# Abstract

With highly developed information technology, people have become accustomed to using virtual keyboards to type and text in various situations. In many scenarios, people need to type with only one hand and use the other hand to do other things. Nonetheless, one-handed interaction with mobile devices is influenced by multiple factors, including variations in keyboard functionality. Notably, mobile device keyboards still lack comprehensive support for one-handed typing, potentially leading to accidental touch, missed touch and other behaviors that can hinder typing efficiency. Our goal is to better understand the user experience of typing with only one hand, and to explore ways to improve the effectiveness and efficiency of typing on mobile devices with one hand. In this article, we provide a detailed description of our study along with our initial design for one-handed typing. In the past weeks, we employed a detailed survey and conducted contextual inquiries to study the potential difficulties and motivation of one-handed typing on mobile devices and developed 6 user requirements. We then established a paper prototype that contains key features such as adjusted key width, improved autocorrect, and revised punctuation keyboard. In this assignment we evaluated our paper prototype via simplified user testings and heuristic evaluation, and evaluate the results against our user requirements. The results show that our design fails to reduce recognition load and might have visibility problems in system status. We will use these feedback to build the high-fidelity prototype in the future.

# Introduction

(The previous are the same as assignment 3)

After building our paper prototype, we moved to the interactive systems evaluation section. We firstly revised the wording of user requirements to improve its testability and objectivity. Then we separately conducted heuristic evaluation with usability experts to identify usability issues with respect to the 10 usability heuristics. Our results show that we still have usability problems mainly in visibility of system status, user control and freedom, and recognition load. We also conducted simplified user testing with stakeholders to test the features and usability of paper prototype against our user requirements. In this task we encouraged the participants to ‘think aloud’ while doing the tasks and we acted as observers to watch for errors and confusions. Our results show that the participants still make errors and get confused when completing several subtasks. In short, we evaluated our paper prototype using simplified user testing and heuristics evaluation to get valuable feedbacks to improve the existing prototype. The details are specified in section 7.

# Related Work

Isaac

# User Requirements

As a group, we first carefully revised each user requirement to improve its testability and objectivity, and then we selected four user requirements against which the qualitative evaluations tested our design. These requirements were selected based on whether they could be feasibly evaluated using qualitative methods and our low-fidelity paper prototype. These four user requirements are listed below.

**User Requirement 2**: User should not need to manually fix any mistakes produced by the system’s keyboard assistive features (e.g., autocorrect) when entering text on their mobile device with one hand (U05-09, U05-10, U05-11, U05-12, U05-13, U05-25, U05-27, U05-30).

**User Requirement 3**: User should be able to remove any text entered on their mobile device using one hand without accidentally removing any other characters or words the user did not intend (U05-25, U05-26, U05-27, U02-06, U04-17).

**User Requirement 4**: User should be able to navigate, communicate, and interact with different keyboard elements using one hand without introducing slips and without straining (overextending) their thumb (hand) or repositioning the mobile device (U04-02, U04-03, U04-05, U04-06, U04-12, U01-05, U01-07, U01-13, U02-02, U02-03, U02-08, U02-17, U02-20, U03-06, U03-08, U03-12, U04-06, U04-07, U04-09, U04-10, U04-11, U05-37).

**User Requirement 5**: User should be able to locate and enter emojis, punctuations, and numbers on the mobile device with one hand more efficiently (faster) than their default (i.e., current or existing) method of entry (U05-15, U05-16, U05-17, U05-37, U04-09, U04-18, U02-08, U03-06, U03-18, U03-19).

# Heuristic Evaluation

## **Purpose**

The purpose of the heuristic evaluation was to get some initial feedback on our design, specifically regarding its usability, from usability experts via our narrow-down, low-fidelity prototype. The feedback we received can be used later to iterate on the prototype and to address its salient usability issues.

## **Method**

First, as a group, we picked one realistic, overarching user goal from the context of use that could be feasibly achieved using our low-fidelity paper prototype: “Message a friend on a mobile device using just the right hand”. This goal was then broken down into subgoals or tasks which the users would perform to accomplish the overall goal. We attempted to make these subgoals/tasks cover all four user requirements we were going to test and (almost) all of the available features of our prototype. Thus, by performing these subgoals/tasks one by one, the user would inevitably explore all parts of the prototype, thus allowing us to later evaluate whether the user requirements were met as a group. The specific subgoals/tasks were discussed in the Tasks & Procedures sections. The same goal and subgoals were used for both heuristic evaluation and simplified user testing.

Next, each team member conducted a heuristic evaluation with a (different) usability expert, a student (not from our team) in EECS 593, to identify usability issues with our prototype and our design in general. During the heuristic evaluation, we demonstrated to the expert how we expect the user to interact with our prototype to accomplish the goal, and the expert rated the usability of the prototype and identified its issues with a list of usability heuristics (see more details in the Tasks & Procedures section).

After each team member concluded their individual heuristic evaluation, as a group, we consolidated the findings of the individual evaluations into one table, showing all usability problems identified and their relevant information including which expert identified the problem, the heuristic violated by the problem, and the severity of the problem. We also analyzed the table to determine which issues should be addressed immediately, so we can resolve them by iterating on the prototype in the future.

## **Tasks & Procedures**

To ensure the quality and consistency of our heuristic evaluations, each team member closely followed the protocol we created as a group, which was a bare-bones, bulleted outline regarding the overall user goal and corresponding subgoals/tasks that we planned to demonstrate using the paper prototype, and the process for conducting the heuristic evaluation. This section elaborated on the protocol, discussing it in detail while maintaining its core aspects, such that it accurately presented what each team member did to conduct the heuristic evaluation.

Each team member (referred to as *the investigator* in the remainder of this section) contacted their own usability expert via email to set up the date and time for a meeting (either online or in person).

After arriving at the meeting, the investigator and the usability expert first exchanged some information, including uniqname and group name. The investigator then briefly explained our focus and context of use (“one-handed text entry on mobile devices”) and the user goal we were going to demonstrate for this heuristic evaluation (“message a friend on a mobile device using just the right hand”). The expert was instructed to record any usability issues/problems they identified in the design/prototype with respect to the 10 usability heuristics, during the demo. The 10 usability heuristics that the expert used to evaluate the prototype are listed below.

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

For each usability issue identified, the expert also indicated to which heuristic the issue corresponds and rated the severity of the issue on a scale of 0 (*not a problem at all*) to 4 (*usability catastrophe*).

After the above information and instructions were clearly conveyed to the usability expert, the heuristic evaluation then began according to the instructions, with the investigator demonstrating the prototype on how the user would use it to achieve the goal, while the usability expert recorded down any usability problems they identified. Specifically, the investigator demonstrated the following subgoals/tasks one by one using the paper prototype:

1. Switch to one-handed keyboard and adjust keyboard width
2. Enter text “Cool, good”
3. Enter “luck”
4. The user realized that they accidentally made a typo, i.e., entered “lyck”, fix the typo
5. The user changed their mind and wanted to enter “kick” instead, replace “luck” with “kick”
6. Enter “!”
7. Enter 😂 emoji
8. Send the message

At any time during the demo, the expert was allowed to ask clarification questions about each subgoal/task, or the design/prototype. After the demonstration ended, the expert gave their notes, the usability problems with their corresponding information, to the investigator and briefly explained each problem. The investigator also had a chance to ask any clarification questions about the issues. The entire heuristic evaluation lasted about 30 minutes. Afterward, the investigator thanked the expert, and the meeting was concluded (Remark: Technically, the investigator and expert then switched roles because the other student had to demonstrate their prototype to us, but this was not important for our study, thus not being presented in the report).

## **Participants (Usability Experts)**

| Encoding | Usability Expert | Group |
| --- | --- | --- |
| E1 (Daniel) | esing | 18 |
| E2 (Franklin) | lkurek | 3 |
| E3 (Isaac) | tonytang | 20 |
| E4 (Jerry) | pinhan | 11 |
| E5 (Yichen) | zixiangz | 20 |

# Heuristic Evaluation Results

table

# Simplified User Testing

## **Purpose**

The purpose of the simplified user testing was to get some initial feedback on our design, specifically regarding both its usefulness and usability, from real stakeholders via our narrow-down, low-fidelity prototype. The feedback we received allows us to not only realize the usability issues regarding our prototype, but also to better understand the context of use and whether our design addresses the user requirements, so we can later iterate on the prototype to improve it.

## **Method**

The same user goal and the corresponding subgoals/tasks from heuristic evaluation were used for the simplified user testing (see more in the Tasks & Procedures section). To briefly reiterate, we collectively picked one user goal and broke it down into subgoals/tasks, which were realistic, concrete, and grounded in the context of use. By doing the tasks, the user would explore all parts of the prototype, giving us the information we need to evaluate our prototype against the user requirements.

Next, each team member conveniently recruited a participant from the stakeholder group for the simplified user testing according to the inclusion/exclusion criteria we defined as a group: The participant 1) must be at least 18 years old, 2) right-handed or primarily use their phone with the right hand, and 3) preferably uses an iPhone (Note: the last criterion is preferred but not required).

Each team member then individually conducted simplified user testing with their participant following the protocol we designed collectively as a group (see specific details/steps of the protocol in the Tasks & Procedures section). Participants used the prototype, with its functionality being wizard-of-oz by the team member, to do each subgoal/task which all taken together accomplish the user goal, while performing a think-aloud by constantly talking and verbalizing their thoughts as they move through the user interface. The think-aloud allows investigators to understand not only what the participants were doing, but also what they were thinking, which may reveal additional insights on the prototype’s issues, leading to a better evaluation of the prototype’s usability and usefulness.

Each team member took notes during (and after) their simplified user testing, regarding the interpretations of the participant’s actions and utterances during the think-aloud in relation to the prototype’s usability and usefulness. Then, as a group, we consolidated the notes to produce high-level findings demonstrating our design’s usability and whether it met the four user requirements we selected for the evaluation. With the analyses of the findings, we can improve our design by iterating on the prototype in the future.

## **Tasks & Procedures**

To ensure the quality and consistency of our simplified user testing, each team member closely followed the protocol we created as a group, which was a bare-bones, bulleted outline regarding the process for conducting the simplified user testing, and the overall user goal and the corresponding subgoals/tasks which the participants had to perform. This section elaborated on the protocol, discussing it in detail while maintaining its core aspects, such that it accurately presented what each team member did to conduct the simplified user testing.

Each team member (referred to as *the investigator* in the remainder of this section) contacted their own participant online, by sending a message inviting them to participate in a user testing study on a design prototype. The message roughly described what the study was about, using a prototype to perform some tasks while narrating their thoughts; estimated duration, 30 minutes; required qualifications (inclusion/exclusion criteria defined early); and that the study had to be recorded (if the investigator needed to). After obtaining the participant’s initial confirmation that they met the qualifications and were willing to do the testing, the participant and the investigator arranged an in-person meeting.

Upon arrival at the meeting and before starting the user testing, the participant was once again informed about the purpose of the study, to evaluate the design prototype’s usability and usefulness, and their responsibilities, to use the prototype to execute a series of short tasks, while performing think-aloud. They were assured that their participation was fully voluntary as they may quit the study at any time. They were also told that the study would be recorded for further analysis (if needed by the investigator) and the data collected from the study would be completely anonymous and confidential. The participant then gave their verbal consent to participate in the user testing had they agreed to all of the conditions mentioned, which they did.

Starting the user testing, the investigator first clearly conveyed and explained the following instructions to the participant. Their overall goal was to “message a friend on a mobile device using just the right hand” (the same goal as heuristic evaluation). They would be given one subgoal/task at a time, which they need to execute on the prototype using just their right hand; completing all of the tasks would result in accomplishing the goal. While using the prototype, they had to perform think-aloud, or in other words, constantly talking and verbalizing their thoughts as they moved through the user interface. A short video was played to the participant to show them an example of think-aloud, for them to better understand what is expected (Link to video: <https://www.nngroup.com/articles/thinking-aloud-demo-video/>).

After the participant indicated that they understood the instructions clearly, the investigator gave the participant (the first frame of) the paper prototype and their first task (while starting the recording if the investigator needed to).

The paper prototype (built and discussed in the previous stage of user-centered design) had 16 frames, each resembling the size of a regular-model iPhone printed on paper and placed on a portable hard surface (with the same/similar size as the frame) such that the participant may hold it with their right hand just like how they would normally hold their phone. As the participant correctly interacted with the prototype (e.g., pressed the expected key on the current frame), the investigator would switch the current frame with the next frame, successfully giving functionality to the paper prototype with wizard-of-oz (the order/flow of frames was presented in Section 6.5).

As the participant tried to execute the first task on the prototype with their right hand while doing think-aloud, the investigator also took notes on the participant’s errors, long stalls, confusion, unexpected paths, statements of distress, and unexpected events and use, indicated by both their actions and the utterances of their thoughts. If the investigator recorded the user testing session, they would also be able to watch the recording later to pick up the details they potentially missed the first time. The investigator also wrote down any questions that they wanted to ask the participant (e.g., Why did you do this action?); these questions were deferred until the end of the user testing (after all tasks were completed). The investigator did not interrupt the participant or ask any questions during the think-aloud because that may introduce extra cognitive load to the participant. Whenever the participant reduced in frequency of think-aloud, or in other words, they stopped talking but they continued to interact with the prototype, the investigator would prompt the participant to “please keep talking”.

After the participant completed the current task, or when the participant had spent a long time on the current task yet still could not figure out how to complete it, the investigator would give them the next task to do. This process continued until all of the tasks had been given to and completed by the participant. The subgoals/tasks that the participant executed on the prototype were the following (listed in the order they were given to the participant).

1. Switch to one-handed keyboard & adjust keyboard width
2. Enter text “Cool, good”
3. Enter “luck”
4. You realized that you accidentally made a typo (i.e., entered “lyck”), fix the typo
5. You changed your mind and wanted to enter “kick” instead, replace “luck” with “kick”
6. Enter “!”
7. Enter 😂 emoji
8. Send the message

After all tasks were given to and executed by the participant, the investigator asked some follow-up questions they had during the think-aloud to the participant. In total, the simplified user testing study lasted about 30 minutes. Once the study was concluded, the investigator thanked the participants for their time.

## **Participants**

| User encoding | Age | Gender | Race | Employment status | Dominant hand | Phone brand | Multi-lingual | Disability |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| U1  (Daniel) | 20 | Man | Asian | Student | Right | iPhone | Yes | No |
| U2  (Franklin) | 23 | Man |  | Student | Right | iPhone |  |  |
| U3  (Isaac) | 22 | Man | Asian | Student |  |  |  |  |
| U4  (Jerry) | 22 | Man | Asian | Employed part-time | Right | iPhone | Yes | No |
| U5  (Yichen) | 22 | Woman | Asian | Employed full-time |  |  | Yes | No |

# Simplified User Testing Results

asdf

# Discussion

asdf

# Conclusion

Our previous survey into one-handed text messaging on mobile devices provided foundational insights that set the stage for our subsequent research. Among the 27 participants, it was evident that one-handed typing is a prevalent method on smartphones. However, it came with its challenges: users found it less comfortable, more challenging, and slower than two-handed typing. This highlighted potential limitations in current smartphone keyboard designs and emphasized the practical importance of our research.

Building on this foundation, our detailed contextual inquiry further illuminated the differences of one-handed text messaging. We discovered that the existing keyboard layout often poses challenges, especially when users are multitasking. The challenges users face with current keyboard layouts, autocorrect features, and the act of switching between different keyboard modes have informed 6 specific user requirements. These requirements will be crucial in guiding the design of future mobile keyboards optimized for one-handed use.

Based on the specific requirements, we derived our initial design as the low-fidelity paper prototype. We also designed several design critiques and iteratively optimized our prototype. Our design mainly established and focused on the ‘sqush’ and ‘scroll’ method so users can comfortably reach all key elements with one hand. Our design also retains most of the traditional QWERTY keyboard layout, ensuring users face a minimum learning curve as well as solving main challenges in one-haned typing.

TBD

In conclusion, the knowledge generated from our initial survey, contextual inquiries, low-fidelity paper prototype, and interactive system evaluation serves as a robust foundation for future work. It not only provides insights and potential solutions into the current challenges users face but also guiding the high-fidelity prototype and product creation. We are optimistic that future researchers and designers will leverage these findings, leading to innovations that cater to the evolving needs of one-handed mobile device users.