# 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. In this study, 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 first employed and refined a survey about the people's experience of one-handed typing, as well as conducting a comprehensive analysis of the collected questionnaire data among 27 participants. In this assignment, we conducted contextual inquiries to study the potential difficulties and motivation of one-handed typing with 5 participants and record their behaviors as interpretation notes. Then we summarized and visualized the notes using different diagrams. Finally we extracted user requirements from the result of contextual inquiries. We believe our work not only aims to identify pain points of people using one-handed typing but also serves as a foundation for future user testing and heuristic evaluation research.

# Introduction

The history of one-handed typing is closely tied to the design of keyboard layouts. The QWERTY keyboard we are familiar with and the oldest was designed with one-handed typing in mind. In the QWERTY layout, more English words can be spelled using only the left hand than using only the right hand. Specifically, more than 3,000 English words can be typed with only the left hand, while only more than 300 words can be typed with only the right hand. The three most common letters in English, ’E’, ’T’, and ’A’, can all be typed with the left hand. [? ] While this is detrimental to right-handed people, it also lends credence to the effectiveness of one-handed typing. In 1936, Dvorak improved the QWERTY keyboard and created the Dvorak Keyboard (also called American Simplified Keyboard, or simply Simplified Keyboard), and Dvorak was specially designed for the efficiency of one-handed typing. [? ] In 1960, Dvorak designed separate left- and right-handed Dvorak layouts for one-handed typing. The two keyboards are generally mirror images of each other, except for some differences in some uncommon keys, which are suitable for left-handed people and right-handed people. In the design, he tried to minimize the need to move the hand from side to side (lateral movement), as well as reduce the movement of the fingers. In the past twenty years, there has been new development in the keyboard for one-handed typing. Edgar Matias et al [? ]invented the Mirrored Keyboard. The idea is to only use one hand (preferably the left one) and type the right-hand letters by holding a key which acts as a modifier key. The layout is mirrored, so the use of the muscle memory of the other hand is possible , which greatly reduces the amount of time needed to learn the layout, if the person previously used both hands to type. This represents people’s continuous pursuit of the combination of ergonomics and typing efficiency.

After entering the 21st century, the rapid development of informatization and the increasingly popular electronic products have enabled people to use virtual keyboards on mobile devices in more scenarios than traditional physical keyboards.[? ] As mobile devices are more integrated into people’s life scenes, people can not only sit at a computer desk and type on a heavy keyboard, but can also conveniently type in coffee shops, classrooms, or on the bus. In different situations, people often free up the other hand to do other things and use only one hand toconveniently complete the typing action. This makes the demand for one-handed typing greatly increased in today’s era. [? ]

People’s pursuit of one-handed typing efficiency piqued our interest and we set our promise as uncovering the challenges that arise with one-handed typing in order to enhance the user experience when typing with a single hand on mobile devices. After preliminary research, we discovered that besides the keyboard layout, other keyboard features like autocomplete, autocorrect, and key sizes, as well as the device’s operating system, can also affect user’s experience with one-handed text entry. To gain deeper insights into users’ experiences with one-handed operation, we meticulously devised a survey and spreaded out to the public. Our survey of the area indicated that many participants do have difficulties using one-handed typing and are not satisfied with current keyboard design (see Section 3). From the survey results, we were also able to narrow down a preliminary focus to be, “mobile text entry with the right hand preferably on an iPhone, specifically regarding fixing typos, switching between numbers/letters, and switching languages”.

At this stage, we aimed to further explore this focus and the context of use in order to ultimately identify the user requirements. However, we could not just directly ask the stakeholders what they need, since they may not be aware of what is possible with existing technology, nor do they know all aspects of different tasks required to accomplish their goals. Fortunately, contextual inquiry could help designers achieve this: It collects field data that can be used to gain a better understand the context of use by identifying different sequences of tasks users perform to

achieve their goal, the flow of information via different artifacts connecting different

stakeholders, and most importantly the potential breakdowns. Together, they inform designers about the user requirements. Thus, with the focus in mind, we conducted contextual inquiries to better understand the focus and identify the user requirements. We interviewed participants for an hour, documenting their actions and thoughts as interpretation notes. Using these notes, we separately drafted flow and sequence diagrams. We then summarized notes and diagrams from multiple team members, creating consolidated flow and sequence diagrams to better ground our understanding of user behaviors. We also created an affinity diagram to better categorize the interpretation results. From these visuals, we identified key user requirements and drew overarching conclusions. (see section 4)

# Related Work

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# Method

## Understanding Context of Use: Contextual Inquiry

The purpose of Assignment 2 was to come up with user requirements based on a better understanding of the context of use, specifically in identifying the tasks performed by the stakeholders and the potential breakdowns within them.

## Method

\instructions{What did the method entail?}

To achieve the purpose of the study, a contextual inquiry (contextual interview), an excellent method for collecting qualitative field data, was first conducted by each team member (more detail in Tasks and Procedures section). The main benefit of this method was that the interviews took place in the context of use. This allowed not only the interviewee (i.e., participant or user) to better recall the memories of their interaction with the technology but also the interviewer to better understand the environment in which the interaction took place, thus successfully collecting field data grounded in real user experiences, instead of laboratory data that may not apply to real-life settings.

After the contextual inquiry was completed, each team member individually interpreted and analyzed their results by extracting different information from the interpretation notes taken during their interview to create sequence diagrams and a flow diagram. A total of seven sequence diagrams and five flow diagrams were created. Each sequence diagram documented the sequence of steps which a participant took to accomplish a goal, allowing us to inspect the intentions behind what each participant did and the potential breakdowns in specific steps. On the other hand, each flow diagram revealed the flow of information and artifacts between different stakeholders mentioned by a participant, and different technologies used by a participant to complete their tasks.

The seven individual sequence diagrams were then consolidated into one consolidated sequence diagram by considering different participants as just one single user identity and merging (taking the union of) the diagrams in which the user did similar sequences of tasks or had similar goals (see Appendix ?). The five individual flow diagrams were also consolidated into one consolidated flow diagram using a similar strategy (see Appendix ?). Lastly, all of the interpretation notes from the five contextual inquiries were consolidated into an affinity diagram, revealing the categories and themes that emerged from the interpretations.

All together, the consolidated sequence diagrams, consolidated flow diagram, and affinity diagram illustrated the big picture, giving us a deeper, more complete understanding of the context of use of one-handed text entry on mobile devices. Consequently, the user requirements were created based on the findings and potential breakdowns we identified from these diagrams and interpretation notes.

## Tasks and Procedures

\instructions{How was consent for participation sought and administered? What did the task entail? Were participants given any prior instructions? What were they? How long did the task take on an average? How did you go about ensuring quality control of tasks?}

To ensure the quality and consistency of the contextual inquiry conducted by different team members, we first created a protocol together as a group, specifying the interview’s focus, duration, and initial questions, the inclusion/exclusion criteria for the participants, the information and tasks given to the participants, and the process of obtaining informed consent. As such, the core aspects of the contextual inquiry remained the same between different team members. We then split up to conduct the contextual inquiry individually, each with one participant. The following paragraphs describe the tasks and procedures we used for all participants, in general.

The participant first received a message from the investigator online, inviting them to participate in an interview; the message contained the interview’s focus, one-handed mobile text entry, estimated duration, one hour, and that it had to be audio-recorded and take place at the context of use. After obtaining the participant’s initial confirmation that they had prior experience with one-handed mobile text entry and were willing to do the interview, the participant and the investigator then met in person. To save transportation time, we met directly at the location in which the participant frequently typed on their smartphone with one hand (i.e., the context of use).

Before starting the interview, the participant was once again informed about the purpose, to better understand the context of use of one-handed text entry on mobile devices, the tasks they had to perform, to respond to questions asked by the interviewer to the best of their ability, and the fact that they were “the expert” in this interview. They were assured that their participation was fully voluntary as they may quit the interview at any time. They were also told that the interview would be recorded for further analysis if needed and the data collected from the interview would be completely anonymous and confidential. The participant then gave their verbal consent to participate in the interview had they agreed to all of the conditions mentioned, which they did.

The contextual inquiry then began. Since our initial focus, being “one-handed text entry on a mobile device, preferably on an iPhone and with the right hand, specifically regarding fixing typos, switching between numbers/letters, and switching languages”, was very narrow, we decided to begin by only asking about the participant’s experience with one-handed mobile text entry in general. If we were out of questions to ask or if the participant actually mentioned these specific aspects of one-handed text entry (fixing typos, etc.), we would then proceed to ask about them. Thus, the first question presented to the participant was, “Please try to think about one specific instance in which you entered text on your phone with one hand. Would you please take us to the location where it [the interaction] happened?” Since we were already at the desired location, we did not have to move and I proceeded to ask the next question, “Would you please try to describe what happened? For example, what prompted you to enter text with one hand? What were you trying to do with the text entry? How did you do it? etc.” All of the remaining questions were based on the participant’s response and factors in the context of use.

The interview lasted approximately an hour. Once the interview concluded, we thanked the participant for their time.

## Participants

\instructions{Please provide demographic information of participants: number of participants, by age, by gender, by disability if relevant for the study, by experience with task, location, any other criteria for recruitment, how they were recruited, were they given any incentives, mode of study conducted (virtual or in-person). How did you decide on the number of participants for your study?}

A total of five participants were conveniently selected, one for each contextual inquiry we conducted individually. Each team member sent out invitations to participate in the interview online to close friends who met the inclusion/exclusion criteria, which was 1) they must be at least 18 years old, and 2) they have prior experience with one-handed text entry on mobile devices. The person who agreed first became the participant. No monetary incentives were provided for the completion of the interview. The demographic information about the participants are listed in Table [?]. For the analysis, each participant was assigned with an encoding from U01 to U05 respectively, and they were collectively referred to as “the user” in the remainder of the report.

Table [?]

| User encoding | Age | Gender | Race | Employment status | Dominant hand | Phone brand | Multi-lingual | Disability |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| U01 |  |  |  |  |  |  |  |  |
| U02 | 22 | Male | Asian | Student | Left | Google Pixel | Yes | No |
| U03 | 27 | Male | Asian | Student | Right | Samsung | Yes | No |
| U04 | 23 | Female | Asian | Employed Full-time | Right | iPhone | Yes | No |
| U05 | 22 | Male | Asian | Employed part-time | Right | iPhone | Yes | No |

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# Results

In this section, we will discuss the results of our contextual inquiry interviews.We have consolidated sequence diagrams and flow diagrams from 5 different interviews, as well as an affinity diagram that contains our interpretations from all 5 interviews.

**Affinity Diagram**

**User frequently uses their phones with one hand throughout the day (Affinity Diagram)**

The contexts in which individuals need to use their phones with one hand is usually when multitasking. Individuals are usually doing something before or while needing to type with one hand. Some participants require typing with one hand while multitasking on daily tasks. For instance, one individual needed to brush their teeth while messaging their friend about a homework assignment. Another context is when the user is walking or actively doing something. These activities often required users to switch their attention back and forth between the phone and their immediate environment, emphasizing the importance of intuitive and efficient one-handed phone operations for user safety and convenience.

**Keyboard layout hinders the user's ability to enter text (Affinity Diagram)**

Almost all participants faced challenges with existing keyboard layouts that hinder their ability to enter text. The users often find it difficult to reach keys on the far edges or opposite side of the phone display while operating one-handed. This results in constant readjustment to their grip of the phone, which in turn causes accidental taps, reducing typing speed and efficiency. In addition, the placement of certain keys is difficult to access with only one hand. This is particularly the case for those buttons on the top left and right corner of the screen, where the thumb is unable to reach. Participants often struggled to locate characters like the question mark, which they expected to find at the bottom right key, mirroring a standard keyboard layout. This unfamiliarity slowed down their typing process.

Punctuation and symbols are another issue that was identified. Accessing specific punctuation marks requires users to switch keyboards, but the switch key is inconveniently placed on the far side of the phone screen. Most users reported that they only use a handful of punctuation marks frequently, implying that the current design might not be optimized for the majority's needs. Some even resorted to skipping punctuation or capitalization entirely because of the difficulties posed by the layout. Lastly, one participant just decided not to capitalize words because of the inconvenience brought by the keyboard’s layout.

**Users usually find some assistive keyboard technologies unhelpful (Affinity Diagram)**

Almost all participants also used various assistive keyboard technologies such as autocorrect or the swipe type feature. However, many participants found that these assistive technologies are not used very effectively. In the case of autocorrect, many participants highlighted cases where autocorrect suggestions are far from or significantly different from the intended word. In addition, one multilingual participant found that autocorrect is intrusive as it tried to correct words across different languages. As a result, one participant resorted to manually capitalizing letters instead of relying on auto-capitalization.

**Users make many slips (typos) texting one handed but is not always an issue to complete the task**

**The size and weight of the phone sometimes causes physical discomfort to the user to text with only one hand**

Our consolidated sequence diagram contains all steps that each participation took to input text with one hand. Although the participants may begin with slightly different contexts (top region of diagram), once they have begun text entry, their procedures begin to fully or partially merge. The participant may encounter certain situations as they enter the main sub-task loop of text entry (center region of diagram), and they would repeat this loop until they have finished their task and jump out of the loop (bottom right corner of diagram). Given our consolidated sequence diagram, the participant usually runs into breakdowns when they: switch to a different keyboard, make a slip (typo) and attempt to correct it, and physically adjust the phone in their hand. The participant would attempt to deal with one of these issues before they begin another new iteration of text entry sub-task and encounter one of the issues again, or not. There is also a case when the participant gives up on entry with one hand and switches to two-hand entry (bottom region of the diagram). In this case the participant would also jump out of the main loop and would go through a different set of procedures before their task is done.

The participants' breakdowns can be generally grouped by the different subtasks in the main loop. During a keyboard switch, the participants experience many issues related to the difficulty of reaching and locating specific keys with only one hand due to the layout of the keyboard. The participant usually makes a typo as some fashion of slip due to muscle memory, proximity of key placements, and awkward hand postures. When the participant attempts to fix a typo, they would encounter issues with assistive features, placement of the delete key. The participant would also have the phone slip out of their hand during input due to larger phone display sizes mandating moving the phone in their hand.e

FLOW DIAGRAM

The consolidated flow diagram shows the flow of information from the user (participant) to a recipient that is either another person or another service/platform. The information flows from the user, through their phone (artifact), and towards the recipient, and the recipient would also return information back. The information takes form as a text message, an email, or some form of query request. The breakdown takes place during the input of these information that are detailed in our sequence diagram.

# User Requirements

We identified the user requirements based on the general themes that emerged from the affinity diagram and breakdowns discovered in consolidated diagrams, while referencing specific interpretation notes. Thus, the user requirements are grounded in the contextual inquiry results and when considered all together, are comprehensive and cover all relevant aspects (breakdowns) related to the context of use. We also tried our best to meet the other rules/principles for each user requirement, including testability, objectivity, and may not imply a solution. However, we realized that there would always be a tradeoff between the rules/principles that a user requirement must satisfy, especially between the requirement’s objectivity and whether the requirement implies a solution. Being more specific would increase objectivity, but would also increase the likelihood of implying a solution. On the other hand, being more abstract would less likely imply a solution, but would also be less objective. Thus, we tried our best to balance these two rules, and occasionally had to prefer one over the other if the requirement made more sense for the context of use in one way over the other.

**Typos**

**User Requirement [1]**: When entering text on mobile devices, user should not make more typos (slips) when operating with one hand compared to operating with both hands (U05-07, U5-08, U05-13, U05-23, U05-27, U05-29, U05-35, U01-14, U01-15, U03-04).

The user frequently made typos, almost every other word, while typing on the phone with one hand (U05-07 to 08, U05-23, U05-35). They expressed frustration and annoyance towards making these slips (U05-13) and switched to typing with both hands when they became too irritated with making typos, even if that meant putting down the artifact that originally occupied their other hand to focus on typing (U05-27). This truly shows the level of frustration of the user with making typos. Moreover, when typing with both hands, the user experienced fewer typos compared to typing with one hand (U05-29). Taken all together, it is clear that there is a salient breakdown in the existing method of one-handed text entry on mobile devices, hence this user requirement.

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**Keyboard assistive feature**

**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).

The autocorrect feature appears to be ineffective and even counterproductive when the user is using one hand to enter text on the phone while multitasking (U05-09 to 13, U05-25). The default autocorrect feature on the phone would automatically change the typo word to a word that the algorithm believes is what the user intended to type, unless the user manually select a suggested word displayed at top of the keyboard (U05-09, U05-11). However, more often than not, the autocorrect feature got it wrong (U05-09), and the resulting word would sometimes be completely different from what the user intended, especially when it was an acronym (U05-10). Moreover, the user could not use the autocorrect feature on this word anymore because the word was now considered as “correct” by autocorrect; consequently, the user had to manually delete and retype the entire word (U05-12). Forgetting to manually select from the suggested words was especially common when the user was using one hand and distracted by the surroundings (U05-11), causing the autocorrect to be in fact counterproductive and making the user very annoyed and frustrated (U05-13). In contrast, the user was able to use the autocorrect feature much more effectively and efficiently when typing with both hands (U05-30). Thus, it is clear that there is a breakdown in the existing autocorrect feature when entering text on the phone with one hand and multitasking.

**Layout**

**User Requirement [3]**: User should be able to fix a typo (mistakenly-spelled word) using one hand independently of keyboard assistive features and without accidentally modifying any other (correctly-spelled) characters or words (U05-25, U05-26, U05-27, U02-06, U04-17).

Despite being helpful, autocorrect could only take the user so far: It was difficult for autocorrect to produce the right suggested words every single time, and when it did not, the user struggled to fix typos with just one hand (U05-25, U05-26, U05-27, U02-06, U04-17). In the case when the user’s other hand was occupied, they had no choice but to manually fix the typo with just one hand by first holding down the delete key, which frequently ended up over-deleting the entire current word and the word before it, rather than just up to and including the letter that differed from the right word (U02-06, U04-17, U05-26). As a result, the participant had to spend more time retyping more letters than necessary. Moreover, the fact that the user would use both hands to fix the typos when the other hand was not occupied (U05-12) and even when the other hand was occupied if they became so frustrated with fixing typos (U05-27) truly indicate the difficulty of fixing typos with just one hand. Therefore, this user requirement was created.

**User Requirement [4]:** Users should be able to navigate, communicate and interact with different keyboard elements accurately (without slips) using one hand 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).

The ability to comfortably reach the edges of the keyboard appeared to be a major breakdown in one-handed text entry on mobile devices. These interpretation notes all showed that, when operating their phone one-handed in utilizing various social media and messaging services, the user had to constantly strain their thumb to reach for different keyboard elements (and other general UI elements) located at the opposite side of the users’ thumb, which was discomfortable and frustrating. For example, some of these keyboard elements include, keyboard-switch key (U03-06, U05-37), the send/enter key (U02-02, U04-10, U04-11), capitalization key (U03-12). Moreover, as the user tried to reach the opposite end of the keyboard, they often misclicked on different keys (e.g., U02-17, U03-08, 04-11). To alleviate the discomfort, the user was sometimes forced to switch from one hand to two hands (e.g., U02-20) or reposition the device (e.g., U01-07). Users who enter text on the phone with one hand almost always need to access all keys on the keyboard with one hand. Thus, ensuring the user can comfortably and accurately interact with all elements on the keyboard one-handed is absolutely essential.

**User Requirement [5]**: User should be able to locate and enter emojis, punctuations, and numerics 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).

There appears to be a breakdown in entering non-letters with one hand, such as emojis (U05-15, U05-16, U05-17, U04-09, U04-18), punctuations, and numbers (U02-08, U03-06, U03-18, U03-19, U05-37). To enter these characters, the user had to first switch the keyboard (e.g., switching from the default letters keyboard to the emojis keyboard) by locating and pressing the keyboard-switch key, which the user struggled on since this key is located at the edge of the keyboard (U05-15, U05-37, U03-18, U03-19). Then, the user had to find the desired characters on the new keyboard, which was also hard to do: For example, to select to desired emoji, the user had to consciously look at the keyboard rather than relying on muscle memory because the emojis keyboard has way more keys (i.e., emojis to choose from) compared to the letters keyboard and it also dynamically changes based on the frequently used emoji of the user (U05-16). Similar experience applies to the punctuations and numbers keyboard (U03-18, U05-37). Furthermore, because the user had to frequently enter these characters, almost in every message they sent, this process drastically slowed down the overall text entry speed (U05-17) and the user eventually stopped entering these characters due to its complexity (U05-37).

**Physical discomfort**

**User Requirement [6]:** Users should be able to hold their mobile device one-handed in a secure manner without inflicting physical discomfort (U01-07, U01-08, U01-09, U01-20, U01-21, U02-09, U02-10, U03-07, U03-13, U03-14, 04-04).

The user experienced difficulty in *holding* the phone with one hand, as indicated by all of these interpretation notes above. The trouble of holding the phone with one hand often led to fatigue (e.g., U02-10), which consequently resulted in the user either dropping their phone or worried that they might drop their phone (e.g., U01-08, U03-07). Sometimes, the user used their pinky as a rest stand to support their mobile devices; however, it did not take long before the phone’s weight tired out the user’s pinky (e.g., U02-09). Dropping a phone can damage it and even make the phone malfunction, which hinders the users' ability to enter text. Thus, it is important to ensure that the user is able to securely and comfortably hold their phones one-handed.

# Discussion

* Why these people have their breakdowns
* Rela

After we conducted our contextual inquiry, our focus did not shift too much. Given the response we received from our participants, the breakdowns they have mostly experienced were still pertaining to general keyboard operations that are already covered by our current focus. However, we also did

Generally speaking, the breakdowns we have compiled are related to several factors: the keyboard layout, assistive features, typos, the size of the mobile device, and the participants' hand postures. In fact, most of these factors are part of the same cause-and-effect chain. A larger phone size and an inconvenient keyboard layout cause larger jumps between keys, and therefore give rise to uncomfortable hand postures while inputting text with a single hand. With an uncomfortable hand posture, the user is likely to commit text entry slips, have their precision and efficiency impaired, and it is even possible that they could drop their phone.

With our focus of text entry with one hand in mind, we can analyze our breakdowns with respect to our user requirements.

Our user requirement [1] is to tackle the breakdown with text entry slips as well as the issues of precision and efficiency that comes along with it.

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# Conclusion

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