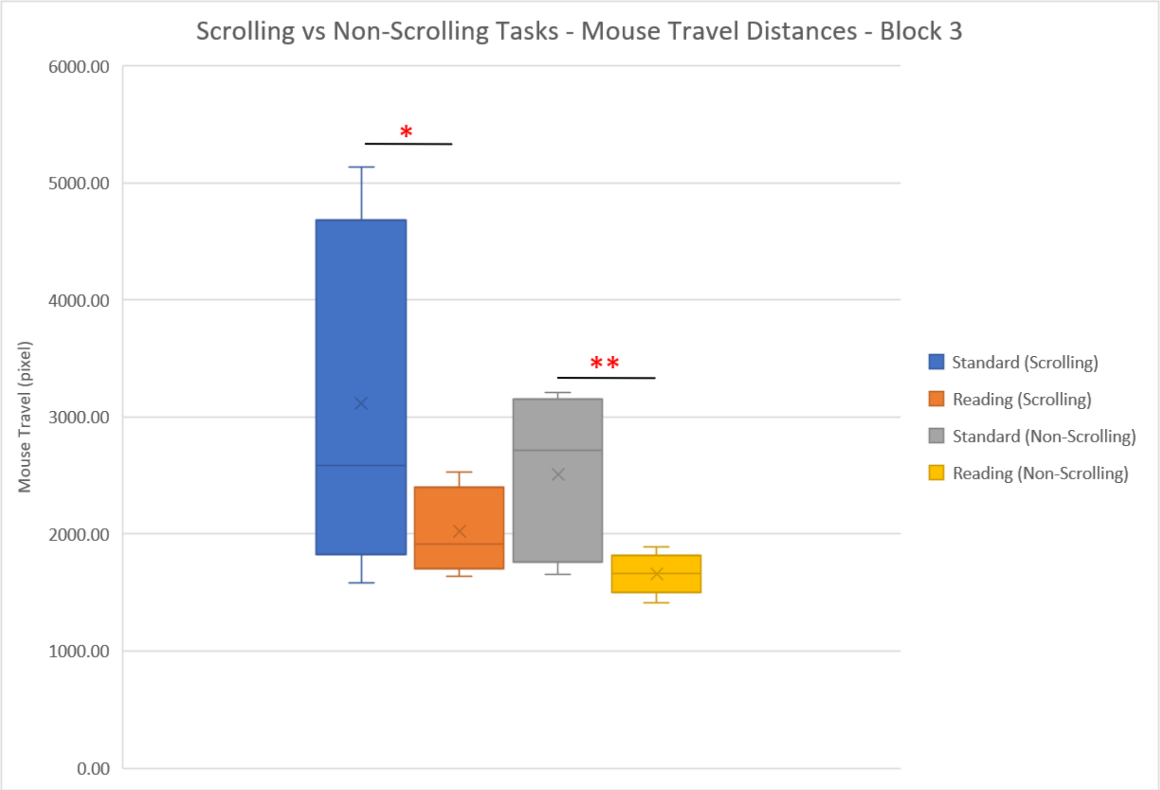


Figure 17. Scrolling vs Non-Scrolling Tasks – Mouse Travel – Block 3

5.2 Efficiency of Expert Users

5.2.1 Method: GOMS-KLM

For any design to be considered satisfactory and useable, it should be efficient and effective for its specified users. However, to systematically examine specific aspects of design, it is crucial to first possess a distinct and precise definition of '*usability*', since it is relevant in this context.

Usability has always been the primary interest of human-computer interaction (Benyon, 2019). The International Organisation for Standardisation defined usability as the 'extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' (ISO 9241-11:2018). As can be noted from this definition, efficiency represents only one aspect of usability, and according to the ISO, it concerns the 'resources used in relation to the results achieved'.

Task times represent one of the costs that users deal with when interacting with a system or an interface to achieve a particular goal. Therefore, an accurate measure of efficiency is required to compare the proposed input method, 'hybrid design', with the efficiency of the standard method. To perform such an accurate comparison, a quantitative analysis tool of the GOMS model known as the keystroke-level model (KLM) was deemed a reliable method for this purpose.

The GOMS provides engineering tools for cognitive modelling of human performance (John and Kieras, 1996). Card, Moran and Newell, the creators of the original model (CMN-GOMS) and its KLM variant, considered users' cognitive model to consist of four components (Card et al., 1983, p. 140,144):

- A set of **Goals** that the user wants to achieve by using the system.
- A set of **Operators**, which describe any elementary perceptual, motor, or cognitive acts whose execution is necessary to change any aspect of the user's mental state or to affect the task environment.
- A set of **Methods** or procedures describing how to achieve the goal.
- A set of **Selection** rules to choose between the competing methods to accomplish a specific goal.

The KLM method, which was used to evaluate the efficiency of the two types of input methods, can be considered a simplified version of GOMS, as the main focus is on the low-level operators (such as keypresses, clicks, pointing) without an explicit analysis of the goals and selection rules (Card et al., 1983).

As introduced by its original creators, the KLM model offers a simple, accurate, and flexible model for the time it takes an expert user to perform an error-free task with a given method on an interactive computer system. This model counts users' keystrokes and includes other low-level operators to estimate task times (Card et al., 1980).

The KLM analysis was calculated for both screens. The first involves an expert user utilising the hybrid design input method on a reading screen. The second accounts for using a conventional input method, such as those found in the standard screens. Moreover, the analysis was performed for two usage scenarios: filling an empty visa application from scratch primarily using the keyboard, and completing the six main tasks of the empirical study using the mouse (see *Appendix H* for excerpts).

The analysis was conducted using the open-source tool Cogulator[7] (Estes, 2016). Furthermore, the standard HTML form controls presented in one of the techniques of WCAG2.0 (Web Content Accessibility Guidelines 2.0) (W3C, 2016) were utilised as a reference to allocate KLM operators when using only the keyboard.

Advantages of GOMS-KLM

The literature is full of arguments and use-cases demonstrating the benefits of GOMS, since it has been used for so long to model human performance. To begin with, the KLM model provides a quick and simple tool that can be learned in a short time compared to conducting real experiments. In addition, it is packaged in such a manner that it can be used by designers to compare two or more alternative designs in the early stages while also remaining accurate enough to aid in making design decisions (Card et al., 1980).

Furthermore, the GOMS is more than a research tool, since it has been applied to multiple domains and real-world systems, producing useful input for the design process. Additionally, it can be used as a usability evaluation tool across several development stages (John and Kieras, 1996).

Finally, numerous researchers who have utilised the GOMS method have reported its success in comparing the efficacy of different systems. The comparative analysis ability of this method has constituted one of its main advantages since its creation (Preece et al., 2002, p. 453).

KLM Analysis Operators

The main operators employed in the analysis (keystroke, pointing, and homing) comprised those defined by Card et al., as they were confirmed to a high degree (Haunold and Kuhn, 1994). However, it was also necessary to find reliable estimations for some high-level operators that the user might come across while performing tasks. These operators apply to tasks such as choosing from Pull-Down lists, scrolling, and selecting a date from the Date-Picker input control. Therefore, some of the composite operators proposed by Jeff Sauro were deemed adequate for this purpose, especially since those operators make the process of estimating tasks faster without any loss in accuracy (Sauro, 2009).

The cognitive calculator tool enables having different syntax with the same operator underneath to make the script readable. Furthermore, the software allows adding models and operators to the pre-installed ones. Therefore, some of the composite operators found in the literature (Sauro, 2009) were added to the calculator tool to be used throughout the analysis. *Table 3* on the next page lists the operators employed in the evaluation and their source.

7 Cogulator: A Cognitive Calculator - http://www.cogulator.io/

Table 3. KLM Operators Used in the Analysis

Operator	Description	Time	Source
Point (P)	Pointing to a target on the screen with a mouse.	1.10 sec	(Card et al., 1980; Kieras, 2001)
Click (BB)	Click the mouse button (pressing and releasing).	200 ms	(Kieras, 2001)
Keystroke (K)	Pressing a key or button on the keyboard. The time for the average noncritical typist (40 wpm) is found recommended for most users.	280 ms	(Card et al., 1980; Kieras, 2001)
Type	Type a sequence of *n* characters on a keyboard.	T= (*n* x K) sec	(Kieras, 2001)
Hands (H)	Homing the hand(s) on the keyboard or other devices such as the mouse.	400 ms	(Card et al., 1980; Kieras, 2001)
Mental; Think; Verify (M)	Those accounts for the time users mentally prepare for physical activities, verify their input, or think about the data that should be retrieved from their memory to complete the task.	1.20 sec	(Kieras, 2001; Olson and Olson, 1990)
Date-Picker	The time it takes to select a date from the Date-Picker input control. This will vary depending on the design of the Date-Picker component.	6.81 sec	(Sauro, 2009)
Pull-Down List (No Page Load)	Selecting an item from a Pull-Down List without accounting for page load.	3.04 sec	(Sauro, 2009)
Scrolling	Scrolling across the screen to reach the required field or input control.	3.96 sec	(Sauro, 2009)

System response operator R(t) comprises one of the original operators of KLM. This operator represents the time users have to wait until the system response to a command or action. However, the KLM model does not demonstrate a theory of system response times, and they are only counted when they require the user to wait for the system. Furthermore, system responses vary among different systems and different commands. In addition, they are not counted in some cases, as expert users can overlap them with the successor mental operations, unless the response does not exceed 1.35 sec (Card et al., 1980). Therefore, it was decided not to include them in the analysis and assume that they are identical constants for both designs.

Mental Times Allocation

Mental operations (**M**s) represent acts of preparation for applying subsequent physical operations (Card et al., 1980). This preparation includes times where the user retrieves units of information from long-term memory (Olson and Olson, 1990), thinks of initiating a task, or verifies actions and input. Although Card et al. provided some heuristics for locating mental operators in their book *The Psychology of Human-Computer Interaction* and other publications (Card et al., 1983, 1980), deciding the appropriate amount of **M**s and their location remains the most challenging aspect of using KLM (Kieras, 2001).

In our analysis, some recommendations suggested by David Kieras (Kieras, 2001) functioned as a guideline to locate mental operators. The rules and cases applied to allocate Ms in the analysis include the following:

- ***Consistency***
  Both designs, standard and reading, utilised the exact same set of KLM operators to deal with each task's input control. However, a few differences occurred on special occasions that were dependent on the type of screen. Those unique differences are discussed in the result section.
- ***Giving attention to the number of Ms rather than the placement***
  To preserve consistency and maintain a reasonably systematic comparison, mental times were allocated cautiously. Therefore, the number of Ms across screens did not differ drastically in a manner that could affect the results, and it was kept at the very minimum (Standard 134; Reading 133).
- ***Initiating each task***
  A mental operator was assigned at the start of each goal where users retrieved the necessary information required to complete the task.

- ***Making a strategy decision***
  A mental operator was allocated whenever the user faced a situation featuring more than one option to continue filling the visa form.
- ***Retrieving a chunk from memory***
  An operator was used when the user recalled information from memory to deal with some input controls. This retrieval occurred when typing in a text field, selecting among multiple options of a set of Radio buttons, using a Date-Picker, or choosing from a Pull-Down list.
- ***Verifying input***
  A mental operator followed each input operation in a text field, Date-picker, or selecting from a set of checkboxes containing more than two options.
- ***Skilled users can overlap Ms with physical operators***
  This rule was only applied when estimating the time it would take expert users to perform input on the elements of the six main tasks used during the empirical study. This overlapping resulted from using the mouse to locate and point the required fields.

Limitations of GOMS-KLM

Likely one of the most noticeable restrictions of KLM is that it assumes users to possess a high level of expertise. Moreover, it expects tasks to be routine units with well-documented methods and the user manifesting an error-free performance. Additionally, this model only predicts one aspect of interface design—namely, task execution times—without accounting for other vital aspects (Card et al., 1980). Such aspects include, for example, but not limited to, learnability, user satisfaction, effectiveness, memorability, accessibility, and recovering from errors.

Furthermore, in some cases, the literature mentioned that GOMS predictions did not match the empirical measurements due to users acting unexpectedly compared to what designers predicted. This further makes it difficult to predict how an average user will perform tasks, such as when using systems designed to be flexible, where errors and unpredicted behaviours accordingly cannot be modelled. These unpredictable behaviours include, among others, individual differences, fatigue, social and organisational factors, mental workloads, and interruptions (Preece et al., 2002, p. 454).

Finally, dealing with assigning mental operators and deciding which value to use can be confusing and overwhelming, as seen from the literature (Card et al., 1980; Kieras, 2001; Olson and Olson, 1990), as well as from the need for more validated composite operators for everyday routine tasks similar to those proposed by Sauro (2009).

5.2.2 Results

As mentioned earlier, the KLM analysis was performed for both reading and standard screens using the same input data. *Table 4* presents the results for each screen in two use scenarios. The first involves filling an empty application from scratch using the keyboard, while the second comprises a situation where a user fills the input controls of the six main tasks of the empirical study using a mouse.

Table 4. KLM Task Times

Screen \ Use Scenario	Full application using a keyboard	Six input controls using a mouse
Standard	430.9 sec (7.18 min)	64.5 sec (1.8 min)
Reading	426.1 sec (7.10 min)	57.2 sec (0.95 min)

It is worth mentioning that the reading screen’s adaptive nature to the content provides it with advantages when combined with the proposed input method. This advantage is evident in the example of filling the visa application using the keyboard. The reading screen’s layout does not display empty sections that are not relevant to the content. Moreover, when the form contains several related sections, and only one can be filled in, there is no need to present the other inapplicable options. As a result, when using this screen’s input method, users will be saved from manually skipping fields and sections that cannot be filled in. Therefore, only the relevant input panels will appear based on the form's previous inputs.

However, when using the standard screen to fill the application, this takes more keystrokes compared to the reading screen, since users need to manually skip the inapplicable fields. For instance, the user needs to skip 14 input controls. This skipping is necessary, since the 'sponsored invitation' section should be empty, as the applicant is not invited by an organisation. Beyond this, it is also necessary to skip one more section, since the applicant's cost of living is not sponsored by another party. However, assuming that the standard solution can somehow save the user from manually skipping irrelevant parts, a new analysis after removing all the extra operators required for skipping showed that it would require 426.1 sec to complete the form. This result is equal to the time spent using the hybrid input method on the reading screen.

Moreover, the time difference between screens when using the mouse in the second scenario (updating the six input controls from the empirical study) is caused by scrolling to find the required fields on the standard screen. Therefore, assuming that all the necessary fields of the six tasks were on the same space with no need to scroll, the time for the standard screen will become 56.6 sec in this case, making it faster than the reading screen by 600 ms. This minor delay is caused by three additional mouse clicks (200 ms each) to show the input panels on screen before being able to edit the relevant input control.

Eventually, when using the Hybrid input method, the additional mouse click discussed above will only appear in a few cases. This will be when the input control required to edit the data does not possess an auto-focus feature. The autofocus usually enables users to enter or select data immediately once the floating input panel appears. For example, input controls like Text fields and Date-Pickers possess this feature. Conversely, other fields that use controls such as Radio-Buttons, List-Boxes, Checkboxes, and Dropdown Lists will require an additional mouse click to show the input panel first before being able to manipulate the input.

It is evident from the KLM analysis times that, in most cases, the combined reading and input method performs better when used by experienced users. However, the KLM model does not account for errors and mistakes. Therefore, it is essential to perform other tests and experiments before generalising the results, especially when considering introducing this method to new users who are unfamiliar with the concept of reading screens.

6 Discussion & Conclusion

6.1 The Feasibility of the Proposed Design

The first research question concerned identifying a solution to enable efficient input for the reading screen. It appears that the proposed design could constitute such a feasible solution, since it attempts to save the visual and positional cues of the original layout. Although the floating panels of the input controls will draw users' attention, the focus will remain restricted to the task of updating that particular field.

The difficulties that users face when introduced to a new system was discussed in the work of Carroll and Rosson (1998). From what they termed 'paradoxes of the active user', the production paradox is particularly relevant in this context. This problem occurs when experienced users continue using previous methods to accomplish tasks rather than investing their limited time into learning new ones. For instance, even though users might be aware that using the new methods would make their work more efficient, they could still prefer previous methods so they can maintain their level of productivity.

Moreover, 'assimilation paradox' represents yet another issue that can hinder the adaptation of new solutions. In this paradox, experienced users have already accumulated expertise and developed patterns of behaviours that will obstruct them from establishing new ones. However, Carroll and Ronsson suggested, among other solutions, mitigating the effects of these paradoxes by making it easy to learn the new system, as well as by introducing solutions that are similar to their previous options or conform to users' expectations (Carroll and Rosson, 1998). It is further believed that the design proposed in this thesis falls under this approach.

For instance, the design is optimised to perform similar to how an experienced user would expect when filling in a form (i.e. by using the keyboard and tabbing to move through input fields). This familiarity should make the training process cost less, since users can apply their previous knowledge to the new method. However, this only applies to the input method itself. Using reading screens represents a separate matter that users can master after sufficient training and usage.

One question arises concerning how the empty fields should be displayed so that they enable input. For instance, if the fields are empty, they will become invisible, and it will thus not be possible for users to know where to click to insert new data. One possible solution can be replacing the empty fields with tags or holders possessing labels for the missing information inside them. These tags should appear only when switching to the input mode, however. The design of these tags can be decided on during the implementation phase. Examples of how such tags can appear would be <Email Address>, [ZipCode, Street & No., City].

6.2 Efficiency for Expert Users

Regarding the second research question concerning the proposed design's efficiency for expert users, the KLM analysis results demonstrated that reading screens should perform better compared to the standard alternatives. However, it will be interesting to test the interface and the input method using skilled users to determine if their evaluation matches the KLM results. Additionally, it is essential to include other factors such as stress, time constraints, and task difficulty when evaluating the proposed design.

Moreover, the KLM model assumes no errors or interruptions when performing the tasks, but this is not the case in most scenarios and domains, especially in fields such as medical care. In addition, it will be interesting to compare the clutter that is perceived by experts for both screens.

One objection regarding the design can be that, by using the fixed floating input panels, some parts of the reading screen will be obstructed. These parts could contain information related to the current task. Therefore, this will force users to depend on retrieving this piece of information from their temporary memory. However, since the panels are only limited to the necessary instructions and input control of a specific field, the effect of this obstruction should be limited to a small space. Moreover, a simple adjustment to the design to enable temporarily hiding the input panel while the user is holding a keyboard key would solve the problem.

Eventually, if the hybrid input method is utilised with a keyboard by an expert user, the cost should be either equivalent to, or even better than, the cost of using the standard approach in most cases. However, there are a few cases where the hybrid method will be slower by a mouse click compared to the standard method (discussed in *section 5.2.2*). Nonetheless, this extra click can be justified by the reduction of clutter as well as the enhanced search and navigation that the reading screens can add to the interface.

6.3 Efficiency for Inexperienced Users

It is interesting to note that the significant differences between the reading and standard screens only occurred during the third block of trials. While three trial blocks are not sufficient to become skilled in using reading screens, the difference could indicate familiarity. It could be that the participants started growing familiar with the reading screen's layout due to the fixed positions of its elements.

Another explanation for the time differences could be due to scrolling's detrimental effect for finding the search targets. For instance, once the participants became more confident with their answers during the first and second trial block, scrolling to reach the target using the standard screen became the only factor slowing them. This explanation corresponds with the literature findings presented in *section 3.1.1*. Moreover, scrolling's negative effect is further confirmed by the Mann-Whitney U test results for the two task categories. These results demonstrate a significant difference in the case of scrolling tasks, while such a difference did not occur for the non-scrolling ones (see *Figure 14* and *Figure 15*).

The differences between mouse distances during the third block of trials can be a result of the screen space variation between screens. The reading screen features less space compared to the standard alternative, since all the unnecessary elements were removed. Additionally, this could be due to participants' personal preferences regarding the manner in which they use the mouse. However, the difference between screens during the non-scrolling tasks was far more significant than the difference during scrolling tasks (P=.003 and P=.03, respectively), even though the reading screen had shorter mouse travel distances in both conditions. Therefore, the standard screen's visual clutter could be the reason behind this substantial difference during the non-scrolling tasks.

Furthermore, upon reviewing the recordings, it was noticed that participants performed unnecessary scrolling during task six. However, the target answer for this task could be selected without scrolling. Therefore, this unnecessary scrolling likely caused extra mouse travel, since the curser did not land on the target when participants stopped scrolling.

Although the participants produced more errors using the reading screen compared to the standard, this confusion could, as explained earlier, be due to the novelty of the presentation layout, as well as other factors, such as preferring speed over accuracy. However, participants corrected most of these errors during the second block of trials and learned to use the tooltip tool to verify their answers. Moreover, it is expected that skilled users who have to deal with similar screens for a long time in their work should not face such an issue.

Finally, the third research question involved evaluating the proposed design's efficiency for the inexperienced users who briefly interacted with its concept. The results of the empirical study appear promising, as the reading screen scored better in task times and mouse travel distances on average compared to the standard screen.

In conclusion, this thesis highlighted the advantages of optimising computer interfaces to support skilled users in finding and reading information. Moreover, the proposed input solution that can be used with these screens appeared to provide some potential benefits, as the evaluations suggested. Therefore, it would be interesting to investigate how other types of applications, beyond medical records and visa applications, could benefit from such a solution. However, each system possesses unique use scenarios, contexts, and objectives. Thus, generalising the results presented in this work should be treated with extreme caution.

6.4 Future Work

There remains considerable room for improvements to the design of the proposed input method. For instance, it would be interesting to possess a fully functional implementation for testing and evaluation by skilled users in real settings. Additionally, it will be interesting to assess other aspects beyond efficiency. These aspects include effectiveness, user satisfaction, and learnability. Moreover, it will be of great interest to re-conduct the empirical study with more participants and a greater number of trials. This could lead to more accurate results and help determine whether or not the task times for the reading screen will continue to decrease.

Finally, the proposed design can be implemented using frameworks such as Electron or Proton Native. These platforms allow creating cross-platform and native desktop apps using web technologies such as JavaScript, HTML, and CSS. Alternatively, it can be implemented using the Qt platform, which also enables creating native apps that take advantage of the native capabilities of the hosting operating system.

7 References

Assistant Secretary for Public Affairs, 2013. User Interface Elements [WWW Document]. Usability.gov. URL /how-to-and-tools/methods/user-interface-elements.html (accessed 8.24.19).

Benyon, D., 2019. Designing User Experience: A guide to HCI, UX and interaction design, Fourth. ed. Pearson Education Limited, Harlow, United Kingdom.

Blijleven, V., Wetzels, M., Jaspers, M., 2017. Workarounds Emerging From Electronic Health Record System Usage: Consequences for Patient Safety, Effectiveness of Care, and Efficiency of Care. JMIR Hum Factors 4.

Borälv, E., Göransson, B., Olsson, E., Sandblad, B., 1994. Usability and efficiency. The HELIOS approach to development of user interfaces. Comput Methods Programs Biomed 45 Suppl, S47-64.

Brown, T., Wyatt, J., 2010. Design Thinking for Social Innovation By. Stanford Social Innovation Review 8, 30–35.

Card, S.K., Moran, T.P., Newell, A., 1980. The keystroke-level model for user performance time with interactive systems. Communications of the ACM 23, 396–410.

Card, S.K., Newell, A., Moran, T.P., 1983. The Psychology of Human-Computer Interaction. L. Erlbaum Associates Inc., Hillsdale, NJ, USA.

Carroll, J., Rosson, M.B., 1998. Paradox of the active user" in interfacing thought: cognitive aspects of human computer interaction 80–111.

Domańska, J., 2018. Rethinking interfaces to medical records (Master’s Thesis). Uppsala University, Department of Information Technology, Uppsala, Sweden.

Estes, S., 2016. Introduction to Simple Workload Models Using Cogulator.

Goransson, B., Lind, M., Pettersson, E., Sandblad, B., Schwalbe, P., 1986. The interface is often not the problem. In: Proceedings of the SIGCHI/GI Conference on Human Factors in Computing Systems and Graphics Interface. ACM, pp. 133–136.

Graziano, A.M., 1932, Raulin, M.L., 2013. Research methods: a process of inquiry, 8th ed. Pearson, Boston.

Haunold, P., Kuhn, W., 1994. A Keystroke Level Analysis of a Graphics Application: Manual Map Digitizing. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI ’94. ACM, New York, NY, USA, pp. 337–343.

John, B.E., Kieras, D.E., 1996. Using GOMS for user interface design and evaluation: which technique? ACM Transactions on Computer-Human Interaction 3, 287–319.

Kieras, D., 2001. Using the Keystroke-Level Model to Estimate Execution Times.

Kushniruk, A., Monkman, H., Borycki, E., Kannry, J., 2015. User-Centered Design and Evaluation of Clinical Information Systems: A Usability Engineering Perspective. In: Patel, V.L., Kannampallil, T.G., Kaufman, D.R. (Eds.), Cognitive Informatics for Biomedicine: Human Computer Interaction in Healthcare. Springer International Publishing, Cham, pp. 141–161.

Mangen, A., Walgermo, B.R., Brønnick, K., 2013. Reading linear texts on paper versus computer screen: Effects on reading comprehension. International Journal of Educational Research 58, 61–68.

Mcknight, P., Najab, J., 2010. Mann-Whitney U Test.

Moacdieh, N., Sarter, N., 2014. Display Clutter: A Review of Definitions and Measurement Techniques. Hum Factors 57, 61–100.

Moacdieh, N., Sarter, N., 2015. Clutter in Electronic Medical Records: Examining Its Performance and Attentional Costs Using Eye Tracking. Hum Factors 57, 591–606.

Moacdieh, N., Sarter, N., 2017. Using Eye Tracking to Detect the Effects of Clutter on Visual Search in Real Time. IEEE Transactions on Human-Machine Systems 47, 896–902.

Moacdieh, N.M., Ganje, T., Sarter, N., 2017. Physician perceptions of clutter in electronic medical records. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 61, 572–572.

Natarajan, K., Stein, D., Jain, S., Elhadad, N., 2010. An analysis of clinical queries in an electronic health record search utility. International Journal of Medical Informatics 79, 515–522.

Norman, D.A., 2005. Human-centered Design Considered Harmful. Interactions 12, 14–19.

Nygren, E., Allard, A., 1996. Between the clicks: Skilled users scanning of pages. In: Designing for the Web: Empirical Studies. Redmond, WA, USA.

Nygren, E., Henriksson, P., 1992. Reading the medical record. I. Analysis of physician's ways of reading the medical record. Computer Methods and Programs in Biomedicine 39, 1–12.

Nygren, E., Johnson, M., Henriksson, P., 1992a. Reading the medical record. II. Design of a human-computer interface for basic reading of computerized medical records. Computer Methods and Programs in Biomedicine 39, 13–25.

Nygren, E., Lind, M., Johnson, M., Sandblad, B., 1992b. The Art of the Obvious. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '92. ACM, New York, NY, USA, pp. 235–239.

Olson, J.R., Olson, G.M., 1990. The Growth of Cognitive Modeling in Human-Computer Interaction Since GOMS. Human-Computer Interaction 5, 221.

Plattner, H., Meinel, C., Weinberg, U., 2009. Design Thinking: Innovation lernen -- Ideenwelten öffnen.

Preece, J., Rogers, Y., Sharp, H., 2002. Interaction design: beyond human-computer interaction. Wiley, New York.

Roman, L.C., Ancker, J.S., Johnson, S.B., Senathirajah, Y., 2017. Navigation in the electronic health record: A review of the safety and usability literature. Journal of Biomedical Informatics 67, 69–79.

Sauro, J., 2009. Estimating Productivity: Composite Operators for Keystroke Level Modeling. In: Jacko, J.A. (Ed.), Human-Computer Interaction. New Trends. Springer Berlin Heidelberg, pp. 352–361.

Schallmo, D., Williams, C., Lang, K., 2018. An Integrated Design Thinking Approach-Literature Review, Basic Principles and Roadmap for Design Thinking. In: Innovation, The Name of The Game. Presented at the ISPIM Innovation Conference, Stockholm, Sweden.

Shelly, G.B., Rosenblatt, H.J., 2011. Chapter 8 User Interface Design. In: Systems Analysis and Design. Course Technology Press, Boston, MA, United States, pp. 354–388.

Tange, H.J., Hasman, A., de Vries Robbé, P.F., Schouten, H.C., 1997. Medical narratives in electronic medical records. International Journal of Medical Informatics 46, 7–29.

W3C, 2016. H91: Using HTML form controls and links | Techniques for WCAG 2.0 [WWW Document]. World Wide Web Consortium (W3C). URL https://www.w3.org/TR/2016/NOTE-WCAG20-TECHS-20161007/H91 (accessed 9.16.19).

Walji, M.F., Kalenderian, E., Tran, D., Kookal, K.K., Nguyen, V., Tokede, O., White, J.M., Vaderhobli, R., Ramoni, R., Stark, P.C., Kimmes, N.S., Schoonheim-Klein, M.E., Patel, V.L., 2013. Detection and characterization of usability problems in structured data entry interfaces in dentistry. International journal of medical informatics 82, 128–38.

Ware, C., 2008. Visual thinking for design. Morgan Kaufmann, Burlington, MA, USA.

8 Appendices

Appendix A - Application for Schengen Visa

Application for Schengen Visa

This application form is free

Photo

1. Surname (Family name) (x)

2. Surname at birth (Former family name(s)) (x)

3. First name(s) (Given name(s)) (x)

4. Date of birth (day-month-year)

5. Place of birth

6. Country of birth

7.Current nationality

Nationality at birth, if different

8.Sex
☐ Male ☐ Female

9. Marital status
☐ Single ☐ Married ☐ Separated ☐ Divorced ☐ Widow(er)
☐ Other (please specify)

10. In the case of minors: Surname, first name, address (if different from applicant's) and nationality of parental authority/legal guardian

11. National identity number, where applicable

12. Type of travel document
☐ Ordinary passport ☐ Diplomatic passport ☐ Service passport ☐ Official passport ☐
☐ Other (please specify)

13. Number of travel document

14. Date of issue

15. Valid until

16. Issued by

17. Applicant's home address and e-mail address

Telephone number(s)

18. Residence in a country other than that country of current nationality
☐ No
☐ Yes. Resident permit or equivalent .... No .... Valid until

* 19. Current occupation

* 20. Employer and employer's address and telephone number. For students, name and address of educational establishment.

21. Main purpose(s) of the journey
☐ Tourism ☐ Business ☐ Visiting family or friends ☐ Cultural ☐ Sports
☐ Official visit
☐ Medical reasons
☐ Study ☐ Transit ☐ Airport transit ☐ Other (please specify)

22. Member State(s) of destination

23. Member state of first entry

24. Number of entries requested
☐ Single entry ☐ Two entries
☐ Multiple entries

25. Duration of the intended stay or transit
Indicate number of days

26. Schengen visas issued during the past three years
☐ No ☐ Yes. Date(s) of validity from .... to...

27. Fingerprints collected previously for the purpose of applying for a Schengen Visa
☐ No ☐ Yes. Date if known...

For official use only

Date of application:

Visa application number:

Application lodged at
☐ Embassy/consulate
☐ CAC
☐ Service provider
☐ Commercial intermediary
☐ Border

Name:

☐ Other:

File handled by:

Supporting documents:
☐ Travel document
☐ Means of subsistence
☐ Invitation
☐ Means of transport
☐ TMI
☐ Other:

Visa decision
☐ Refused
☐ Issued:
☐ A
☐ C
☐ LTV

☐ Valid
From.................................
Until ....

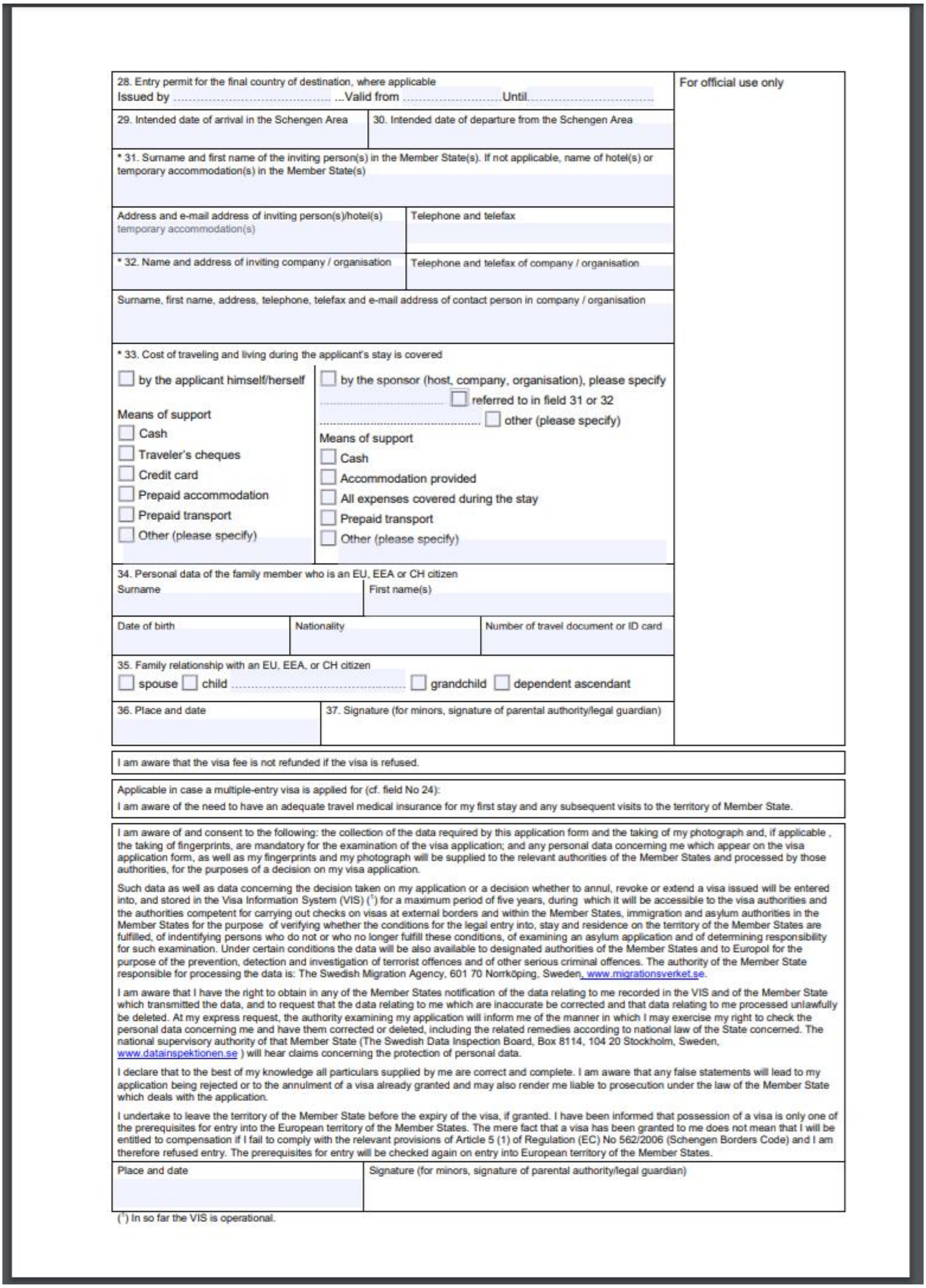
Number of entries
☐ 1 ☐ 2 ☐ Multiple

Number of days:

The field marked with * shall not be filled in by family members of EU,EEA or CH citizens (spouse, child or dependent ascendant) while exercising their right to free movement. Family members of EU,EEA or CH citizens shall present documents to prove this relationship and fill in fields No 34 and 35.

(x) Fields 1-3 shall be filled in accordance with the data in travel document.

MIGR 119031 rev. 2 2015-05-19



28. Entry permit for the final country of destination, where applicable
Issued by ....Valid from ....Until.................................

For official use only

29. Intended date of arrival in the Schengen Area

30. Intended date of departure from the Schengen Area

* 31. Surname and first name of the inviting person(s) in the Member State(s). If not applicable, name of hotel(s) or temporary accommodation(s) in the Member State(s)

Address and e-mail address of inviting person(s)/hotel(s) temporary accommodation(s)

Telephone and telefax

* 32. Name and address of inviting company / organisation

Telephone and telefax of company / organisation

Surname, first name, address, telephone, telefax and e-mail address of contact person in company / organisation

* 33. Cost of traveling and living during the applicant's stay is covered

☐ by the applicant himself/herself

Means of support
☐ Cash
☐ Traveler's cheques
☐ Credit card
☐ Prepaid accommodation
☐ Prepaid transport
☐ Other (please specify)

☐ by the sponsor (host, company, organisation), please specify
.... ☐ referred to in field 31 or 32
.... ☐ other (please specify)

Means of support
☐ Cash
☐ Accommodation provided
☐ All expenses covered during the stay
☐ Prepaid transport
☐ Other (please specify)

34. Personal data of the family member who is an EU, EEA or CH citizen
Surname

First name(s)

Date of birth

Nationality

Number of travel document or ID card

35. Family relationship with an EU, EEA, or CH citizen
☐ spouse ☐ child .... ☐ grandchild ☐ dependent ascendant

36. Place and date

37. Signature (for minors, signature of parental authority/legal guardian)

I am aware that the visa fee is not refunded if the visa is refused.

Applicable in case a multiple-entry visa is applied for (cf. field No 24):
I am aware of the need to have an adequate travel medical insurance for my first stay and any subsequent visits to the territory of Member State.

I am aware of and consent to the following: the collection of the data required by this application form and the taking of my photograph and, if applicable , the taking of fingerprints, are mandatory for the examination of the visa application; and any personal data concerning me which appear on the visa application form, as well as my fingerprints and my photograph will be supplied to the relevant authorities of the Member States and processed by those authorities, for the purposes of a decision on my visa application.

Such data as well as data concerning the decision taken on my application or a decision whether to annul, revoke or extend a visa issued will be entered into, and stored in the Visa Information System (VIS) ([1]) for a maximum period of five years, during which it will be accessible to the visa authorities and the authorities competent for carrying out checks on visas at external borders and within the Member States, immigration and asylum authorities in the Member States for the purpose of verifying whether the conditions for the legal entry into, stay and residence on the territory of the Member States are fulfilled, of indentifying persons who do not or who no longer fulfill these conditions, of examining an asylum application and of determining responsibility for such examination. Under certain conditions the data will be also available to designated authorities of the Member States and to Europol for the purpose of the prevention, detection and investigation of terrorist offences and of other serious criminal offences. The authority of the Member State responsible for processing the data is: The Swedish Migration Agency, 601 70 Norrköping, Sweden, www.migrationsverket.se.

I am aware that I have the right to obtain in any of the Member States notification of the data relating to me recorded in the VIS and of the Member State which transmitted the data, and to request that the data relating to me which are inaccurate be corrected and that data relating to me processed unlawfully be deleted. At my express request, the authority examining my application will inform me of the manner in which I may exercise my right to check the personal data concerning me and have them corrected or deleted, including the related remedies according to national law of the State concerned. The national supervisory authority of that Member State (The Swedish Data Inspection Board, Box 8114, 104 20 Stockholm, Sweden, www.datainspektionen.se) will hear claims concerning the protection of personal data.

I declare that to the best of my knowledge all particulars supplied by me are correct and complete. I am aware that any false statements will lead to my application being rejected or to the annulment of a visa already granted and may also render me liable to prosecution under the law of the Member State which deals with the application.

I undertake to leave the territory of the Member State before the expiry of the visa, if granted. I have been informed that possession of a visa is only one of the prerequisites for entry into the European territory of the Member States. The mere fact that a visa has been granted to me does not mean that I will be entitled to compensation if I fail to comply with the relevant provisions of Article 5 (1) of Regulation (EC) No 562/2006 (Schengen Borders Code) and I am therefore refused entry. The prerequisites for entry will be checked again on entry into European territory of the Member States.

Place and date

Signature (for minors, signature of parental authority/legal guardian)

([1]) In so far the VIS is operational.

Figure 18 The Original Schengen Visa Application[8]

[8] https://www.migrationsverket.se/download/18.5e83388f141c129ba6312919/1485556220819/blvisa_119031_en.pdf

Appendix B - List of Input Controls (Visa Form)

#	Field name	Input Control	Length (characters)	Available Options
1	Surname (Family name)	Text field	60	-
2	Surname at birth (Former family name(s))	Text field	60	-
3	First name(s) (Given name(s))	Text field	60	-
4	Date of birth (day-month-year)	Date picker	14	-
5	Place of birth	Text field	20	-
6	Country of birth	Dropdown list	-	List of countries
7	Sex	Radio buttons	-	• Male • Female
8	Current nationality	Dropdown list	-	List of countries
	Nationality at birth, if different	Dropdown list	-	List of countries
9	Marital status	Dropdown list	-	• Single • Married • Separated • Divorced • Widow(er) • Other
	if Other is selected			
	Other	Text field	24	-
10	National identity number (where applicable)	Text field	60	-
11	(In the case of minors, info of parental authority/legal guardians:)			
	Surname	Text field	20	-
	First name	Text field	20	-
	Address (if different from applicant)			
	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries
	Nationality of parental authority/ legal guardian	Dropdown list	20	List of countries
12	Type of travel document	Dropdown list	-	• Ordinary passport • Diplomatic passport • Service passport • Official passport • Other
	if Other is selected			
	Other	Text field	40	-
13	Number of travel document	Text field	20	-
14	Date of issue	Date picker	14	-
15	Valid until	Date picker	14	-
16	Issued by	Text field	15	-
17	Applicant's home address			
	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries

	Email	Text field	40	-
	Telephone number(s)	Text field	20	-
18	Residence in a country other than that country of current nationality	Radio buttons	-	• No • Yes
	if Yes is selected			
	Resident permit of equivalent no.	Text field	10	-
	Valid until	Date picker	14	-
19	Current occupation	Text field	60	-
20	Employer and employer's address and telephone number. For students, name and address of educational establishment.			
	Name	Text field	20	-
	Address			
	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries
	Telephone	Text field	20	-
21	Main purpose(s) of the journey	Checkbox list	-	• Tourism • Business • Visiting family or friends • Cultural • Sports • Official visit • Medical reasons • Study • Transit • Airport transit • Other
	if Other is selected			
	Other	Text field	20	-
22	Member State(s) of destination	Text field	30	-
23	Member state of first entry	Dropdown list	20	List of EU countries
24	Number of entries requested	Dropdown list	-	• Single entry • Two entries • Multiple entries
25	Duration of the intended stay or transit	Text field	4	-
26	Schengen visas issued during the past three years	Radio buttons	-	• No • Yes
	if Yes is selected			
	Date(s) of validity			
	from	Date picker	14	-
	to	Date picker	14	-
27	Fingers collected previously during the past three years	Radio buttons	-	• No • Yes
	if Yes is selected			
	Date if known	Date picker	14	-
28	Entry permit for the final country of destination, where applicable			
	Issued by	Text field	20	-
	Valid from	Date picker	14	-
	Until	Date picker	14	-
29	Intended date of arrival in the Schengen Area	Date picker	14	-
30	Intended date of departure from the Schengen Area	Date picker	14	-
31	Surname and first name of the inviting person(s) in the Member State(s). If not applicable, name of hotel(s) or temporary accommodation(s) in the Member State(s)	Text field	40	-
	Address and e-mail address of inviting person(s)/hotel(s) temporary accommodation(s)			

	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries
	Email	Text field	40	-
	Telephone and telefax	Text field	20	-
32	Inviting company/organisation			
	Name	Text field	30	-
	Company Address			
	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries
	Telephone and telefax	Text field	20	-
	Contact person in company/organisation			
	Surname	Text field		-
	First name	Text field		-
	Address			
	Street name and No.	Text field	20	-
	Zipcode	Text field	6	-
	City	Text field	15	-
	Country	Dropdown list	-	List of countries
	Email	Text field	40	-
	Telephone and telefax	Text field	20	-
33	Cost of travelling and living during the applicant’s stay is covered			
	By the applicant himself/herself	Checkbox Item	-	-
	Means of support	List boxes	-	• Cash • Traveller’s cheques • Credit card • Prepaid accommodation • Prepaid transport
	Other	Checkbox Item	-	-
	If Other is checked			
	Other (please specify)	Text field	15	-
	by the sponsor (host, company, organisation)	Checkbox Item	-	-
	Referred to in field 31,32	* Radio button	-	-
	If Referred is checked			
	Sponsor	Text field	15	-
	Other	* Radio button	-	-
	If Other is checked			
	Other (please specify)	Text field	20	-
	Means of support	List boxes	-	• Cash • Accommodation provided • All expenses covered during the stay • Prepaid accommodation • Prepaid transport
	Other	Checkbox Item	-	-
	If Other is checked			
	Other (please specify)	Text field	15	-

34	Personal data of the family member who is an EU, EEA or CH citizen			
	Surname	Text field	30	-
	First name(s)	Text field	25	-
	Date of birth	Date picker	-	-
	Nationality	Dropdown list	-	List of EU, EEA countries + CH
	Number of travel document or ID card	Text field	20	-
35	Family relationship with an EU, EEA, or CH citizen			
	Related citizen	Radio buttons	-	• Spouse • Child • Grandchild • Dependent ascendant
	Citizen's full name	Text field	20	-

Table 5. List of The Input Controls in The Visa Form

* Same Radio Button set

Note: the default option shown in the dropdown menus is <Not Selected>

Overview of Table 5

Input Control Type	Frequency of occurrence
Text fields	56
Dropdown list	15
Date picker	12
Radio button list	6
Checkbox list	5
List boxes	2
Total	**96**

Text fields width on the screen

Length (characters)	Width (pixels)
6	50
10	90
15	115
20	144
24	175
30	210
40	280
60	415

Appendix C - Standard Screen

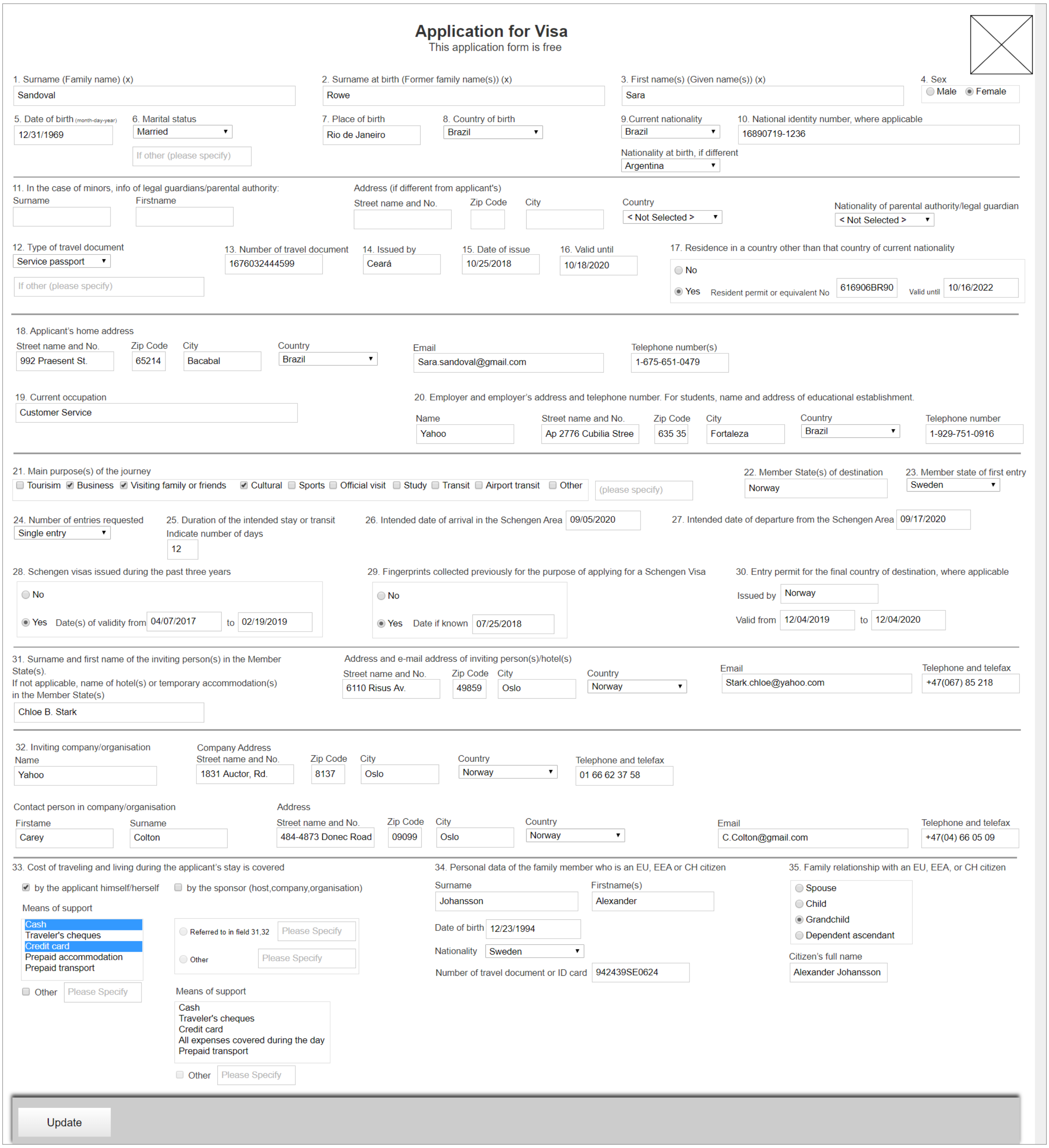
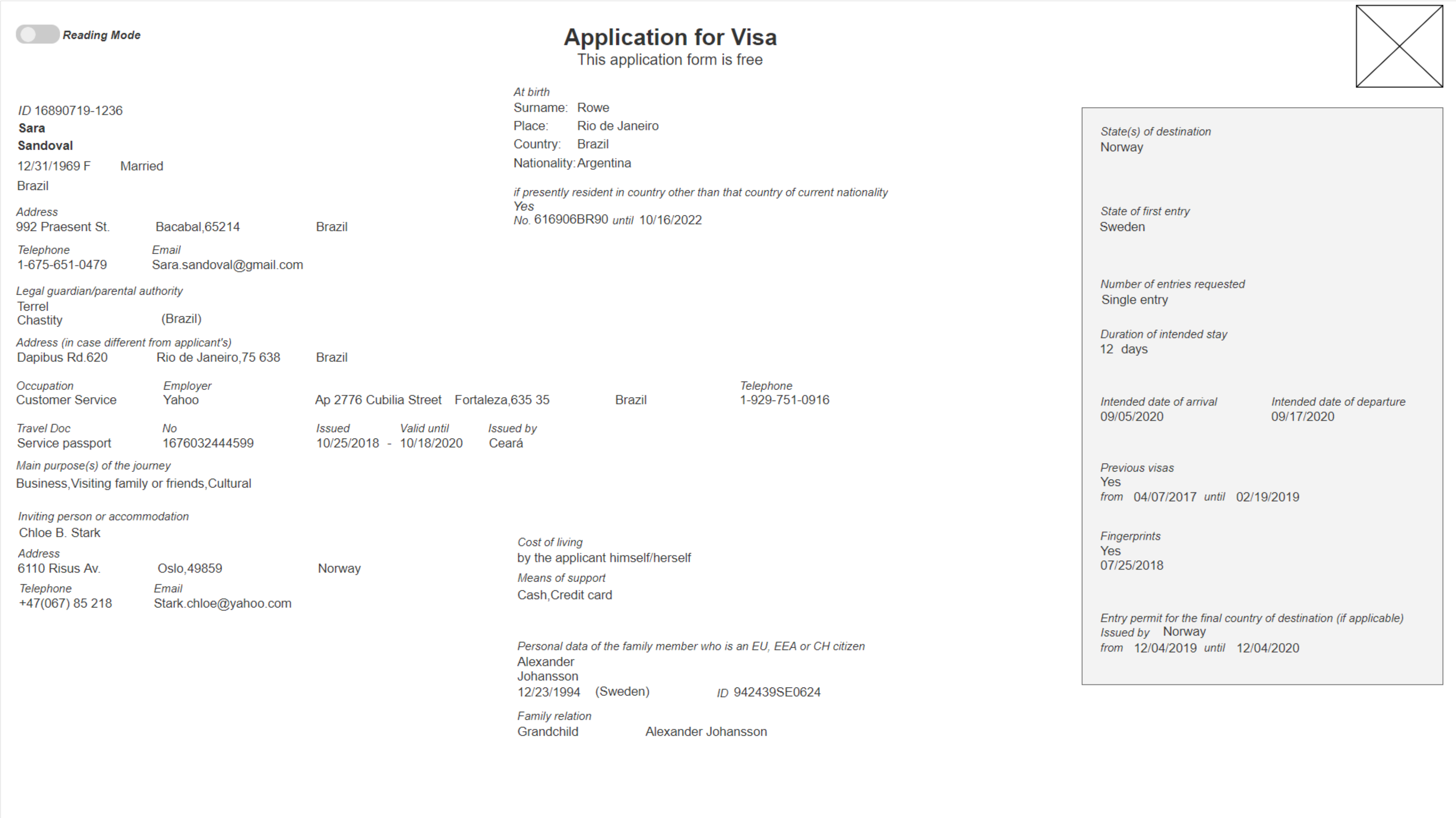


Figure 19. Standard Screen (High Quality)

Appendix D - Reading Screen Layout


Reading Mode

Application for Visa
This application form is free

ID 16890719-1236
Sara
Sandoval
12/31/1969 F Married
Brazil

Address
992 Praesent St. Bacabal,65214 Brazil

Telephone 1-675-651-0479
Email Sara.sandoval@gmail.com

Legal guardian/parental authority
Terrel
Chastity (Brazil)

Address (in case different from applicant's)
Dapibus Rd.620 Rio de Janeiro,75 638 Brazil

At birth
Surname: Rowe
Place: Rio de Janeiro
Country: Brazil
Nationality: Argentina

if presently resident in country other than that country of current nationality
Yes
No. 616906BR90 *until* 10/16/2022

Occupation Customer Service
Employer Yahoo
Ap 2776 Cubilia Street Fortaleza,635 35 Brazil
Telephone 1-929-751-0916

Travel Doc Service passport
No 1676032444599
Issued 10/25/2018 - *Valid until* 10/18/2020
Issued by Ceará

Main purpose(s) of the journey
Business,Visiting family or friends,Cultural

Inviting person or accommodation
Chloe B. Stark
Address
6110 Risus Av. Oslo,49859 Norway
Telephone +47(067) 85 218
Email Stark.chloe@yahoo.com

Cost of living
by the applicant himself/herself
Means of support
Cash,Credit card

Personal data of the family member who is an EU, EEA or CH citizen
Alexander
Johansson
12/23/1994 (Sweden) *ID* 942439SE0624
Family relation
Grandchild Alexander Johansson

State(s) of destination
Norway

State of first entry
Sweden

Number of entries requested
Single entry

Duration of intended stay
12 days

Intended date of arrival 09/05/2020
Intended date of departure 09/17/2020

Previous visas
Yes
from 04/07/2017 *until* 02/19/2019

Fingerprints
Yes
07/25/2018

Entry permit for the final country of destination (if applicable)
Issued by Norway
from 12/04/2019 *until* 12/04/2020

Figure 20. Reading Screen (High Quality)

Appendix E - Reading Screen with Hybrid Input Method

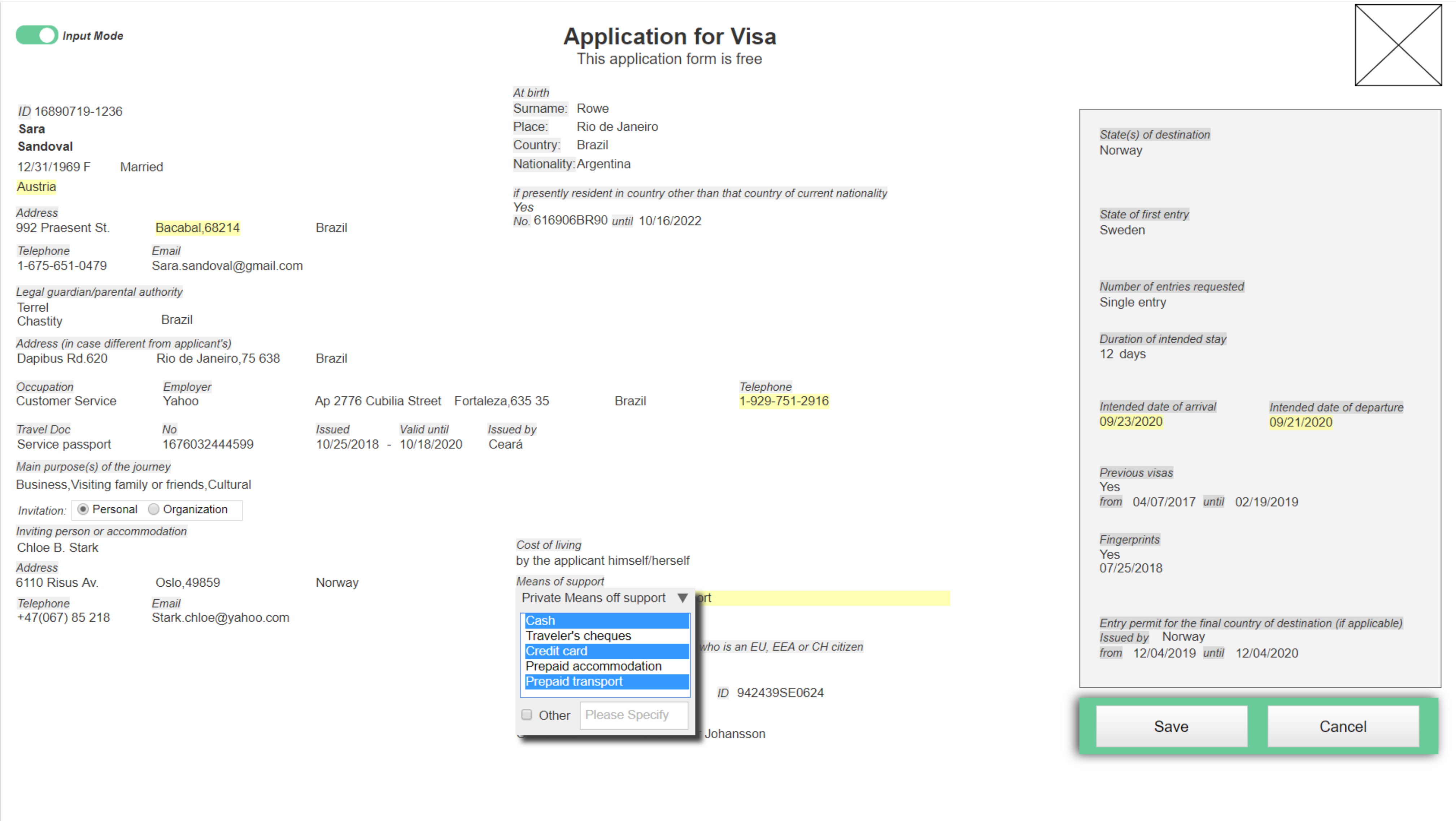


Figure 21. Hybrid Input Method Implemented on Reading Screen

Appendix F – Example of the Tasks Cards

1

Your task:

Find and click on the surname (i.e. last name, family name) of the legal guardian.

- *To start this task:* Click on the white square in the upper right corner of the screen.
- *To mark that the task is completed:* Click on the black square in the upper right corner of the screen

Appendix G – Raw Data Tables

Standard Screen Task Times

First Block of Trials

Table 6. Trial Block 1 – Standard Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P02	18.79	120.73	67.37	40.60	10.13	18.25	***45.98***
P03	5.18	4.98	5.58	48.64	10.98	12.58	***14.66***
P04	11.52	12.36	5.29	13.26	11.42	5.70	***9.93***
P05	47.94	36.24	8.74	25.42	9.57	13.78	***23.62***
P06	19.34	21.32	10.00	23.84	22.34	7.52	***17.39***
P07	10.17	56.30	5.11	21.97	8.50	20.14	***20.37***
P11	23.96	92.97	43.92	31.42	21.94	29.72	***40.66***
P16	11.82	27.10	8.04	6.14	7.75	14.55	***12.57***
Minimum	5.18	4.98	5.11	6.14	7.75	5.70	***9.93***
Maximum	47.94	120.73	67.37	48.64	22.34	29.72	***45.98***
Mean	**18.59**	**46.50**	**19.26**	**26.41**	**12.83**	**15.28**	
Standard Dev.	13.30	41.01	23.38	13.79	5.87	7.59	

Second Block of Trials

Table 7. Trial Block 2 – Standard Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P02	6.84	32.39	3.25	10.99	6.76	3.97	***10.70***
P03	3.12	3.11	4.31	5.80	11.78	3.20	***5.22***
P04	2.59	4.79	3.19	4.79	8.58	3.39	***4.56***
P05	4.56	4.19	5.59	7.74	8.24	4.98	***5.88***
P06	7.18	3.25	4.39	10.37	7.19	4.38	***6.13***
P07	3.32	10.18	13.17	11.18	8.60	11.79	***9.71***
P11	26.31	28.79	15.26	22.30	28.16	23.68	***24.08***
P16	4.11	5.71	2.85	4.79	2.77	4.56	***4.13***
Minimum	2.59	3.11	2.85	4.79	2.77	3.20	***4.13***
Maximum	26.31	32.39	15.26	22.30	28.16	23.68	***24.08***
Mean	**7.25**	**11.55**	**6.50**	**9.75**	**10.26**	**7.49**	
Standard Dev.	7.88	12.00	4.87	5.74	7.65	7.10	

Third Block of Trials

Table 8. Trial Block 3 – Standard Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P02	5.57	5.97	4.57	8.19	9.11	4.19	**6.27**
P03	2.39	7.58	3.56	3.79	7.32	5.17	**4.97**
P04	2.39	4.06	2.37	13.16	4.43	3.09	**4.92**
P05	7.17	6.77	2.78	6.36	4.37	3.79	**5.21**
P06	8.90	5.17	3.17	4.95	3.76	6.16	**5.35**
P07	6.48	14.39	5.05	14.32	11.05	6.95	**9.71**
P11	13.69	64.30	10.59	69.14	44.95	46.30	**41.50**
P16	2.99	2.98	2.19	3.28	8.17	3.17	**3.80**
Minimum	2.39	2.98	2.19	3.28	3.76	3.09	**3.80**
Maximum	13.69	64.30	10.59	69.14	44.95	46.30	**41.50**
Mean	**6.20**	**13.90**	**4.29**	**15.40**	**11.65**	**9.85**	
Standard Dev.	3.86	20.65	2.74	22.10	13.70	14.79	

Mouse Travel Distances: Standard Screen

Table 9. Mouse Movement Tables - Standard Screen

Mouse Movement – Standard Screen - Block 1							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P02	7170.26	9967.37	4259.68	3888.53	3878.92	3661.04	***5470.97***
P03	5113.60	3370.43	4285.02	23323.78	6354.44	7610.25	***8342.92***
P04	3537.05	2308.89	2529.88	2256.96	4299.84	2185.73	***2853.06***
P05	3116.24	1522.30	1704.50	2635.33	2814.25	2444.29	***2372.82***
P06	2991.94	2747.39	2278.67	5001.83	4438.07	2301.24	***3293.19***
P07	6881.16	3844.04	1685.14	5412.32	2273.53	4110.80	***4034.50***
P11	3254.44	4365.56	4338.18	5394.00	4670.37	4965.41	***4497.99***
P16	3294.76	6338.18	1835.44	2770.19	3868.21	3774.09	***3646.81***
Minimum	2991.94	1522.30	1685.14	2256.96	2273.53	2185.73	***2372.82***
Maximum	7170.26	9967.37	4338.18	23323.78	6354.44	7610.25	***8342.92***
Mean	4419.93	4308.02	2864.56	6335.37	4074.70	3881.60	
Standard Dev.	1742.16	2710.82	1218.12	6981.03	1233.39	1798.00	

Mouse Movement – Standard Screen - Block 2							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P02	5524.16	6458.19	1329.29	3421.04	5488.13	5276.73	***4582.92***
P03	3010.87	1978.67	2289.72	6223.72	9374.78	2093.80	***4161.93***
P04	2133.21	1663.47	1344.49	1894.03	3282.86	1931.13	***2041.53***
P05	1939.03	1260.13	1096.68	2460.67	1582.53	1966.80	***1717.64***
P06	2886.05	1472.72	2008.95	3439.97	2644.48	2050.55	***2417.12***
P07	3293.38	2166.61	1745.08	2905.88	3988.75	1924.78	***2670.75***
P11	5125.50	2079.31	1559.26	4806.27	1657.27	5976.08	***3533.95***
P16	2734.01	2147.38	821.94	2537.64	1011.14	2189.67	***1906.96***
Minimum	1939.03	1260.13	821.94	1894.03	1011.14	1924.78	***1717.64***
Maximum	5524.16	6458.19	2289.72	6223.72	9374.78	5976.08	***4582.92***
Mean	3330.78	2403.31	1524.43	3461.15	3628.74	2926.19	
Standard Dev.	1312.62	1672.00	480.66	1417.30	2741.68	1679.39	

Mouse Movement – Standard Screen - Block 3							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P02	4573.02	3438.67	1583.67	4771.71	3696.02	2213.69	***3379.46***
P03	2460.86	4600.76	1347.22	2516.58	8297.56	4098.30	***3886.88***
P04	2230.89	1203.42	1290.69	2110.70	2881.78	1935.37	***1942.14***
P05	2953.32	1558.74	792.76	2495.05	2634.57	1884.76	***2053.20***
P06	3238.50	1942.58	2903.47	2459.85	2896.23	3267.71	***2784.72***
P07	5260.16	2138.00	1318.28	2923.45	3159.00	2685.00	***2913.98***
P11	3009.94	3987.73	1355.60	5253.06	5720.92	5260.02	***4097.88***
P16	1954.12	1711.74	700.42	2417.17	2229.79	2322.22	***1889.24***
Minimum	1954.12	1203.42	700.42	2110.70	2229.79	1884.76	***1889.24***
Maximum	5260.16	4600.76	2903.47	5253.06	8297.56	5260.02	***4097.88***
Mean	3210.10	2572.71	1411.51	3118.45	3939.48	2958.38	
Standard Dev.	1076.15	1177.69	629.94	1119.14	1925.74	1113.88	

Reading Screen Task Times

First Block of Trials

Table 10. Trial Block 1 – Reading Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P01	3.92	7.31	17.51	4.98	3.52	3.33	***6.76***
P08	8.99	52.78	9.38	15.54	9.66	10.98	***17.89***
P09	5.56	3.72	42.45	27.31	17.13	3.96	***16.69***
P10	9.37	8.99	10.58	7.58	10.20	5.79	***8.75***
P12	14.58	79.57	13.35	6.15	9.98	4.76	***21.40***
P13	10.87	13.60	7.77	11.35	5.91	11.71	***10.20***
P14	7.32	4.58	3.72	11.78	10.57	4.73	***7.12***
P15	4.12	6.59	13.33	14.19	4.19	3.71	***7.69***
Minimum	3.92	3.72	3.72	4.98	3.52	3.33	***6.76***
Maximum	14.58	79.57	42.45	27.31	17.13	11.71	***21.40***
Mean	**8.09**	**22.14**	**14.76**	**12.36**	**8.90**	**6.12**	
Standard Dev.	3.63	28.26	11.93	7.11	4.38	3.32	

Second Block of Trials

Table 11. Trial Block 2 – Reading Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P01	4.66	6.19	3.39	3.78	2.72	2.05	***3.80***
P08	6.26	22.04	3.99	3.59	2.98	2.04	***6.82***
P09	9.39	3.85	21.98	3.77	6.19	3.18	***8.06***
P10	13.83	2.91	5.69	11.37	4.38	4.51	***7.12***
P12	10.54	10.05	3.51	12.45	12.10	4.38	***8.84***
P13	4.78	6.04	3.65	4.44	13.59	6.38	***6.48***
P14	12.37	6.97	4.60	4.38	9.19	2.52	***6.67***
P15	3.00	2.80	2.72	2.53	2.20	1.79	***2.51***
Minimum	3.00	2.80	2.72	2.53	2.20	1.79	***2.51***
Maximum	13.83	22.04	21.98	12.45	13.59	6.38	***8.84***
Mean	**8.10**	**7.61**	**6.19**	**5.79**	**6.67**	**3.36**	
Standard Dev.	3.98	6.31	6.44	3.83	4.45	1.61	

Third Block of Trials

Table 12. Trial Block 2 – Reading Screen Task Times

Time on Task *(Seconds)*	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	***Participant's Average*** *(Seconds)*
P01	3.80	3.05	2.19	2.19	3.12	1.86	***2.70***
P08	2.99	2.80	2.00	2.57	3.79	3.19	***2.89***
P09	5.11	2.88	11.00	2.99	3.39	3.17	***4.76***
P10	5.39	2.53	2.19	3.39	3.39	5.39	***3.71***
P12	3.79	4.20	3.94	4.52	6.98	2.58	***4.34***
P13	4.98	3.72	2.73	3.59	8.17	3.39	***4.43***
P14	5.51	2.99	3.57	3.93	7.59	3.30	***4.48***
P15	2.18	1.73	1.73	1.79	2.12	1.60	***1.86***
Minimum	2.18	1.73	1.73	1.79	2.12	1.60	***1.86***
Maximum	5.51	4.20	11.00	4.52	8.17	5.39	***4.76***
Mean	**4.22**	**2.99**	**3.67**	**3.12**	**4.82**	**3.06**	
Standard Dev.	1.22	0.74	3.06	0.92	2.36	1.16	

Mouse Travel Distances – Reading Screen

Table 13. Mouse Movement Tables - Reading Screen

Mouse Movement – Reading Screen - Block 1							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P01	2724.77	1681.60	3277.98	2711.18	2710.00	941.17	***2341.12***
P08	4107.11	17061.97	2947.79	4983.70	3670.80	5273.49	***6340.81***
P09	3987.68	1571.22	2196.12	1679.63	7305.94	1252.46	***2998.84***
P10	2766.99	2241.75	2892.56	2689.54	2024.47	1272.17	***2314.58***
P12	2647.96	7402.53	3092.80	1853.11	2865.98	775.09	***3106.25***
P13	2001.56	5170.60	1665.05	3999.80	3118.37	6756.78	***3785.36***
P14	2603.14	1469.91	1454.97	2861.89	3749.11	2907.86	***2507.81***
P15	3248.52	1747.29	3891.35	2030.89	2455.11	1741.23	***2519.07***
Minimum	2001.56	1469.91	1454.97	1679.63	2024.47	775.09	***2314.58***
Maximum	4107.11	17061.97	3891.35	4983.70	7305.94	6756.78	***6340.81***
Mean	3010.97	4793.36	2677.33	2851.22	3487.47	2615.03	
Standard Dev.	724.11	5403.29	834.71	1131.02	1648.20	2233.44	

Mouse Movement – Reading Screen - Block 2							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P01	2971.04	3467.01	1756.20	2181.02	2261.92	767.12	***2234.05***
P08	3583.44	6344.65	1634.11	2416.29	2154.98	920.67	***2842.36***
P09	2322.62	1440.29	1491.34	2539.77	2099.55	826.88	***1786.74***
P10	2654.59	1073.06	1290.28	2179.22	2492.03	1319.12	***1834.72***
P12	2078.81	1280.28	1373.18	3273.64	3417.25	976.42	***2066.60***
P13	2006.12	1771.35	1353.56	2979.37	5012.48	2841.29	***2660.70***
P14	3884.55	1943.11	2218.21	2027.10	3871.31	1354.02	***2549.72***
P15	2294.47	1152.33	1903.76	1905.89	2167.82	763.81	***1698.01***
Minimum	2006.12	1073.06	1290.28	1905.89	2099.55	763.81	***1698.01***
Maximum	3884.55	6344.65	2218.21	3273.64	5012.48	2841.29	***2842.36***
Mean	2724.45	2309.01	1627.58	2437.79	2934.67	1221.16	
Standard Dev.	699.86	1801.94	319.34	476.17	1067.00	694.16	

Mouse Movement – Reading Screen - Block 3							
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Participant's Avg**
Mouse Movement (Pixels)							
P01	2694.37	1562.35	2041.68	1958.32	3094.12	942.71	**2048.93**
P08	2235.91	1043.23	1214.21	1895.69	3088.26	793.86	**1711.86**
P09	2293.44	984.04	1535.33	1763.34	2729.13	1057.21	**1727.08**
P10	2695.21	1012.41	1119.80	1599.52	2378.01	1810.70	**1769.28**
P12	2983.17	951.79	1314.33	1755.31	2717.68	708.48	**1738.46**
P13	1929.20	1067.82	1255.30	1670.95	4852.46	1807.71	**2097.24**
P14	2645.79	1487.27	1367.61	2433.00	3516.91	1104.63	**2092.54**
P15	2170.85	969.90	1363.12	1736.66	2202.25	839.44	**1547.04**
Minimum	1929.20	951.79	1119.80	1599.52	2202.25	708.48	***1547.04***
Maximum	2983.17	1562.35	2041.68	2433.00	4852.46	1810.70	***2097.24***
Mean	2455.99	1134.85	1401.42	1851.60	3072.35	1133.09	
Standard Dev.	350.85	244.45	286.30	261.26	832.37	437.31	

Scrolling vs Non-Scrolling Tasks

Standard Screen Task Times

Table 14. Standard Screen Task Times – Scrolling vs Non-Scrolling

Standard Screen - Block 2								
Time on Task (Seconds)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P02	6.84	3.25	3.97	***4.69***	32.39	10.99	6.76	***16.71***
P03	3.12	4.31	3.20	***3.54***	3.11	5.80	11.78	***6.90***
P04	2.59	3.19	3.39	***3.06***	4.79	4.79	8.58	***6.05***
P05	4.56	5.59	4.98	***5.04***	4.19	7.74	8.24	***6.72***
P06	7.18	4.39	4.38	***5.32***	3.25	10.37	7.19	***6.94***
P07	3.32	13.17	11.79	***9.43***	10.18	11.18	8.60	***9.99***
P11	26.31	15.26	23.68	***21.75***	28.79	22.30	28.16	***26.42***
P16	4.11	2.85	4.56	***3.84***	5.71	4.79	2.77	***4.42***
			Median	***4.87***			***Median***	***6.92***
			25%	***3.77***			***25%***	***6.56***
			75%	***6.34***			***75%***	***11.67***
			Min	***3.06***			***Min***	***4.42***
			Max	***21.75***			***Max***	***26.42***

Standard Screen - Block 3								
Time on Task (Seconds)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P02	5.57	4.57	4.19	***4.78***	5.97	8.19	9.11	***7.76***
P03	2.39	3.56	5.17	***3.71***	7.58	3.79	7.32	***6.23***
P04	2.39	2.37	3.09	***2.62***	4.06	13.16	4.43	***7.22***
P05	7.17	2.78	3.79	***4.58***	6.77	6.36	4.37	***5.83***
P06	8.90	3.17	6.16	***6.08***	5.17	4.95	3.76	***4.63***
P07	6.48	5.05	6.95	***6.16***	14.39	14.32	11.05	***13.25***
P11	13.69	10.59	46.30	***23.53***	64.30	69.14	44.95	***59.46***
P16	2.99	2.19	3.17	***2.78***	2.98	3.28	8.17	***4.81***
			Median	***4.68***			***Median***	***6.72***
			25%	***3.48***			***25%***	***5.58***
			75%	***6.10***			***75%***	***9.13***
			Min	***2.62***			***Min***	***4.63***
			Max	***23.53***			***Max***	***59.46***

Reading Screen Task Times

Table 15. Reading Screen Task Times – Scrolling vs Non-Scrolling

Reading Screen - Block 2								
Time on Task (Seconds)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P01	4.66	3.39	2.05	***3.37***	6.19	3.78	2.72	***4.23***
P08	6.26	3.99	2.04	***4.10***	22.04	3.59	2.98	***9.54***
P09	9.39	21.98	3.18	***11.52***	3.85	3.77	6.19	***4.60***
P10	13.83	5.69	4.51	***8.01***	2.91	11.37	4.38	***6.22***
P12	10.54	3.51	4.38	***6.14***	10.05	12.45	12.10	***11.53***
P13	4.78	3.65	6.38	***4.94***	6.04	4.44	13.59	***8.02***
P14	12.37	4.60	2.52	***6.50***	6.97	4.38	9.19	***6.85***
P15	3.00	2.72	1.79	***2.50***	2.80	2.53	2.20	***2.51***
			Median	***5.54***			***Median***	***6.53***
			25%	***3.91***			***25%***	***4.51***
			75%	***6.88***			***75%***	***8.40***
			Min	***2.50***			***Min***	***2.51***
			Max	***11.52***			***Max***	***11.53***

Reading Screen - Block 3								
Time on Task (Seconds)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P01	3.80	2.19	1.86	***2.62***	3.05	2.19	3.12	***2.79***
P08	2.99	2.00	3.19	***2.73***	2.80	2.57	3.79	***3.05***
P09	5.11	11.00	3.17	***6.43***	2.88	2.99	3.39	***3.09***
P10	5.39	2.19	5.39	***4.32***	2.53	3.39	3.39	***3.10***
P12	3.79	3.94	2.58	***3.44***	4.20	4.52	6.98	***5.23***
P13	4.98	2.73	3.39	***3.70***	3.72	3.59	8.17	***5.16***
P14	5.51	3.57	3.30	***4.13***	2.99	3.93	7.59	***4.84***
P15	2.18	1.73	1.60	***1.84***	1.73	1.79	2.12	***1.88***
		Median		***3.57***		***Median***		***3.10***
		25%		***2.70***		***25%***		***2.99***
		75%		***4.18***		***75%***		***4.92***
		Min		***1.84***		***Min***		***1.88***
		Max		***6.43***		***Max***		***5.23***

Mouse Travel - Scrolling vs Non-Scrolling

Table 16. Standard Screen Mouse Distances – Scrolling vs Non-Scrolling

Standard Screen - Block 2								
Mouse Movement (Pixels)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P02	5524.16	1329.29	5276.73	***4043.39***	6458.19	3421.04	5488.13	***5122.45***
P03	3010.87	2289.72	2093.80	***2464.80***	1978.67	6223.72	9374.78	***5859.06***
P04	2133.21	1344.49	1931.13	***1802.94***	1663.47	1894.03	3282.86	***2280.12***
P05	1939.03	1096.68	1966.80	***1667.50***	1260.13	2460.67	1582.53	***1767.78***
P06	2886.05	2008.95	2050.55	***2315.18***	1472.72	3439.97	2644.48	***2519.06***
P07	3293.38	1745.08	1924.78	***2321.08***	2166.61	2905.88	3988.75	***3020.41***
P11	5125.50	1559.26	5976.08	***4220.28***	2079.31	4806.27	1657.27	***2847.62***
P16	2734.01	821.94	2189.67	***1915.21***	2147.38	2537.64	1011.14	***1898.72***
		Median		***2318.13***		***Median***		***2683.34***
		25%		***1887.14***		***25%***		***2184.77***
		75%		***2859.45***		***75%***		***3545.92***
		Min		***1667.50***		***Min***		***1767.78***
		Max		***4220.28***		***Max***		***5859.06***

Standard Screen - Block 3								
Mouse Movement (Pixels)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P02	4573.02	1583.67	2213.69	***2790.13***	3438.67	4771.71	3696.02	***3968.80***
P03	2460.86	1347.22	4098.30	***2635.46***	4600.76	2516.58	8297.56	***5138.30***
P04	2230.89	1290.69	1935.37	***1818.98***	1203.42	2110.70	2881.78	***2065.30***
P05	2953.32	792.76	1884.76	***1876.95***	1558.74	2495.05	2634.57	***2229.45***
P06	3238.50	2903.47	3267.71	***3136.56***	1942.58	2459.85	2896.23	***2432.89***
P07	5260.16	1318.28	2685.00	***3087.81***	2138.00	2923.45	3159.00	***2740.15***
P11	3009.94	1355.60	5260.02	***3208.52***	3987.73	5253.06	5720.92	***4987.24***
P16	1954.12	700.42	2322.22	***1658.92***	1711.74	2417.17	2229.79	***2119.57***
		Median		***2712.79***		***Median***		***2586.52***
		25%		***1862.46***		***25%***		***2201.98***
		75%		***3100.00***		***75%***		***4223.41***
		Min		***1658.92***		***Min***		***2065.30***
		Max		***3208.52***		***Max***		***5138.30***

Table 17. Reading Screen Mouse Distances – Scrolling vs Non-Scrolling

Reading Screen - Block 2								
Mouse Movement (Pixels)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P01	2971.04	1756.20	767.12	***1831.45***	3467.01	2181.02	2261.92	***2636.65***
P08	3583.44	1634.11	920.67	***2046.07***	6344.65	2416.29	2154.98	***3638.64***
P09	2322.62	1491.34	826.88	***1546.95***	1440.29	2539.77	2099.55	***2026.54***
P10	2654.59	1290.28	1319.12	***1754.66***	1073.06	2179.22	2492.03	***1914.77***
P12	2078.81	1373.18	976.42	***1476.14***	1280.28	3273.64	3417.25	***2657.06***
P13	2006.12	1353.56	2841.29	***2066.99***	1771.35	2979.37	5012.48	***3254.40***
P14	3884.55	2218.21	1354.02	***2485.59***	1943.11	2027.10	3871.31	***2613.84***
P15	2294.47	1903.76	763.81	***1654.01***	1152.33	1905.89	2167.82	***1742.01***
		Median		***1793.06***		***Median***		***2625.25***
		25%		***1627.25***		***25%***		***1998.60***
		75%		***2051.30***		***75%***		***2806.39***
		Min		***1476.14***		***Min***		***1742.01***
		Max		***2485.59***		***Max***		***3638.64***

Reading Screen - Block 3								
Mouse Movement (Pixels)	**Non-Scrolling Tasks**				**Scrolling Tasks**			
	Task 1	Task 3	Task 6	***Participant's Average***	Task 2	Task 4	Task 5	***Participant's Average***
P01	2694.37	2041.68	942.71	***1892.92***	1562.35	1958.32	3094.12	***2204.93***
P08	2235.91	1214.21	793.86	***1414.66***	1043.23	1895.69	3088.26	***2009.06***
P09	2293.44	1535.33	1057.21	***1628.66***	984.04	1763.34	2729.13	***1825.50***
P10	2695.21	1119.80	1810.70	***1875.24***	1012.41	1599.52	2378.01	***1663.31***
P12	2983.17	1314.33	708.48	***1668.66***	951.79	1755.31	2717.68	***1808.26***
P13	1929.20	1255.30	1807.71	***1664.07***	1067.82	1670.95	4852.46	***2530.41***
P14	2645.79	1367.61	1104.63	***1706.01***	1487.27	2433.00	3516.91	***2479.06***
P15	2170.85	1363.12	839.44	***1457.80***	969.90	1736.66	2202.25	***1636.27***
		Median		***1666.37***		***Median***		***1917.28***
		25%		***1585.95***		***25%***		***1772.02***
		75%		***1748.32***		***75%***		***2273.46***
		Min		***1414.66***		***Min***		***1636.27***
		Max		***1892.92***		***Max***		***2530.41***

Appendix H – GOMS-KLM Excerpts

Hybrid Screen
57.2 s
Task time

* Input mode of the hybrid screen is activated, and the user is using the mouse to perform six tasks.

*Task 1
Goal Fill text filed (Surname of the legal guardian)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type chastity
.Verify (1200 ms)

*Task 2
Goal Select from Radio button (Fingerprints collected previously)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Think (1200 ms) of the required data "Yes or No"
.Point (1100 ms) to target "Yes" radio button
.Click (200 ms) at the button to select "Yes"
.Think (1200 ms) of the required data "Date of collection"
.Date-picker "Selecting the date"
.Verify (1200 ms)

*Task 3
Goal Select from a Drop-Down list (Nationality at birth)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Think (1200 ms) of the required data
.Pull-Down_List

*Task 4
Goal Select multiple items from List Box (Means of support)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Mental (1200 ms) recall the applicable answer for this applicant "Cash"
.Point (1100 ms) at the option "Cash"
.Click (200 ms) to select (Cash)
.Mental (1200 ms) recall the applicable answer for this applicant "Credit card"
.Point (1100 ms) at the option "Credit card"
.Click (200 ms) to select (Credit card)
.Verify (1200 ms)

*Task 5
Goal Fill text filed (Email)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type stark.chloe
.Keystroke Shift
.Type @
.Type yahoo.com
.Verify (1200 ms)

*Task 6
Goal Fill text filed (Duration of intended stay)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to show input panel
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type 12
.Verify (1200 ms)

Standard Screen
64.5 s
Task time

* The user is using the mouse to perform the six tasks measured during the experiment.
* Scrolling operator (3960 ms from Sauro,2009).
*Assuming that the user is expert with performing these tasks and the scrolling is very precise where it can show the required filed without hiding other parts of the screen that may contain necessary fields in the next task, therefore, the scrolling number is kept to the minimum.

***Task 1**
Goal Fill text filed (Surname of the legal guardian)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to apply focus
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type chastity
.Verify (1200 ms)

***Task 2**
Goal Select from Radio button (Fingerprints collected previously)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Scrolling (3960 ms) down to make the field visible
.Point (1100 ms) at the location of the field
.Think (1200 ms) of the required data "Yes or No"
.Point (1100 ms) to target "Yes" radio button
.Click (200 ms) at the button to select "Yes"
.Think (1200 ms) of the required data "Date of collection"
.Date-picker "Selecting the date"
.Verify (1200 ms)

***Task 3**
Goal Select from a Drop-Down list (Nationality at birth)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Think (1200 ms) of the required data
.Pull-Down_List

***Task 4**
Goal Select multiple items from List Box (Means of support)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Scrolling (3960 ms) down to make the field visible
.Point (1100 ms) at the location of the field
.Mental (1200 ms) recall the applicable answer for this applicant "Cash"
.Point (1100 ms) at the option "Cash"
.Click (200 ms) to select (Cash)
.Mental (1200 ms) recall the applicable answer for this applicant "Credit card"
.Point (1100 ms) at the option "Credit card"
.Click (200 ms) to select (Credit card)
.Verify (1200 ms)

***Task 5**
* This task doesn't require scrolling since the targeted field is visible from the scrolling made during the previous task.
Goal Fill text filed (Email)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to apply focus
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type stark.chloe
.Keystroke Shift
.Type @
.Type yahoo.com
.Verify (1200 ms)

***Task 6**
Goal Fill text filed (Duration of intended stay)
.Mental (1200 ms) Initiating the task
.Hands (400 ms) on the mouse
.Point (1100 ms) at the location of the field
.Click (200 ms) at the field to apply focus
.Think (1200 ms) of the required data
.Hands (400 ms) to keyboard
.Type 12
.Verify (1200 ms)