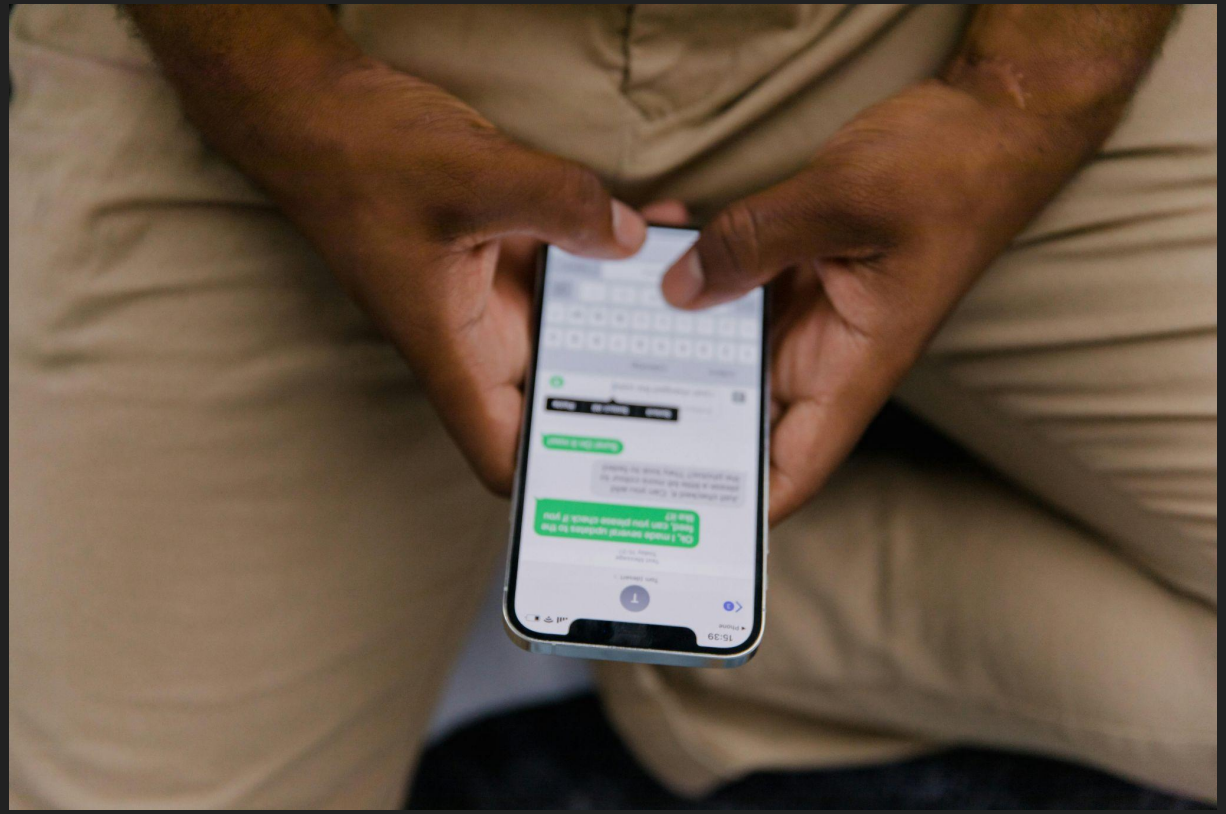
SkipWriter:

LLM-Powered Abbreviated Writing on Tablets

Zheer Xu[1], Shanqing Cai[2], Mukund Varma T[3], Subhashini Venugopalan[2], Shumin Zhai[2]

[1] DARTMOUTH [2] Google [3] UC San Diego



Conventional Predictive Interfaces

Word Forward Suggestion

N-gram LM

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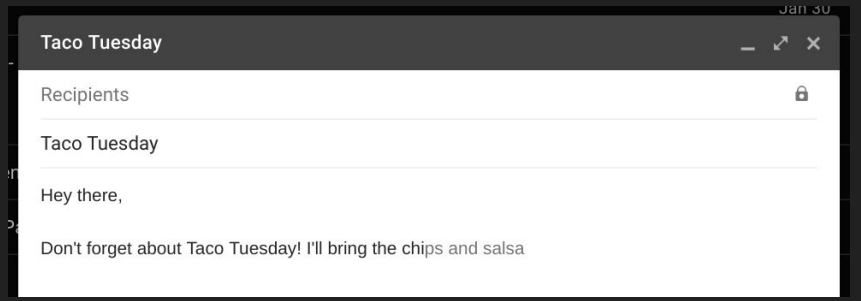

Phrase Forward Suggestion

Transformer-based LLM

Source: Chen et al. *Gmail Smart Compose: Real-Time Assisted Writing*. KDD 2019.

Phrase Abbreviation

As far as I know	AFAIK
Sounds good to me	SGTM
See you later	CUL8R
Never mind	NVM
What are you doing	?RU doing
Forget it	4get it

Common phrase abbreviations in SMS Language

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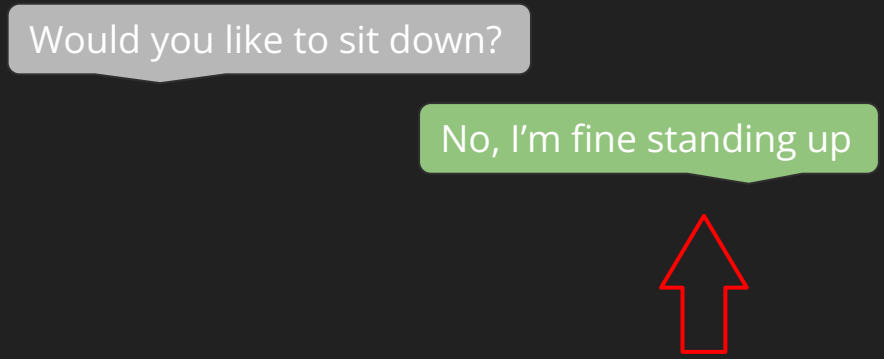


Using LLM to expand Initial-only phrase abbreviation for dialogues

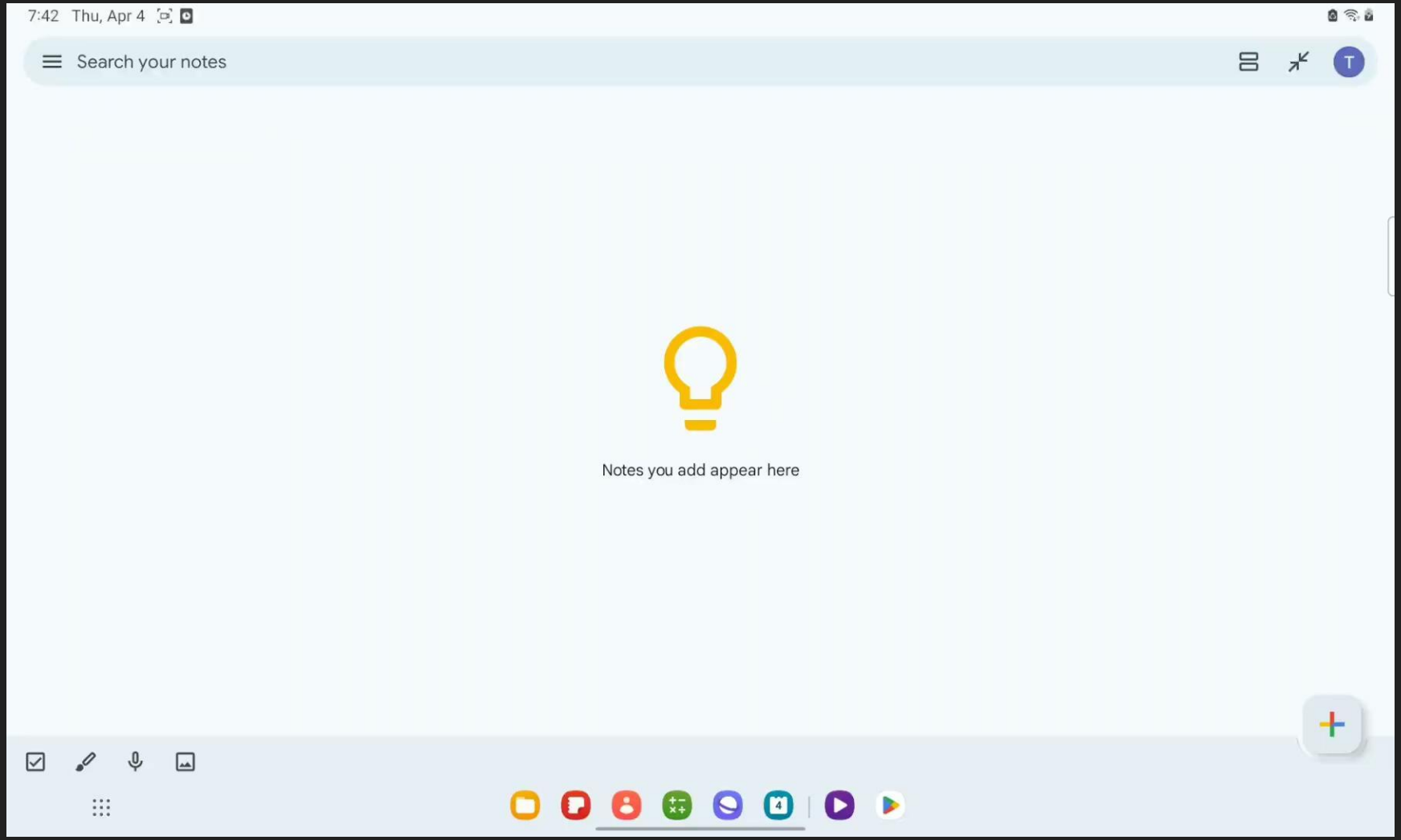
Source: Cai et al. *Context-Aware Abbreviation Expansion Using Large Language Models*. NAACL 2022.

Research Goal

- Generic text input where text can be abbreviated in chunks

- Minimize human input efforts by harnessing a LLM decoder


Input Modality
Abbreviation Form
Decoder Training
Interface Design


7:42 Thu, Apr 4
Search your notes
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Notes you add appear here

Input Modality: Handwriting

- Handwriting has prolonged stress on the hand and wrist.

Input Modality: Handwriting

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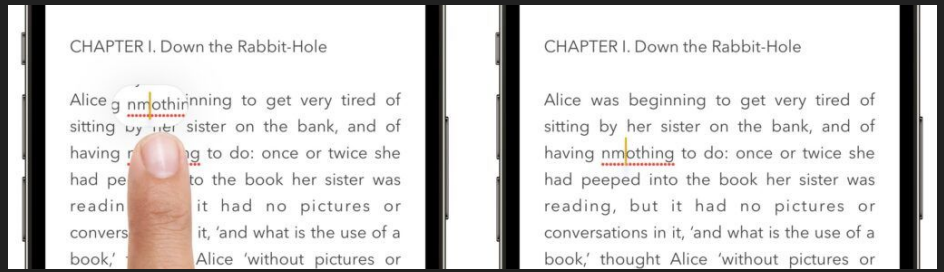
- Handwriting has the flexibility of pen-based interaction.
  - “Random Access” instead of an insertion cursor



Featured image by iStock.com/Ralf Geithe

Abbreviation Form

Variable-length Prefix-based Abbreviation

Example*: when would you come home*

Tianshi Li, Philip Quinn, and Shumin Zhai. *C-PAK: Correcting and completing variable-length Prefix-based Abbreviated Keystrokes. A*CM Trans. Comput. Hum. Interact. Jul 2022.

Abbreviation Form

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- Easy to complete/extend in a progressive way

LLM-Powered Abbreviation Decoder

- In-production handwriting recognizer + LLM for abbreviation decoder (PaLM2)

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- Preceding context is also utilized for decoding.

LLM-Powered Abbreviation Decoder

- Handwriting recognizer (ML Kit) + LLM for abbreviation decoder (PaLM2)

- Arbitrarily generate abbreviations for fine-tuning the LLM.
  - Target text: “have a way of”
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- Data source: 4 public datasets (papers, reviews, news, wiki)

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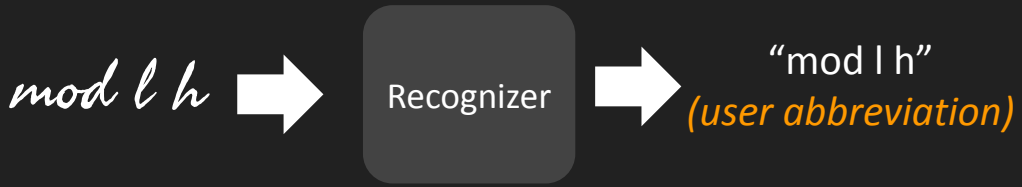

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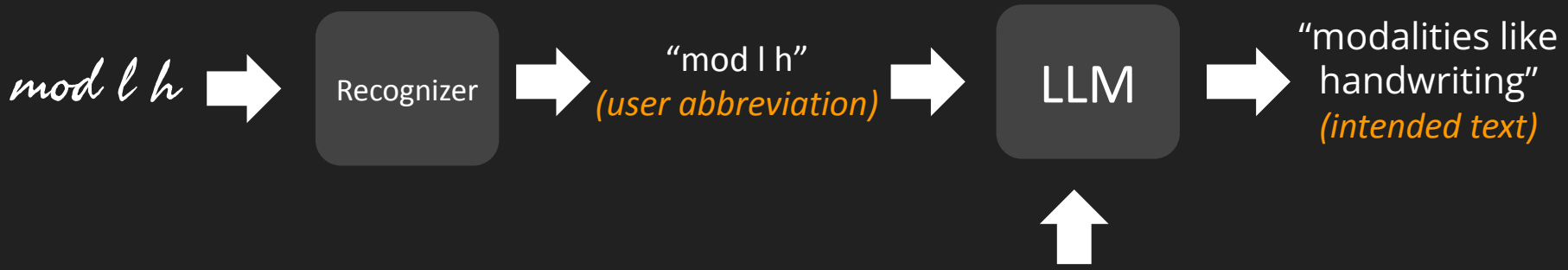

Abbreviation Generation

Question: How to generate the prefix abbreviation for each word?

- Random Sampling
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  - For the word “zebra”, “z” or “ze” is probably sufficient for disambiguation.
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- Solution: inversely tie the probability to the frequency of a prefix in English corpus

Abbreviation Generation

Question: How to generate the prefix abbreviation for a word?

- Prefix Entropy

$$H_{\text{prefix}} = -\sum_{w \in W} p(w) \log(p(w))$$

prefix: a character sequence

W: the set of all words start with the sequence *prefix*

Abbreviation Generation

Question: How to generate the prefix abbreviation for a word?

- Progressively determine each character

$$P_i = \frac{H(c_1, c_2, \ldots, c_{i-1})}{H_0}$$

P_i : the probability of the i^{th} character being included

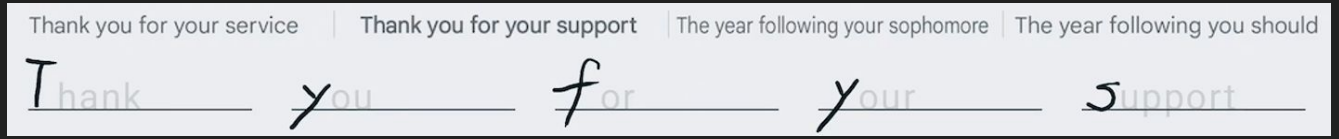
$H(c_1, c_2, \ldots c_{i-1})$: the prefix entropy of the sequence before the i^{th} character

H_0: the entropy of an empty sequence

Interface Design

Goal: encourage the user to employ more efficient (i.e., shorter but effective) abbreviations

Interface Design



- Easy editing
  - Ambient reminder for users to leave space for future completion

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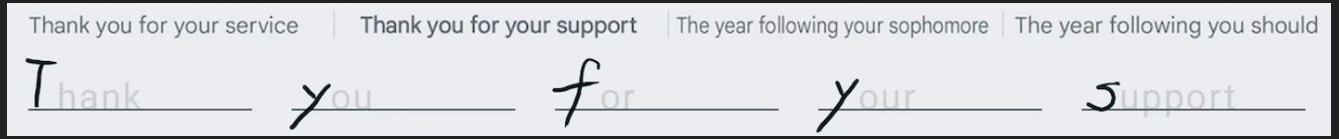
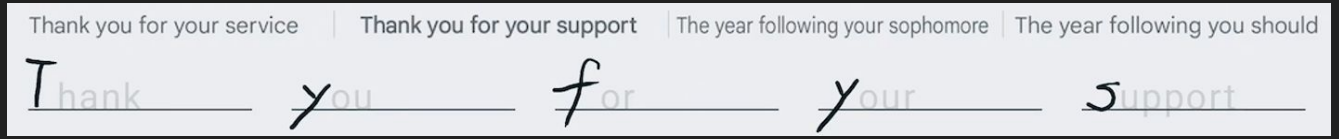


- Easy editing
  - Ambient reminder for users to leave space for future completion
  - Reduces the overhead of completion and encourages users to try aggressive abbreviation

Interface Design: Segmented Rule



- Easy retroactive editing

Intended text: “when would you come home”

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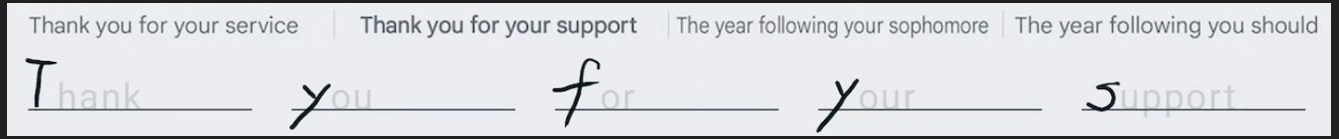

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Intended text: “when would you come home”

User writes: *w w y c h*

Prediction: When will you come here

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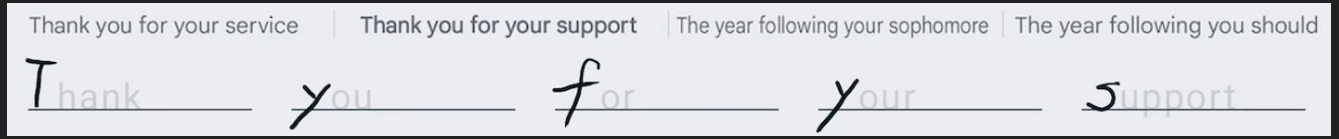

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Intended text: “when would you come home”

User writes: *w w y c h*

Prediction: When will you come here

User edits: *w wo y c ho*

Prediction: When would you come home

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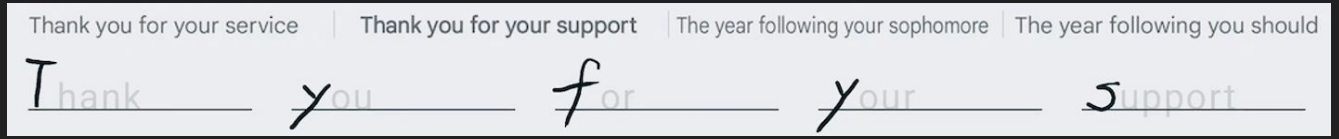

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Otherwise, the user may “charge ahead” to avoid subsequent edits:

wh wo yo co ho

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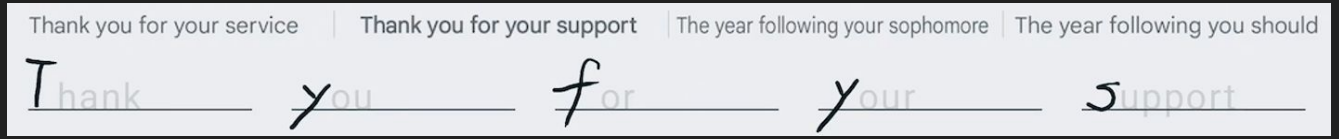

- Easy editing
- Low-cost word delimiters for robust recognition

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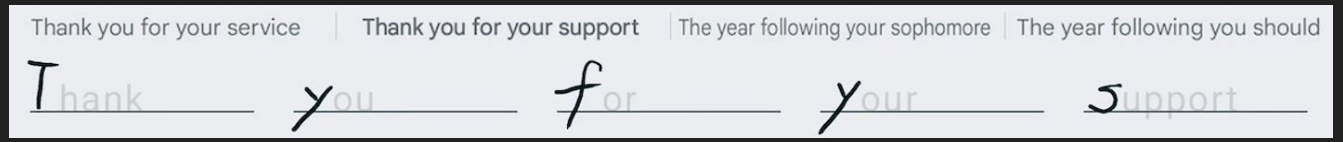

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"*w wo y c ho*" can be mis-recognized as "w woye ho"

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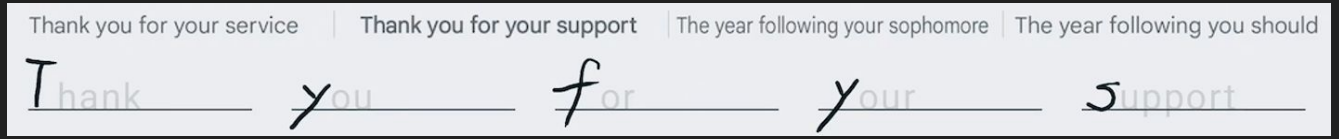
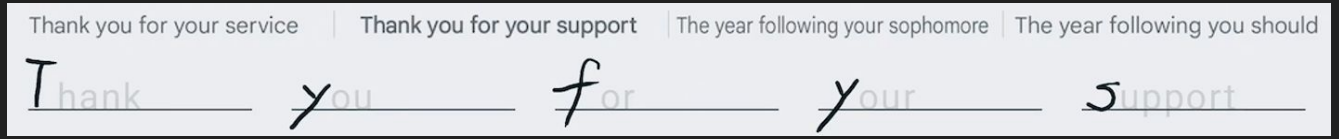
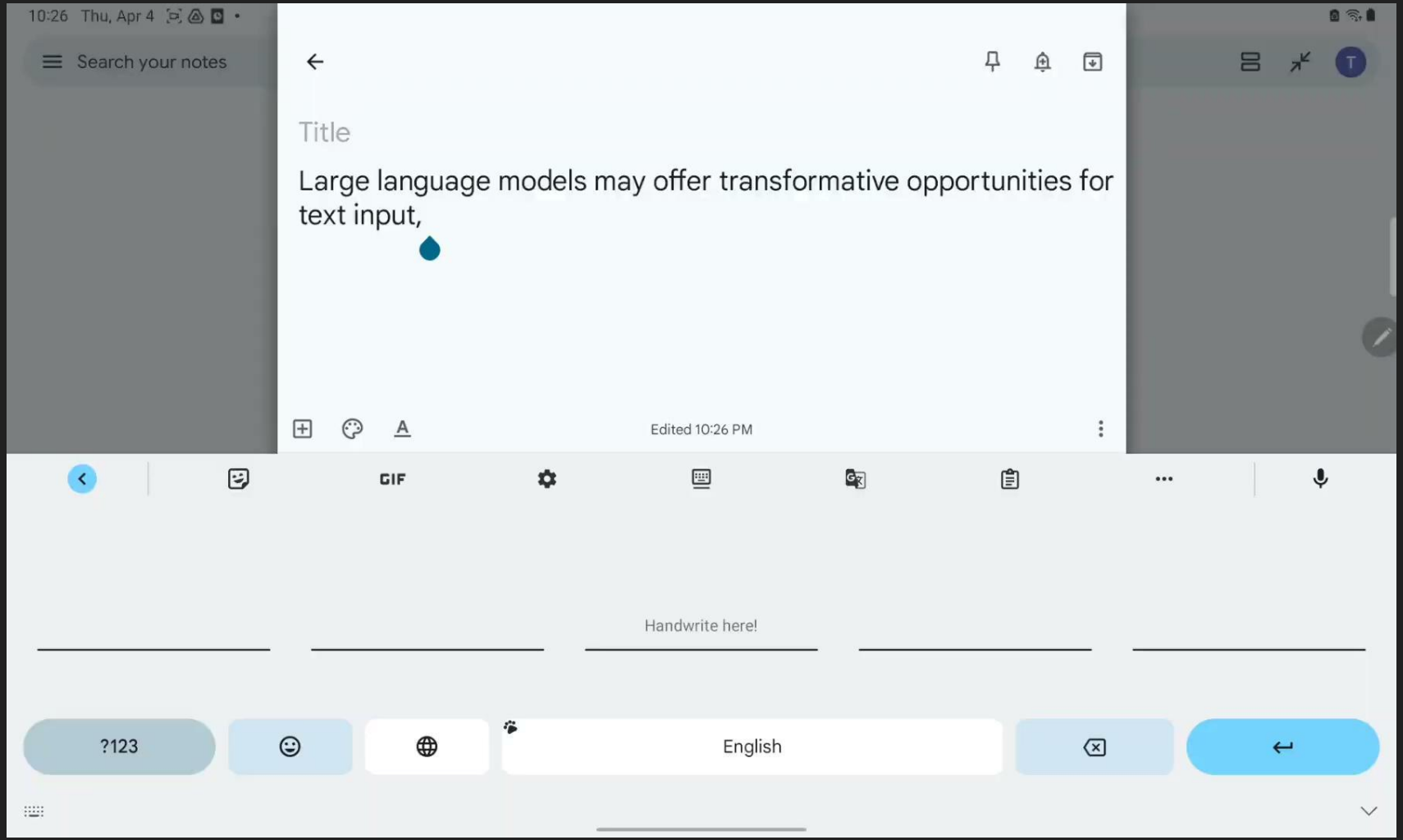


- Easy retroactive editing
- Low-cost delimiters for robust recognition
  - Separate handwriting recognition in each segment

Interface Design



- Easy editing
- Low-cost word delimiters for robust recognition
- Inline visualization of top candidate to minimize attention switch


10:26 Thu, Apr 4
Search your notes
Title
Large language models may offer transformative opportunities for text input,
Edited 10:26 PM
GIF
Handwrite here!
?123
English

User Evaluation

	Abbreviated Handwriting	Conventional Handwriting
Speed (Word Per Minute)	25.78 WPM	24.18 WPM
Word Error Rate (%)	2.08%	4.05%
Traversal Distance per Character *(Metric for physical efforts)*	11.41 mm **(60.19% ↓)**	18.74 mm

Offline Simulation

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  - Step 4: Get the final abbreviation.

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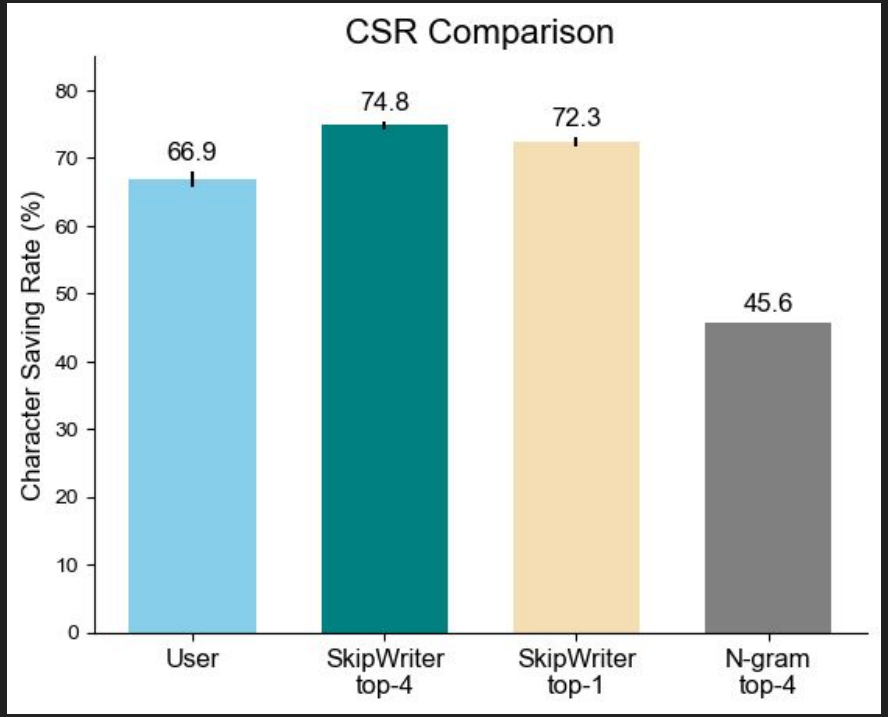
- Compare the User CSR v.s. Simulated CSR
  - Character Saving Rate (CSR): percentage of characters skipped in the abbreviation.

Offline Evaluation



Take-away Messages

- LLM can effectively decode phrase abbreviations and achieve high character savings.

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- Users can utilize the LLM’s power to write and abbreviate efficiently on SkipWriter interface with diminished physical efforts.

Thank you!

Discussion on Cognitive Load

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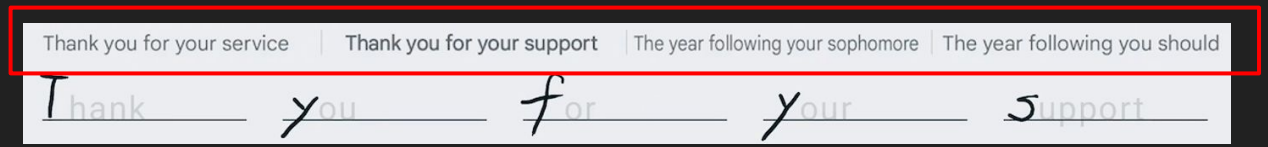
- Common problem in phrase-level input:
  - compare, search, and complete a phrase of multiple words
- Future improvements
  - Decoder: latest foundational models + human data to train an end-to-end decoder
  - Interface: highlight the differences among the candidates



Contributions

AI-Generated

Text Creation

(ChatGPT etc.)

Contributions

AI-Assisted

Text Input

AI-Generated

Text Creation

(ChatGPT etc.)

Future Directions

- On-device reference
- Personalization
- Mitigating cognitive load
- Real word deployment and evaluation

Abbreviations for other languages

Text input is fundamentally a sequence of target acquisition tasks. (i.e., abbreviated input -> partial sequence)

- Adaptation should be based on primary units of that language
  - Word-Based Languages (e.g., English)
  - Syllable-Based Languages (e.g., Chinese)
  - Morphological or Agglutinative Languages (e.g., Turkish, Japanese)
  - Root-Based or Semitic Languages (e.g., Arabic, Hebrew)
  - Polysynthetic Languages (e.g., Inuktitut, Mohawk)