Research paper on evaluation of eye-tracking-based solutions as an instrument for communication

Nayan Adhikari[1], Supervisors?[1], and
Other authors?[2]

[1] Department of Computer Science, OsloMet Oslo Metropolitan University,
[2] Department of Art, Design and Technology, OsloMet
Oslo Metropolitan University,
P.O. Box 4 St. Olavs plass, N-0130 Oslo, Norway

Abstract. This paper evaluates existing Eye-Gaze Tracking Technology (EGTT) based Augmentative and Alternative Communication (AAC) software, focusing on user interface design and user interaction, to find good and challenging features in the interface. Based on the assessment, we carried out the development of an evolutionary user interface prototype for symbol-based AAC. We performed usability testing of the interface and evolved the interface design based on the users' feedback. The testing of the interface spanned usability of different communication features in the application to understand better interface design and easier communication process. We executed the testing with fourteen participants in two iterations of testing. A better interface design houses a clear navigation system, consistency in the layout for better predictability, ambient visual information like border colour, and harmony between label and icon for better perception. Additionally, we can reduce the number of interactions in the interface to complete a task for a better user experience. This paper can be an inspiration for future research that can be done by addressing some issues like testing the interface with targeted users and validating the interface in different languages. Furthermore, developing an interface with a programming language to make the interaction more dynamic, and testing the interface using an eye-tracker, will give better insight on usability of the interface.

Keywords: eye tracker · augmented communication · accessibility · social inclusion · education.

1 Introduction and background

A segment of the world population is living with some form of speech disability accompanied by motion dysfunction. Since the verbal mode of communication is the most preferred and convenient mode of communication, it is difficult for individuals living with such inabilities to perform bidirectional communication effectively. With motion disfunction, it is even more difficult for these individuals to live an independent life for their daily schedules are planned and assisted by caretakers. With the barrier in the bidirectional communication due to speech disorder as well as physical inability, the life of individuals living with speech and motion impairment suffer from diminishing quality of life.

With augmentative and alternative communication (AAC) technique (strategy or way of doing) and technology (implementation of technique using scientific principles), individuals living with speech disability and motion dysfunction can supplement their communication strategy. AAC strategies categorised into unaided, that leverages the use of gestures, facial expression and eye-gaze; and aided, that make use of pictures, pictographs, words, letters and sophisticated devices to enhance existing ability or use alternative means of communication instead of using a verbal or handwritten mode of communication. These aided AAC technologies are further categorised into non-electronic eye gaze tracking system, that uses no sophisticated electronic components like E-tran (Swift, 2012), a low-tech text based communication board made of transparent plastic, and electronic eye gaze tracking system, that uses different electronic components and software accompanied to them making sophisticated as well as more feature-rich, like I-series from Tobii, which communication device that leverages gaze control, [3], and EyeGaze Edge , another gaze enabled communication device, [4].

Electronic eye-gaze tracking technology for communication is a computer system preferably a portable tablet personal computer that leverages the use of eye gesture for pointing in the screen instead of using a mouse or hand. It makes use of the camera component to track eye movement and software drive the camera to estimate the eye gaze location in the computer screen. In the computer system, interactive computer software as AAC is used to convert the eye-gaze gesture into communication. These softwares follow different design principles and strategies (Constable, Bach, Frishman, Jeffrey, & Robson, 2017; Kumar & Krol, 1992) to convert the eye gaze gesture into communicable statements. AAC softwares like Communicator 5[5] (Gosmanova et al., 2017), Text Talker[6] and Gazetalk (Bates, Donegan, Istance, Hansen, & Räihä, 2007) uses alphanumeric virtual keyboard and Unidad[7], LAMP word for life[8] (Van Donsel, 2017), and Snap Core First[9] uses symbol keyboards.

Availability of such devices and softwares provides better chances to the individual living with motor and verbal impairment to communicate with other people, hence the quality of life of the individuals living with the mentioned condition may improve. The potential improvement in the user interface and accessibility of the softwares that particularly uses symbols and pictograms to perform communication can further enhance the experience of the user to use and make communication.

In this paper, we will discuss the user interface design of existing symbol-based AAC software with the aim of identifying the elements in the screen that are more easier to understand and operate as well as difficult. Moreover, for a systematic

[3] https://www.tobiidynavox.com/products/i-series/
[4] https://eyegaze.com/products/eyegaze-edge/
[5] https://www.tobiidynavox.com/software/windows-software/communicator-5-gold-english-us/
[6] https://thinksmartbox.com/product/text-talker/
[7] https://www.prentrom.com/prc_advantage/unidad-espanol-language-system
[8] https://www.prentrom.com/prc_advantage/lamp-words-for-life-language-system
[9] https://www.tobiidynavox.com/software/windows-software/snap-for-windows/

survey on possible notches for further development we discuss better user interfaces and way to make the process in the interface more efficient. In section 2, we will start with understanding criteria for evaluating the existing symbol-based AAC solutions, and describe their interface and process design for communication, analyse the interface and process design in term of usability and universal design principles, find the areas of improvement. In section 3, we design a prototype addressing the problems. In section 4, test it with the users and finally in section 5 we come up with results.

2 Methods and tools

In this study, we design and present a prototype for Eye-Gaze Tracking Technology (EGTT) for AAC interface for easier and faster communication. In the design process, we follow the practice of designing prototype commonly followed by designers.

We start with understanding the present state of the art solutions available for EGTT based AAC, where we did a comprehensive literature survey.

Moving on, we evaluate the features, functions and constraints for a symbol-based AAC software. In this phase, we start with the evaluation criteria, based on which we tried to find problems in existing solutions. For faster and more accessible communication, we consider listed criteria for evaluating the existing solutions.

1. Literacy requirement.
2. Cross-Platform support.
3. Localisation and internalisation of application language as well as vocabulary in the communication application.
4. Speed in the use of communication application.
5. Evaluation of communication features application.
6. Cost factor.
7. Autonomy while using and configuring the application.

Afterwards, we identified the targeted user group who can benefit from this new design. Since we designed this interface for people who need AAC for communication and cannot use the existing solutions for various reasons. Reasons can range from diminishing vision accompanied with verbal and motion impairment. And children who need to develop an understanding of the language for communication, and to the people who may not have access to use commercial AAC software.

To make communication possible, AAC software ought to have some features accessible via the user interface. Since the AAC is conceptualised to used by people navigating with eyes, many user interface features must comply to meet the users' ability and demand. There is a list of requirements for an AAC that must meet the demand of user navigating the application with their eyes, namely (Bhaskar, Naidu, Babu, & Govindarajulu, 2011).

1. Comprehensibility, the interface should follow comprehensible steps to execute tasks—adequate information on the screen to understand and perform tasks in a meaningful order.

2. Clarity, clear and distinguishable information on the screen.
3. Configurable and control, The application should have features to customise so that it can meet the users' specific needs. Users can configure the application without the intervention of a caretaker.
4. Consistency and Predictability, an application should look and work in a similar way. With consistency, users require less learning of the ins and outs of the user interface less and can do more with fewer efforts. With consistency, the application becomes more predictable that result in fewer mistakes while using the interface.
5. Efficiency, reduce the number of interactions in the interface. Interactions must not be wasted.
6. Familiarity, user interface components should follow a natural pattern and imitate users behaviour. Also, the interface needs to employ multiple languages to use the application based on their need.
7. Flexibility, the application should employ more than one mode of interaction, more than one way to carry out the communication.

Following these requirements, we generated possible models for a minimum viable solution. This minimum viable solution contained all the necessary features for a communication application and customisation features accessible to the user using EGTT as an input medium. We designed the interface upholding the various user interface design concepts of universal design and usability principles for designing a better symbol-based AAC. These design principles and concepts helped us identifying the features and functions required and constraints that may limit our design for better communication.

For the usability testing, we recruited 14 participants and tested the interface design in two iterations. In the first iteration, we develop a low-fidelity interface, to check the usability of the communication process. In the second iteration, we design a high fidelity interface addressing the issues in the low fidelity design, and additionally we incorporate visually pleasing aesthetic and interaction animations. There was no preference on participants' background while choosing them. All the participants were students from Oslo Metropolitan University and the University of Oslo.

We performed the test using a MacBook Pro 13-inch laptop and a mouse, and we did not use any eye-tracking device in the usability testing. We used the InVision Studio, a free user interface prototyping tool, for designing the interface prototype. InVision Studio provides a rapid prototyping feature with interactive and animation features.

3 Development of a prototype

We intended the following functionality in this project.

1. Alarm
2. Talk
3. Conversation History in the Talk Application

4. Add Words in the Talk Application
5. Autonomy in Customisation of Application

The first functionality in our prototype was the "Ring Alarm" (figure 1), when user selects the button on the home screen it generates a ringing noise with a dialogue box to dismiss the alert to get attention of nearby caretaker. It is the fastest possible way of communicating with nearby people in an emergency. The button "Ring Alarm" is accompanied by an icon making it easy to understand.

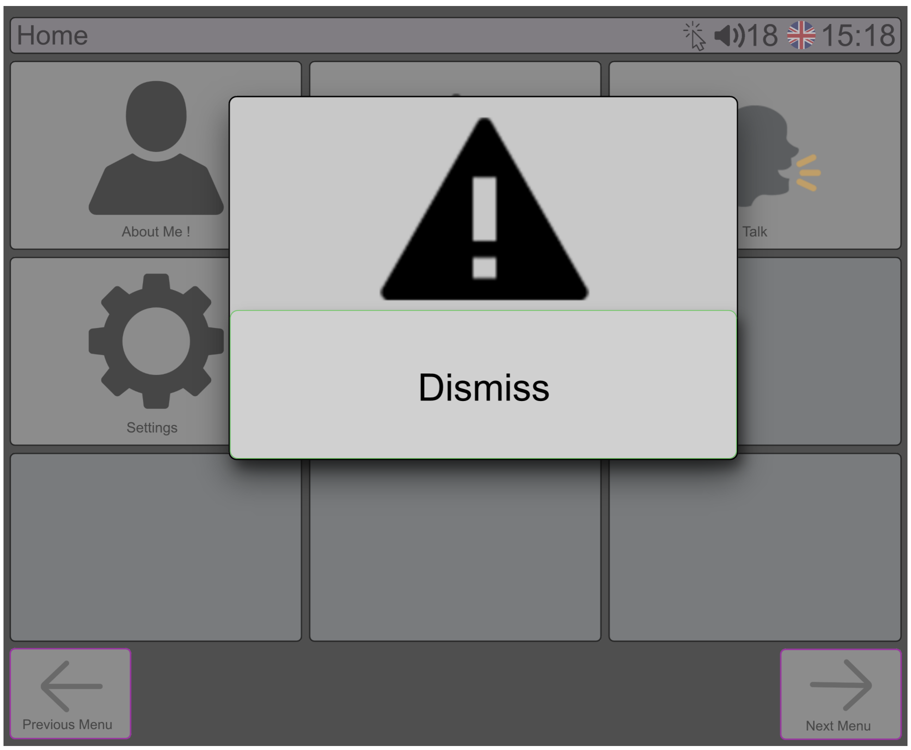

Fig. 1. Snapshot of the "Ring Alarm" dialogue in the home screen.

The second important functionality is the "Talk" application (see figure 2), user navigates using category buttons, finds appropriate words, and constructs statement for communication. Selected words get populated in a text area at the top centre of the interface. With this, the user perceives the information of currently selected words. If the user finds something wrong with the statement, they can edit the statement before speaking using the remove and clear buttons. For faster communication, a row of suggested words is available to select anytime at their convenience. With this, the user can complete a statement with relatively fewer interactions.

Another functionality addressed in the study is the conversation history as shown in figure 3. In the conversation history window, past conversation statements are

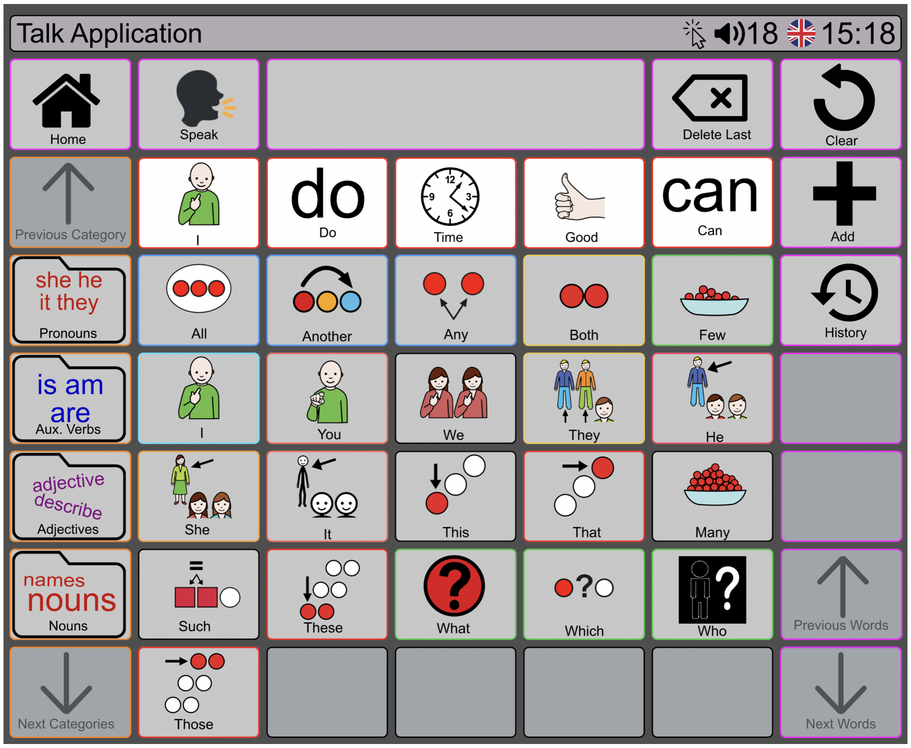

Fig. 2. Screenshot of the "Talk" application main window.

arranged by date in descending order with the current date as default. To find conversation from previous days, the user can select a date or day buttons in the left column of the application. In this window, the user chooses a statement and press speak button to send feedback or press edit and edit the statement before sending feedback if the user finds something wrong. This process reduces a considerable amount of interaction and can contribute to a faster communication process.

We also include a function that enable user to add new words to the system without the intervention of caretaker. The user selects the add word button located at the right column of the talk application interface. On interaction with the "Add" button from the talk application, the application prompts the user to add a word window where the user enters a label for a new word and selects an icon, vocabulary and category. Icon gives a meaningful pictorial representation of the label, vocabulary is where the word resides, and category helps to search for the word quickly.

The "Conversation History" and "Add Word" features evolved from the phrase library feature for the previous iteration of the prototype design. Segregating the phrase library feature to conversation history and add word resulted in faster communication and adding custom words to the system.

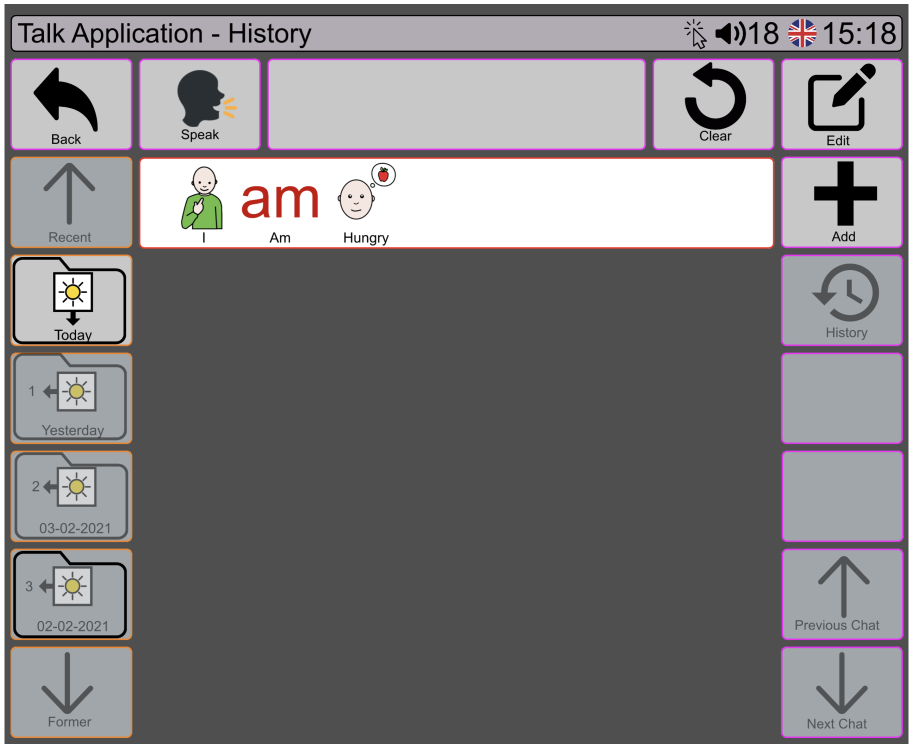

Fig. 3. Conversation History window inside the talk application.

The user customises the application using a different menu under settings. The user can access these settings with less interaction from the home screen because of the relatively flat menu hierarchy. Additionally, the consistency of layout and navigation buttons in the application makes it even more convenient for the user to navigate around.

Additionally, the user can find information on the current application configuration like sound, interaction mode, the application language, time and current window location from the title bar at the top of the application. With this, the user gets better insight into the application configuration from anywhere in the interface.

4 Testing, Evaluation and Limitations

Upon testing the interface design with 14 participants in two iterations, we got insights into interface design based on the participants' experience and behaviour. The following outputs were

1. Ambient information in the form of symbols and colours increases the meaning to the interface. The ambient information, including distinguishing button groups

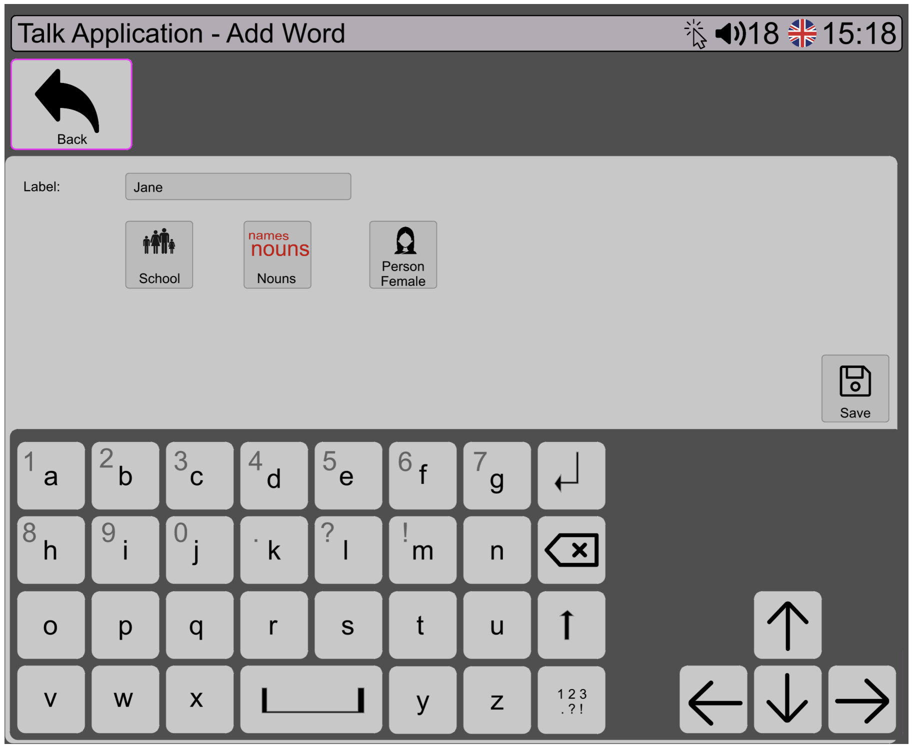

Fig. 4. Add Words

based on colour, border colour and using icons like folders for representing similar information, increased the clarity of the interface.

2. The application state information, title of the current window, time, language and volume, represented using text and symbols in the title bar, gave clear meaning. Similar symbols and test are common to other application making them more familiar to the participants. But the interaction mode symbol was less common to other applications making it hard to perceive.
3. Users tend to notice symbols and graphic representation of data rather than textual information more often. Information represented using icons and graphics tends to create ambiguity if the meaning of icons and text do not align.
4. Missing information like suffix in the volume level, symbols representing conflicting meaning for "Like" and "Love", and "Love" and "Health" icons create more confusion at first use.
5. We also noted some features could be distracting the users. For example, using sharp colours like red for the icons sometimes increase distraction. And there are higher chances of mistakes and confusion when using similar icons for different functions in the same interface. One participant was confused with a back arrow button used in the footer for pagination with the previous windows button in the navigation where we used a twisted back arrowhead. Similarly, the consistent

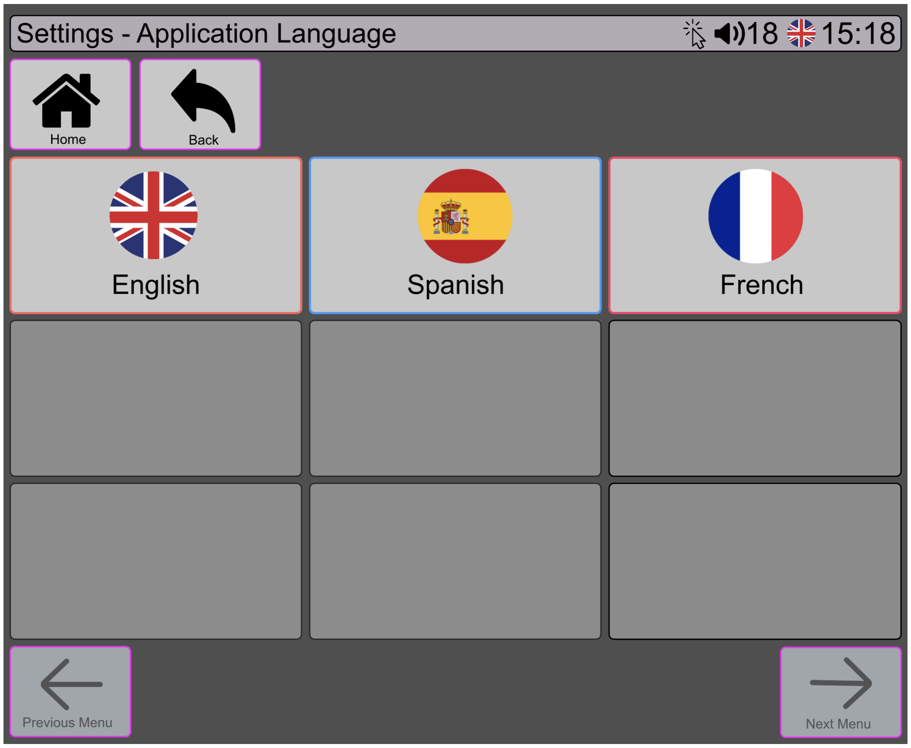

Fig. 5. Settings - Language

representation of interface components with different functions increase confusion. Non-interactive information and interactive buttons, if represented using the same layout, creates confusion.

The interface was revised also accordingly to these new feedback. A qualitative evaluation of final version includes the following remarks.

Tasks that take fewer interactions to complete are easier to understand with higher chances of success. A flat menu hierarchy decreases the number of interaction when executing a task. In the interface starting from the home screen, participants can reach anywhere in the application in less than three clicks. Additionally, the configurable application settings without the intervention of the caretaker added extra usability in the settings menu.

First, the use of consistent navigation and a predictable menu decrease mistakes while navigating to reach the destination window. But the participants repeatedly navigated from one setting menu to another using the home button rather than using a back button. The certainty of the menu sometimes results in relatively more interactions for performing the task.

Second, one participant searched the setting button in the talk application rather than starting from the home screen. For such cases, it is better to add redundant buttons in the applications where applicable.

Although the predictive next word suggestion feature has undoubtedly increased the number of interactions while constructing statements in the talk application, finding or predicting words was slower. Often participants were not sure of the location of words in the categories. For a symbol-based AAC software, usually, a language system plays determining role for a faster speed and better user experience.

5 Conclusions and Future Direction

The objective of this study was to design a better user interface for symbol-based AAC that provides an opportunity for effortless communication to the users. Based on the evidence from evolutionary prototyping and testing of the interface, we can see a relationship between interface design and speed and ease of communication.

Although the use of graphic raises clarity to the information given in the interface, using irrelevant, bright, and misleading images, create confusion. A notable diminished in the perception of the interface by the users can be noticed. Icons that do not reflect the meaning of labels, the use of icons with bright red colour, and a less familiar icon used for interaction mode in the title bar were cases where the users find it difficult to understand the meaning in the interface components. For the given case, the chance of misinterpretation is higher when users rely on the graphical representation of information.

Additionally, using similar icons to represent different information can be misinterpreted. In general, love and health are described using a heart icon; back and pagination left are defined using a different variant of the left arrowhead icon when used in different contexts, which leads to confusion. We this, we can observe occasional mistakes that needed to compensate using few interactions. An extra interaction is effort consuming and tedious for people using the interface using an eye tracker.

We tested the prototype with a group of students and were unable to recruit participants from targeted users for the usability testing because of the Covid-19 pandemic. We can perform the test on the targeted users for a more accurate outcome.

Consistency in the layout of the interface increase speed of interaction as it increases predictability. But speed is also influenced by other factors such as the number of interactions (Jiménez Iglesias, Aguilar, Sánchez, & Pérez-Montoro Gutiérrez, 2018) to complete a task. Thus, several factors are influencing the success of task completion, which may raise some issues with respect to limitations.

Additionally, the navigation in the interface is another reason for faster task execution. Applications, one way or other, have navigation implemented. But the critical questions lie in how the navigation is being implemented in the interface. The navigation buttons where users find it easy to locate, preferably at the left side of the interface, lead to a better navigation experience since participants found it hard to notice the buttons on the right side of the interface.

But before drawing any conclusion, we need more evidence to relate between the user perception of interface component and their location in the interface.

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