CHI 2018
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Pervasive Human Computer Interaction
Department of Computer Science and Technology
Tsinghua University

ForceBoard: Subtle Text Entry Leveraging Pressure

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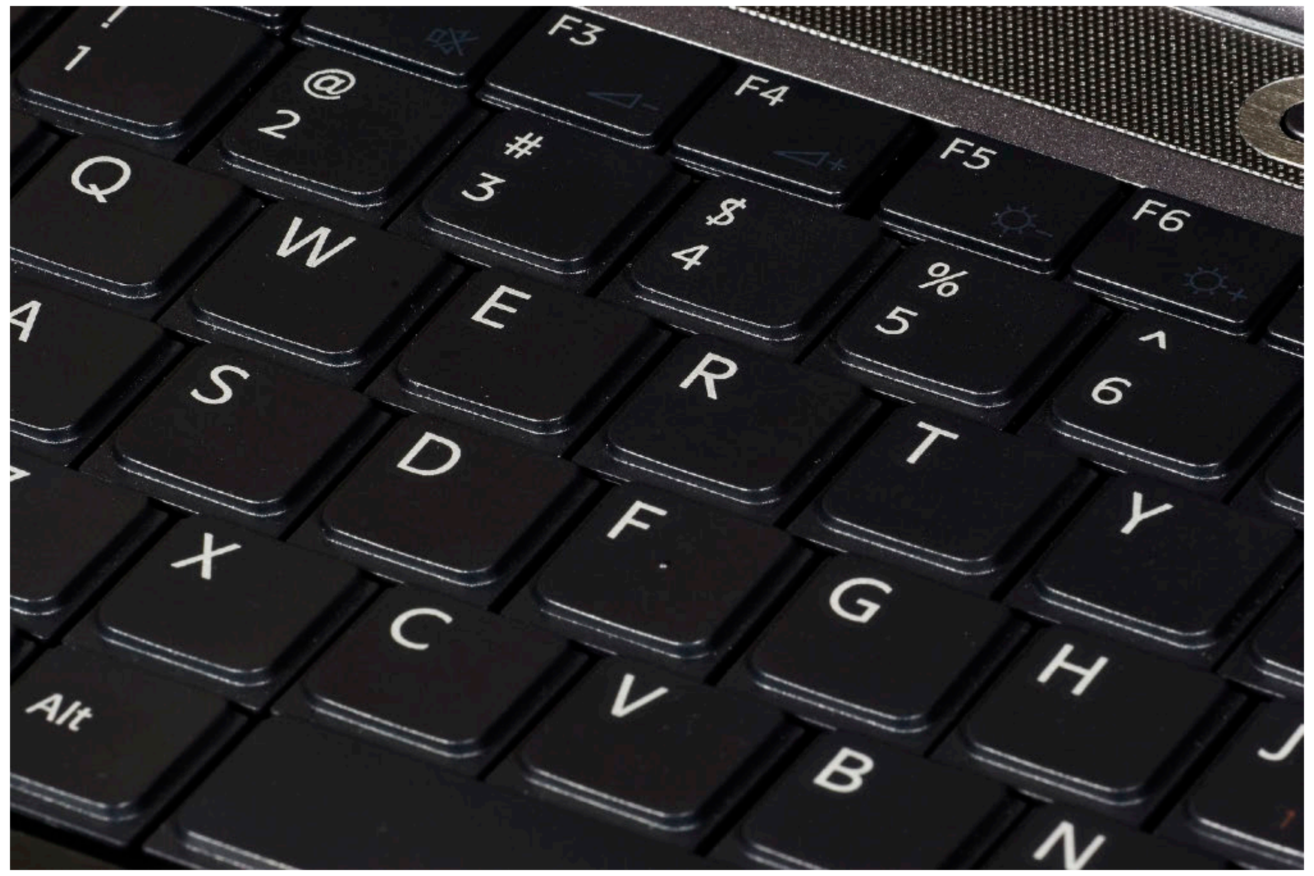
Traditional text entry methods

Touch
input



Physical
keyboards
or buttons

Wet
screen

Limited
device size

ForceBoard: Pressure-based text entry

- One-dimensional
- Using pressure as the only channel for text entry
- Text entry with subtle motion


1x
9:41 AM
typing_
abcdefghijklmnopqrstuvwxyz
×
typing
tyrosine
synovial
symptom
symptoms
synovium
Pres

0.3x
9:41 AM
typing on ForceBoard is_
abcdefghijklmnopqrstuvwxyz
is
it
in
go
do
jr

Outline

- Pilot Study: Making design decisions
- User Study 1: Error model of pressure control
- Design and Implementation
- User Study 2: Performance evaluation
- Applications and Limitations

Pilot Study: Making design decisions

- Keyboard Layout: A-Z; QWERTY; ENBUD
- Cursor Width: 1, 3, 5, 7, 9
- Selection Method: Dwell and Quick Release

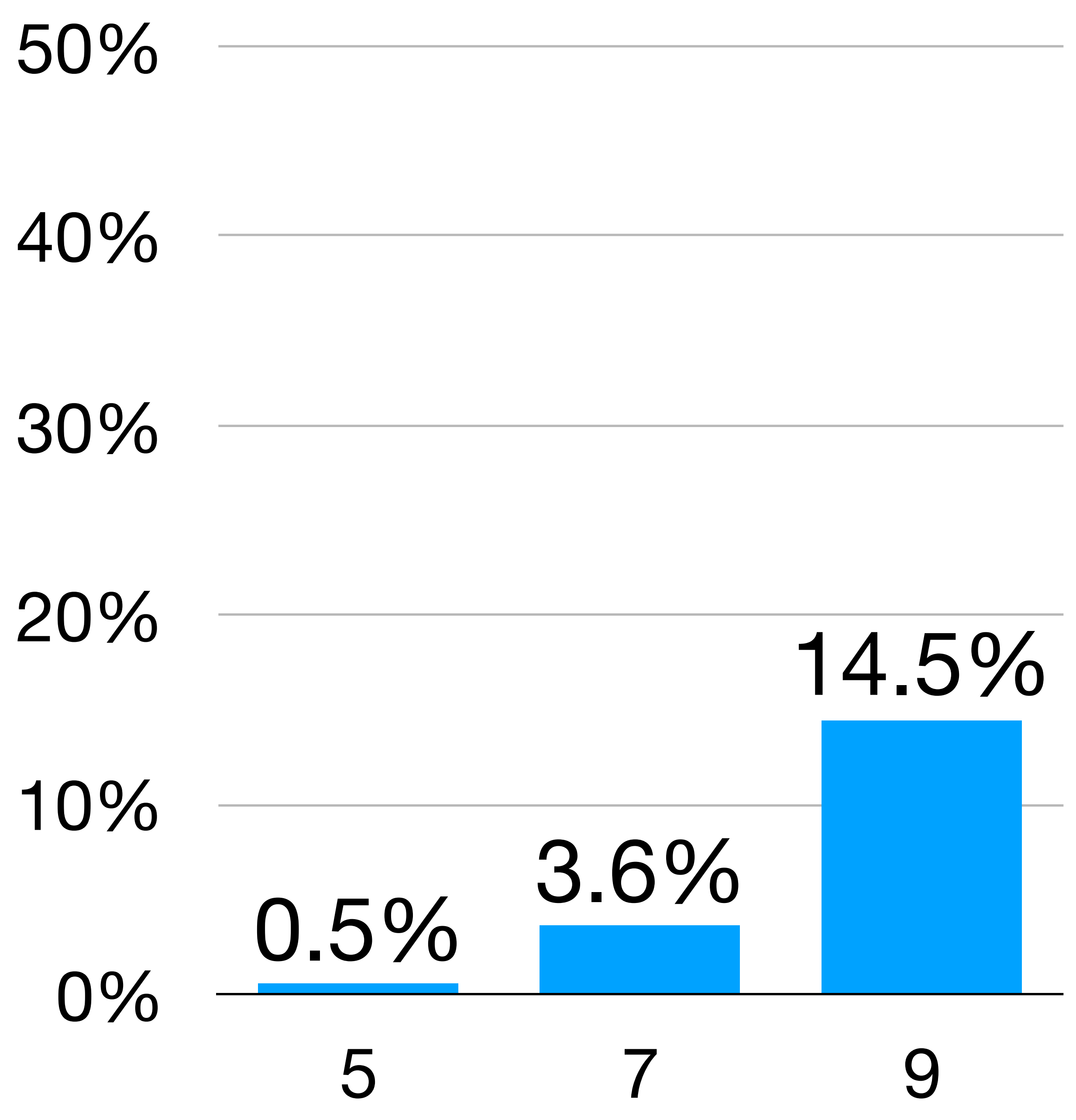
An example condition for the pilot study
- Keyboard layout: A-Z
- Cursor width: 5
- Selection Method: Dwell (not illustrated)

Keyboard Layout

- Keyboard layouts:
  - abcdefghijklmnopqrstuvwxyz (Alphabetical A-Z)
  - qwertyuiopasdfghjklzxcvbnm (QWERTY)
  - enbudjcoflyqthvigmxrzpkwas (ENBUD)
- Users were not familiar with the QWERTY or ENBUD layout in one-dimension
- Users preferred the alphabetical layout

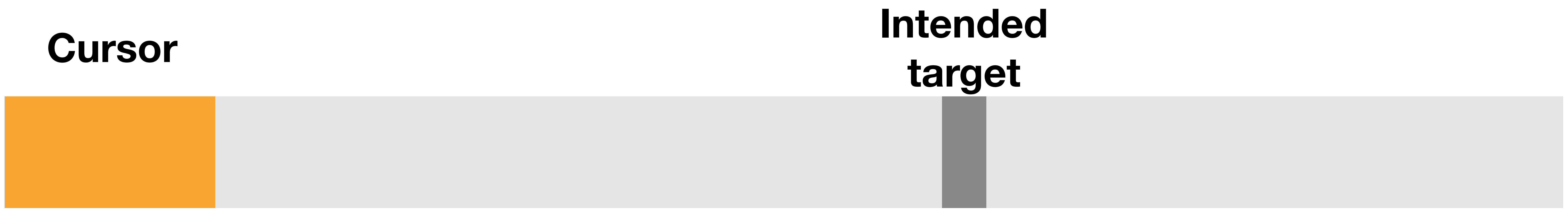
Cursor Width

- Tested 1, 3, 5, 7, 9-letter-wide cursors
- Users reported difficulty controlling the cursor for widths < 5
- Simulation with a 10,000-word language model show that a 9-letter-wide cursor would lead to too much conflicts
- Chose cursor widths 5 & 7

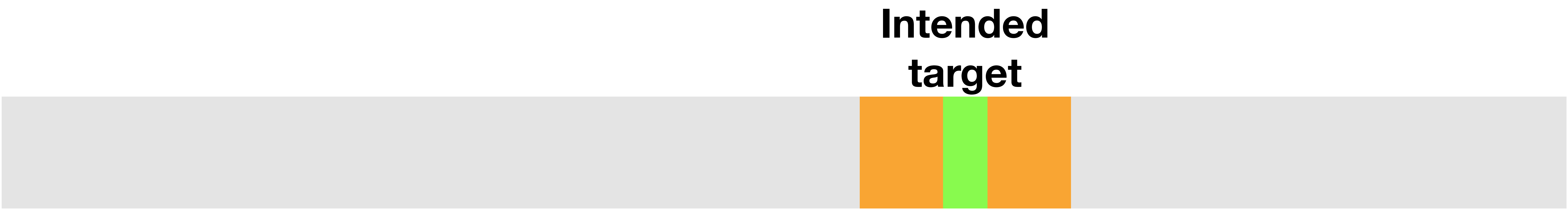


Selection Method: Dwell and Quick Release

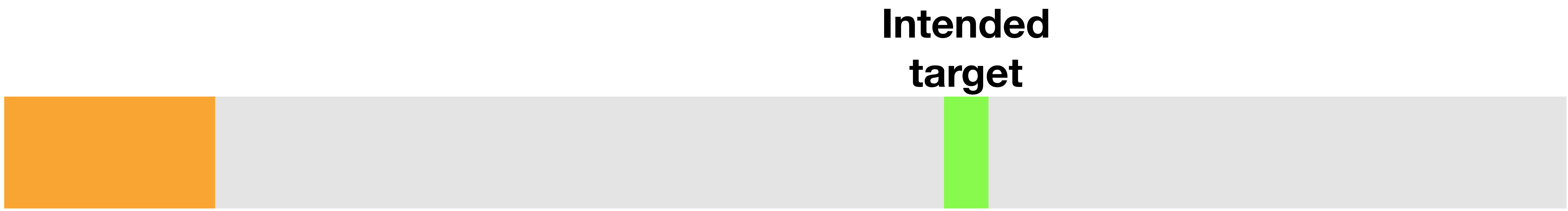
Dwell



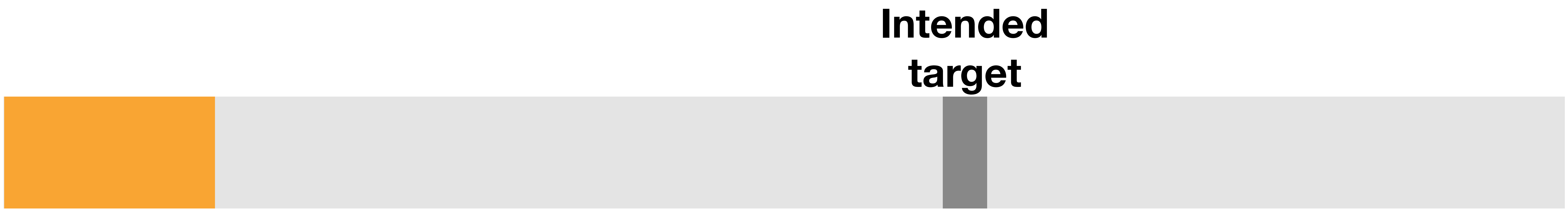
Dwell



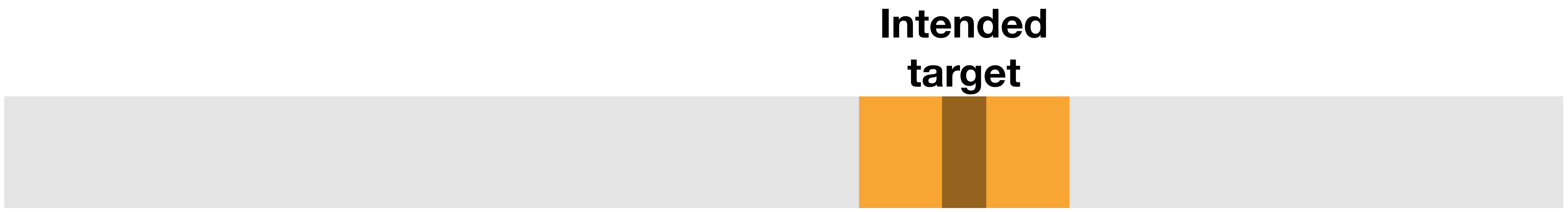
Dwell



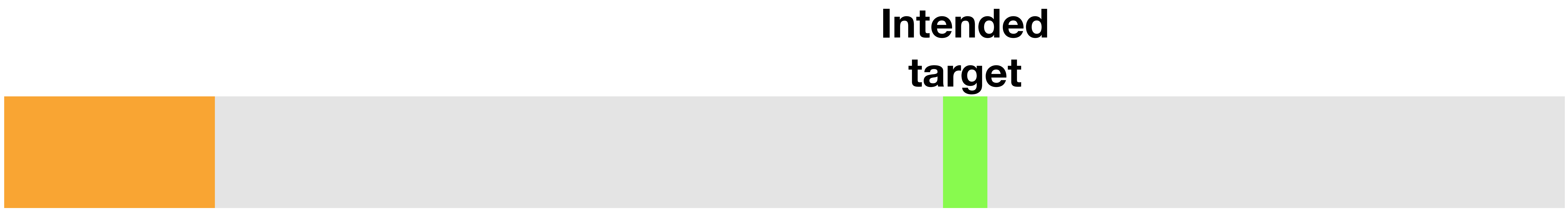
Quick Release



Quick Release



Quick Release



Selection Method: Dwell vs. Quick Release

- Dwell: holding pressure for 300 ms selects the target
- Quick Release: releasing pressure selects the target
- Users preferred Quick Release and considered it to be much faster

Selection Method: Dwell vs. Quick Release

- Dwell: holding pressure for 300 ms selects the target
- Quick Release: releasing pressure selects the target
- Users preferred Quick Release and considered it much faster
- In-contact Quick Release: keep the thumb in contact with the screen after selecting each letter

Pilot Study: Summary

- Alphabetical one-dimensional keyboard layout
- Cursor width should be 5 or 7
- In-contact Quick Release

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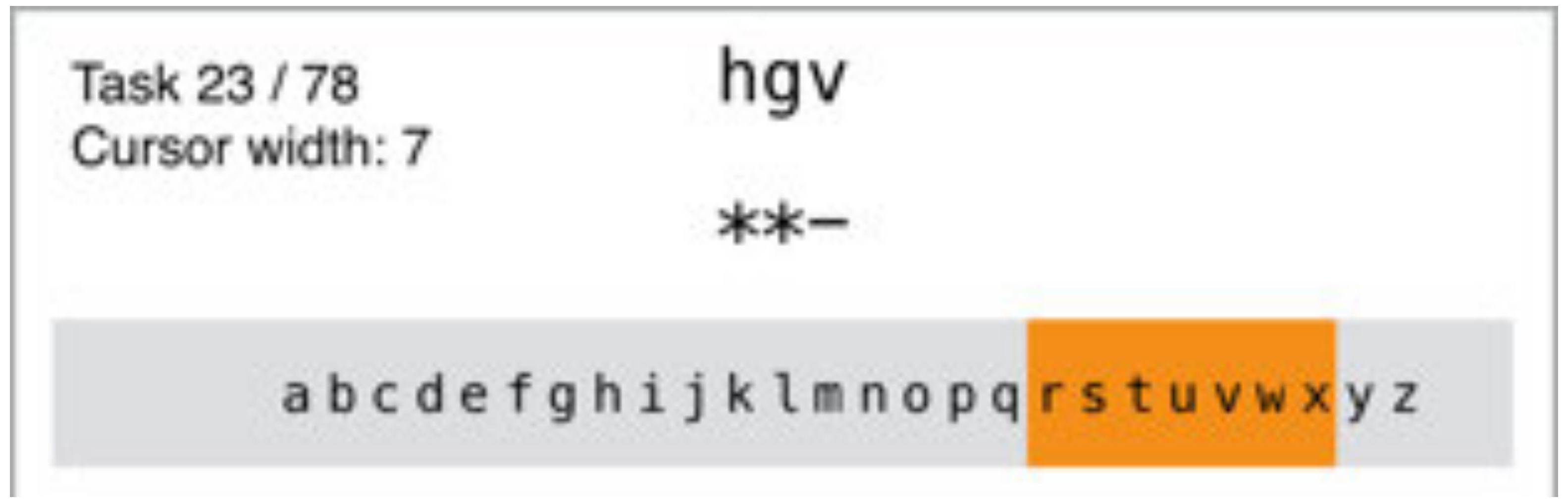
Study 1: Error model of pressure control

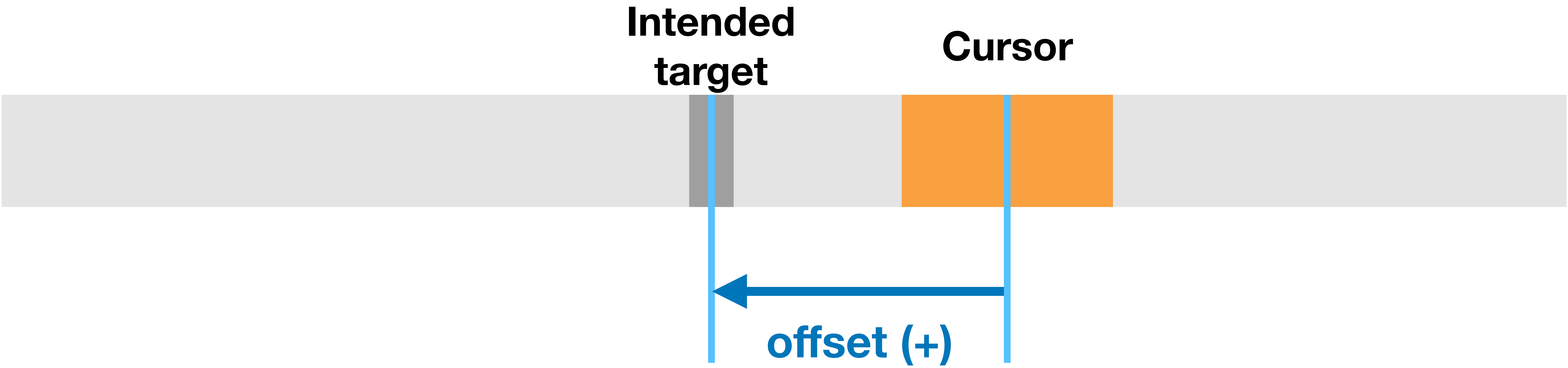
- Wizard of Oz approach



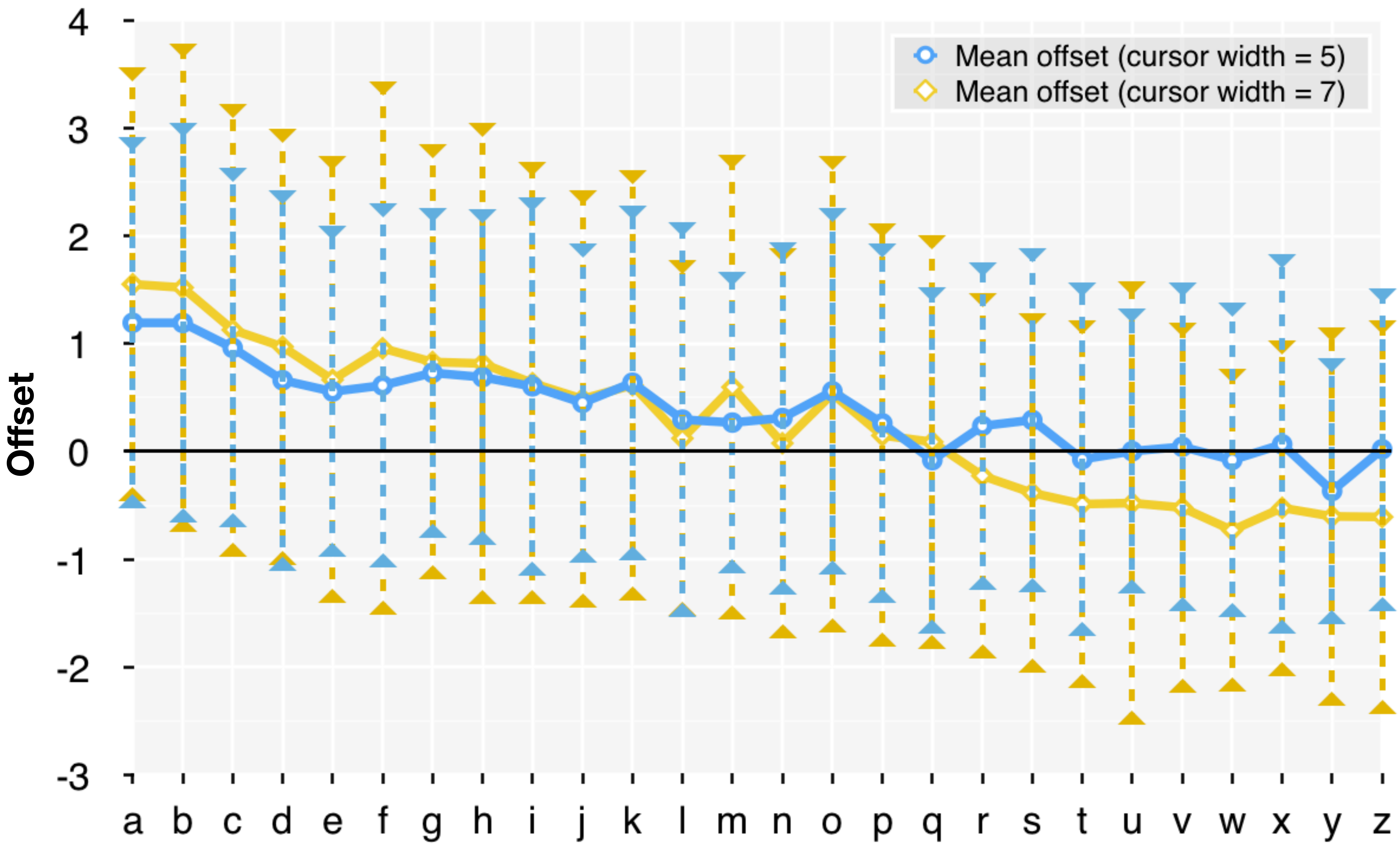
- Cursor widths 5 or 7
- Random 3-letter sequences

Study 1: Error model of pressure control

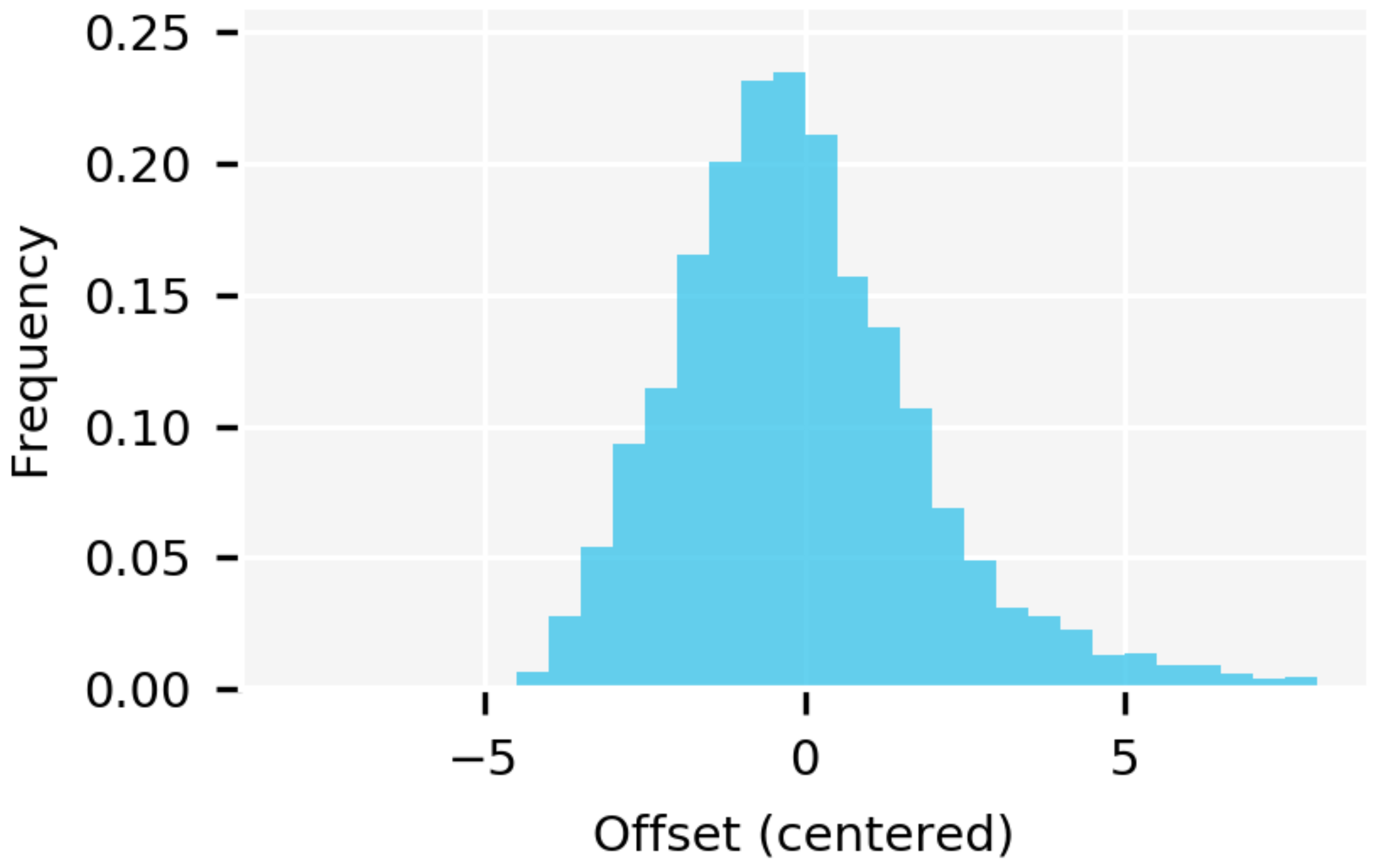
- Offset: distance between the cursor location at Quick Release and the intended target center



- Offset is position when the cursor overshoots the target position



Mean offset (cursor width = 5)
Mean offset (cursor width = 7)
Offset
4
3
2
1
0
-1
-2
-3
a b c d e f g h i j k l m n o p q r s t u v w x y z



0.25
0.20
0.15
0.10
0.05
0.00
Frequency
−5
0
5
Offset (centered)

Error model of pressure control

- Distribution of Offset

- Miss rate: percentage of pressure input where users completely overshot or undershot the target letter

  - 5-letter-wide cursor: 7.7% missed

  - 7-letter-wide cursor: 5.8% missed

- Users attempted to release pressure and move the cursor to the intended position

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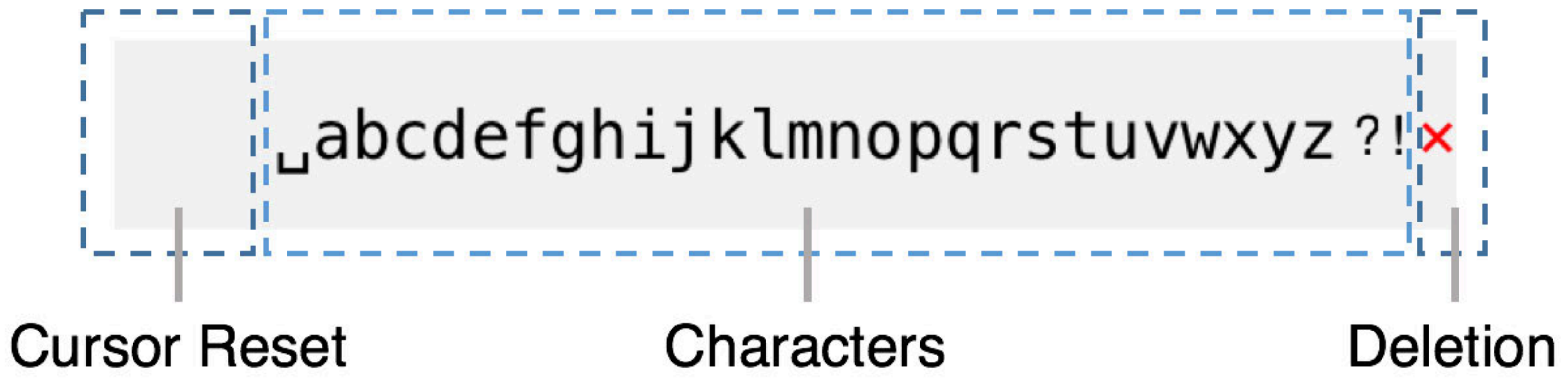
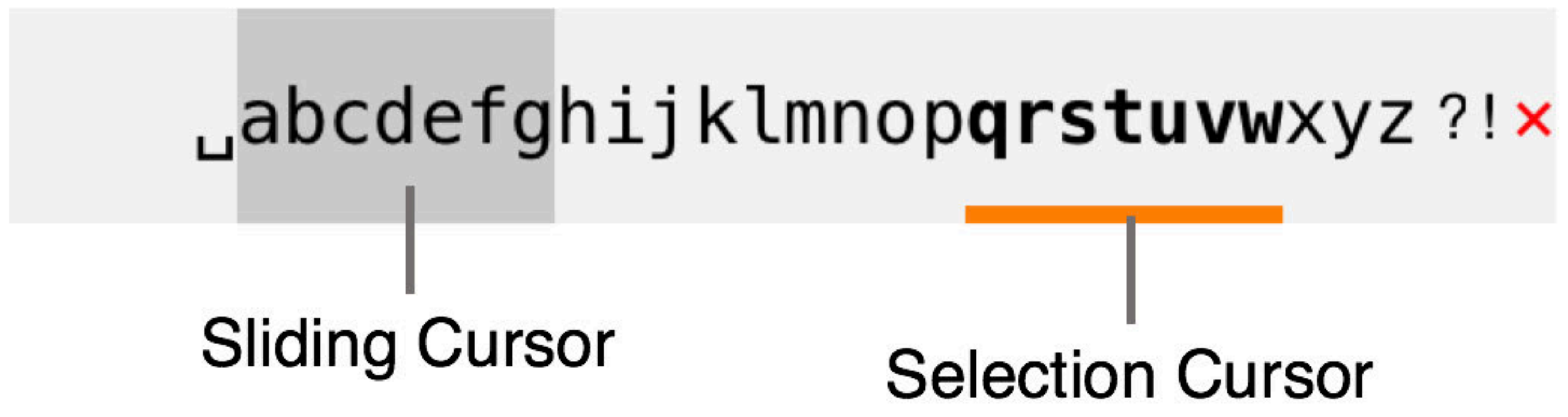
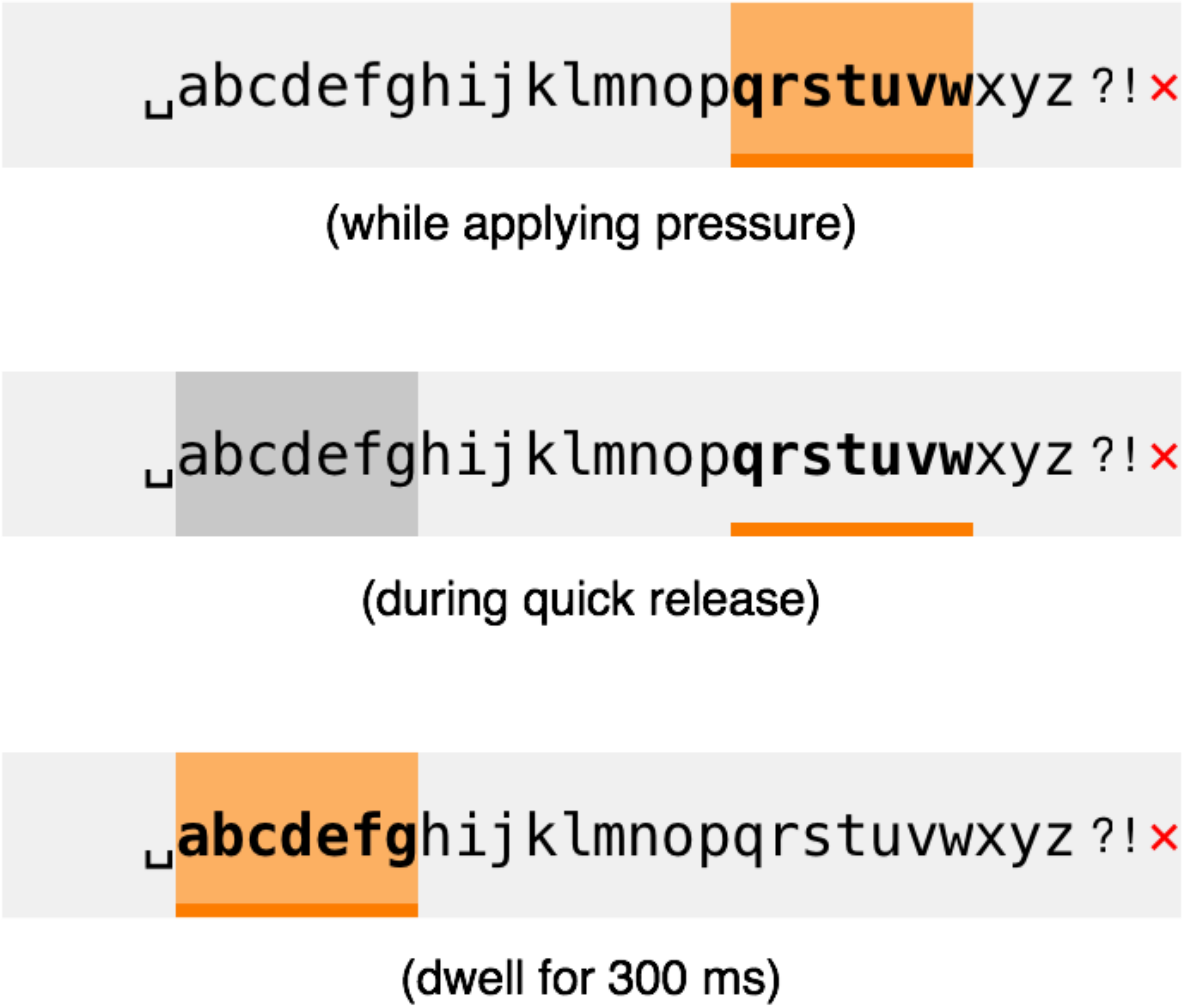
Interaction Design

- One-dimensional keyboard regions



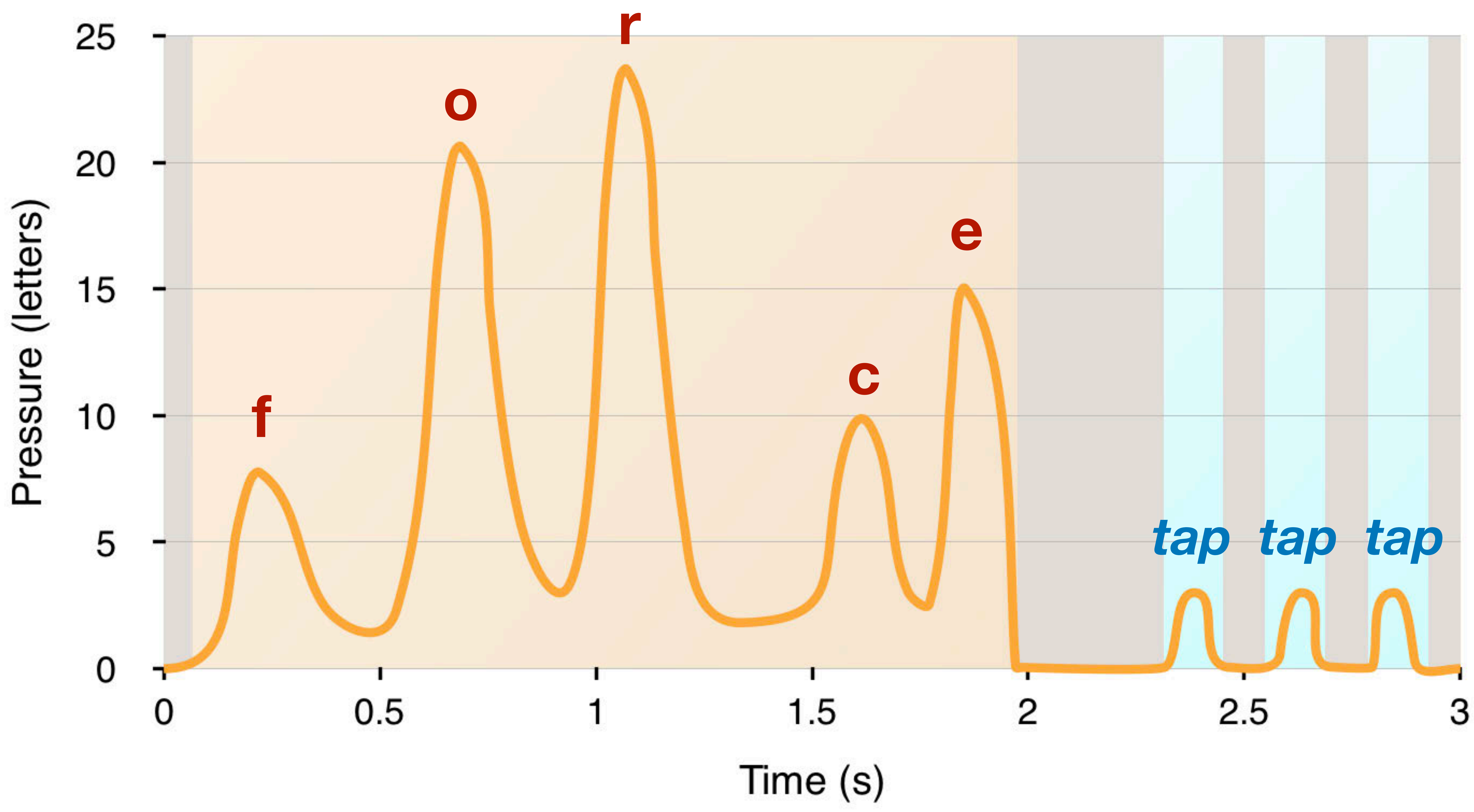
- Two cursors to help with overshooting target position




␣abcdefghijklmnopqrstuvwxyz?!×
(while applying pressure)
␣abcdefghijklmnopqrstuvwxyz?!×
(during quick release)
␣abcdefghijklmnopqrstuvwxyz?!×
(dwell for 300 ms)

- Selecting a candidate word:
  tap to select the next one; long press to select the previous one

- Inputting the word “force”



Word prediction

- Statistical decoding: error model of pressure control + unigram language model (10,000 words)
- User input a sequence of pressure $I = p_1 p_2 ... p_n$

$$P(w|I) = \frac{P(w) \cdot P(I|w)}{P(I)}$$

- Suppose pressure applied for each letter to be independent

$$P(I|w) = \prod_{i=1}^{n} P(p_i|l_i)$$

- OOV words can be entered by selecting each individual letter

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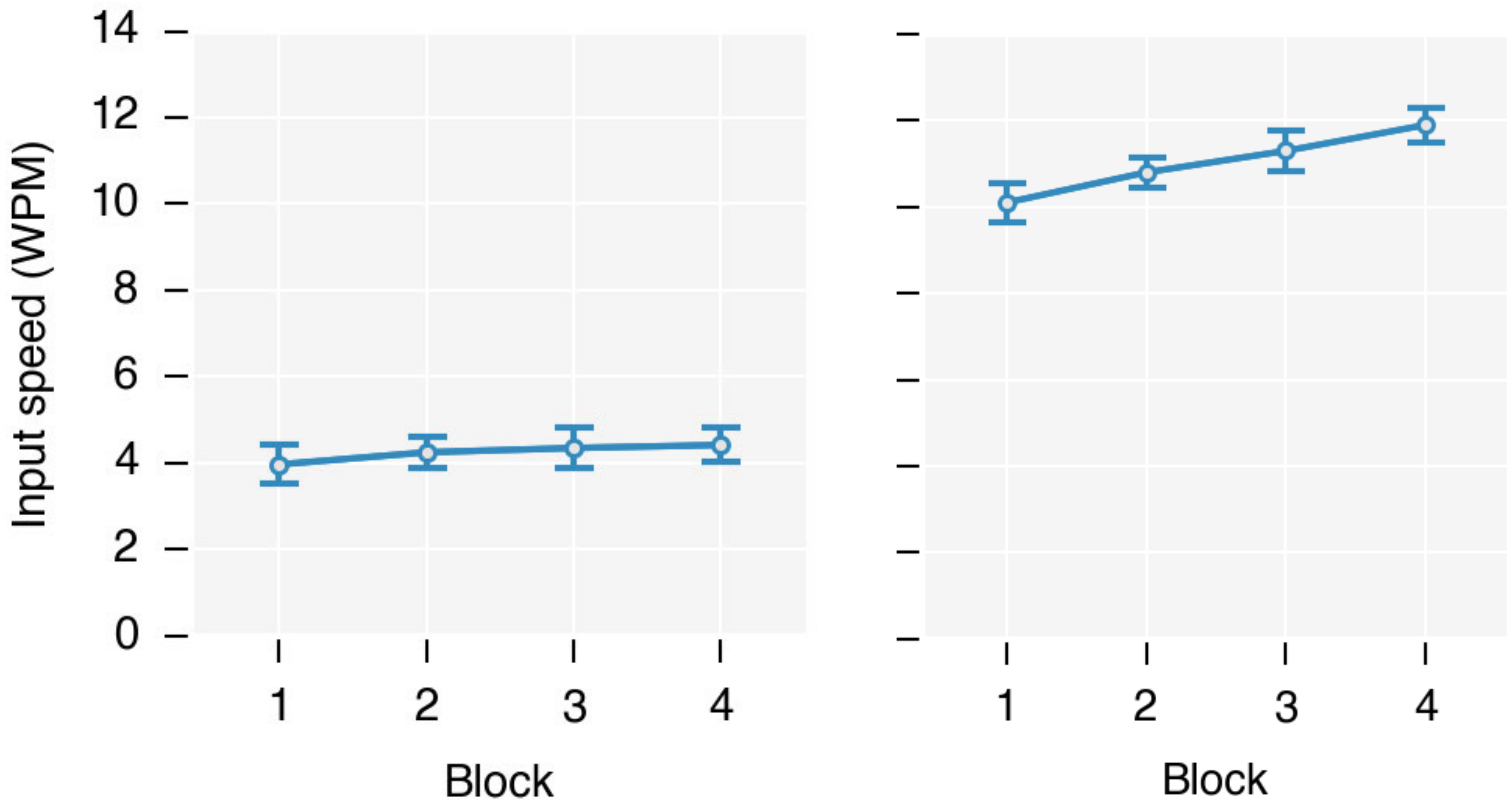
User Study 2: Performance evaluation

- 12 users with no experience with pressure-based input
- A character-level session and a Word-level session
- Users entered two phrases as a warm-up before each session
- Character-level session: 2 phrases × 4 blocks
- Word-level session: 10 phrases × 4 blocks

Results

- *Error rates*
  - Uncorrected: 1.1% for character-level; 0.47% for word-level
  - Corrected: 2.0% for character-level; 1.8% for word-level

- *Text entry rate*
  - Character-level:
    average: 4.24 wpm
    last block: 4.42 wpm
  - Word-level:
    average: 11.04 wpm
    last block: 12.80 wpm



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Applications

- When device form-factor is limiting
- When finger movement is not desired
- When capacitive touchscreens are infeasible
- When used with a separate display

Scenario 1: Secret Typing

Limitations and future work

Limitations

- Slower than touch-based keyboards
- Requires continuous visual attention

Future work

- Longitudinal study on learning, fatigue, and mental stress
- Investigate rate control instead of position control
- More sophisticated language models

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Summary

- Pressure as the main input channel
- Subtle thumb movement
- Modeled continuous pressure control
- 11 wpm after 10 minutes training

One-Dimensional Handwriting: Inputting Letters and Words on Smart Glasses (CHI '16)

https://dl.acm.org/citation.cfm?id=2858542

Understanding the Uncertainty in 1D Unidirectional Moving Target Selection (CHI '18)

https://dl.acm.org/citation.cfm?doid=3173574.3173811

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