

A RESPONSIBLE RESEARCH: HUMAN SUBJECTS RESEARCH PROTECTIONS



(a) Sang Hyun S's PEERRS Certificate

(b) Isaac T's PEERRS Certificate



(c) Yichen Z's PEERRS Certificate

(d) Franklin K's PEERRS Certificate



(e) Zi Rui Z's PEERRS Certificate

B SURVEY AND QUESTIONNAIRE INSTRUMENTS

B.1 Initial Questionnaire Design

How do you text on your phone?

* Indicates required question

How do you text on your phone?

You are invited to participate in a survey about how people enter text on their phone. The survey should take about 5 minutes.

Your participation is voluntary and there are no risks involved. Your responses will be completely anonymous. We will not be able to link your responses to you and at no point will you be asked for any identifying or contact information.

Thank you.

1. You must be **at least 18** years old and **use a smartphone** in order to participate in * the survey. By clicking on I agree, you are confirming your agreement with these conditions and you are consenting to participate in this survey.

Mark only one oval.

I agree

I do not agree [Skip to section 6 \(End of Survey\)](#)

Demographics

2. What is your age?

Mark only one oval.

18-25

26-40

41-60

61-80

80+

3. What is your employment status?

Mark only one oval.

Employed full-time

Employed part-time

Self-employed

Unemployed

Retired

Student

Other: _____

4. How many languages are you proficient in?

Mark only one oval.

1

2

3

4+

5. Do you have a disability?

Mark only one oval.

- Yes
- No
- I don't know
- I prefer not to answer

6. How often do you use a smartphone?

Mark only one oval.

- Several times an hour
- Several times a day
- Once a day
- Several times a week
- Rarely

Mobile Text Entry with One Hand

7. Have you ever entered text (typed on the virtual keyboard) on your smartphone with one hand? *

Mark only one oval.

- Yes
- No *Skip to question 24*

Mobile Text Entry with One Hand Continued

8. How often do you find yourself needing to enter text on your phone with one hand?

Mark only one oval.

- Several times an hour
- Several times a day
- Once a day
- Several times a week
- Rarely

9. In what situations do you find yourself entering text on your phone with one hand?

Select all that apply.

Check all that apply.

- On transportation
- Walking
- Eating
- Other: _____

10. How comfortable are you with holding your phone with one hand?

Mark only one oval. _____

Very Uncomfortable

1

2

3

4

5

Very Comfortable

11. Do you usually enter text with your phone in a vertical or horizontal position?

Mark only one oval.

Vertical

Horizontal

12. What is the level of difficulty you find when entering text with one hand compared to entering text with both hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

13. What is your typing speed when entering text with one hand compared to entering text with both hands?

Mark only one oval.

Much Faster

1

2

3

4

5

Much Slower

14. How often do you make mistakes when entering text with one hand compared to entering text with both hands?

Mark only one oval. _____

Much Less Often

1

2

3

4

5

Much More Often

15. What is the level of difficulty you find when fixing mistakes/typos with one hand compared to fixing mistakes/typos with both hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

16. What is your opinion on the autocorrect feature of your phone's keyboard?

Mark only one oval.

Very helpful

Helpful

Neither helpful nor not helpful

Not helpful

Very not helpful

17. What is your opinion on the usability of your phone's 'qwerty' keyboard when typing single-handed?

Mark only one oval.

- Very usable
- Usable
- Neither usable nor not usable
- Not usable
- Very not usable

18. What do you think of the size of the keys on your smartphone's virtual keyboard?

Mark only one oval.

- Too big
- Too small
- Neutral (just right)

19. How often do you find yourself switching between numbers and letters?

Mark only one oval.

- Almost always
- Frequently
- Occasionally
- Rarely
- Never

20. What is the level of difficulty you find when switching between numbers and letters using one hand compared to that of two hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

21. How often do you switch languages on your keyboard?

Mark only one oval.

Almost always

Frequently

Occasionally

Rarely

Never

22. What is the level of difficulty you find when switching languages using one hand compared to that of two hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

23. What is your dominant hand?

Mark only one oval.

Left

Right

Ambidextrous

Other Mobile Text Entries

24. How comfortable are you typing on your phone without looking at the keyboard?

Mark only one oval. _____

Very Uncomfortable

1

2

3

4

5

Very Comfortable

25. How often do you use autocomplete (predictive text) when typing?

Mark only one oval.

Almost always

Frequently

Occasionally

Rarely

Never

26. What is your opinion on the autocomplete feature of your phone's keyboard?

Mark only one oval.

- Very Helpful
- Helpful
- Neither helpful nor not helpful
- Not helpful
- Very not helpful
- N/A

27. How often do you use customized shortcuts in your smartphone to increase typing efficiency?

Mark only one oval.

- Almost always
- Frequently
- Occasionally
- Rarely
- Never
- N/A

28. How often do you use customized gestures to increase your typing efficiency?

Mark only one oval.

- Almost always
- Frequently
- Occasionally
- Rarely
- Never

29. Have you ever tried other 3rd party keyboard apps to improve typing experience?

Mark only one oval.

Yes

No

30. What is the level of difficulty of entering text on a smartphone compared to that of a computer?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

31. What are some other text entry methods that you have tried/used on your smartphone? Select all that apply.

Check all that apply.

- Speech to text
- Predictive text
- Swipe/gesture to complete words
- Stylus pencil
- Physical external keyboard
- Other: _____

End of Survey

Thank you for completing the survey!

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Google Forms

B.2 Final Questionnaire Design

How do you text on your phone?

* Indicates required question

How do you text on your phone?

You are invited to participate in a survey about how people enter text on their phone. This survey will be used to gain a better understanding of the difficulties of texting with one hand. The survey should take about 7 minutes.

Your participation is voluntary and there are no risks involved. Your responses will be completely anonymous. We will not be able to link your response to you and at no point will you be asked for any identifying or contact information.

Thank you.

1. You must be **at least 18** years old and **have used a smartphone before** in order * to participate in the survey. By clicking on I agree, you are confirming your agreement with these conditions and you are consenting to participate in this survey.

Mark only one oval.

I agree

I do not agree [Skip to section 6 \(End of Survey\)](#)

General

2. On average, how long do you use your smartphone per day?

Mark only one oval.

Less than 2 hours

At least 2 hours but less than 4 hours

At least 4 hours but less than 6 hours

6 hours or more

3. What brand is your smartphone?

Mark only one oval.

Apple

Google

Leveno

Motorola

Samsung

Xiaomi

Other: _____

4. Have you ever entered text (typed on the virtual keyboard) on your smartphone with one hand? *

Mark only one oval.

Yes

No *Skip to question 19*

Mobile Text Entry with One Hand

5. How often do you enter text on your phone with one hand?

Mark only one oval.

Almost always

Frequently

Occasionally

Rarely

6. How comfortable are you with typing on your phone with one hand?

Mark only one oval. _____

Very Uncomfortable

1

2

3

4

5

Very Comfortable

7. Do you usually enter text with your phone in a vertical or horizontal position?

Mark only one oval.

Vertical

Horizontal

8. What is the level of difficulty you find when entering text with one hand compared to entering text with both hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

9. What is your typing speed when entering text with one hand compared to entering text with both hands?

Mark only one oval.

Much Faster

1

2

3

4

5

Much Slower

10. How often do you make mistakes when entering text with one hand compared to entering text with both hands?

Mark only one oval. _____

Much Less Often

1

2

3

4

5

Much More Often

11. What is the level of difficulty you find when fixing mistakes/typos with one hand compared to fixing mistakes/typos with both hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

12. What is your opinion on the autocorrect feature of your phone's keyboard?

Mark only one oval.

Very Unhelpful

1

2

3

4

5

Very Helpful

13. What is your opinion on your phone's keyboard layout when typing single-handed?

Mark only one oval.

Hard to use

1

2

3

4

5

Easy to use

14. What do you think of the size of the keys on your smartphone's (default) virtual keyboard?

Mark only one oval.

Too big

Too small

Neutral (just right)

15. What is the level of difficulty you find when switching between numbers and letters using one hand compared to that of two hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

16. How often do you switch languages (including emojis) on your keyboard?

Mark only one oval.

Almost always

Frequently

Occasionally

Rarely

Never

17. What is the level of difficulty you find when switching languages using one hand compared to that of two hands?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

18. What is your dominant hand?

Mark only one oval.

Left

Right

Ambidextrous

Other Mobile Text Entries

19. How comfortable are you typing on your phone without looking at the keyboard?

Mark only one oval. _____

Very Uncomfortable

1

2

3

4

5

Very Comfortable

20. What is your opinion on the autocomplete (predictive text) feature of your phone's keyboard?

Mark only one oval.

Very Unhelpful

1

2

3

4

5

Very Helpful

21. What is your opinion on customized shortcuts for typing? (e.g., type 'omw', turns into 'on my way')

Mark only one oval.

Very Unhelpful

1

2

3

4

5

Very Helpful

22. Have you ever tried other 3rd party keyboard apps on your phone?

Mark only one oval.

Yes

No

23. What is the level of difficulty of entering text on a smartphone compared to that of a computer?

Mark only one oval.

Much Easier

1

2

3

4

5

Much Harder

24. What are some other text entry methods that you have tried/used on your smartphone? Select all that apply.

Check all that apply.

Speech to text

Predictive text

Swipe/gesture to complete words

Stylus pencil

Physical external keyboard

Other: _____

Demographics

25. What is your age?

Mark only one oval.

- 18-25
- 26-40
- 41-60
- 61-80
- 80+

26. What is your race/ethnicity? Please select all that apply

Check all that apply.

- White
- Latinx or Latin American
- Black or African American
- American Indian or Alaska Native
- Asian
- South Asian
- Middle Eastern or North African
- Native Hawaiian or Pacific Islander
- Prefer not to answer
- Other: _____

27. What is your gender identity?

Mark only one oval.

- Man
- Woman
- Non-binary / Gender fluid
- Indigenous or other cultural minority gender (e.g., two-spirit)
- Prefer not answer
- Other: _____

28. What is your employment status?

Mark only one oval.

- Employed full-time
- Employed part-time
- Self-employed
- Unemployed
- Retired
- Other: _____

29. How many languages are you proficient in (reading/writing)?

Mark only one oval.

- 1
- 2
- 3
- 4+

30. Do you have a disability?

Mark only one oval.

- Yes
- No
- I don't know
- Prefer not to answer

End of Survey

Thank you very much for completing the survey!

If possible, would you please forward this survey to people you know who are over 18 and have used a smartphone? Thank you!

This content is neither created nor endorsed by Google.

Google Forms

B.3 Anonymized and De-identified Questionnaire Data

Timestamp	You must be at least 18 y	On average, how long do you leave your smartphone connected to the power source?	What brand is your smartphone?
9/21/2023 21:05:50	I agree	At least 2 hours but less than 6 hours	Google
9/21/2023 21:13:47	I agree	6 hours or more	Apple
9/21/2023 21:34:28	I agree	6 hours or more	Apple
9/21/2023 21:47:28	I agree	6 hours or more	Apple
9/21/2023 21:50:32	I agree	6 hours or more	Apple
9/21/2023 21:59:08	I agree	6 hours or more	Apple
9/21/2023 22:23:04	I agree	At least 4 hours but less than 6 hours	Apple
9/21/2023 22:33:48	I agree	At least 2 hours but less than 6 hours	Samsung
9/21/2023 23:02:12	I agree	6 hours or more	Apple
9/22/2023 5:08:09	I agree	At least 2 hours but less than 6 hours	Asus, Huawei
9/22/2023 10:08:02	I agree	At least 4 hours but less than 6 hours	Apple
9/22/2023 10:16:26	I agree	At least 4 hours but less than 6 hours	Apple
9/22/2023 15:49:47	I agree	6 hours or more	Apple
9/22/2023 17:31:01	I agree	At least 4 hours but less than 6 hours	Apple
9/22/2023 20:17:18	I agree	Less than 2 hours	Apple
9/22/2023 20:41:03	I agree	At least 2 hours but less than 6 hours	Apple
9/22/2023 20:56:49	I agree	At least 4 hours but less than 6 hours	Apple
9/22/2023 21:12:25	I agree	At least 4 hours but less than 6 hours	Apple
9/23/2023 0:18:10	I agree	At least 4 hours but less than 6 hours	Samsung
9/23/2023 14:27:11	I agree	6 hours or more	Apple
9/23/2023 16:35:59	I agree	At least 4 hours but less than 6 hours	Apple
9/23/2023 23:11:08	I agree	At least 2 hours but less than 6 hours	Apple
9/23/2023 23:22:58	I agree	At least 2 hours but less than 6 hours	Apple
9/23/2023 23:52:13	I agree	At least 4 hours but less than 6 hours	Apple
9/23/2023 23:59:24	I agree	At least 2 hours but less than 6 hours	Apple
9/24/2023 10:56:31	I agree	At least 4 hours but less than 6 hours	Apple
9/24/2023 15:12:36	I agree	6 hours or more	Xiaomi

Have you ever entered te:	How often do you enter te	How comfortable are you	Do you usually enter text
Yes	Occasionally	3	Vertical
Yes	Frequently	5	Vertical
Yes	Rarely	2	Vertical
Yes	Occasionally	2	Vertical
Yes	Occasionally	1	Vertical
Yes	Occasionally	2	Vertical
Yes	Occasionally	2	Vertical
Yes	Rarely	2	Vertical
Yes	Occasionally	3	Vertical
Yes	Frequently	2	Vertical
Yes	Occasionally	2	Vertical
Yes	Rarely	2	Vertical
Yes	Rarely	1	Vertical
No			
Yes	Occasionally	3	Vertical
Yes	Occasionally	3	Vertical
Yes	Almost always	3	Vertical
Yes	Frequently	4	Vertical
Yes	Occasionally	2	Vertical
Yes	Occasionally	4	Vertical
Yes	Rarely	4	Vertical
Yes	Occasionally	3	Vertical
Yes	Occasionally	4	Vertical
Yes	Rarely	4	Vertical
Yes	Rarely	2	Vertical
Yes	Rarely	2	Horizontal
Yes	Occasionally	3	Vertical

What is the level of difficulty	What is your typing speed	How often do you make mistakes	What is the level of difficulty
4	4	3	4
3	4	4	5
4	4	3	3
4	4	4	4
4	5	5	3
4	3	5	4
5	4	4	3
4	4	4	4
5	4	3	4
5	5	5	5
4	4	3	4
5	4	3	5
5	5	3	3
4	4	3	3
4	5	3	4
5	5	4	4
4	4	4	5
4	5	4	3
4	4	3	4
4	4	4	4
3	4	4	4
4	4	5	4
3	4	3	4
4	4	3	4
4	3	3	4
4	4	5	3

What is your opinion on the size of the font?	What is your opinion on the size of the font?	What do you think of the size of the font?	What is the level of difficulty of the font?
4	5	Neutral (just right)	4
2	3	Neutral (just right)	4
3	3	Neutral (just right)	5
2	2	Too big	5
4	3	Too small	3
3	2	Neutral (just right)	2
4	2	Neutral (just right)	4
3	3	Neutral (just right)	5
3	1	Too small	3
2	1	Neutral (just right)	3
4	3	Neutral (just right)	5
5	3	Neutral (just right)	3
4	2	Neutral (just right)	3
2	3	Neutral (just right)	3
2	4	Neutral (just right)	5
4	3	Neutral (just right)	3
4	3	Neutral (just right)	5
4	3	Neutral (just right)	3
3	3	Neutral (just right)	3
2	2	Too small	3
4	3	Neutral (just right)	3
1	3	Neutral (just right)	2
1	3	Neutral (just right)	3
3	5	Neutral (just right)	5
3	2	Neutral (just right)	3
5	2	Neutral (just right)	4

How often do you switch	What is the level of difficulty	What is your dominant hand	How comfortable are you
Frequently	3	Right	4
Occasionally	4	Right	5
Frequently	4	Right	1
Frequently	4	Right	2
Frequently	3	Left	1
Frequently	3	Right	1
Frequently	4	Right	5
Frequently	4	Right	2
Frequently	4	Right	2
Almost always	3	Right	1
Frequently	4	Right	4
Frequently	3	Right	2
Frequently	4	Right	4
			2
Rarely	3	Right	3
Frequently	5	Right	3
Occasionally	3	Left	4
Never	3	Right	5
Frequently	3	Right	4
Frequently	3	Ambidextrous	3
Occasionally	3	Left	1
Frequently	3	Right	2
Rarely	3	Right	2
Frequently	3	Right	4
Frequently	3	Right	3
Almost always	3	Right	4
Frequently	4	Right	1

What is your opinion on tr	What is your opinion on c	Have you ever tried other	What is the level of diffic
4	4 Yes		3
2	1 No		3
3	3 No		3
2	4 No		5
2	1 No		5
2	2 Yes		5
4	2 No		4
2	5 Yes		5
2	1 No		3
3	5 Yes		4
4	1 No		4
3	1 No		2
4	4 No		4
3	2 Yes		4
2	4 No		4
2	1 No		5
4	1 No		2
5	2 No		3
4	5 No		4
4	2 No		3
2	3 Yes		5
4	4 No		4
3	2 No		4
4	4 No		3
2	5 No		4
4	5 No		5
5	1 Yes		4

What are some other text entry methods?	What is your age?	What is your race/ethnicity?	What is your gender identity?
Predictive text, Swipe/gesture	18-25	South Asian	Man
Speech to text, Predictive	18-25	White, Asian	Man
Swipe/gesture to complete	18-25	Asian	Man
Predictive text	18-25	Asian	Man
Speech to text	18-25	Asian	Man
Predictive text	18-25	Asian	Woman
	18-25	White, Asian	Man
Swipe/gesture to complete	18-25	Asian	Non-binary / Gender fluid
Swipe/gesture to complete	18-25		Man
Speech to text, Swipe/gesture	26-40	Asian	Man
Swipe/gesture to complete	18-25	Asian	Woman
Speech to text, Predictive	18-25	Asian	Woman
Speech to text, Predictive	18-25	Asian	Woman
Swipe/gesture to complete	18-25	Asian	Man
Speech to text, Predictive	18-25	Asian	Man
Predictive text, Swipe/gesture	18-25	Asian	Man
Speech to text, Predictive	18-25	Asian	Man
Swipe/gesture to complete	18-25	Asian	Man
	18-25	Asian	Man
Predictive text, Swipe/gesture	18-25	Asian	Woman
Swipe/gesture to complete	18-25	Asian	Man
N/A	18-25	Asian	Man
	18-25	Asian	Man
Predictive text, Stylus pen	18-25	White, Asian	Man
Speech to text, Swipe/gesture	18-25	Asian	Woman
Swipe/gesture to complete	18-25	Asian	Woman
Swipe/gesture to complete	18-25	Prefer not to answer	Prefer not answer

What is your employment	How many languages are you fluent in?	Do you have a disability?
Unemployed	2	No
Unemployed	1	No
Employed full-time	2	No
Unemployed	2	No
Unemployed	2	No
Unemployed	3	I don't know
Student	2	No
Unemployed	3	Yes
Student	1	No
student	3	I don't know
Unemployed	3	No
Unemployed	3	No
Employed part-time	2	No
Student	2	No
Employed full-time	1	No
Student	2	No
Employed full-time	1	No
Employed full-time	1	No
Employed part-time	3	No
Unemployed	2	No
Employed full-time	1	No
Unemployed	2	No
Employed part-time	2	No
Employed full-time	2	No

C CONTEXTUAL INQUIRY

C.1 Individual Interpretations

Interpretation Notes

U01 - 01 Participant is holding his dinner and receives a text from friend	U01 - 02 Participants struggle to get phone out of pocket to text a friend with only one hand	U01 - 03 Participant sits down and continues to text one handed while eating with the other hand	U01 - 04 One handed, the participant can only use one hand to access/go through/text on phone	U01 - 05 Most desired way of texting are on the far left of the screen opposite of thumb
U01 - 06 Participant can easily unlock phone by swiping up and using face id with one hand	U01 - 07 Participant has to constantly readjust phone in his hand to reach the app/icons	U01 - 08 Participant dropped phone due to instability	U01 - 09 Participants struggles to text and texts slowly because swiping makes it hard to hold phone	U01 - 10 Participant sends short messages to friend
U01 - 11 Participant then navigated to the youtube app to search videos to watch	U01 - 12 Participant uses swipe to text only when using one hand, usually easier to get letters on other side of the screen	U01 - 13 Tapping is too difficult to accurately reach the other side of the phone	U01 - 14 Makes more mistakes tapping with one hand than swiping	U01 - 15 When participant switched to two handed mode, participant made less errors than with one handed texting
U01 - 16 When participants makes spelling mistakes, uses autocorrect only because autocorrect is not good enough	U01 - 17 Uses swipe to text because it deletes the whole word if one or one letter when using backspace	U01 - 18 Participant texts with one hand when texting with friends because mistakes are okay	U01 - 19 Switches to two hands when writing emails and finishing assignments because has better accuracy when texting with two hands	U01 - 20 Participant finishes his dinner freeing his other hand. The participant now uses both hands due to stability and comfort
U01 - 21 Participants no longer texts one hand now that both hands are free	U01 - 22 In order to use emoji, special characters, participants need to free their other hand to access them with the other hand	U01 - 23 Participant only uses swipe to text because unaware of how other features to help text with one hand		

Fig. 50. Daniel's Interpretation

Improving One-Handed Textual Entry on Mobile Devices



Fig. 51. Yichen's Interpretation

U05-01: The participant replied to a text message from his friend on his phone with one hand while walking outside.	U05-02: The participant received a notification while walking, so he took his phone out from his pocket with his left hand, and unlocked the phone with FaceID to read the message.	U05-03: The participant decided to immediately reply back, so he began typing on his phone with his left hand only, while his right hand was in his pocket (doing nothing important).	U05-04: The participant typed by repeatedly lifting up his left thumb and pressing down each letter (key) in each word he wanted to enter.	U05-05: While typing, the participant had to multitask by constantly switching between looking at his phone (to ensure correctness) and his surroundings (to ensure safety).
U05-06: The participant felt the speed of typing with one hand was much slower than with both hands, but he still kept typing with just his left hand.	U05-07: The participant made a lot of typos (almost every other word), which were caused by mis-pressing the keys because two keys on the keyboard were either too close/adjacent, or too far,	U05-08: Sometimes, when the participant mis-pressed one keyletter, almost all of the remaining letters in the word were consequently mis-pressed too.	U05-09: The autocorrect feature rarely changed the mistakenly-spelled word to right word participant wanted.	U05-10: Sometimes, the resulting word of autocorrect was similar to the similar letter to what was intended, but it was significantly different when the intended word was an acronym.
U05-11: The participant tried to use the autocorrect feature to its full capacity, which asked choosing one of the 3 suggested words, but constantly delaying the change by clicking the screen that having a higher chance to get the right word. He also had to constantly look away from his phone to check his surroundings while typing.	U05-12: The participant had to manually fix the typos or the incorrect autocorrected words by holding down the delete key with his right thumb to delete either the entire word (if the participant had typed more than what he wanted) or use auto-correct using the keyboard again to enter the correct word, and then repeat the word with both thumbs.	U05-13: The participant was somewhat annoyed and frustrated at the typos and the incorrect resulting words produced by the autocorrect feature.	U05-14: After fixing the typos with both hands, the participant switched back to typing with just his left hand (thumb) to enter the rest of the message (while walking and constantly checking his surroundings).	U05-15: The participant wanted to enter a message, so he unlocked his iPhone and tried to use Google keyboard by constantly looking down on his phone to locate the language switch key and pressing it with his left thumb.
U05-16: The participant continued looking at their phone to pick the desired emoji, since the emoji keyboard was not always faster than the regular letter keyboard and also does not follow a fixed pattern as it lists the most recently used emojis first.	U05-17: Typing emojis drastically slowed down the overall typing speed and the participant switched between the emoji keyboard and letters keyboard for almost every message.	U05-18: After the participant completed the message and made sure it did not have any typos/mistakes, he sent out the message and kept the phone open (unlocked), holding it in his left hand while walking for his friend to reply.		
U05-19: The participant had a text conversation with his friend while in the bathroom brushing teeth.	U05-20: While brushing his teeth with his right hand in the bathroom, the participant was scrolling through his phone with his left hand and suddenly wanted to message one of his friends about a homework assignment.	U05-21: The participant typed the message on his phone with his left thumb, holding the phone far away from him since he did not want to get the phone wet or dirty.	U05-22: Despite also brushing his teeth, the participant was looking at his phone (concentrated on the keyboard and the message) the whole time while typing.	U05-23: The participant made a typo, which he had to fix with one hand because his right hand was occupied.
U05-24: The participant was able to better use the autocorrect feature this time, as he was constantly looking at the phone and could manually pick the intended word from the 3 suggested ones (with his left thumb).	U05-25: When the 3 suggested words did not include the one which the participant wanted to type, the participant had to hold down the delete key with his left thumb until all the letters up to and including the mistake/typo were deleted.	U05-26: The participant often over-deleted, deleting the entire current word and part of the previous word too, since he held down the delete key with their left hand, which is not his dominant hand.	U05-27: When the participant became really annoyed and frustrated at fixing typos and the slow typing speed, so the participant put down the toothbrush and typed with both hands.	U05-28: When the text the participant had to enter was very long, the participant put down the toothbrush, and typed with both hands.
U05-29: When typing with both hands, the participant made much fewer errors, since each thumb was able to type on a different half of the keyboard, thus requiring much smaller jumps between key presses.	U05-30: When typing with both hands (and constantly looking at the phone), the participant was able to use the autocorrect feature effectively and quickly, and manually and quickly pick the intended word from the 3 suggested ones (using either his left or right thumb).	U05-31: When trying with both hands, the participant typed the message much faster, since two hands are functioning at the same time (and also because of the above two reasons, fewer errors and effectively using autocorrects).		
U05-32: The participant searched something on Google using his phone with one hand while walking outside.	U05-33: While walking outside, the participant suddenly came across the idea of PageRank in his mind, and he had an urge to know what it was at that moment (did not want to wait).	U05-34: The participant pulled his phone out from his left pocket and held it with his left hand, opened Google and began typing the search query with his left thumb.	U05-35: The participant made a typo; however, he did not fix the typo because he knew that Google would be able to know what he was searching for even with a typo.	U05-36: Although Google could recognize typos, the participant did not purposely skip any letters to speedup typing.
U05-37: The participant skipped special characters (e.g., hyphen, underscore), symbols, numbers etc, since to enter these, the participant had to switch to a different keyboard.				

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U03-01	U03-02	U03-03	U03-04	U03-05
He was on the public transport, he was walking and holding a bag in the other hand. He stopped to text to a friend standing, and was not able to type really well.	He was having a lot of typo issues, and he didn't even want to fix it, and just sent it regardless of the errors.	He didn't bother fix the typos because he knew the recipient would understand anyways.	He thinks his finger is too thick and he scraped the spacebar when trying to text, and he had unwanted blank spaces in the middle of the words.	The user uses G-board, which allows a mix of three language keyboards (able to type umlaut and accent symbols) and has a row on top for number keys.
U03-06	U03-07	U03-08	U03-09	U03-10
Finding punctuation is hard with a single hand. He needs to switch to a punctuation keyboard, and the switch key is on the other (left) side of the phone screen.	He had to put his thumb in an awkward position (over-extending) and it felt like he would drop the phone like that.	When his thumb reached the left side of the screen, his palm would touch some keys unintentionally.	He did not have autocorrect on because he thinks it is intrusive and forces autocorrect on stuff that he thinks shouldn't be corrected, especially so since he has a multilingual keyboard.	His keyboard's autocomplete suggestions were on, but the content he typed was too easy and he just ignored autocomplete suggestions and just typed manually.
U03-11	U03-12	U03-13	U03-14	U03-15
He doesn't have auto capitalization and he capitalized manually.	He did try to capitalize words once with one hand and realized it's too hard so he stopped capitalizing entirely.	He got annoyed by the fact that he wasn't typing properly with one hand and so he wanted to sit down.	He sat down on a seat and freed up his other hand so he could type with both hands.	He did not walk and text because he thinks it is dangerous and inefficient. He would never text and walk.
U03-16	U03-17	U03-18	U03-19	U03-20
He had the height of the keys adjusted to make it easier to type beforehand.	He still typed wrong with both hands. He had a smaller phone, and keys are smaller as result.	It was easier for him to go to the punctuation keyboard with both hands, but there are 3 rows of punctuation and it is hard to locate the one that he wants	On average, he does not use most of the punctuations on the keyboard. He only frequently uses a handful common ones.	He did not use the auto-period feature (with a double type of space) but because he needs to type multiple spaces, and the feature would insert periods where he doesn't want.

Fig. 53. Franklin's Interpretation

U01-01 The participant wanted to schedule an interview time with a company recruiter via email while they were eating after seeing an email notification pop up. The participant was using chopsticks with their right hands, and texting with their right hand. The participant is multitasking.	U01-02 When typing their email reply, they used the return key very frequently in order to format the email so that it looked professional. Each time they hit the return key, they would unintentionally touch the scrollbar or delete key. They had to retype or delete the accidental key presses, slowing down their typing speed.	U01-03 The participant had trouble reaching the keys on the right half of the keyboard. They had to constantly readjust the phone by tilting against their palms in order for their thumb to reach the right-most keys. The participant's hands were relatively small for an Pixel 7 Pro display.	U01-04 The participant frequently switched from typing words via individual keys to swipe typing the words. They swipe typed longer words and used individual keys for shorter words.	U01-05 The participant frequently changed their wording and sentences by selecting individual words instead of using the delete key. The sentences are positioned at the top of the screen, so the participant had to constantly shift the phone up and down in order to reach those words.
U01-06 Participants used the long press delete feature to delete many words at once, but often deleted more words than intended.	U01-07 The participant used the word predict feature as frequently as possible to reduce their need for typing.	U01-08 Participant heavily relies on autocorrect frequently to correct simple mistakes, and continues to type even when it predicts incorrectly.	U01-09 Participant manually corrects errors after finishing writing the sentence	U01-10 Participant wanted to ask the recruiter a question and needed to type a question mark. It took the participant a lot longer to find where the question mark is on the keyboard because they were unfamiliar with the layout. Participants had an initial reflex to reach for the bottom right key, as this is where the question mark is found on a standard keyboard.
U01-11 The phone kept sliding down along the table when the participant refocused on eating their food. The participant had to reposition their phone and use their pinky to support the bottom of the phone to prevent slippage.	U01-12 They had to sometimes put the phone down because their thumbs were too fatigued from typing.	U01-13 They wanted to concentrate on eating so that the food doesn't get cold, so they had to put the phone down (flat on the table) to take a break.	U01-14 When the phone was flat on the table, they switched to typing with their index finger. Participants felt that this was more comfortable on their muscles, but reduced their visibility for eating.	U01-15 Food sometimes dropped on their phone's display, since the phone is lying right behind their rice bowl. Participant had to wipe the display before continuing the email, which slowed down their typing speed.
U01-16 Participant liked the ease of typing when the phone is flat on the table and the visibility of holding it with their left hand, and often switches between both methods.	U01-17 The participants also texted their parents in Chinese while eating. They used the PinYin input method and used the predictive feature to type characters.	U01-18 The predictive feature is sometimes mispredicted, so they have to click on the bottom arrow to expand the keyboard and scroll within a table of characters to find the specific character they want. It is hard to find the specific character because they all look quite similar.	U01-19 Participant often misclicks the voice recognition key because it is positioned at the bottom arrow expansion button.	

Fig. 54. Isaac's Interpretation

C.2 Individual Sequence Diagrams

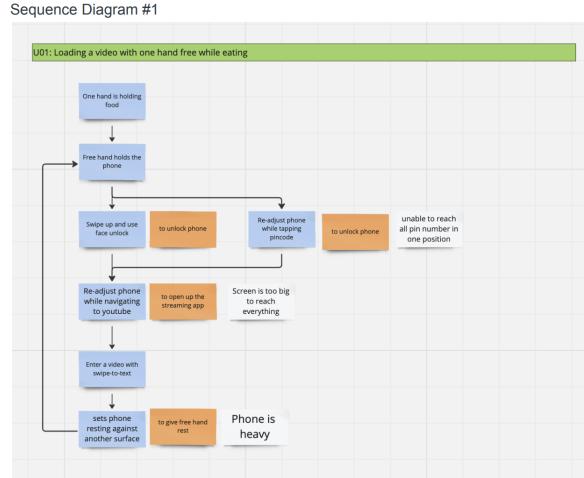


Fig. 55. Daniel's Sequence Diagram 1

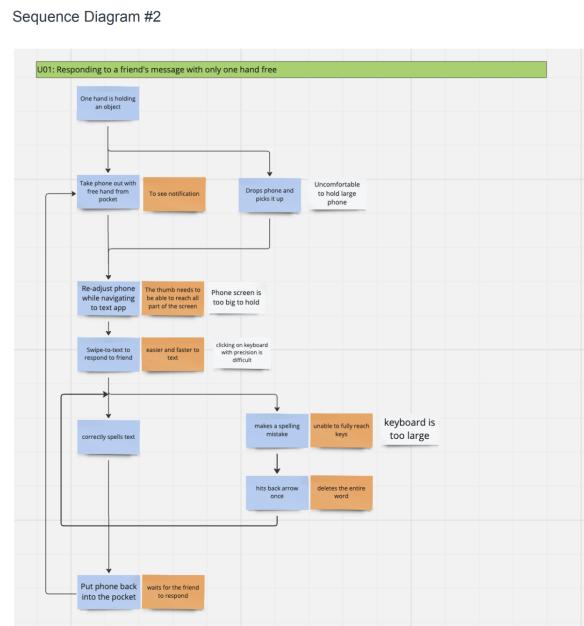


Fig. 56. Daniel's Sequence Diagram 2

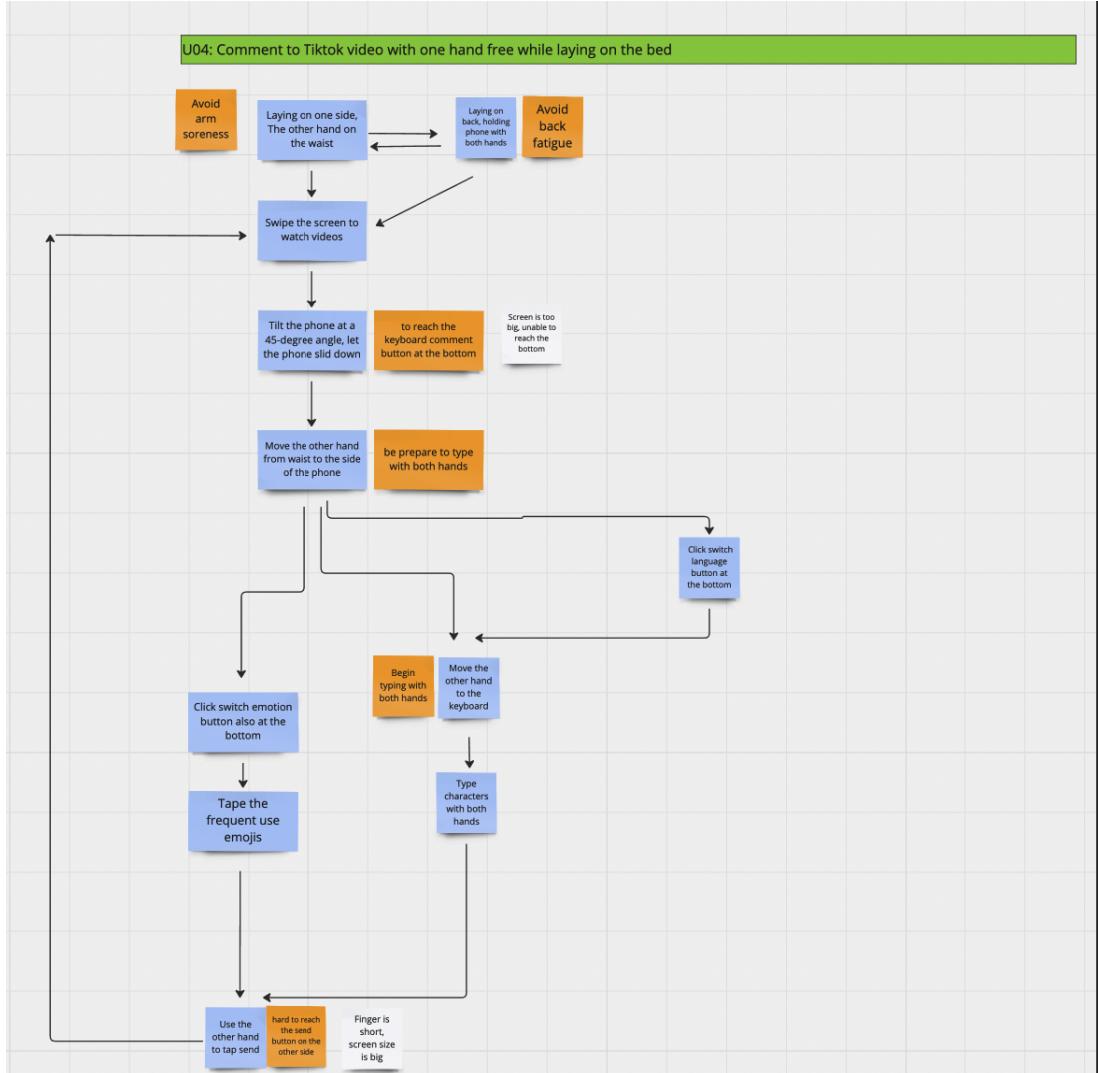
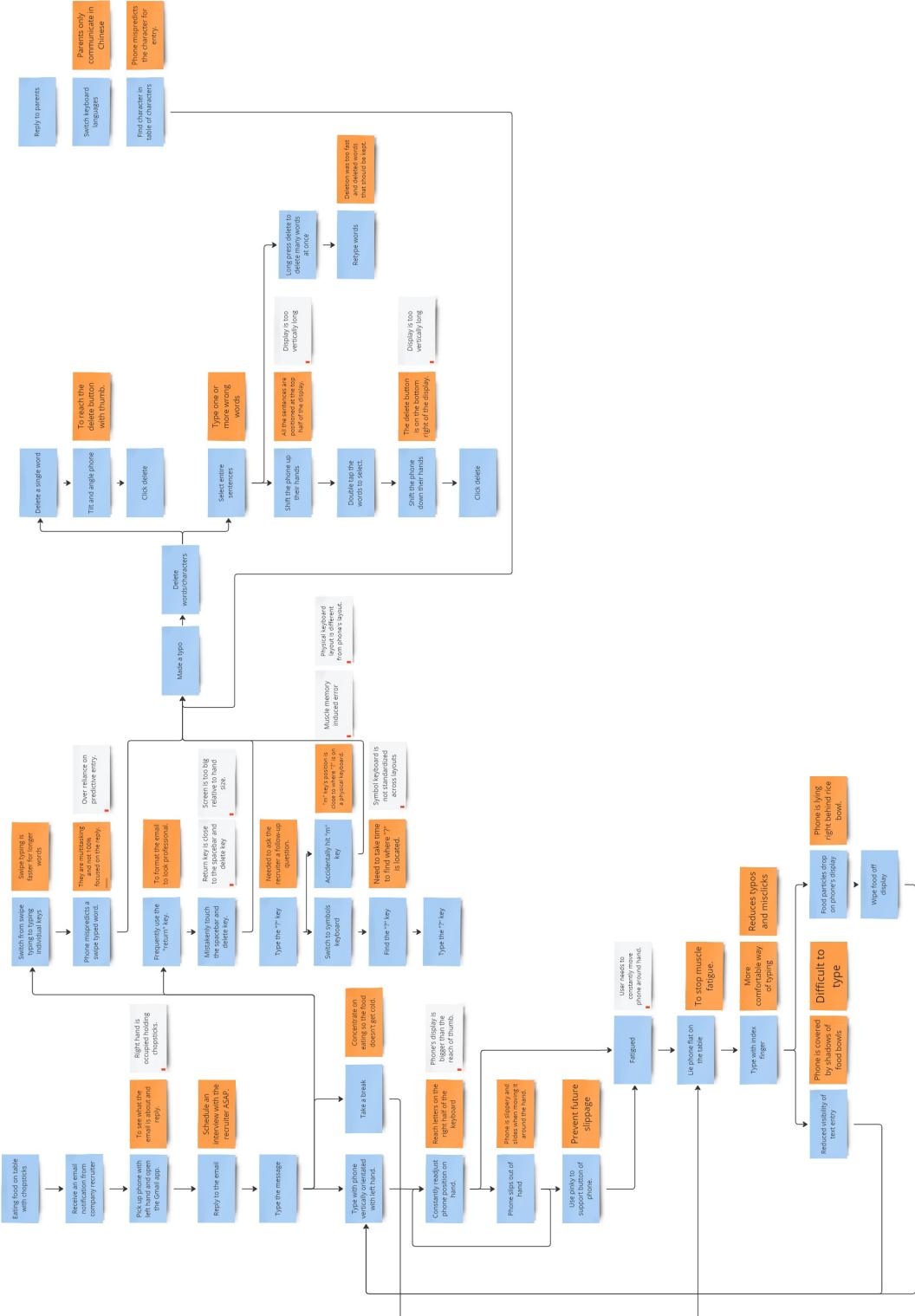


Fig. 57. Yichen's Sequence Diagram

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Fig. 58. Isaac's Sequence Diagram

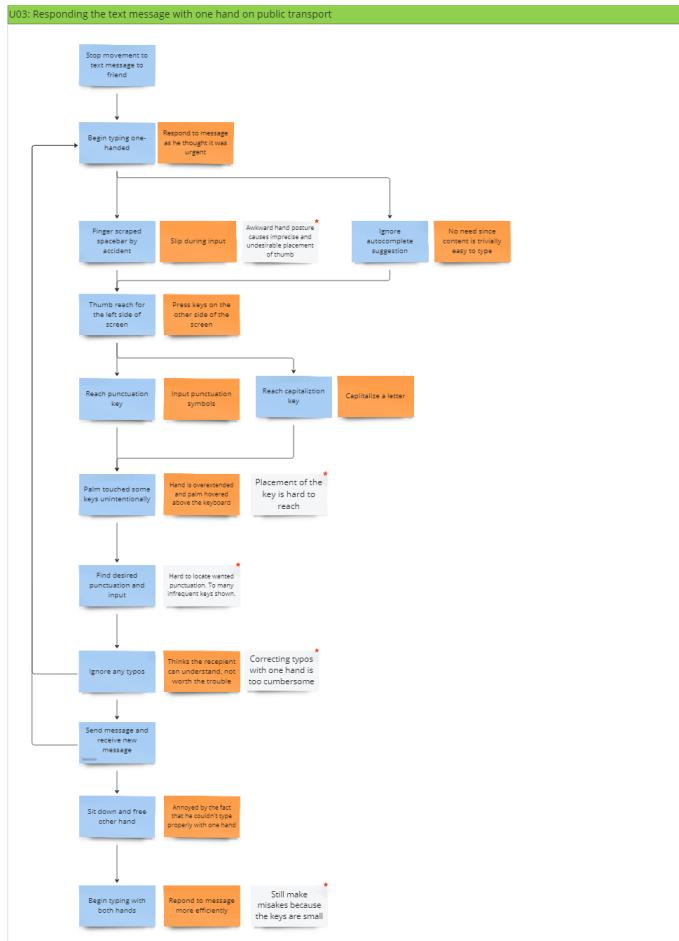


Fig. 59. Franklin's Sequence Diagram

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U05: Reply to a friend's message with one hand while walking outside

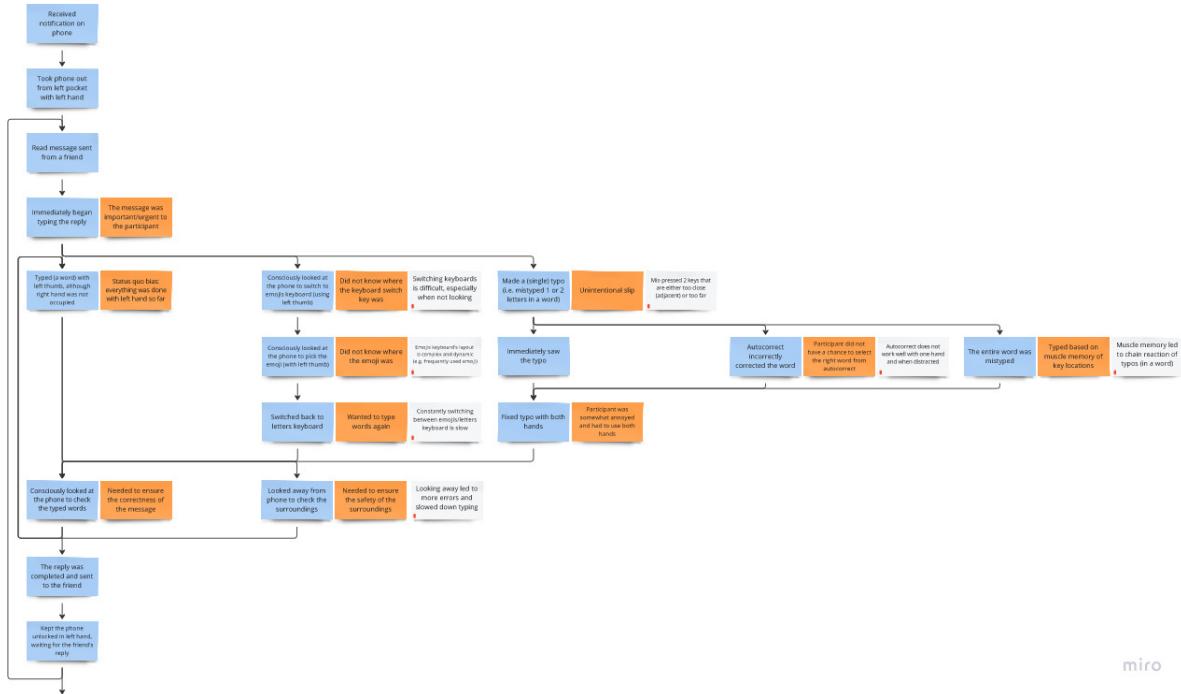


Fig. 60. Jerry's Sequence Diagram 1

U05: Text friend while brushing teeth in the bathroom

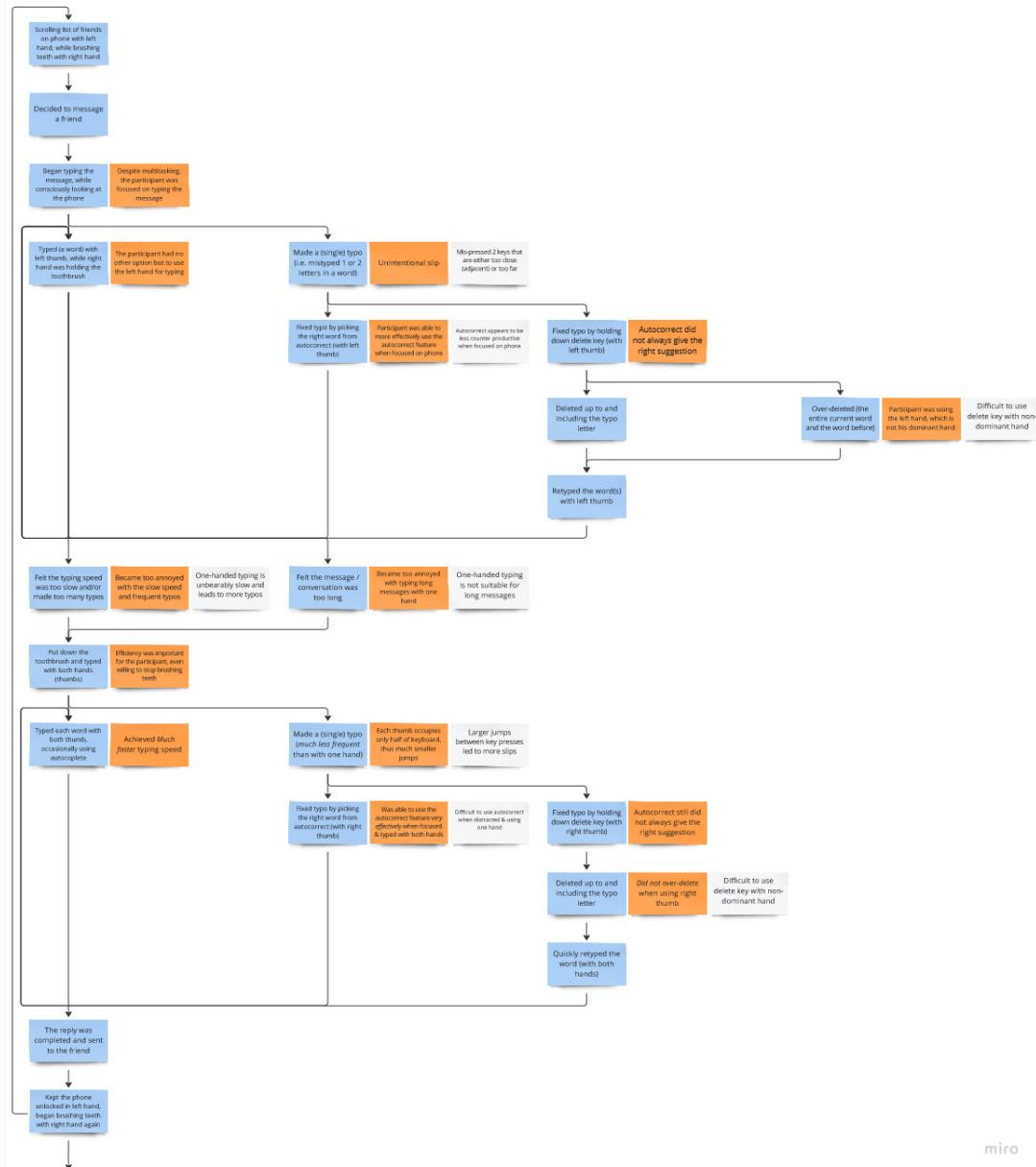


Fig. 61. Jerry's Sequence Diagram 2

Improving One-Handed Textual Entry on Mobile Devices

U05: Google search using phone with one hand while walking outside

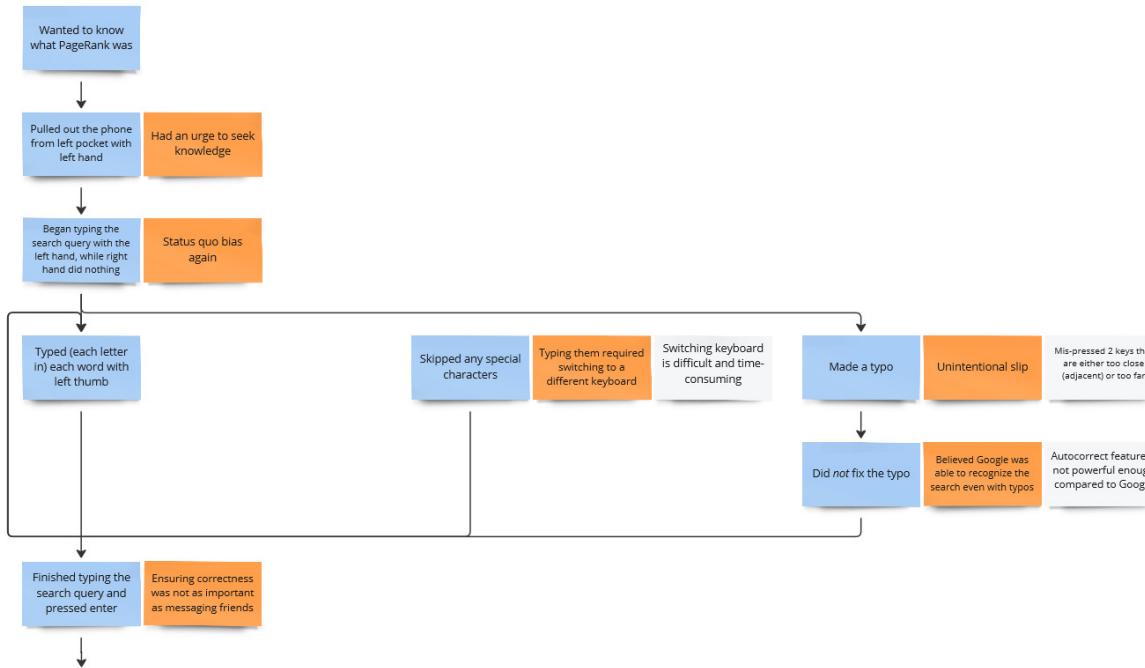


Fig. 62. Jerry's Sequence Diagram 3

C.3 Individual Flow Diagrams

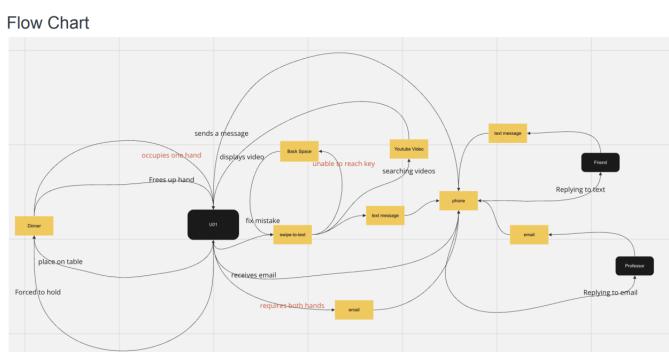


Fig. 63. Daniel's Flow Chart

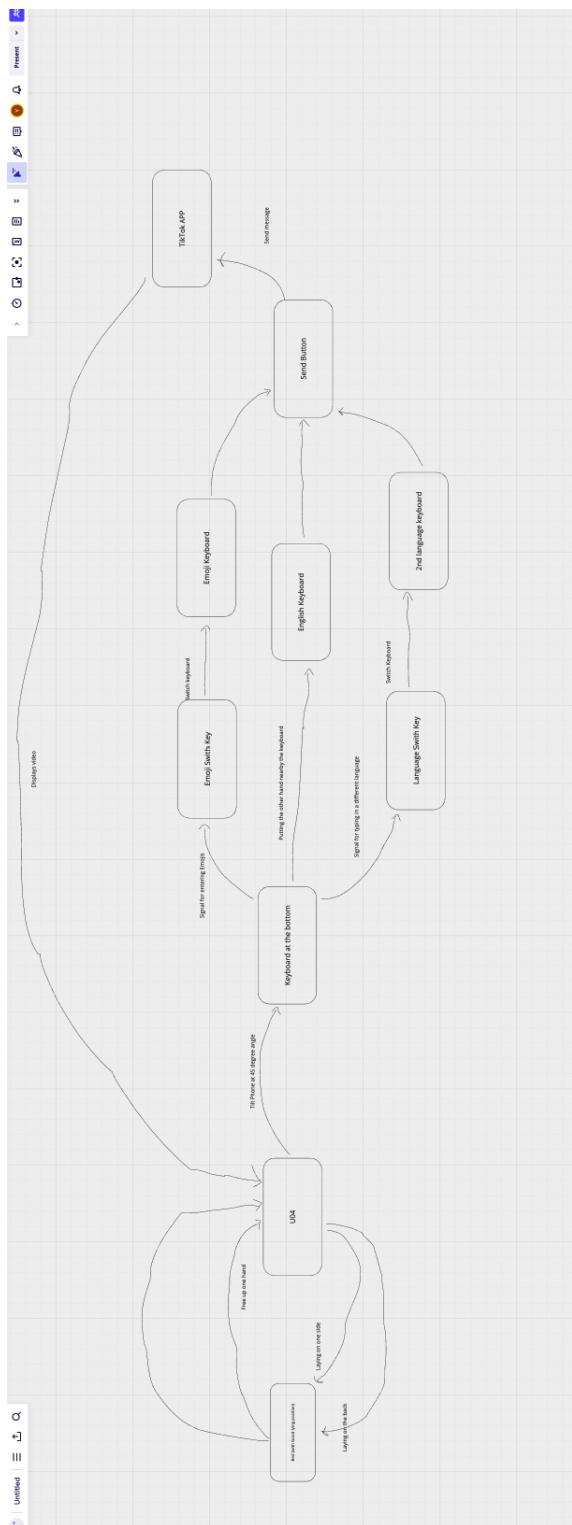


Fig. 64. Yichen's Flow Chart
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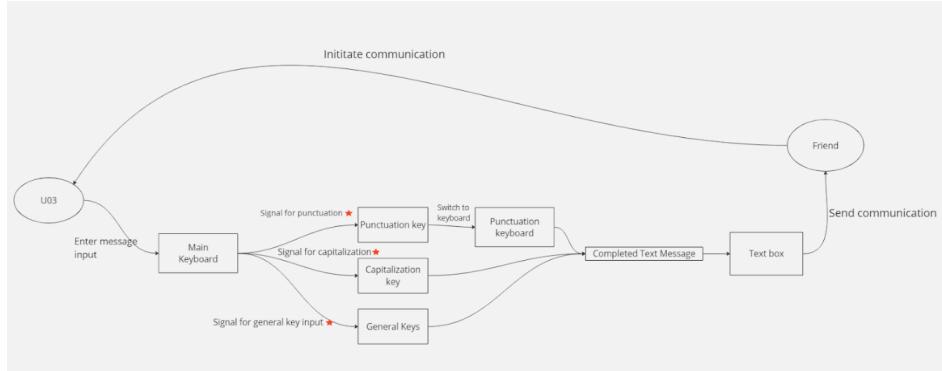


Fig. 65. Franklin's Flow Chart

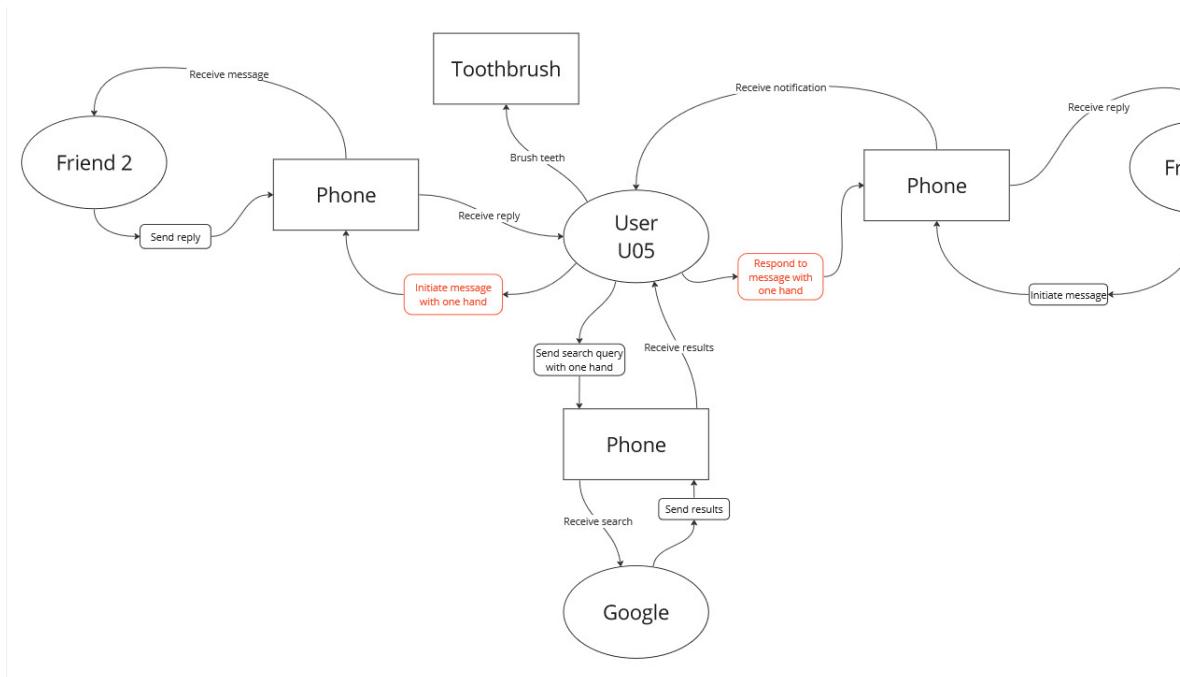


Fig. 66. Jerry's Flow Chart

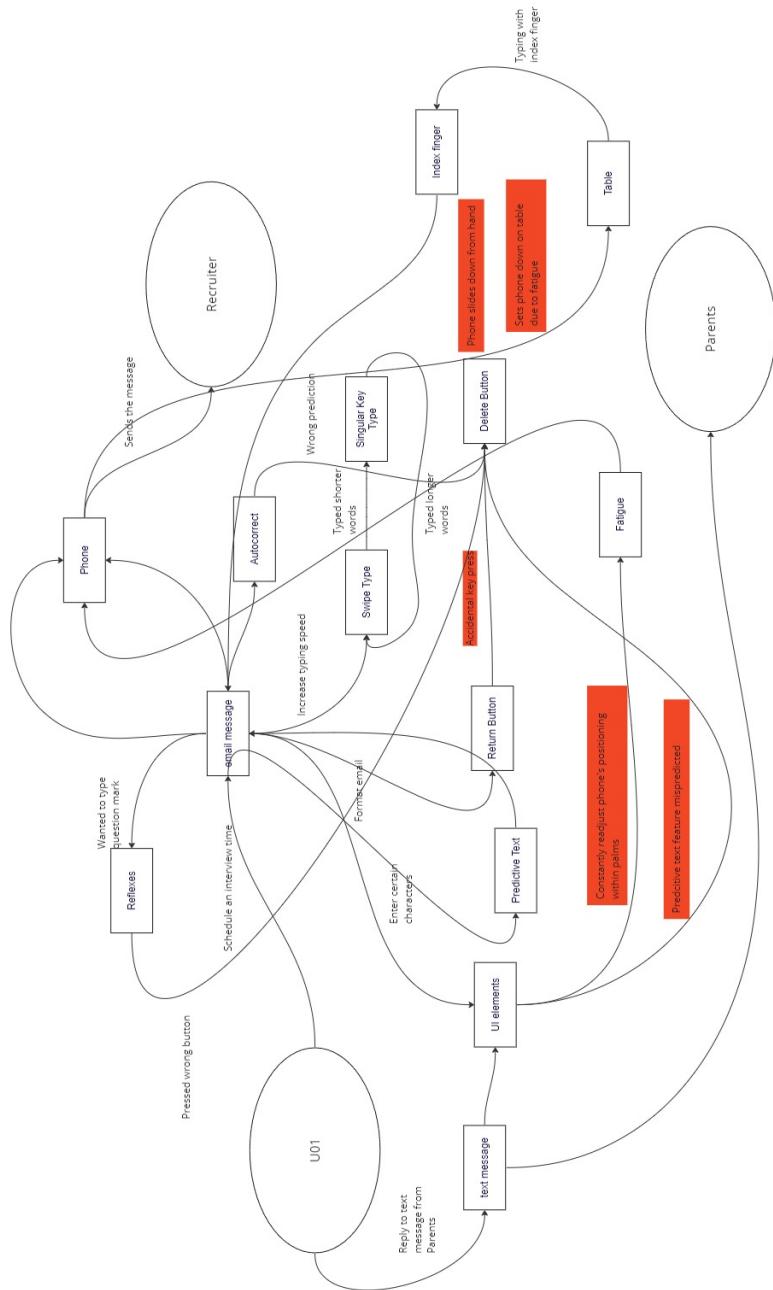
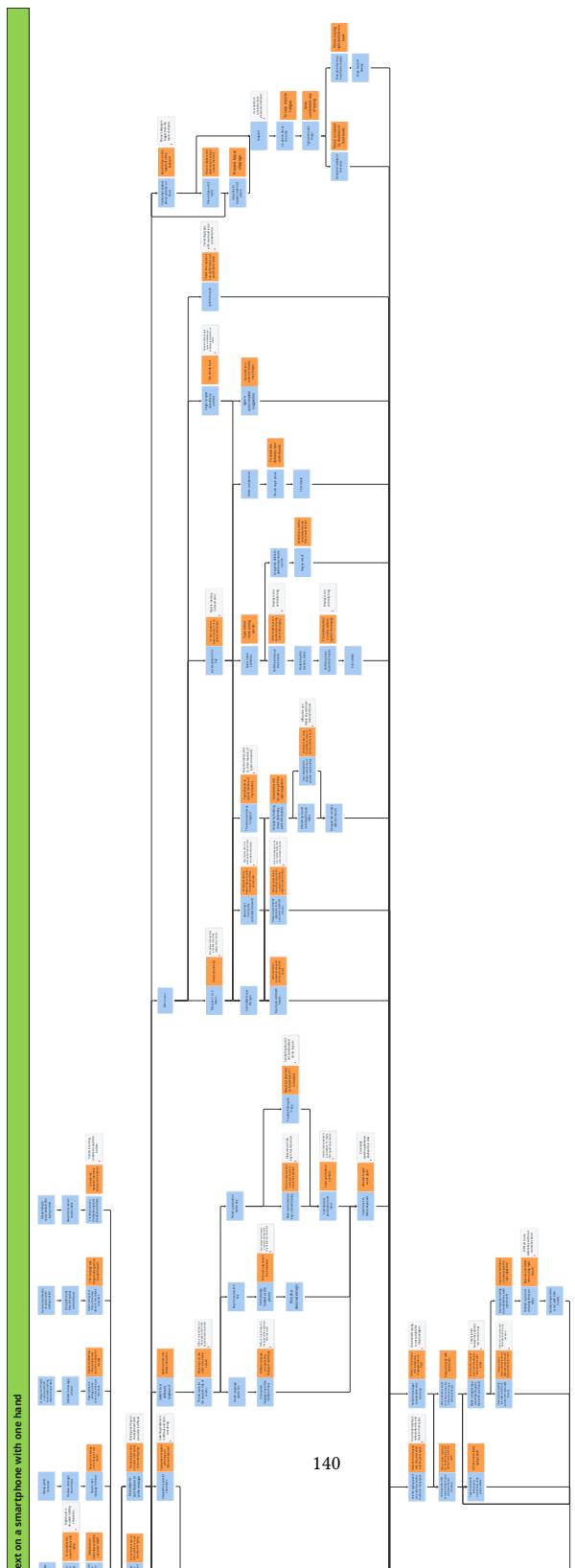
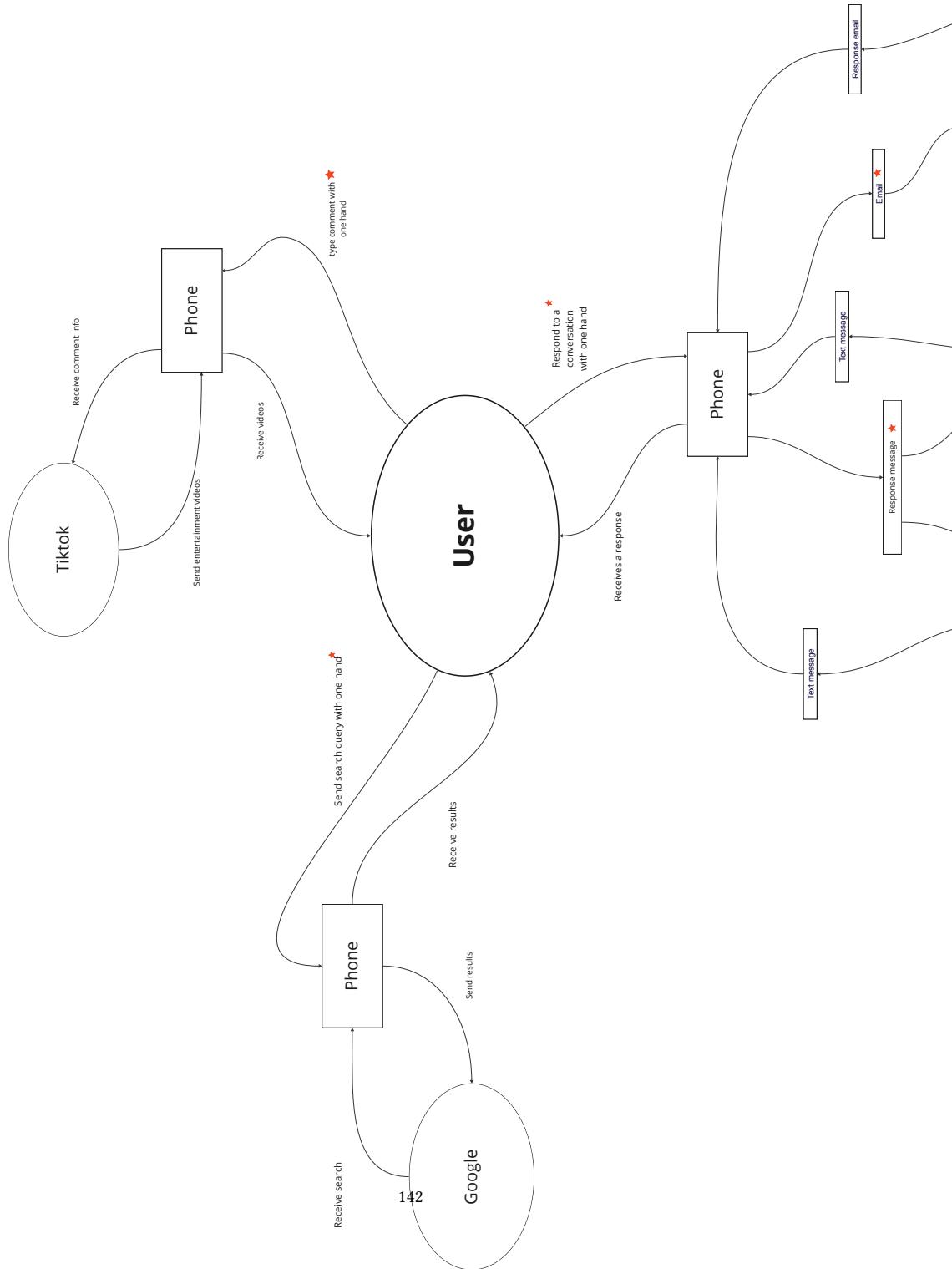


Fig. 67. Isaac's Flow Chart

C.4 Consolidated Sequence Diagrams



C.5 Consolidated Flow Diagrams



C.6 Affinity Diagram

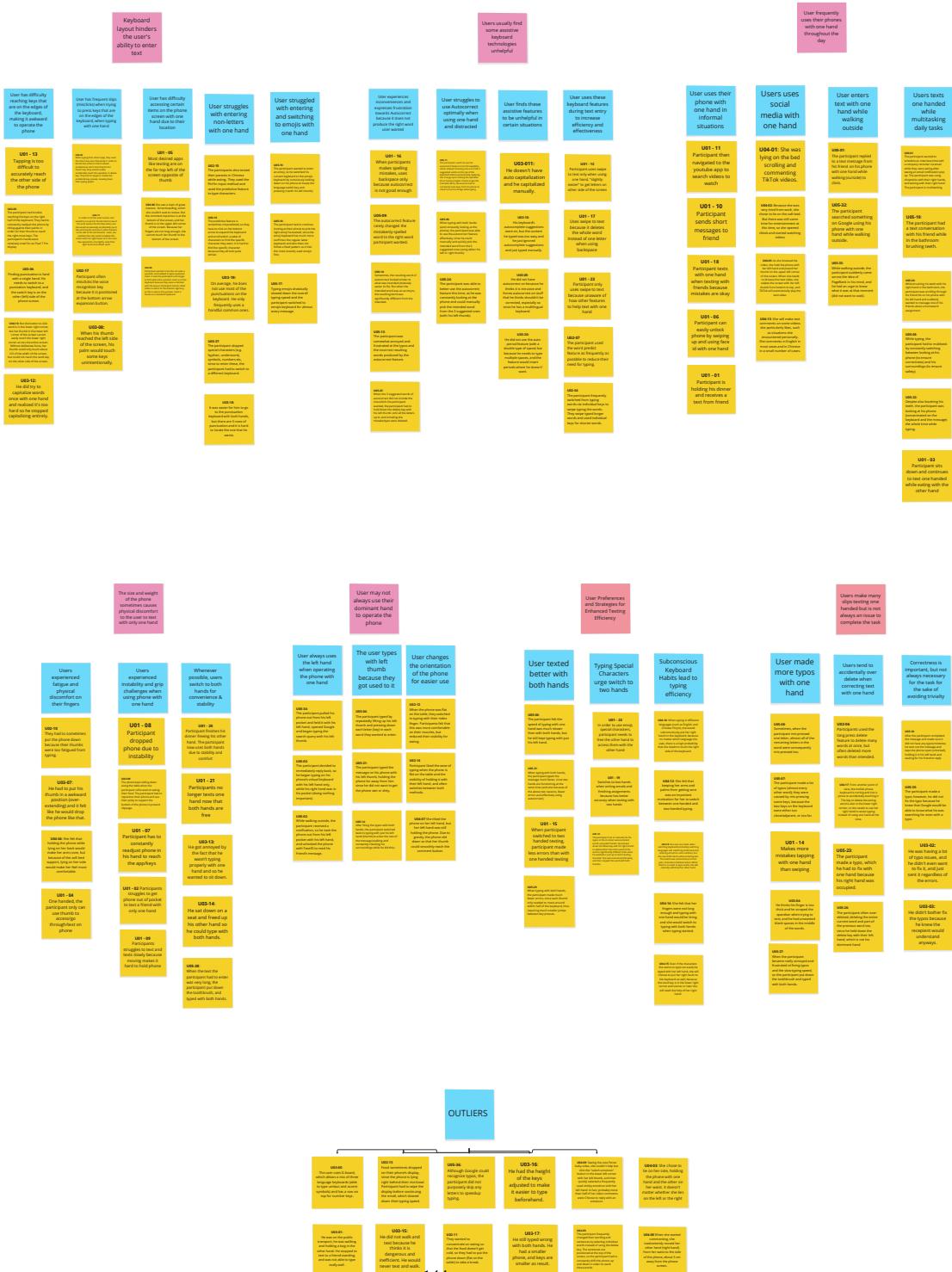


Fig. 70. Consolidated Affinity Diagram. [Link to affinity diagram on Miro Board.](#)

D LOW FIDELITY PROTOTYPES

D.1 Individual Personas

Daniel's Individual Persona: My persona is grounded on the following interpretation notes from the affinity diagram: U01-01, U04 - 02, U02 - 01, U03 - 08, U05 - 07, U01 - 23, U01- 18, U01 - 19, U05 - 20. My persona is named Robert. Robert is a 19 year-old male college student who uses his iPhone daily. While he holds his phone with both one or two hands, Robert mostly holds his phone with one hand at home because he needs at least one hand to do chores like cooking or brushing his teeth. Additionally, Robert comes home exhausted from classes, so he prefers to use minimal effort needed. At home, Robert mostly uses his phone to communicate with his friends and professors about assignments. He communicates with his friend via text and his professor via email. While he does not care too much about typos when texting, he wants his emails to be error free to appear more professional. He faces many challenges when he types one handed on his phone keyboard. His iPhone is larger than his hand, so he needs to support his phone using his pinky on the bottom. However, this limits his ability to text accurately and quickly since he needs to constantly overextend his thumb across the keyboard. Therefore, Robert has to choose between making typos or dropping his phone. He is aware of a few assistive features like swipe-to-text features to increase the typing speed, but Robert still has to extend his thumb which tires his hand. Furthermore, many UI elements in the email app are on the upper end of the screen, so Robert has to constantly readjust his hand to reach those elements. This resulted in Robert dropping his phone a couple of times.

Yichen's Individual Persona: Name: Rita, Profile:

- Works at a technology company
- Female, Mid-20's, Single
- Bilingual, fluent in English and Chinese
- Rent in the city apartment
- Uses an iPhone, specifically, iPhone12
- Frequently types with one hand
- Has few friends nearby, goes home directly after work
- Enjoys browsing TikTok videos
- Be willing to share and interact, and like to share ideas with others
- Pet lover, has a ferret

Rita is a tech-savvy young woman in her mid-20s, currently employed at a prominent technology company. She's a bilingual talent, fluently speaking both English and Chinese, a skill that serves her well in her professional and personal life. Rita resides in a cozy city apartment and relies on her trusty iPhone 12 for all her digital needs. Frequently typing with one hand, she's become adept at multitasking on her device. Her limited circle of friends in the city means she typically heads straight home after work, where she's greeted by her beloved ferret, her furry companion in her city life. Rita's leisure moments often involve leisurely browsing TikTok videos, a platform where she enjoys sharing ideas and interacting with the online community. Whether it's tech insights or adorable pet antics, Rita is always willing to share and engage with others. Rita is a laid-back individual who knows how to unwind after a long day of work. Her favorite post-work ritual involves reclining on her bed, typically resting on her side. With her trusty smartphone in hand, she holds it with her left hand, her thumb strategically placed on the upper left corner of the screen for easy access to her favorite apps. Rita's online journey often takes her through a fascinating

blend of English and Chinese content, seamlessly switching between keyboards as she navigates the digital landscape. Whether she's catching up on the latest TikTok trends or communicating with friends in different languages, Rita's tech-savvy approach to relaxation perfectly complements her modern and multicultural lifestyle.

Franklin's Individual Persona: Thomas is a graduate student in his mid-twenties who majors in political science. He comes from a cosmopolitan background and is quadrilingual (Mandarin, Wu, English, Japanese), and knows German as his secondary language. He uses android smartphones and a third-party keyboard to make typing easier, but he still finds issues with it. He normally does not type one-handed unless he is in a situation that forces him to do so. His dominant hand is his right hand. Thomas lives in an apartment outside of campus. Everyday he commutes to campus via public transportation (bus, subway, etc.). He usually communicates with his friends by Discord on his smartphone. Thomas is a very tech-savvy person, and also a tech junkie who pays attention to the most state-of-the-art computer hardware news, despite not being an engineer-person himself. He likes to watch youtube videos about tech in general. He is very knowledgeable about his needs regarding technology and knows how to min-max the performance of his technologies. He usually knows the ins and outs of the things he uses and the configuration behind them. He is very good at getting the most out of his tools under a reasonable budget while making life much easier. His friends usually consult him if they want to build their own PCs. Thomas in general is a curious and cultured person. He likes to learn about new things, even those that are outside of his expertise. He enjoys learning about other cultures and languages. He has also traveled and studied in different countries. He enters multiple languages on his phone and he uses his third-party keyboard that allows a mix-lingual keyboard (inputs French/German/English).

Isaac's Individual Persona: Jack is a 21 year old college student who is currently studying business management. He is in his fourth year of college, so his daily life is extremely hectic and busy. Not only does he want to get good grades in class, but he also needs to juggle his spare time between studying, his social life, and job searching. Therefore, more often than not, during his free time, he finds himself consistently multitasking between many tasks. His primary goal right now in life is to find a job before he graduates. Therefore, he is always looking for potential emails from companies to see if he got rejected or moved on to the next round of interviews.

Like many other people his age, he is extremely addicted to his phone. He finds himself constantly checking his phone and getting sidetracked. Whether that be while eating, walking, or brushing his teeth, he is always glued to his phone. He feels that his mobile phone is a part of his identity. In addition, his phone is always next to him because he wants to be notified as soon as possible whether someone texted him or when he receives an email. He wants to be constantly updated with the most recent news and feels bad if he leaves someone on read, so he will reply as soon as possible. Jack is also bilingual, he speaks both Chinese and English. He mainly speaks Chinese to his parents, and uses English during the day. The apps that he uses daily are WeChat, TikTok, Gmail, Chrome, and the Notes app. He finds himself always switching between these few apps, as well as needing to type one-handed while using these apps on the go.

Jerry's Individual Persona: Kevin is a 21-year-old college student in the US who uses his iPhone everyday. He identifies as Asian and is fluent in English, Mandarin/Chinese, and Korean. However, he mainly uses English whenever performing any tasks on his phone. He is right-handed and does not have any physical disability [Referencing survey and contextual inquiry participants]. Usually, Kevin uses his phone with both hands when he is exclusively focused on just the phone. However, whenever Kevin uses his phone when he is performing other tasks or when one hand is

occupied, such as eating, brushing his teeth, walking outside, on public transportation, and lying on his bed, all of which also happen very frequently, he tends to operate his phone with just one hand [Referencing context of use identified from the affinity diagram and specific interpretation notes]. In the situations when he is using the phone with one hand, Kevin is either messaging his friends and family, browsing social media like YouTube and TikTok, or searching things on Google. All of these activities involve entering text using the virtual keyboard on the phone with just one hand, which Kevin significantly struggles with, specifically in terms of

- (1) the high frequency of typos;
- (2) difficulty in fixing the typos caused by counterproductivity of autocorrect and delete;
- (3) inconvenient location of certain keys (like punctuations, emojis, and other special characters);
- (4) uncomfortable size of keyboard and phone leading to difficulty to reach all keys and physical discomfort

Thus, Kevin has the following specific desires/needs.

- (1) Kevin wants to minimize the amount of typos he makes when he is entering text with one hand, which should not be more than the amount of typos when he is typing with both hands [Referencing User Requirement 1].
- (2) Kevin wants to easily fix any typos using one hand without doing any redundant actions (i.e. more than what is necessary) such as
 - (a) correcting mistakenly-corrected words by keyboard assistive features like autocorrect [Referencing User Requirement 2], or
 - (b) accidentally deleting correctly-spelled letters/words not part of the typo [Referencing User Requirement 3].
- (3) Kevin wants to be able to easily locate and enter non-alphabet characters with one hand, including emojis, punctuations, and numbers [Referencing User Requirement 5].
- (4) Kevin wants to be able to comfortably reach all keyboard elements while securely holding the phone with one hand [Referencing User Requirement 4, 6].

In essence, Kevin's high-level goal is to enter text on his phone with one hand accurately (1), efficiently (2, 3), and comfortably (4).

D.2 Individual Sketches

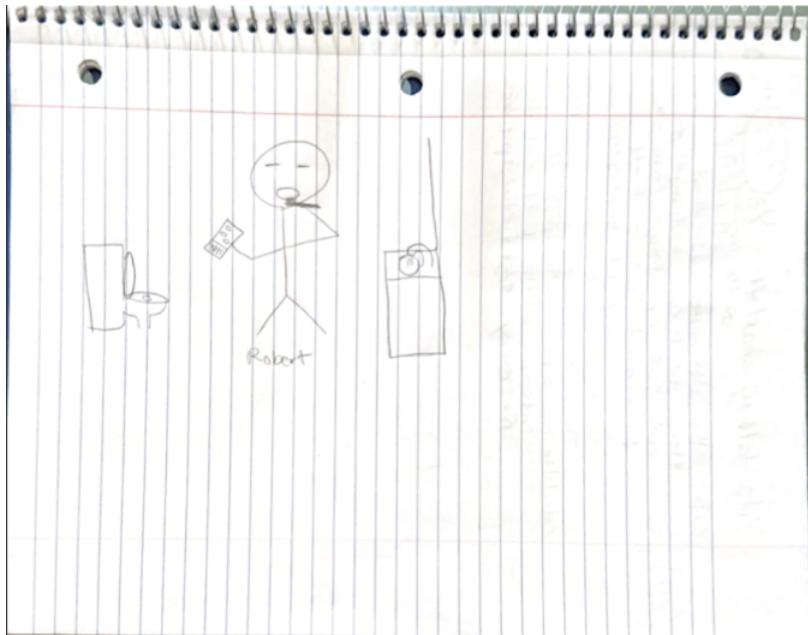


Fig. 71. Daniel Sketch 1

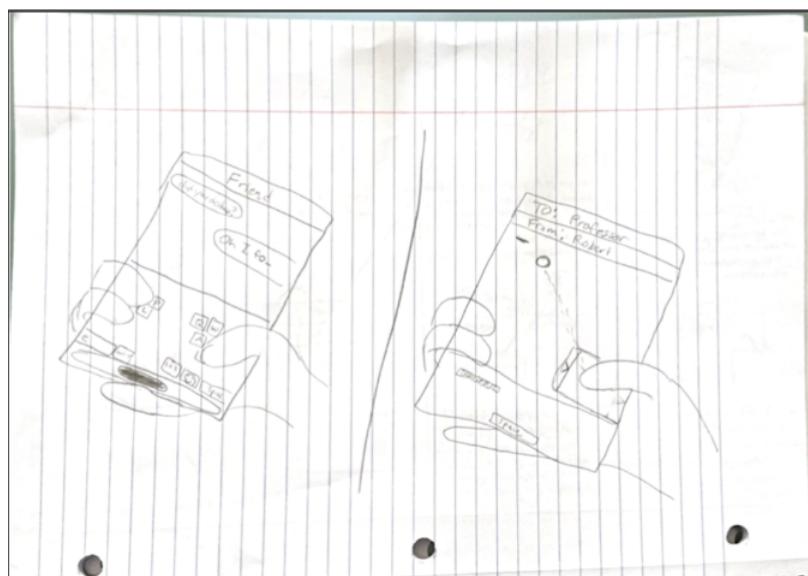
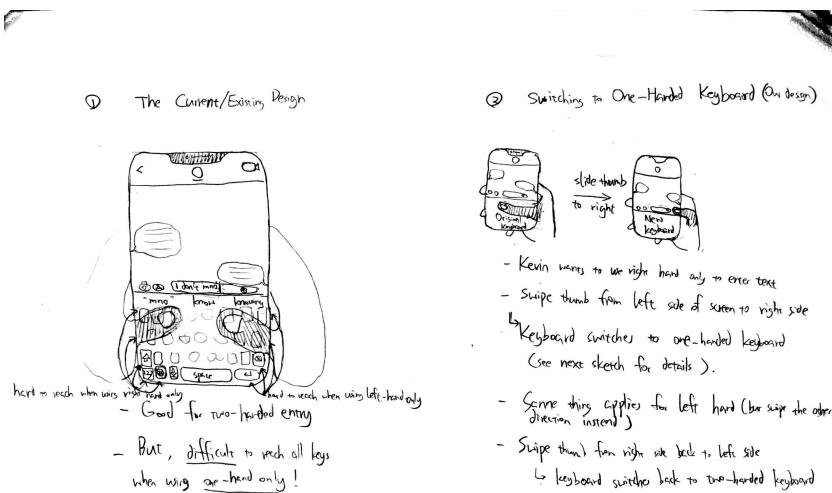


Fig. 72. Daniel Sketch 2

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Scanned with CamScanner

Fig. 73. Jerry Sketch 1, 2

③ My Design Sketch

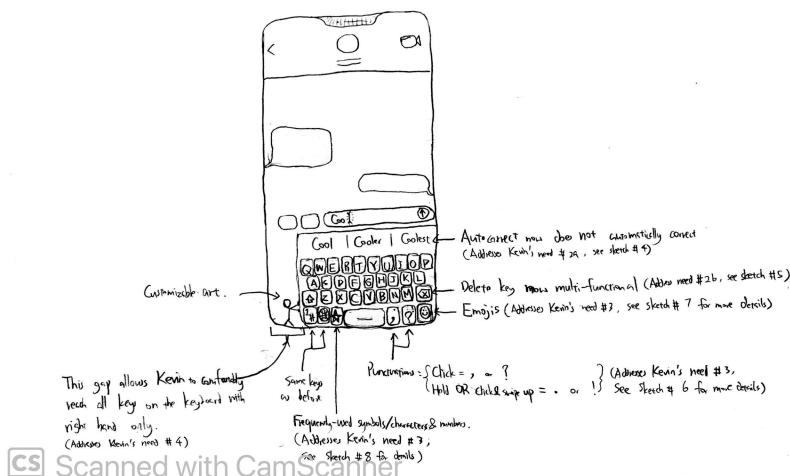
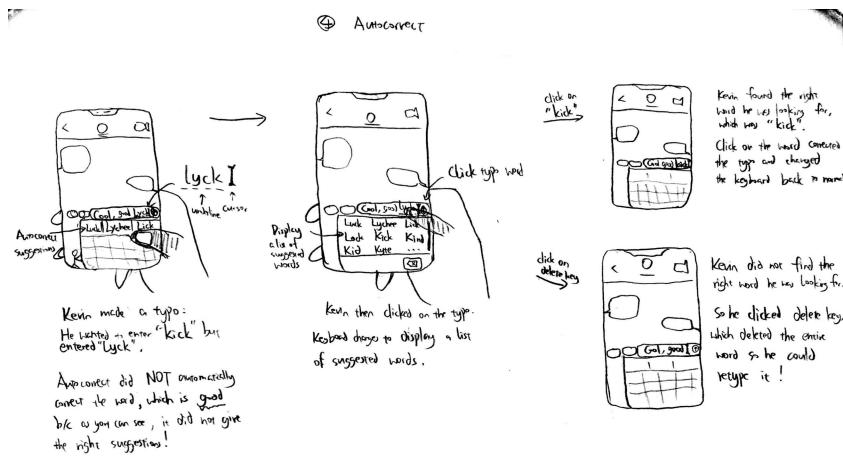
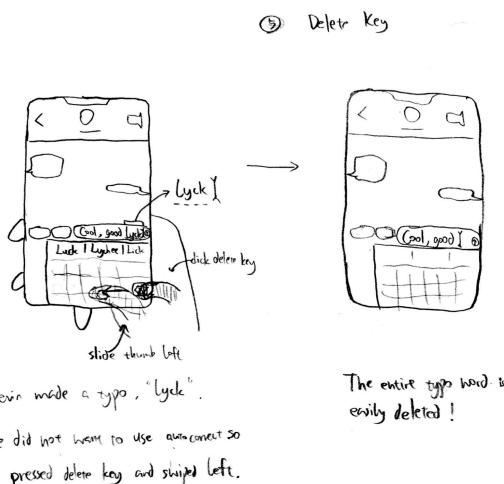


Fig. 74. Jerry Sketch 3



Scanned with CamScanner

Fig. 75. Jerry Sketch 4



Scanned with CamScanner

Fig. 76. Jerry Sketch 5

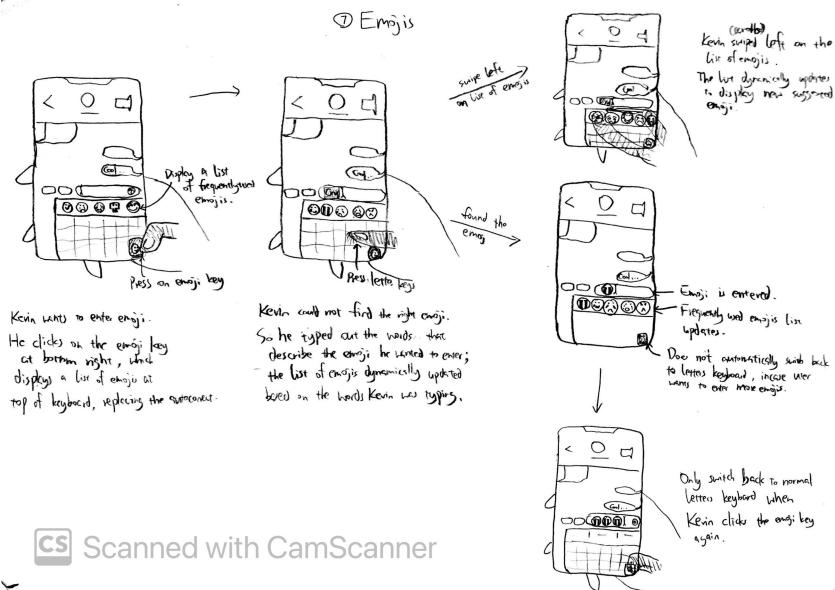
⑥ Punctuation



Scanned with CamScanner

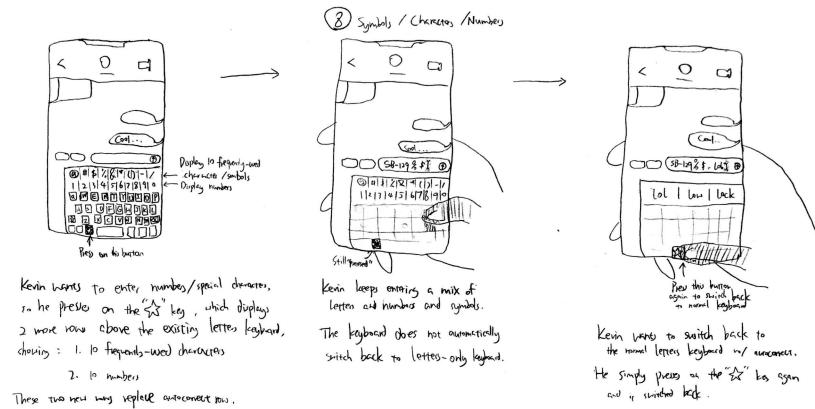
Fig. 77. Jerry Sketch 6

⑦ Emojis



Scanned with CamScanner

Fig. 78. Jerry Sketch 7



Scanned with CamScanner

Fig. 79. Jerry Sketch 8

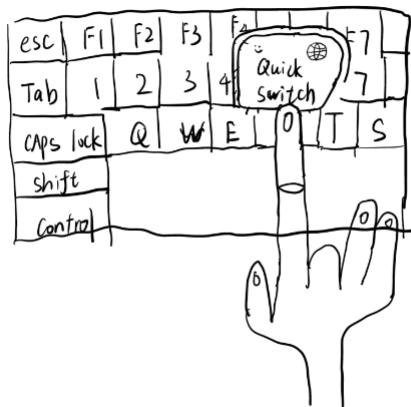


Fig. 80. YiChen Sketch 1: Quick switch function key that can switch among different keyboards (e.g. languages)



Fig. 81. YiChen Sketch 2: One-handed mode that allow users to type in one hand easily

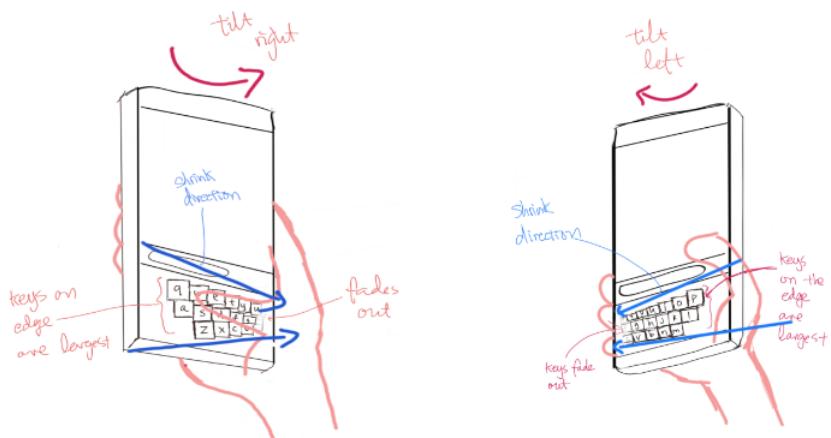


Fig. 82. Franklin Sketch 1 and 2: When the phone is tilted right. When the phone is tilted left

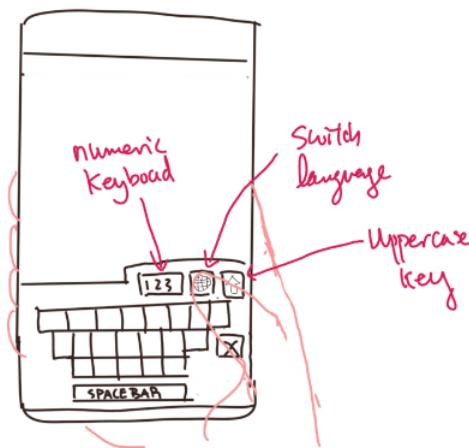


Fig. 83. Franklin Sketch 3: The new layout puts functional keys to the upper right

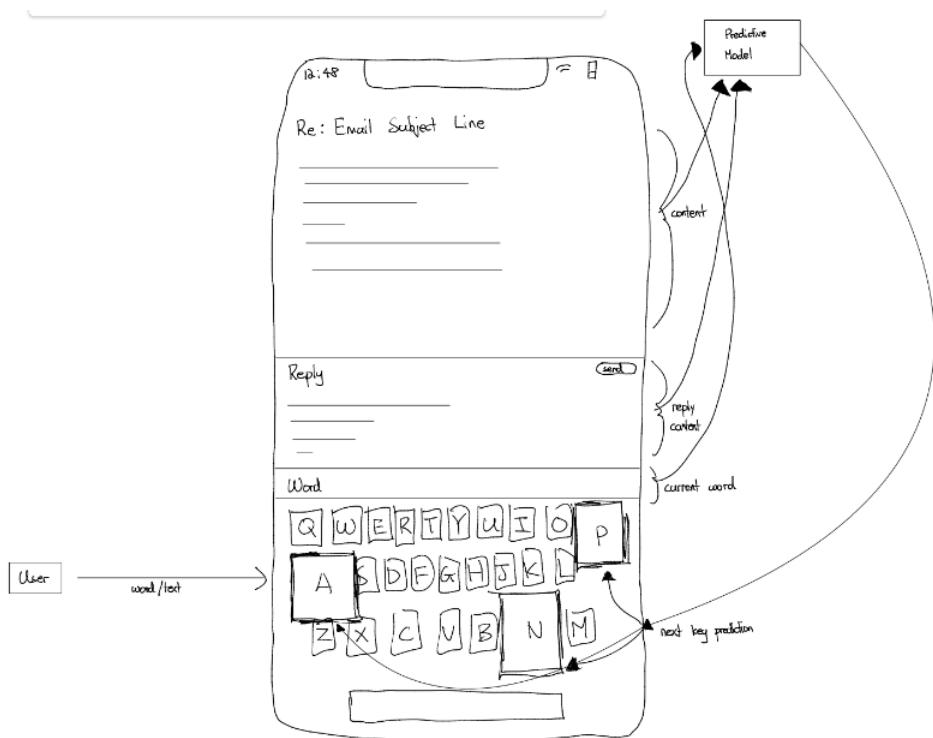


Fig. 84. Isaac Sketch 1: Predictive enlargement feature

D.3 Individual Storyboards

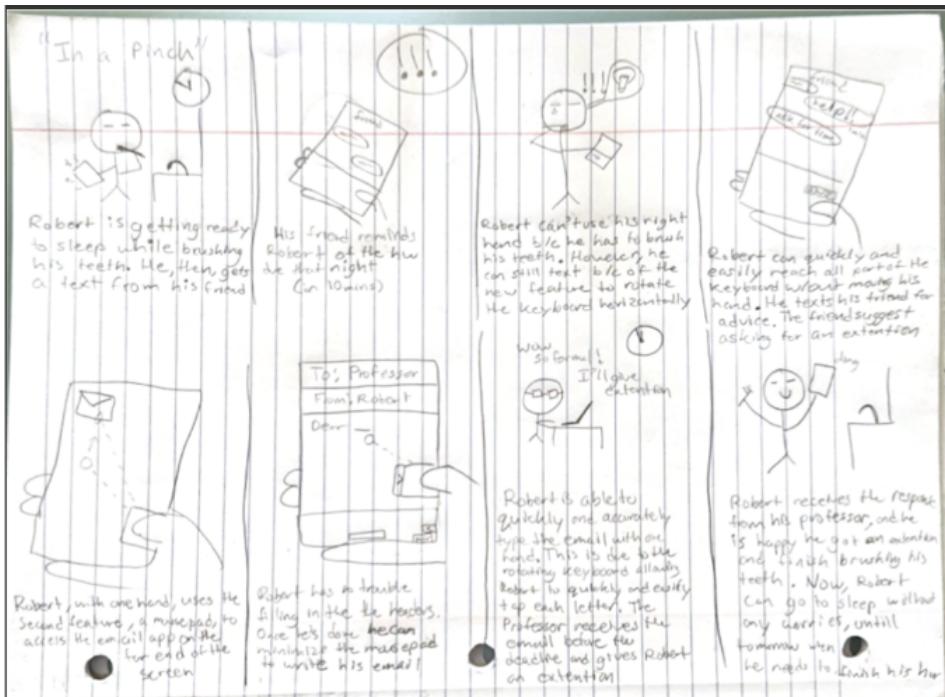
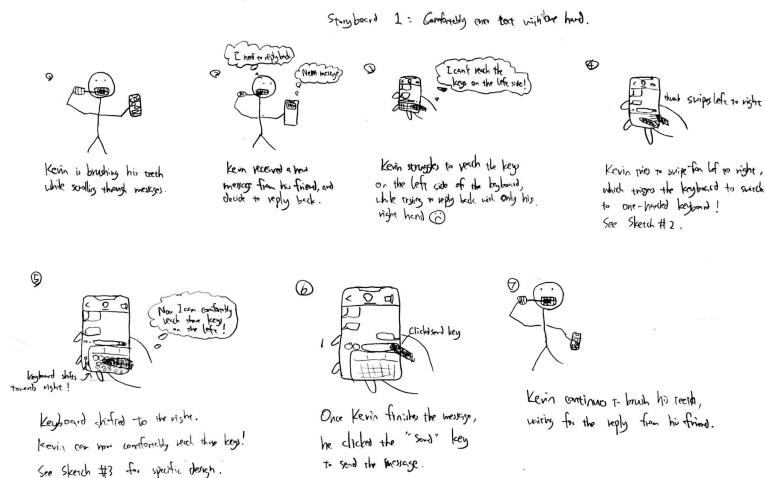


Fig. 85. Daniel Storyboard



Scanned with CamScanner

Fig. 86. Jerry Storyboard 1

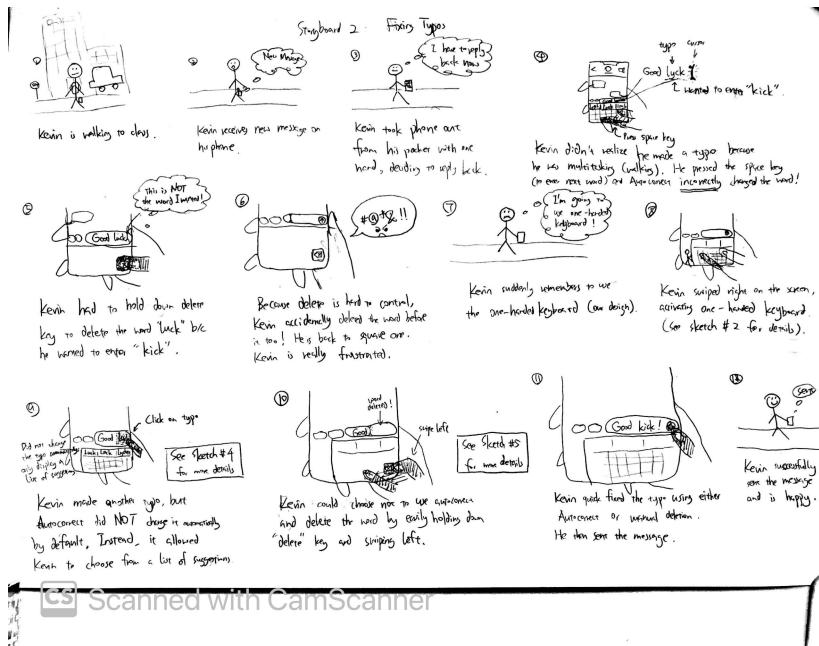


Fig. 87. Jerry Storyboard 2

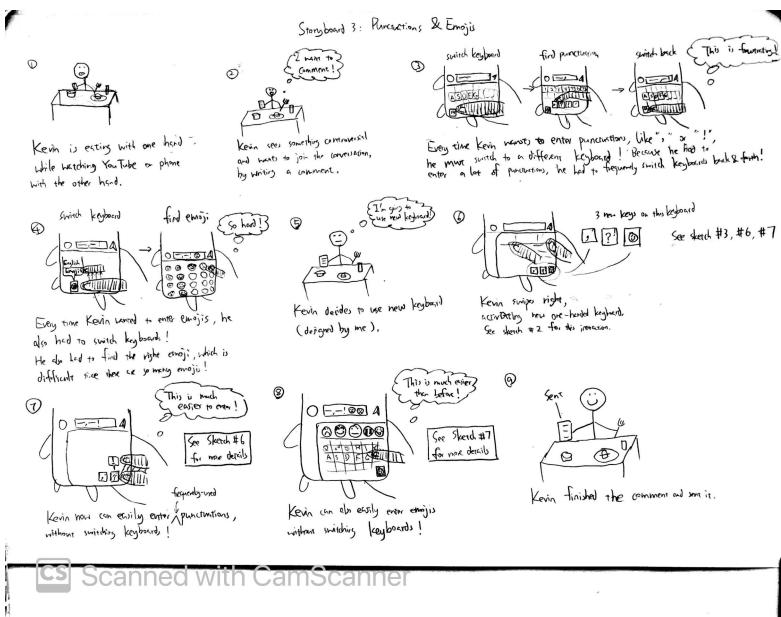
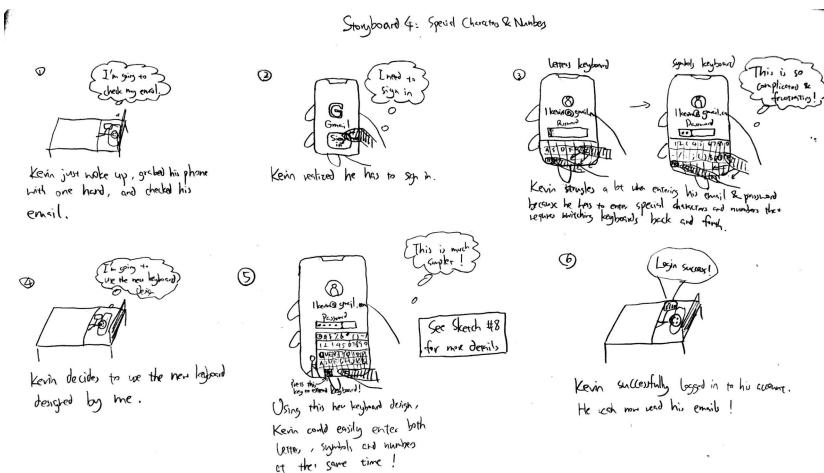


Fig. 88. Jerry Storyboard 3

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CS Scanned with CamScanner

Fig. 89. Jerry Storyboard 4

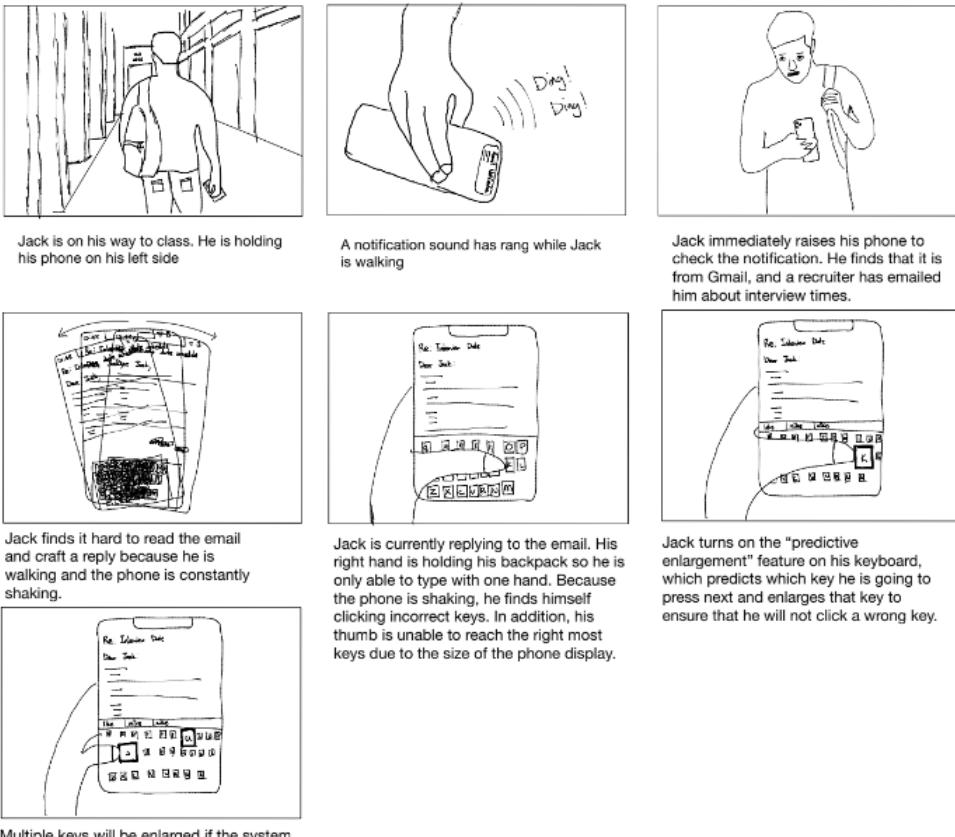
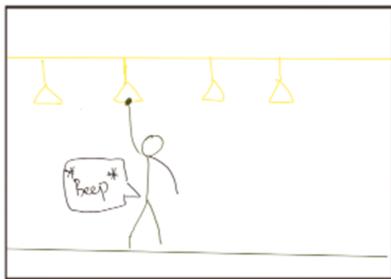
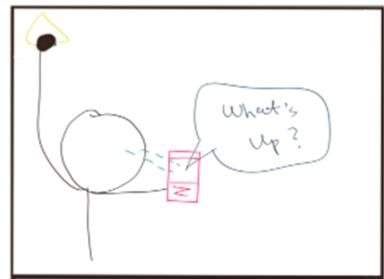


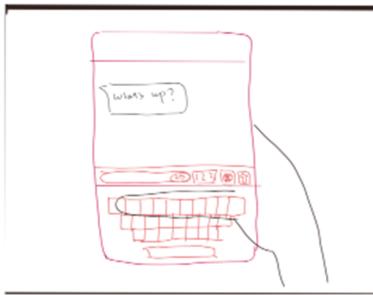
Fig. 90. Isaac Storyboard



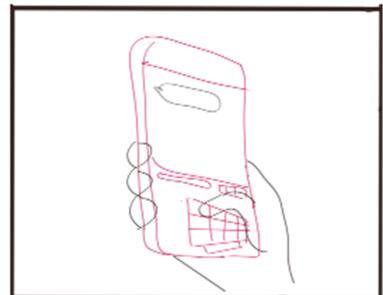
1. Thomas is on the bus, with one hand holding the hand rail. He receives a Discord message from a friend.



2. Thomas sees the message and prepares to type one handed, as his other hand isn't free at the moment.



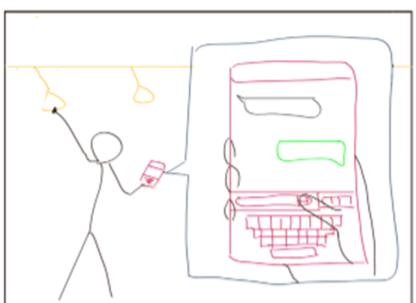
3. If he types normally, when he reaches towards far keys, it can cause a strain on the thumb, creating a bad hand posture, and the palm could touch other keys unwarrantedly.



4. Now with his phone tilted, it is easier for him to reach the farthest keys without compromising his hand posture.



5. He can enter uppercase and switch keyboard with ease by just tapping the keys close to his hand without needing to reach to the opposite end of the phone.



6. Now he can enter text and reply messages comfortably while having a grip on his phone. He does not worry about dropping his phone because he does not let the phone slide in his hand while being able to press the keys he wants with ease.



Fig. 92. YiChen Storyboard

D.4 Final Persona

Name: Jack

Occupation: College student

Age: 21 years old

Jack is a 21 year old college student who is currently studying business management. He is in his fourth year of college, so his daily life is extremely hectic and busy. Not only does he want to get good grades in class, but he also needs to juggle his spare time between studying, his social life, and job searching. Therefore, more often than not, during his free time, he finds himself consistently multitasking between many tasks. His primary goal right now in life is to find a job before he graduates. Therefore, he is always looking for potential emails, text messages, messages on social media from companies to see if he got rejected or moved on to the next round of interviews.

Like many others his age, he uses an iPhone 13 and is extremely addicted to it. He finds himself constantly checking his phone and getting sidetracked. In addition, his phone is always next to him because he wants to be notified as soon as possible whether someone texted him or when he



Fig. 93. Picture of Jack

receives an email. He wants to be constantly updated with the most recent news and feels bad if he leaves someone on read, so he will reply as soon as possible. Jack is also bilingual, he speaks both Chinese and English; he occasionally speaks Chinese to his parents, and mainly uses English during the day. Usually, Jack uses his phone with both hands when he is exclusively focused on just the phone. However, whenever Jack uses his phone when he is performing other tasks or when one hand is occupied, such as eating, brushing his teeth, walking outside, on public transportation, and lying on his bed, all of which also happen very frequently, he tends to operate his phone with just one hand.

In the situations when he is using the phone with one hand, Kevin is either messaging his friends and family on iMessage or WeChat, checking messages on Gmail or LinkedIn, browsing social media like YouTube and TikTok, or searching things on Google. All of these activities involve entering text using the virtual keyboard on the phone with just one hand, which Jack significantly struggles with, specifically in terms of:

- (1) the high frequency of typos;
- (2) difficulty in fixing the typos caused by counter productivity of auto correct and delete;
- (3) inconvenient location of certain keys (like punctuations, emojis, and other special characters);
- (4) uncomfortable size of keyboard and phone leading to difficulty to reach all keys and physical discomfort

Thus, Jack has the following specific desires/needs.

- (1) Jack wants to minimize the amount of typos he makes when he is entering text with one hand, which should not be more than the amount of typos when he is typing with both hands [User Requirement 1].
- (2) Jack wants to easily fix any typos using one hand without doing any redundant actions (i.e. more than what is necessary) such as
 - (a) correcting mistakenly-corrected words by keyboard assistive features like autocorrect [User Requirement 2], or

- (b) accidentally deleting correctly-spelled letters/words not part of the typo [User Requirement 3].
- (3) Jack wants to be able to easily locate and enter non-alphabet characters with one hand, including emojis, punctuations, and numbers [User Requirement 5].
- (4) Jack wants to be able to comfortably reach all keyboard elements while securely holding the phone with one hand [User Requirement 4, 6].

D.5 Final Sketches

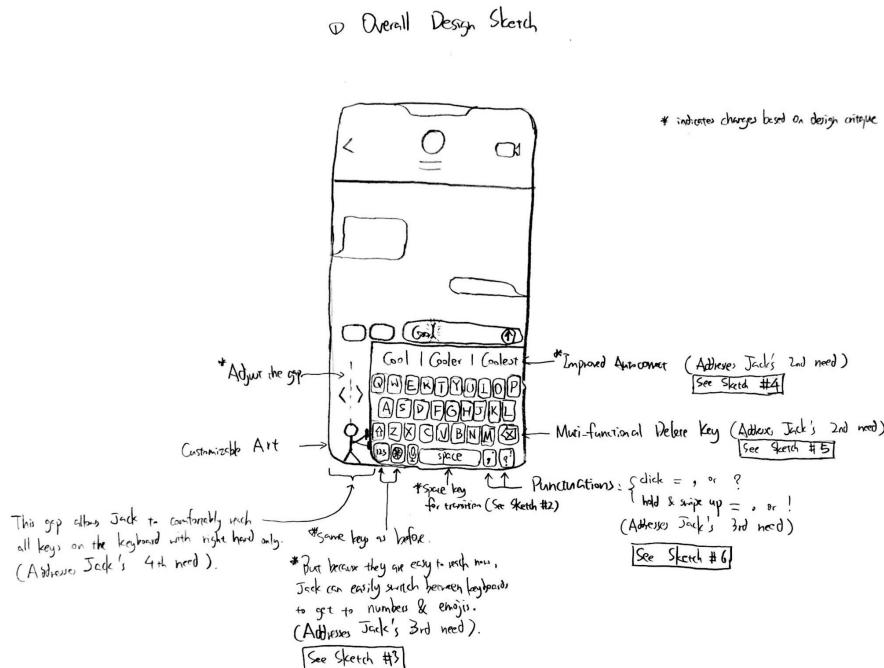


Fig. 94. Sketch 1

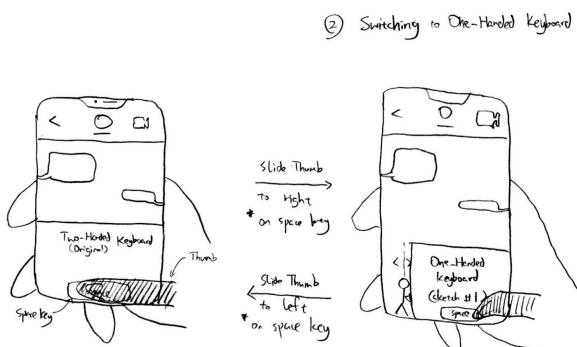


Fig. 95. Sketch 2

- Jack wants to use right hand to enter text
- He slides thumb from left side to right side on the space key
- L → switches to one-handed keyboard.
- Currently, only focused on right-handed text entry.
- Side thumb in the opposite direction on space key to switch back to two-handed keyboard.

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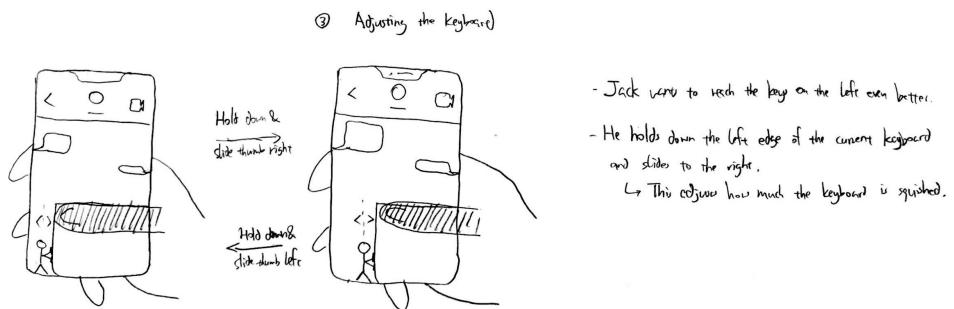


Fig. 96. Sketch 3

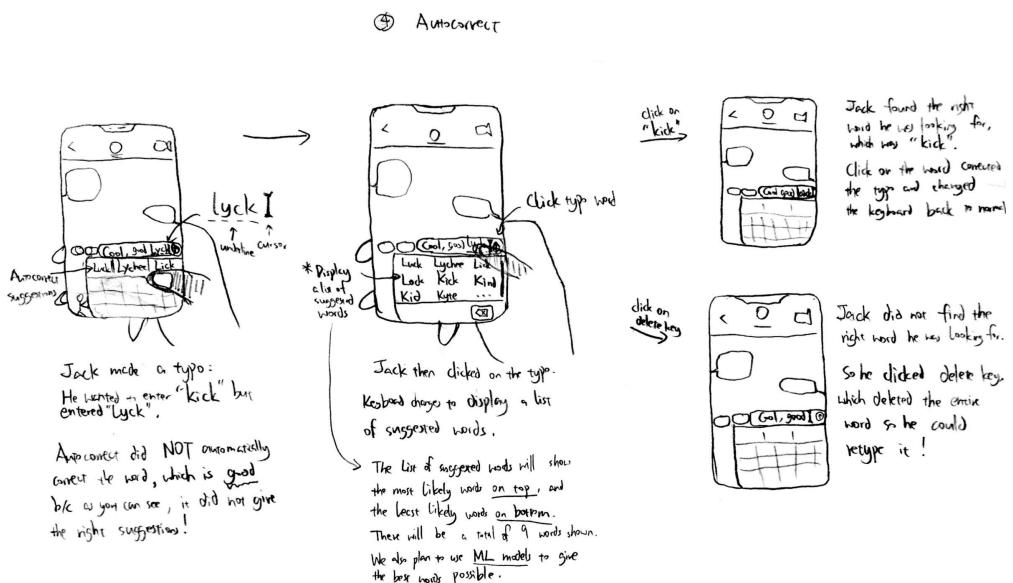


Fig. 97. Sketch 4

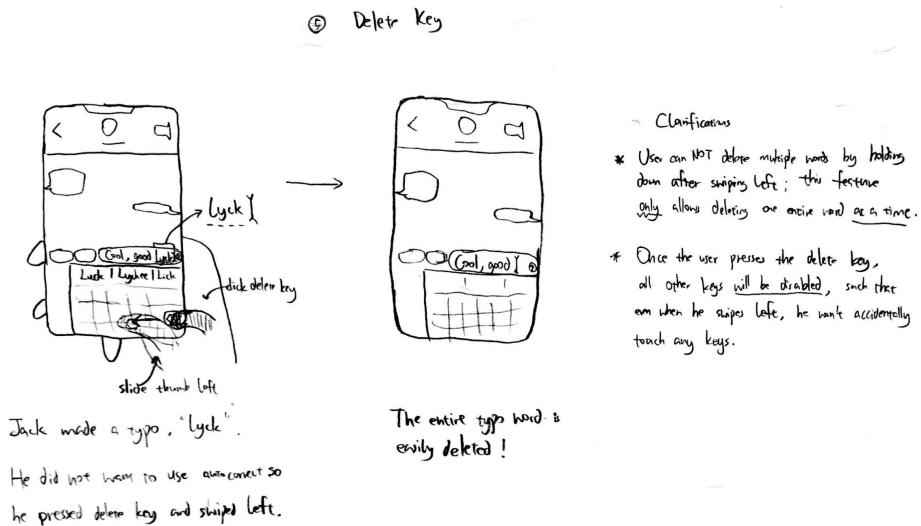


Fig. 98. Sketch 5

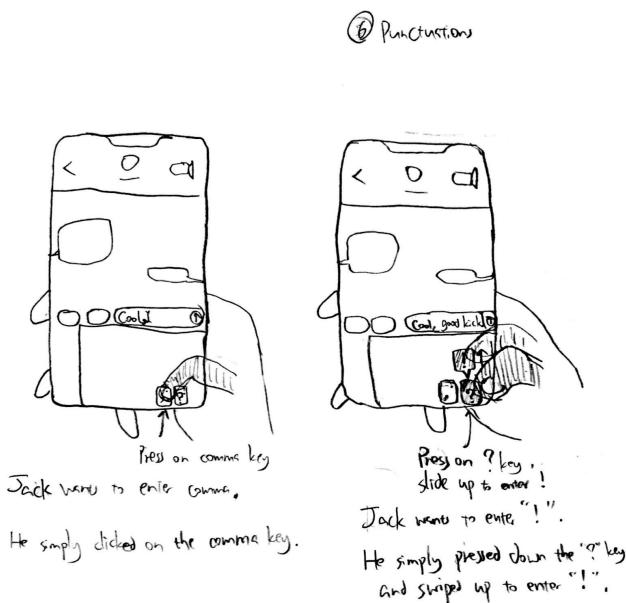


Fig. 99. Sketch 6

D.6 Final Storyboards

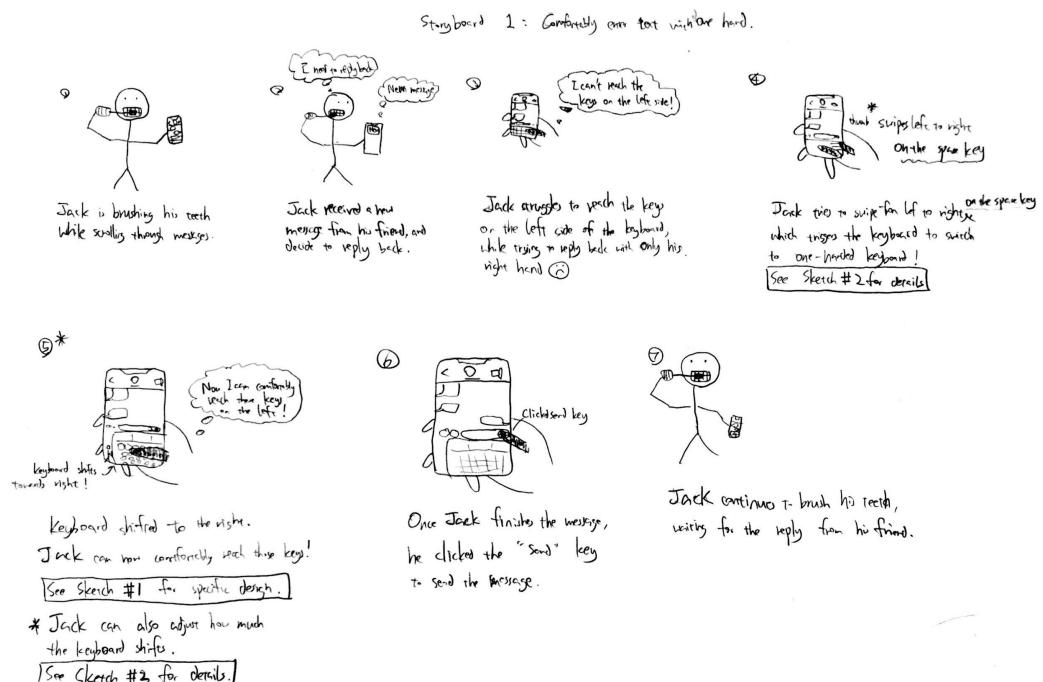


Fig. 100. Storyboard 1

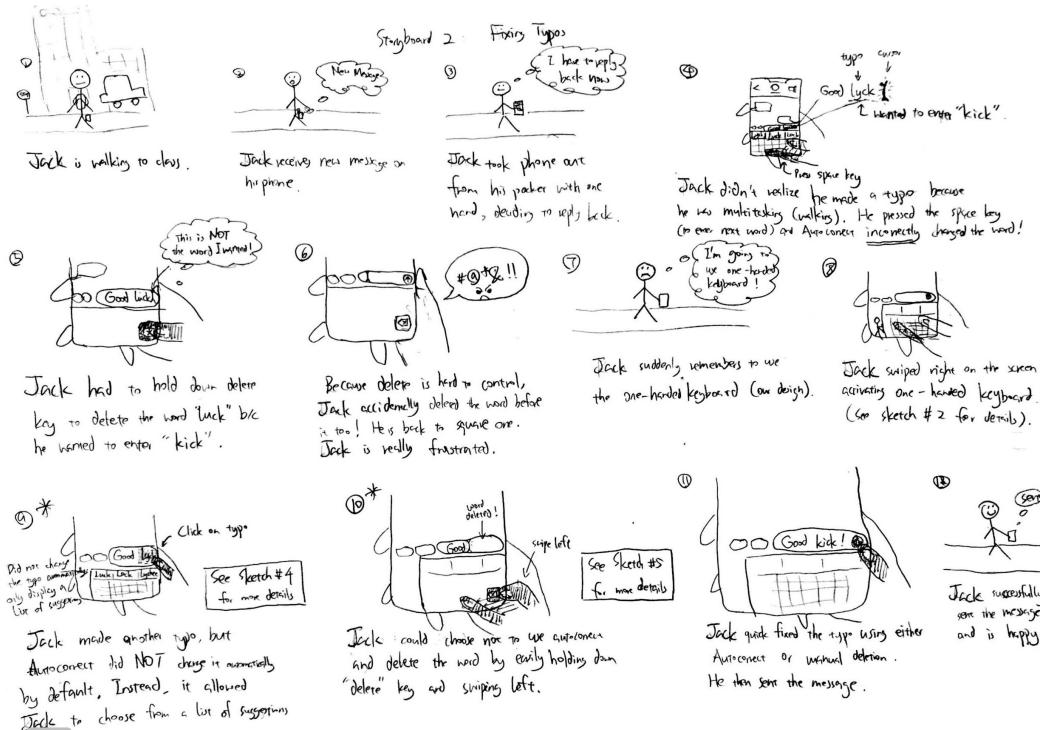


Fig. 101. Storyboard 2

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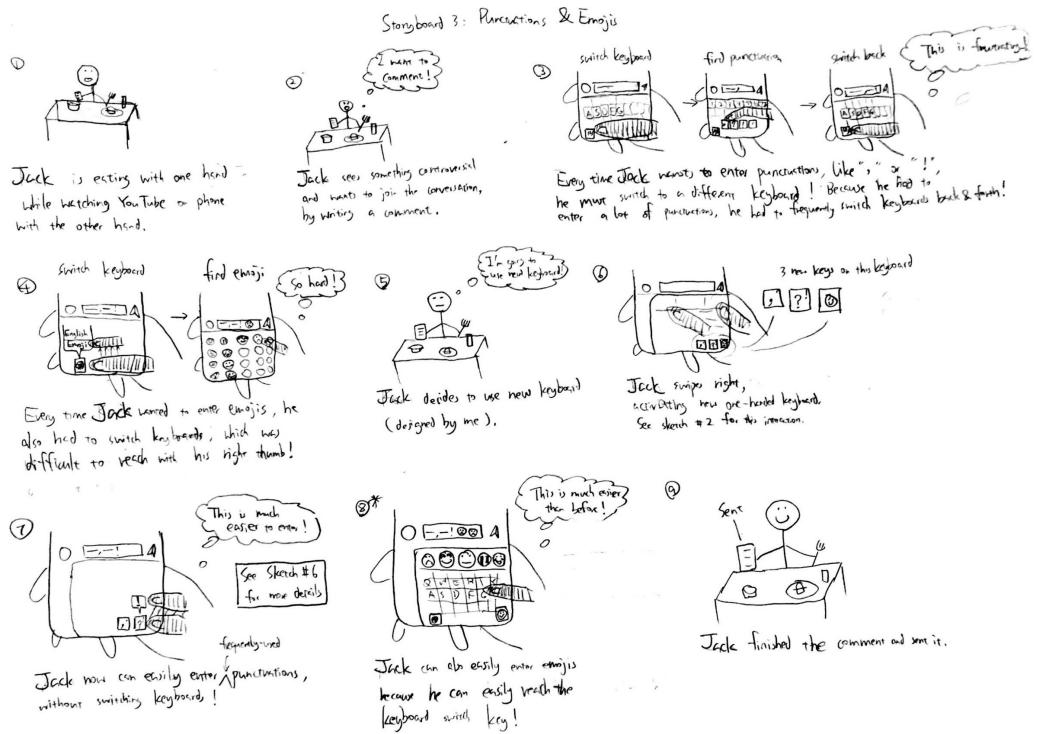


Fig. 102. Storyboard 3

D.7 Final Paper Prototype



E USABILITY EVALUATION

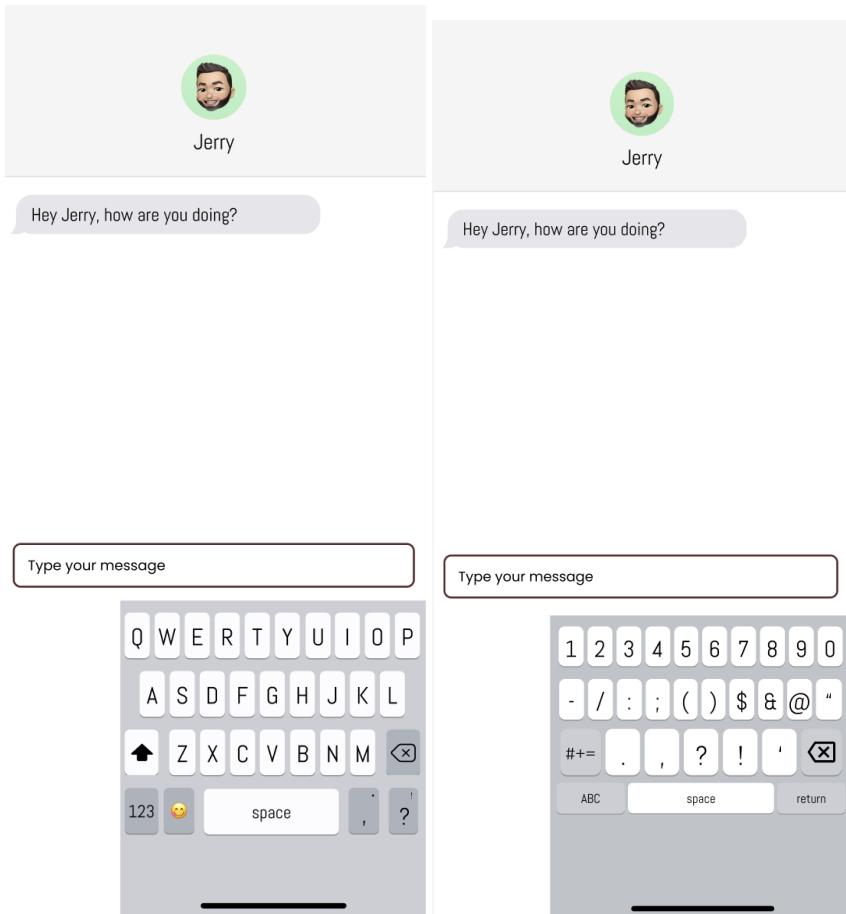
E.1 Individual Heuristic Evaluation Notes

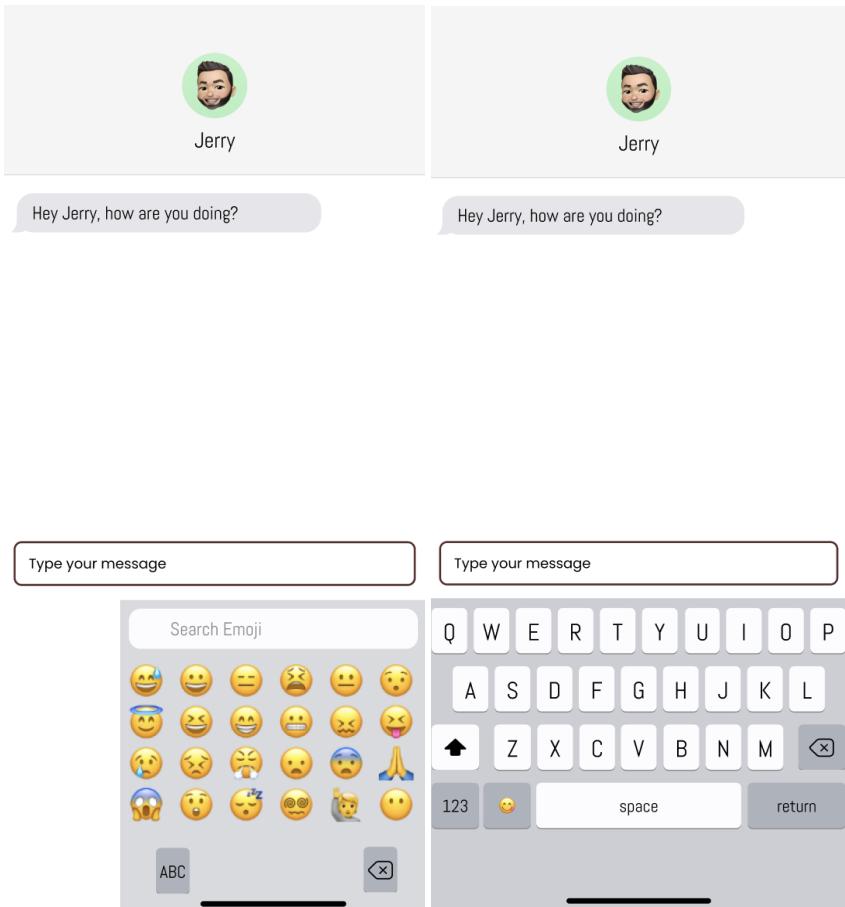
E.2 Individual Simplified User Study Notes

E.3 Anonymized and De-identified Simplified User Study Transcripts

F USER EVALUATION

F.1 Apparatus Screenshots





Improving One-Handed Textual Entry on Mobile Devices

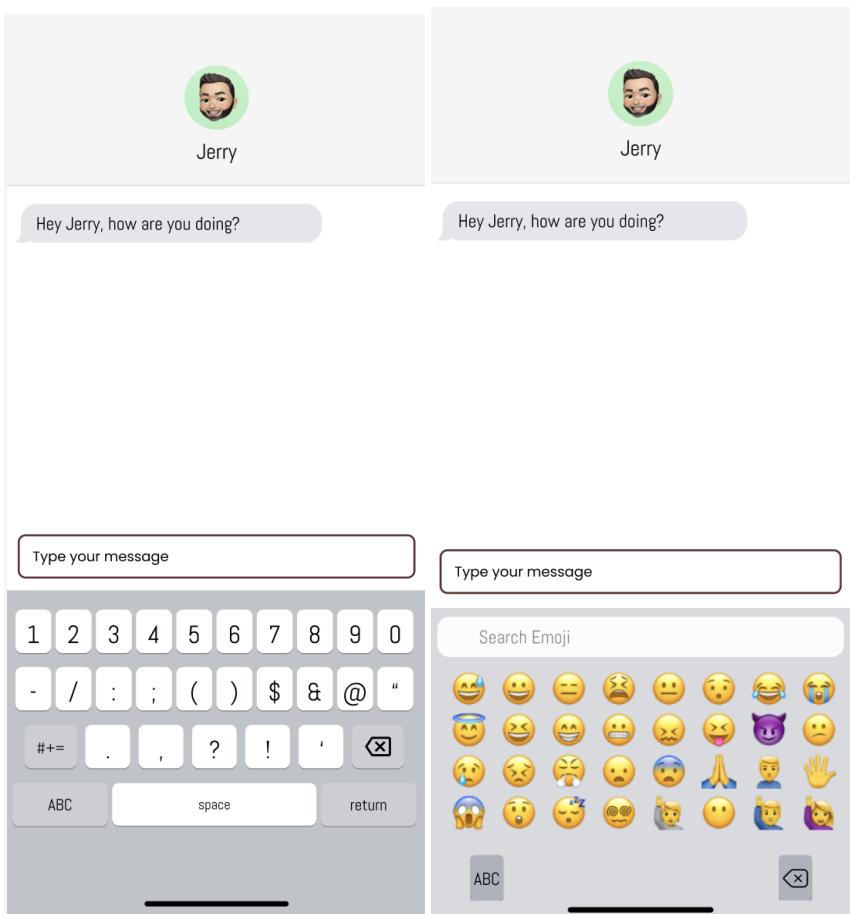


Fig. 105. Overall Caption for the Six Images

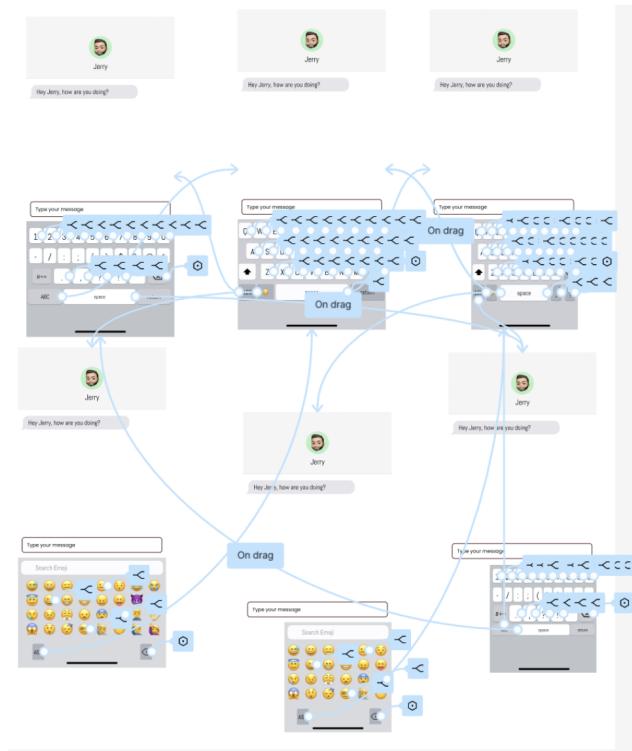


Fig. 106. Functional Prototype UI FFlow

F.2 Anonymized and De-identified Participants Data

Participant 1:

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	29.12	42.59	24.79
Existing Keyboard Design	30.16	43.43	23.05

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	12.54	25.18	25.95
Existing Keyboard Design	24.12	33.92	28.41

Fig. 107. Daniel's Participant 1

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Participant 2:
Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	30.27	38.07	26.34
Existing Keyboard Design	34.64	39.52	35.80

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	15.22	27.32	22.46
Existing Keyboard Design	20.22	33.88	23.68

Fig. 108. Daniel's Participant 2

Participant 3:
Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	45.95	58.40	57.58
Existing Keyboard Design	37.10	47.04	39.76

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	26.57	44.40	32.12
Existing Keyboard Design	29.08	42.45	35.18

Fig. 109. Daniel's Participant 3

Participant 1

Session 1 (do not count towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	32.72	28.08	31.88
Existing Keyboard Design	31.32	25.00	28.55

Session 2 (counts towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	17.38	28.04	20.26
Existing Keyboard Design	20.93	30.31	22.45

Fig. 110. Jerry's Participant 1

Participant 2

Session 1 (do not count towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	9.93	26.73	19.82
Existing Keyboard Design	13.22	18.99	15.33

Session 2 (counts towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	10.09	17.69	16.83
Existing Keyboard Design	12.96	17.63	16.36

Fig. 111. Jerry's Participant 2

Participant 3

Session 1 (do not count towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	21.41	33.39	28.63
Existing Keyboard Design	36.40	40.09	64.79

Session 2 (counts towards statistical analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	21.01	24.42	24.70
Existing Keyboard Design	41.86	33.39	36.31

Fig. 112. Jerry's Participant 3

Participant 1:

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	35.33	41.38	38.91

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	18.88	32.22	14.55
Existing Keyboard Design	21.03	30.18	16.97

Fig. 113. Isaac's Participant 1

Participant 2:

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	44.15	59.23	37.51
Existing Keyboard Design	35.65	48.10	29.66

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	34.20	39.88	32.41
Existing Keyboard Design	31.75	37.01	24.38

Fig. 114. Isaac's Participant 2

Participant 3:

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	21.89	33.45	23.93
Existing Keyboard Design	22.15	28.40	26.65

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	14.97	23.94	17.08
Existing Keyboard Design	19.09	22.77	21.78

Fig. 115. Isaac's Participant 3

Participant 1

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	16.91	38.94	25.34
Existing Keyboard Design	26.27	36.46	32.70

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	24.47	30.54	31.72
Existing Keyboard Design	22.10	38.94	25.44

Fig. 116. Franklin's Participant 1

Participant 2

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	15.34	25.59	26.10
Existing Keyboard Design	32.20	29.57	31.99

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	18.41	22.68	26.64
Existing Keyboard Design	26.86	29.89	31.15

Fig. 117. Franklin's Participant 2

Participant 3

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	27.13	37.32	33.66
Existing Keyboard Design	40.96	39.55	41.30

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	27.36	29.85	34.37
Existing Keyboard Design	25.61	29.80	29.65

Fig. 118. Franklin's Participant 3

Participant 1: (U5-1)

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	31.24	29.56	27.42
Existing Keyboard Design	23.34	27.31	28.35

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	18.67	25.54	23.33
Existing Keyboard Design	21.09	26.32	22.51

Fig. 119. YiChen's Participant 1

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Participant 2: (U5-2)

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	42.31	38.45	40.29
Existing Keyboard Design	38.69	37.56	42.91

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	23.31	22.56	19.58
Existing Keyboard Design	29.50	20.08	18.84

Fig. 120. YiChen's Participant 2

Participant 3: (U5-3)

Session 1 (do not count towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	16.09	24.56	25.87
Existing Keyboard Design	21.05	18.92	26.01

Session 2 (counts towards analysis)

	Time for punctuation (s)	Time for emoji (s)	Time for numbers (s)
Our Keyboard Design	17.04	21.87	19.89
Existing Keyboard Design	20.78	25.41	21.01

Fig. 121. YiChen's Participant 3