Solution principles for

Uncertain Interaction

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Visions of the Future

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- Ubiquitous sensing
  - Smart home, Internet of Things, etc.
- Pervasive agents
  - Spoken dialogue-based command and query interfaces
- Virtual reality
  - Portable office, training, immersive data analytics
- Phone without a phone
  - Optical see-through head-mounted displays with form factors comparable to everyday glasses

Visions of the Future

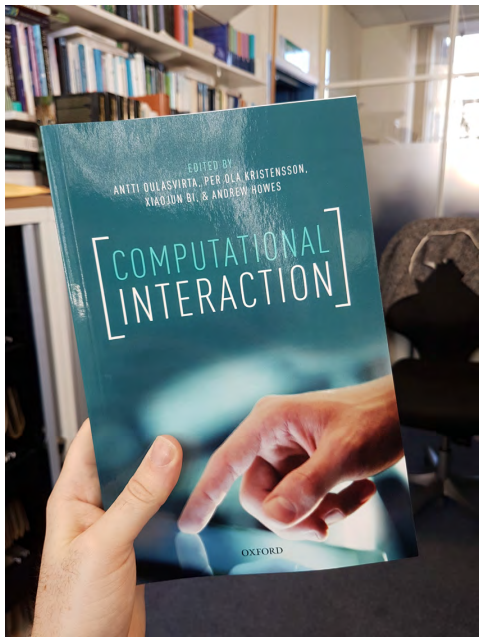
- Ubiquitous sensing
  - Smart home, Internet of Things, etc.
- Pervasive agents

All assume fluid interfaces based on fundamentally **uncertain** interaction

  - Portable office, training, immersive data analytics
- Phone without a phone
  - Optical see-through head-mounted displays with form factors comparable to everyday glasses

Computational interaction

- Classic human-computer interaction (HCI) method does not handle user interface design under uncertainty very well
- Classic HCI method is underpinned on eliciting user needs using a variety of processes and then an iterative process of design and evaluation, in which design is driven by design ingenuity rather than principles
- This means:
  - No automated design work
  - No explicit model
  - Data influenced design only through the designer
- Computational interaction is an emerging discipline in HCI which proposes user interface development by allowing algorithms to perform work, by explicit modelling, and by allowing data to directly influence design.



Computational interaction

- Computational interaction would typically involve at least one of:
  I. an explicit mathematical model of user-system behavior;
  II. a way of updating that model with observed data from users;
  III. an algorithmic element that, using this model, can directly synthesise or adapt the design;
  IV. a way of automating and instrumenting the modeling and design process;
  V. the ability to simulate or synthesise elements of the expected user-system behavior.

Intelligent text entry as an example of designing interaction under uncertainty

Principles of intelligent text entry

Kristensson, P.O. 2009. Five challenges for intelligent text entry methods. *AI Magazine* **30**(4): 85-94.

Principles of intelligent text entry

1. Letters simplified to line marks

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Principles of intelligent text entry

1. Letters simplified to line marks
2. Common word stems compressed into simple line marks or dots
3. Common word stems identified by word frequency analysis of the book of psalms


MONK AT WORK. (From *Lacroix.*)

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Principles of intelligent text entry

- In other words:


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Principles of intelligent text entry

- In other words:
  1. Optimise speed by minimsing the amount of information users have to articulate
  2. Exploit redundancies in natural languages by creating a language model


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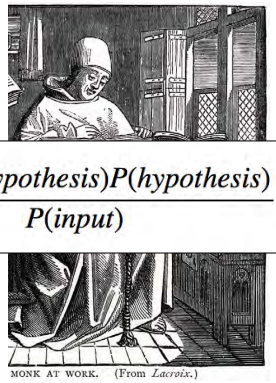
Principles of intelligent text entry

- ...which can often be thought of as an inference problem:



$$P(hypothesis|input) = \frac{P(input|hypothesis)P(hypothesis)}{P(input)}$$

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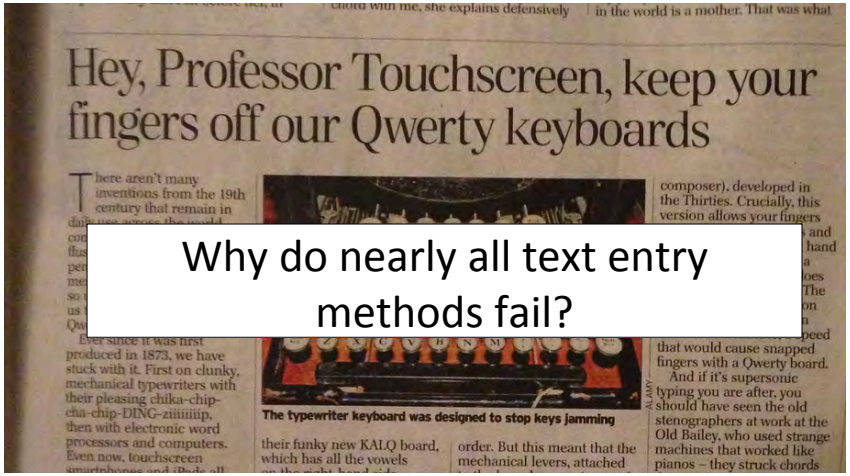
Hey, Professor Touchscreen, keep your fingers off our Qwerty keyboards

There aren't many inventions from the 19th century that remain in

composer), developed in the Thirties. Crucially, this version allows your fingers

that would cause snapped fingers with a Qwerty board.

And if it's supersonic typing you are after, you should have seen the old stenographers at work at the Old Bailey, who used strange machines that worked like pianos – they struck chords

The typewriter keyboard was designed to stop keys jamming

their funky new KALQ board, which has all the vowels

order. But this meant that the mechanical levers, attached

produced in 1873, we have stuck with it. First on clunky, mechanical typewriters with their pleasing chika-chip-cha-chip-DING-ziiiiiiip, then with electronic word processors and computers. Even now, touchscreen

Why do nearly all text entry methods fail?

Mainstream mobile text entry methods

Mainstream mobile text entry methods

Graffiti

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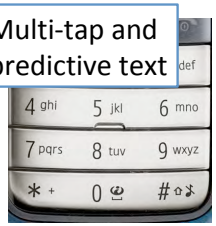
Graffiti

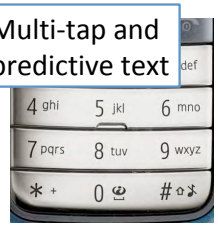
Multi-tap and predictive text



Mainstream mobile text entry methods

Graffiti

Multi-tap and predictive text



Touchscreen keyboards

Mainstream mobile text entry methods

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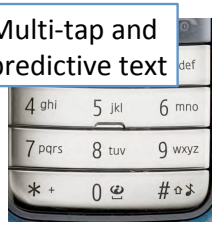

Touchscreen keyboards

Gesture keyboards

Mainstream mobile text entry methods

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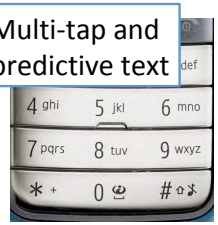
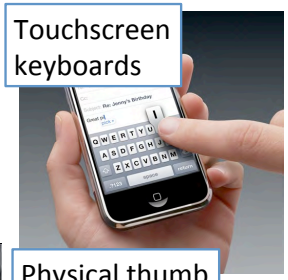


Touchscreen keyboards



Gesture keyboards

Physical thumb keyboards

Mainstream mobile text entry methods

- Entry and error rate
- Learning curve, familiarity and immediate efficacy
- Form factor, preparation time and comfort
- User engagement
- Visual attention and cognitive resources
- Privacy
- Single vs. multi-character entry
- Specification vs. navigation
- One-handed vs. two-handed
- Task integration
- Robustness
- Device independence
- Computational demands
- Manufacturing and support cost
- Localisation
- Market acceptance

Mainstream mobile text entry methods

- **High effective entry rate**
  - Among the fastest of their generation
- **High familiarity and high immediate efficacy**
  - Either extremely easy-to-learn or very similar to existing technology (or both)

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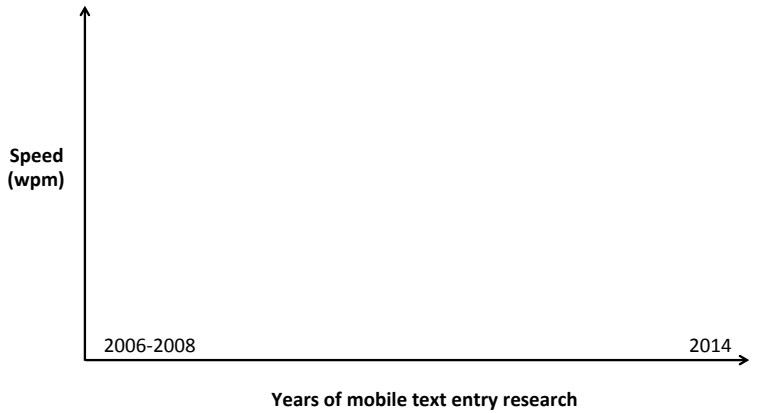
Mobile text entry: the state of the art



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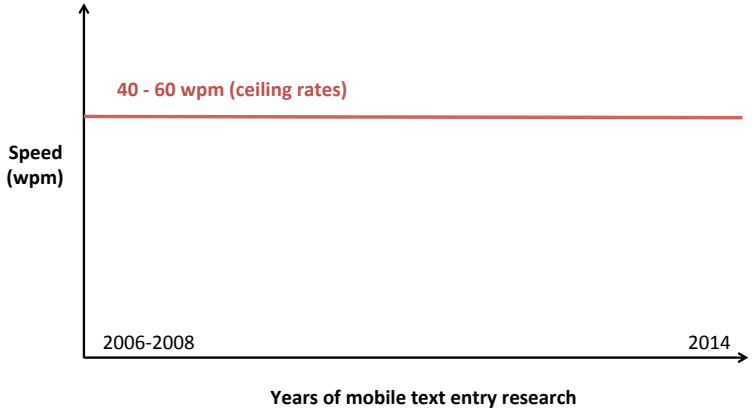

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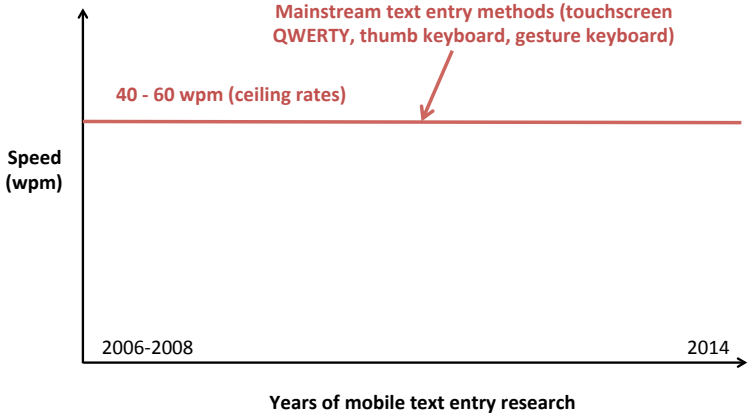

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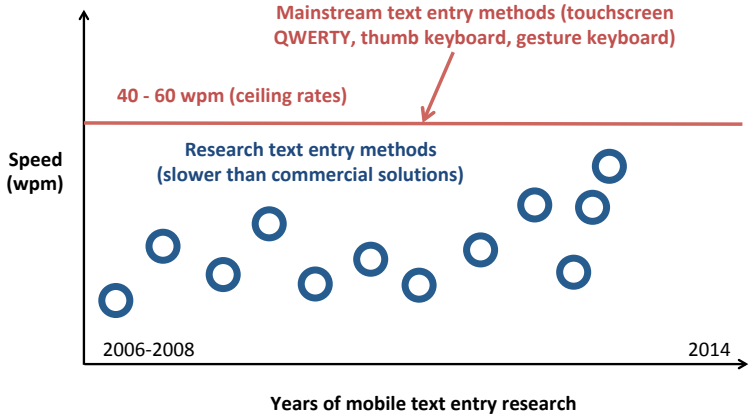

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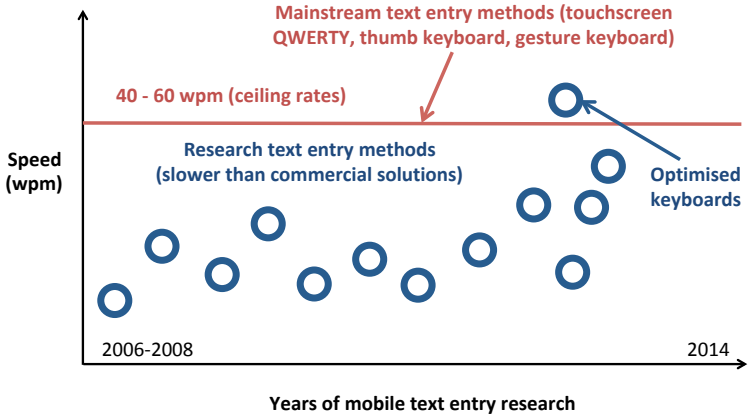

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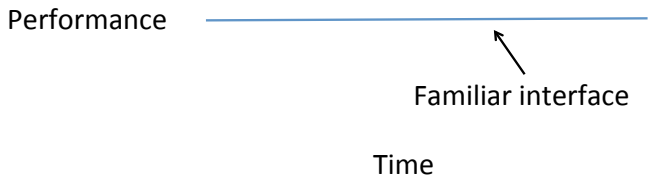
- support cost
- Localisation
- Market acceptance

The cross-over point

Performance

Time

The cross-over point



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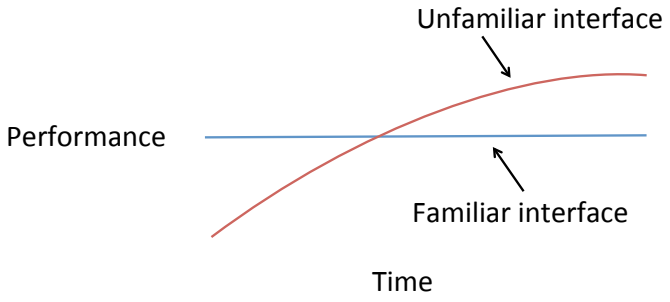

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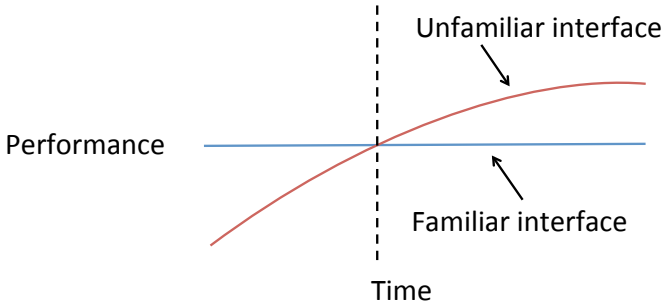

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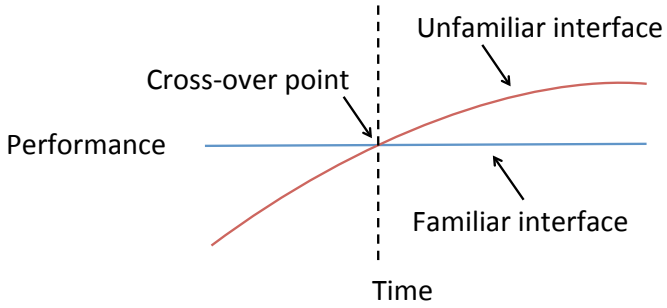

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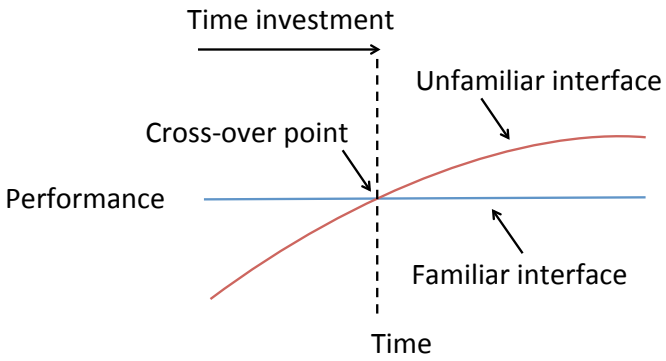

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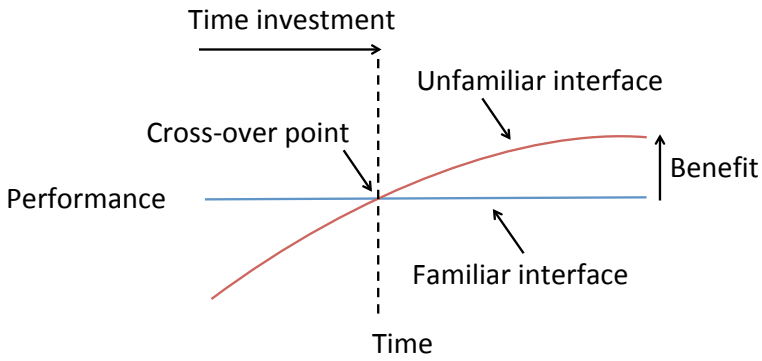

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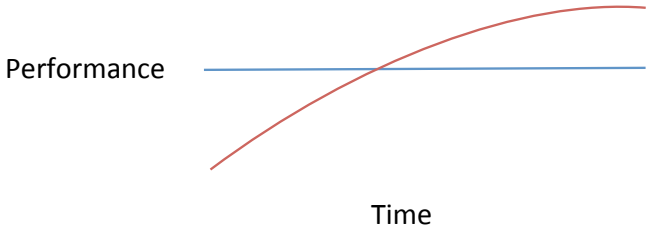

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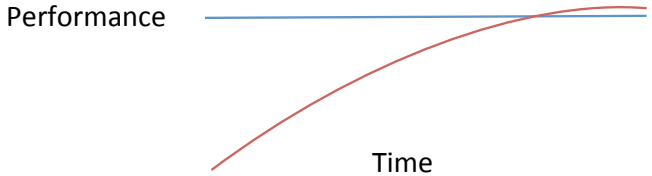

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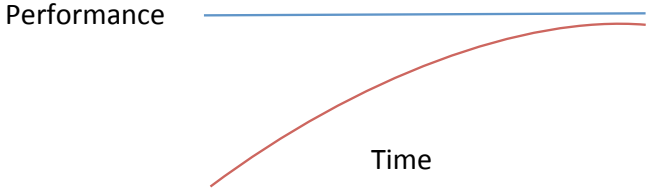

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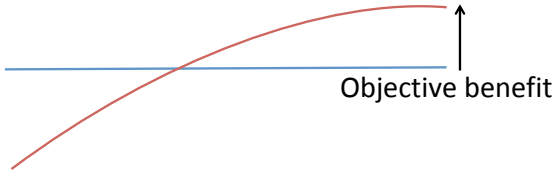

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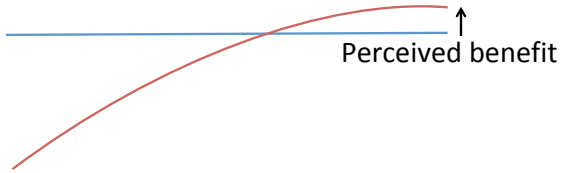

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The narrow design space

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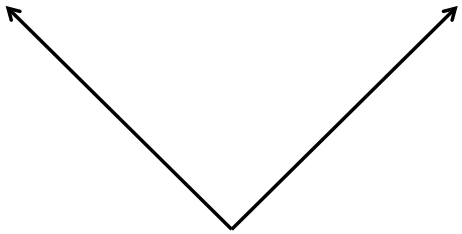

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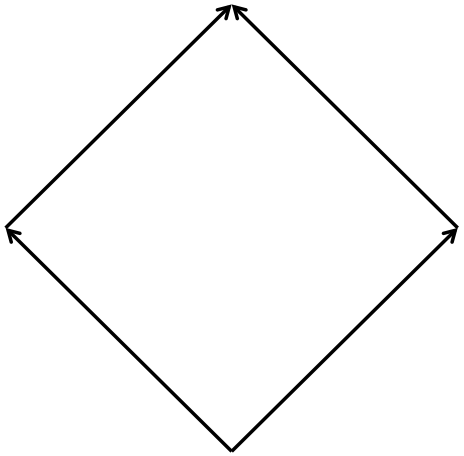

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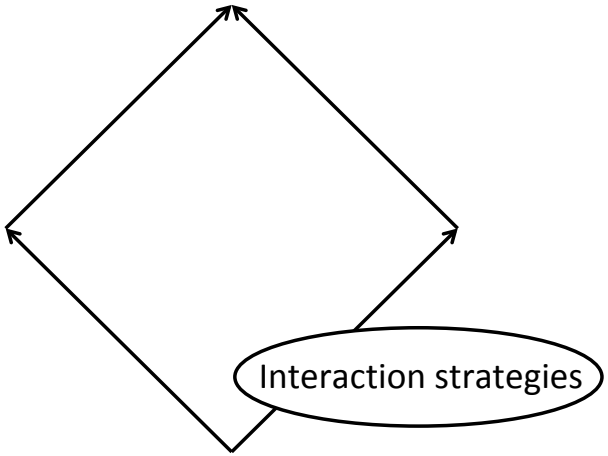

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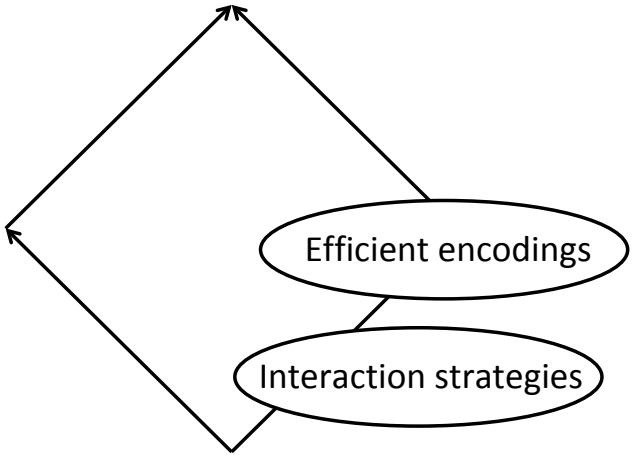

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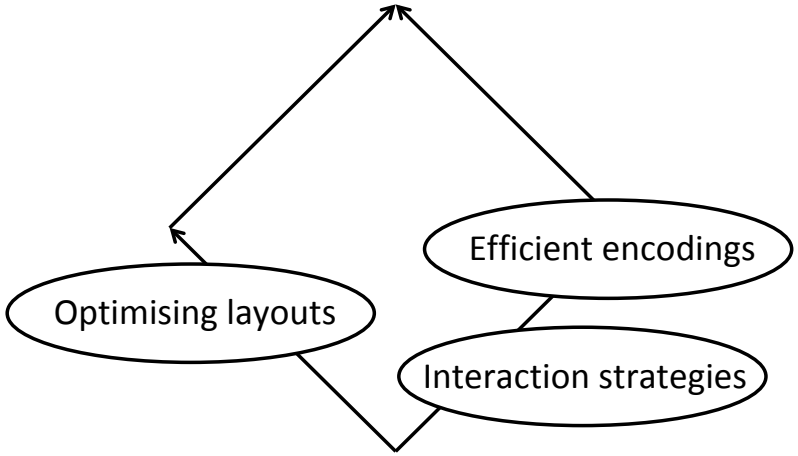

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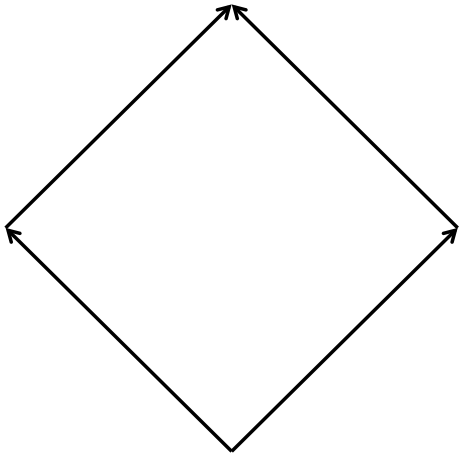

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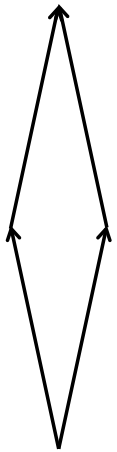


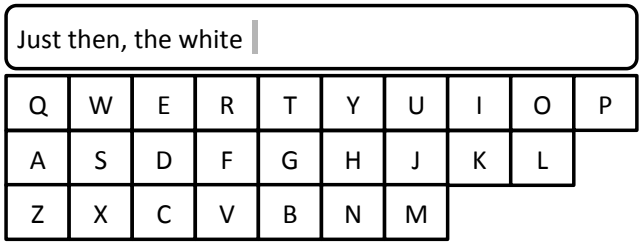
The narrow design space

Solution principles

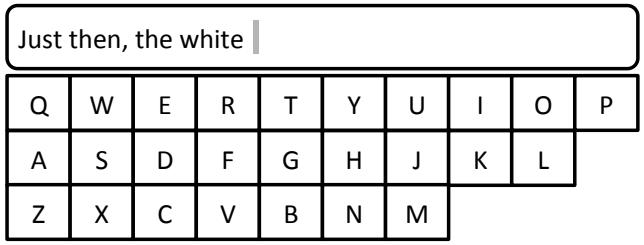
- From closed to open-loop
  - Avoid the need for a visual feedback loop
- Continuous novice-to-expert transition
  - Avoid explicit learning
- Path dependency
  - Avoid redesigning the interaction layer
- Flexibility
  - Enable users to compose and edit in a variety of styles without explicit mode switching
- Probabilistic error correction
  - Use the hypothesis space to design optimal error correction strategies
- Fluid regulation of uncertainty
  - Allow users to seamlessly influence the inference process
- Efficiency
  - Let users' creativity be the bottle-neck

From Closed to Open Loop

Reimaging the keyboard



How gesture keyboards work



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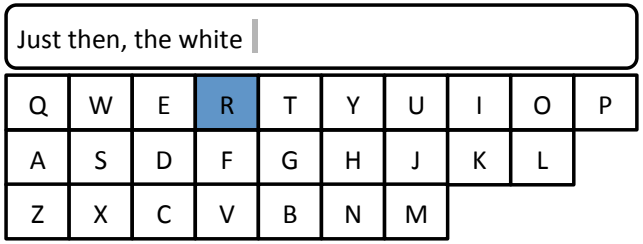

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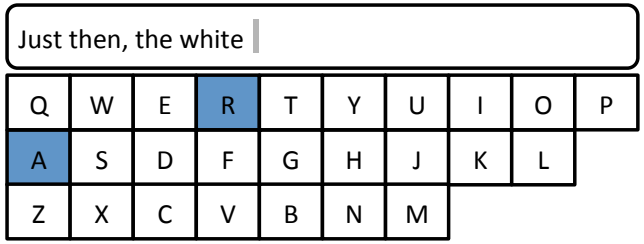

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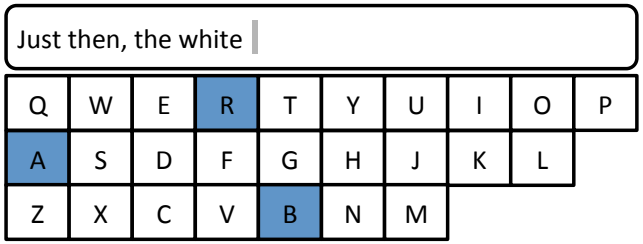

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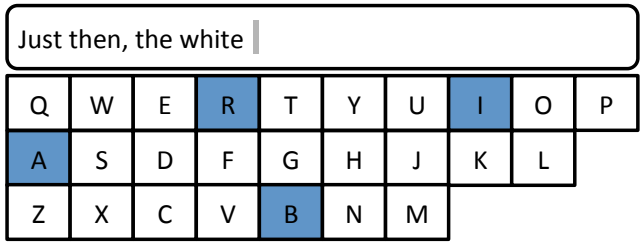

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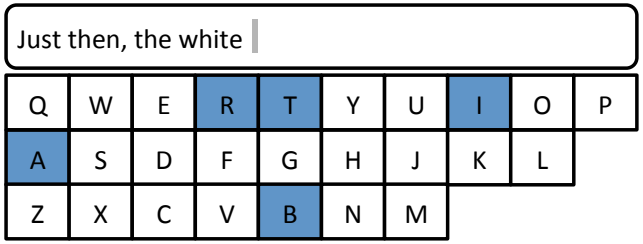

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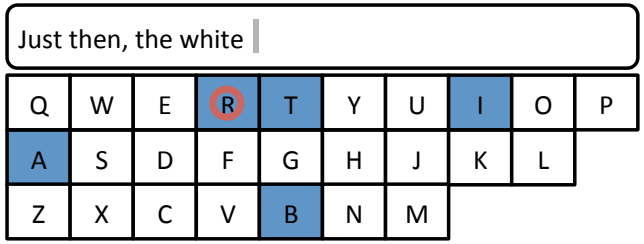

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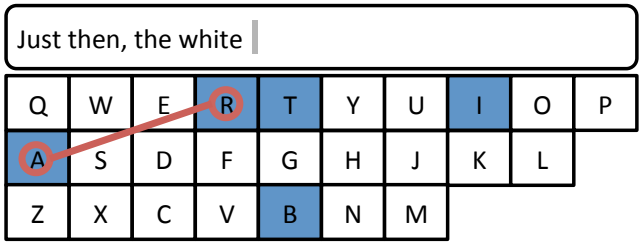

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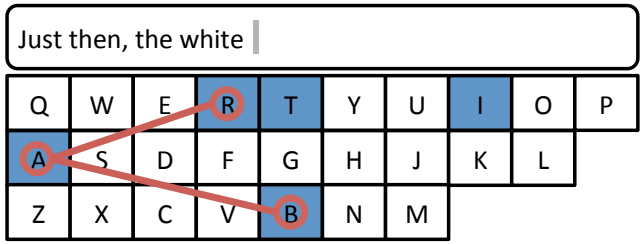

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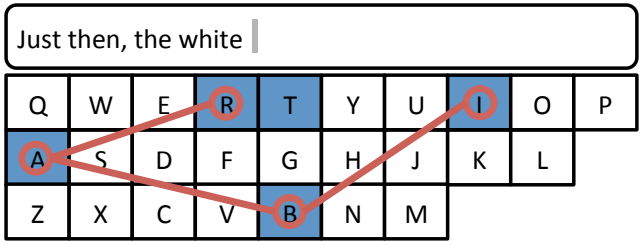

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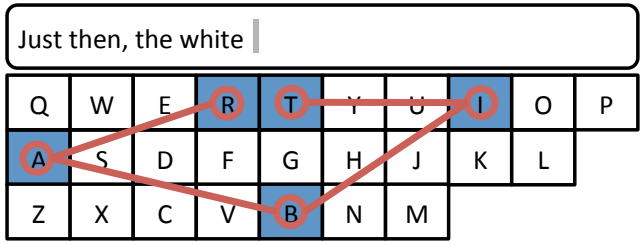

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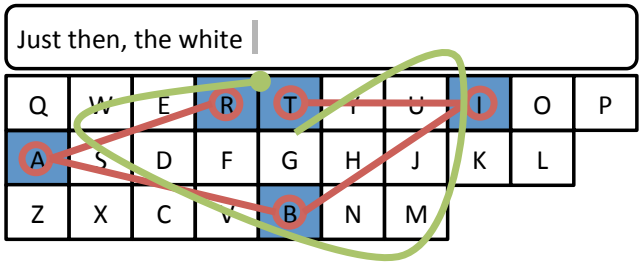

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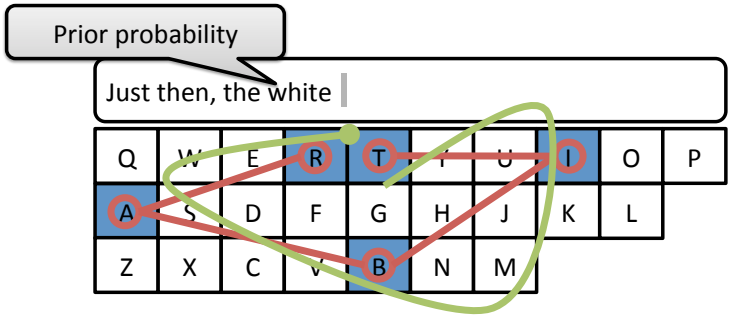
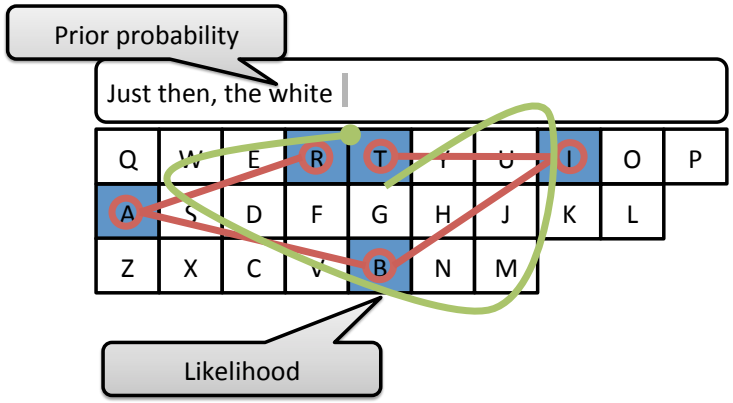


How gesture keyboards work



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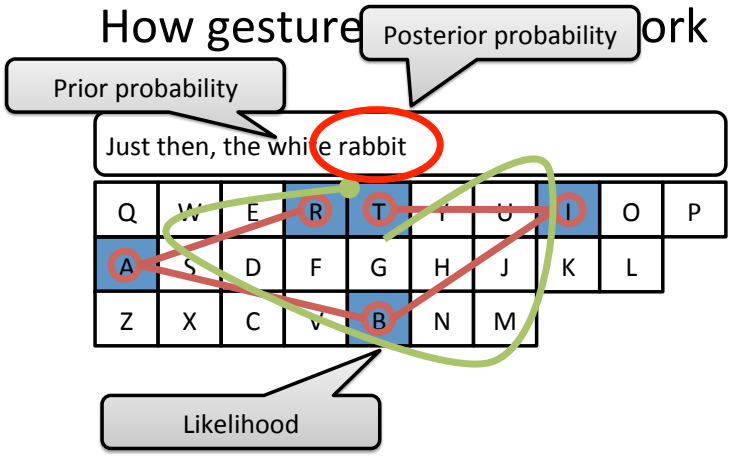
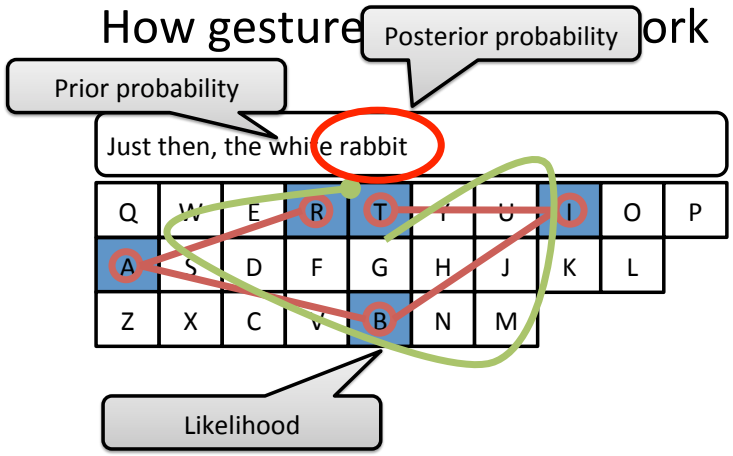


How gesture [illegible]ork



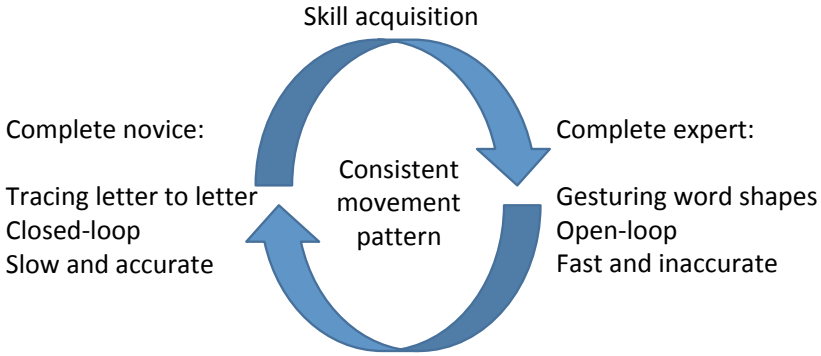
Decoding noisy gestures into text using a combination of gesture recognition and language modelling

Closed- and open-loop

- Closed-loop:
  - Continuous feedback-driven interaction
  - Visually-guided motion
  - Slow and precise
  - Modelled well by the "crossing law"
    - Average movement time = $a + b \log_2(D/W+1)$; a and b are linear regression coefficients; D and W are the distance and width to the crossing goal respectively
- Open-loop:
  - Not feedback-driven
  - Direct recall from motor memory
  - Fast and imprecise
  - No good model exits
- Gesture keyboard interaction is a mix of closed- and open-loop interaction

Continuous Novice-to-Expert Transition

Continuous transition from novice to expert behaviour



Path Dependency

Clio and the Economics of QWERTY

By PAUL A. DAVID*

Cicero demands of historians, first, that we tell true stories. I intend fully to perform my duty on this occasion, by giving you a homely piece of narrative economic history in which "one damn thing follows another." The main point of the story will become plain enough: it is sometimes not possible to uncover the logic (or illogic) of the world around us except by understanding how it got that way. A *path-dependent* sequence of economic changes is one of which important influences upon the eventual outcome can be exerted by temporally remote events, including happenings dominated by chance elements rather than systematic forces. Stochastic processes like that do not converge automatically to a fixed-point distribution of outcomes, and are

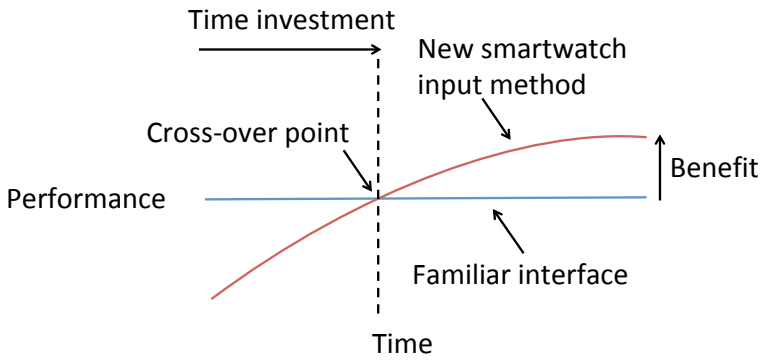
I. The Story of QWERTY

Why does the topmost row of letters on your personal computer keyboard spell out QWERTYUIOP, rather than something else? We know that nothing in the engineering of computer terminals requires the awkward keyboard layout known today as "QWERTY," and we all are old enough to remember that QWERTY somehow has been handed down to us from the Age of Typewriters. Clearly nobody has been persuaded by the exhortations to discard QWERTY, which apostles of DSK (the Dvorak Simplified Keyboard) were issuing in trade publications such as *Computers and Automation* during the early 1970's. Why not? Devotees

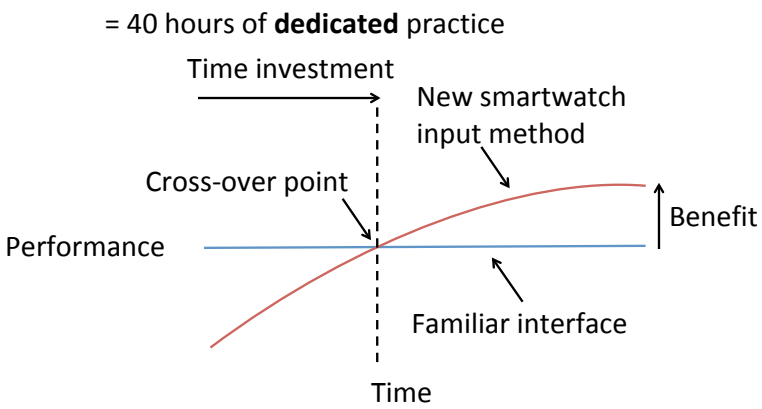
Example: typing on a smartwatch

- Small screen size is obviously a constraint
- Many naïve solutions:
  - Progressive zooming techniques
  - Reduce keyset (á la the old telephone keypad techniques)
  - Various multi-stroke strategies
- **All slow**
- **All demand user learning** (no immediate efficacy)

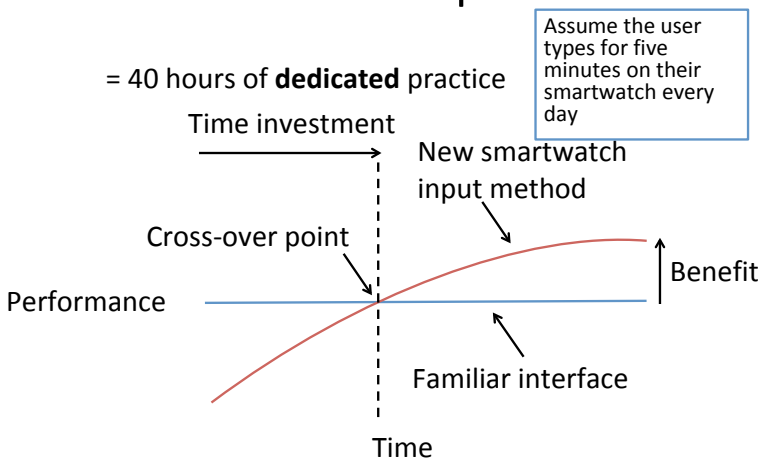
The cross-over point



The cross-over point



The cross-over point



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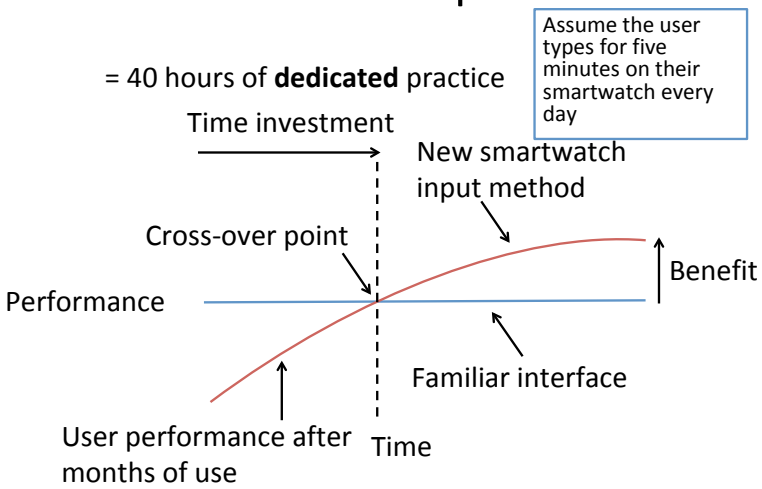
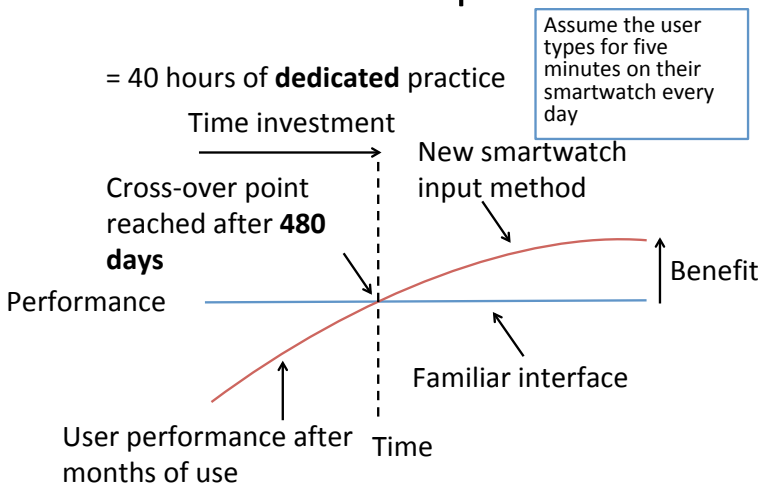


The cross-over point



Mainstream mobile text entry methods

- Entry and error rate
- Learning curve, familiarity and immediate efficacy
- Specification vs. navigation
- One-handed vs. two
- **High effective entry rate**
  - Among the fastest of their generation
- **High familiarity and high immediate efficacy**
  - Either extremely easy-to-learn or very similar to existing technology (or both)
- Single vs. multi-character entry
- support cost
- Localisation
- Market acceptance

Mainstream mobile text entry methods

- Entry and error rate
- Learning curve, familiarity and immediate efficacy
- Specification vs. navigation
- One-handed vs. two
- **High effective entry rate**
- **H** **e efficacy**
- similar to
- It takes a very long time to learn QWERTY (or learn a new layout)
- S entry
- Localisation
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Mainstream mobile text entry methods

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- It takes a very long time to learn QWERTY (or learn a new layout)
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- **Keep QWERTY**
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Mainstream mobile text entry methods

- Entry and error rate
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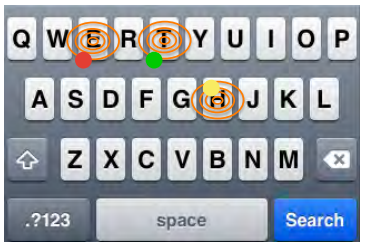
- One-handed vs. two

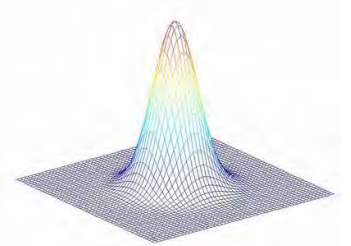
- **High effective entry rate**
- **H… …e efficacy**
  - It takes a very long time to learn QWERTY (or learn a new layout)
  - Users are familiar with touchscreen QWERTY
  - **Keep QWERTY**

…similar to

- S… entry
- Localisation
- Market acceptance

Touch modelling





2D Gaussians centered at each key.
Separate variances in the x- and y-dimensions.

$$P(Letters|Taps) \propto \underbrace{P(Taps|Letters)}_{\text{touch model}} \underbrace{P(Letters)}_{\text{language model}}$$

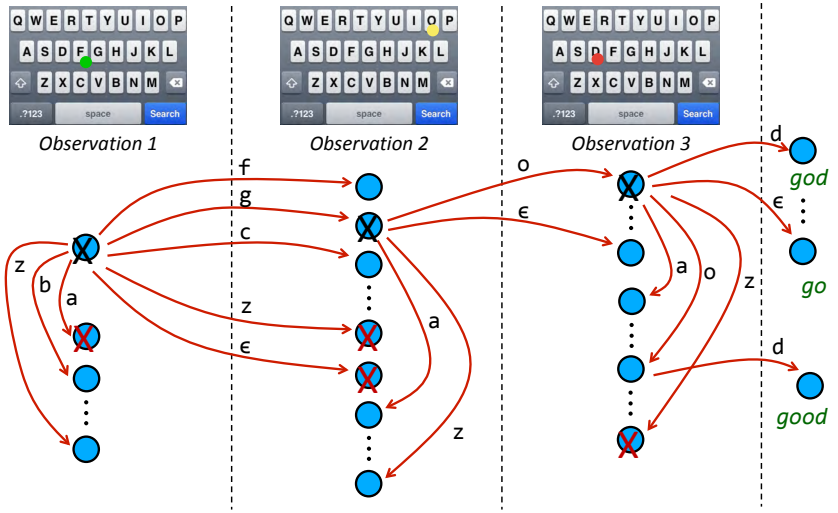
Vertanen, K., Memmi, H., Emge, J., Reyal, S. and Kristensson, P.O. 2015. VelociTap: investigating fast mobile text entry using sentence-based decoding of touchscreen keyboard input. *In Proceedings of the 33rd ACM Conference on Human Factors in Computing Systems (CHI 2015)*. ACM Press: 659-668.

Language modelling

- Language models:
  - **12-gram letter** model
  - **4-gram word** model with unknown word
  - Trained on **billions of words** of data
    - Twitter, blog, social media, Usenet, and web data
  - Optimized for **short email-like messages**
  - Letter + word language model = ~4 GB memory

Vertanen, K., Memmi, H., Emge, J., Reyal, S. and Kristensson, P.O. 2015. VelociTap: investigating fast mobile text entry using sentence-based decoding of touchscreen keyboard input. *In Proceedings of the 33rd ACM Conference on Human Factors in Computing Systems (CHI 2015)*. ACM Press: 659-668.

Decoding

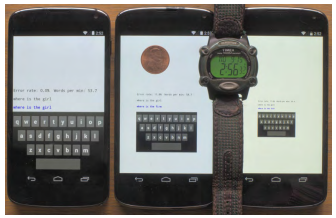


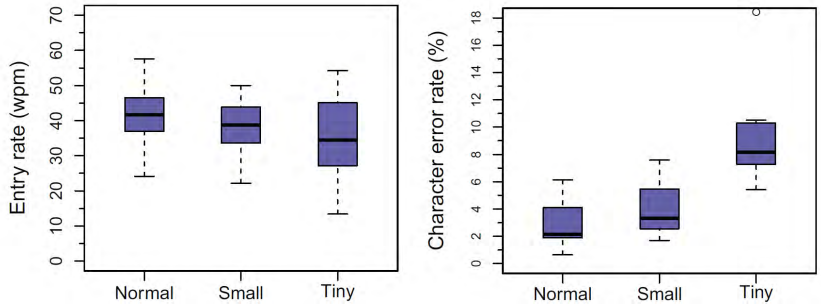
Tokens track: probability, LM context, traceback

Beam prune to keep tractable

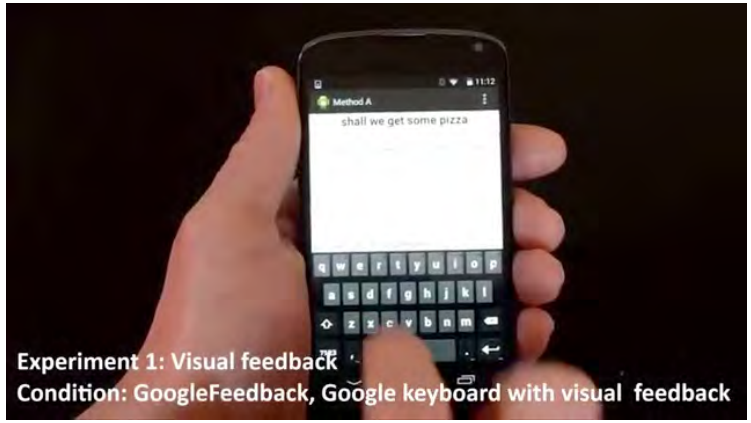
Entry and error rate

Condition	
Normal	Standard portrait keyboard, 60mm wide
Small	Big smartwatch, 40mm wide
Tiny	Small smartwatch, 25mm wide





Typing on a tiny keyboard



Speech recognition error correction: the standard method

- User: “the cat sat”

Flexibility

Speech recognition error correction: the standard method

- User: “the cat sat”
- System: “the bat sat”

Speech recognition error correction: the standard method

- User: “the cat sat”
- System: “the bat sat”
- User: “select bat”

Speech recognition error correction: the standard method

- User: “the cat sat”
- System: “the bat sat”
- User: “select bat”
- System: “the bat sat dissect rat”

Speech recognition error correction: the standard method

- User: “the cat sat”
- System: “the bat sat”
- User: “select bat”
- System: “the bat sat dissect rat”
- (User: “I hate this…”)

The flexible multimodal fusion approach

- User speaks: “the cat sat”

The flexible multimodal fusion approach

- User speaks: “the cat sat”
- System: “the bat sat”

The flexible multimodal fusion approach

- User speaks: “the cat sat”
- System: “the bat sat”
- User gestures the word: “cat”

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- User speaks: “the cat sat”
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The flexible multimodal fusion approach

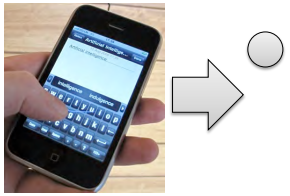
- User speaks: “the cat sat”
- System: “the bat sat”
- User gestures the word: “cat”
- System: “the cat sat”

- The system automatically identifies the error location and corrects the error

Kristensson, P.O. and Vertanen, K. 2011. Asynchronous multimodal text entry using speech and gesture keyboards. *In Proceedings of the 12th Annual Conference of the International Speech Communication Association (Interspeech 2011)*. ISCA: 581-584.

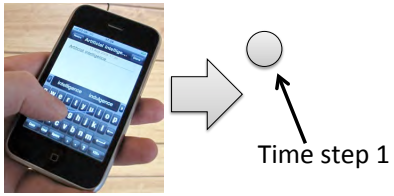
Output from a text entry modality

Gesture keyboard



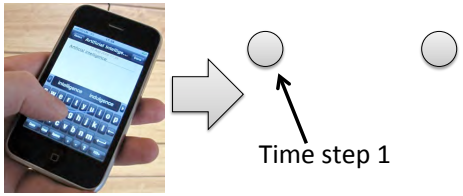
Output from a text entry modality

Gesture keyboard

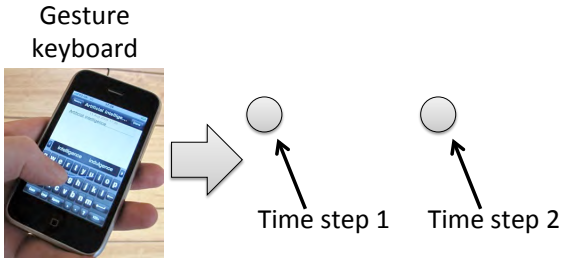


Output from a text entry modality

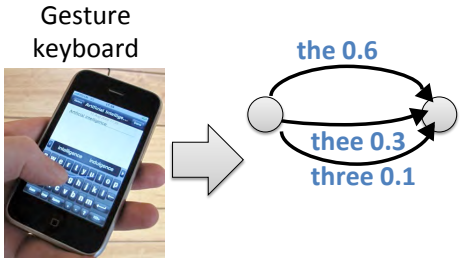
Gesture keyboard



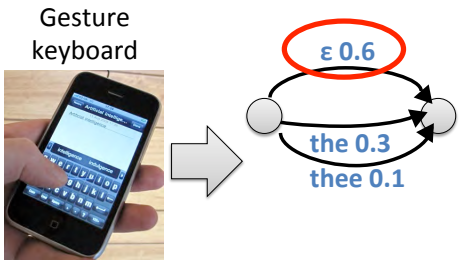
Output from a text entry modality



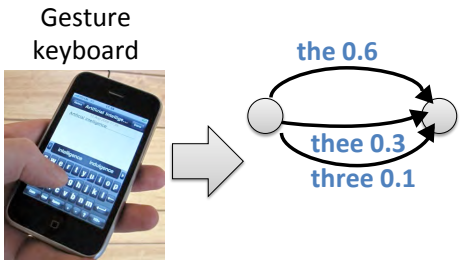
Output from a text entry modality



Output from a text entry modality

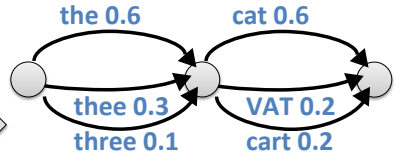


Output from a text entry modality

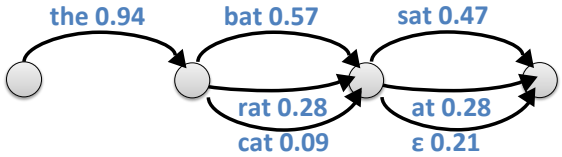


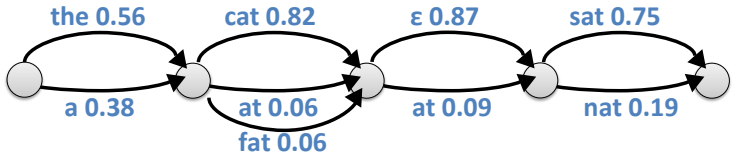
Output from a text entry modality

Gesture keyboard

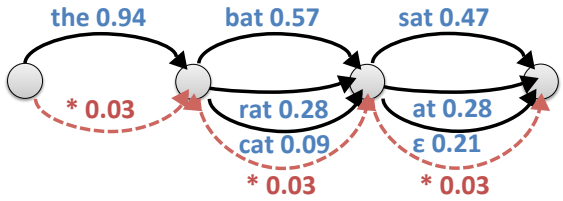


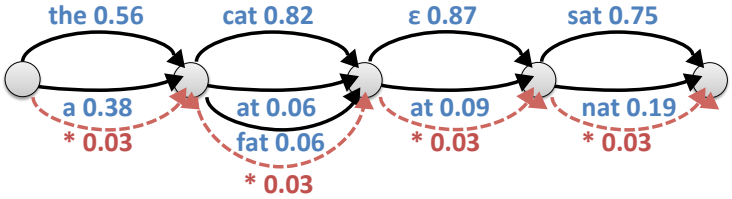
Output from two text entry modalities



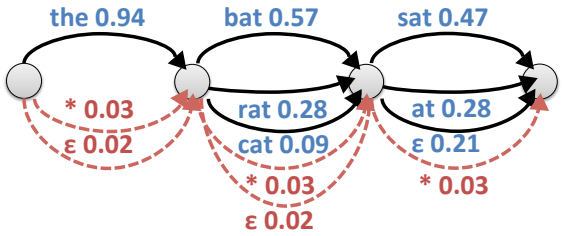


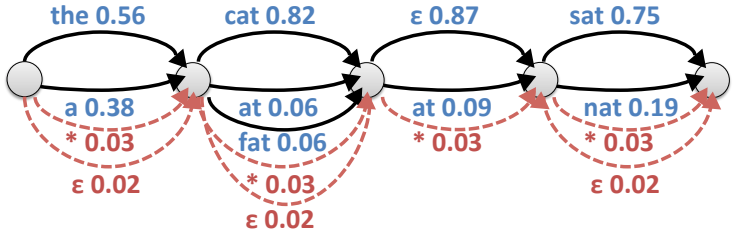
Softening the word confusion networks: adding **wild-card transitions**



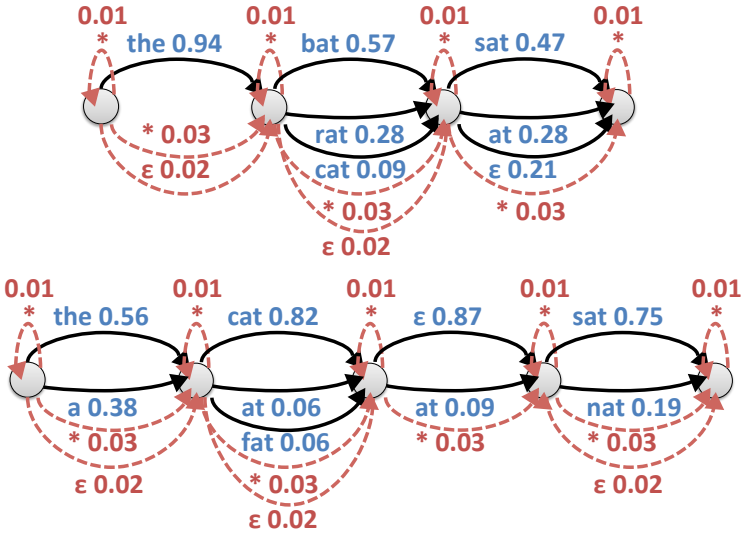


Softening the word confusion networks: adding **epsilon transitions**

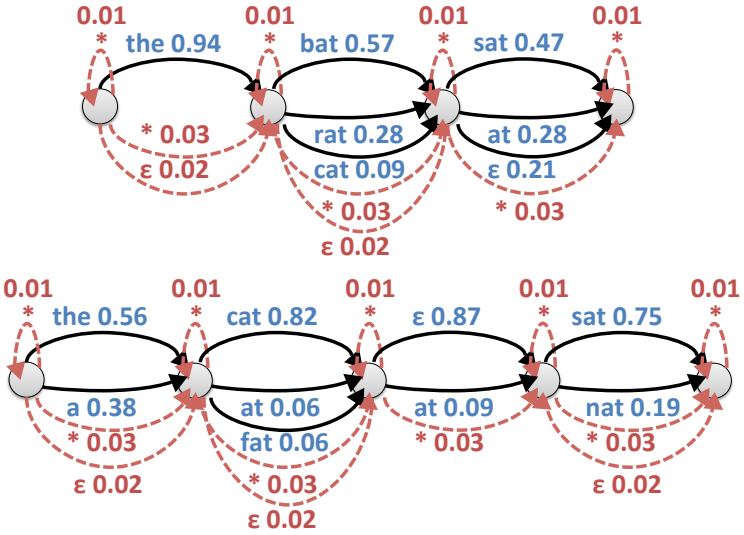




Softening the word confusion networks: adding **wild-card self-loops**



Search for the highest joint path in both recognition modalities



Speech-only flexible repair

Probabilistic error correction

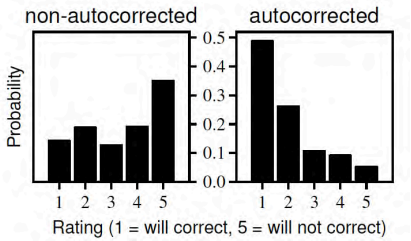
Probabilistic error correction

- For any probabilistic text entry method…
  - Capable of assigning posterior probability distributions to words
- …there exists a **hypothesis space**
- The best result is the maximum probability path in this hypothesis space
  - However, it need not be the one the user intended
- By exposing part of the hypothesis space to users, high efficiencies can be gained when users correct words

Fluid regulation of uncertainty

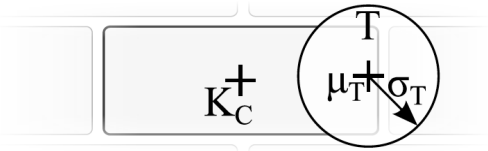
The auto-correct trap

- Auto-correct is great when it works
- However, when auto-correct fails error correction activities exhibit a high penalty
- The solution is to provide users with more **agency** and allow them to regulate their **certainty**



Weir, D., Pohl, H., Rogers, S., Vertanen, K. and Kristensson, P.O. 2014. Uncertain text entry on mobile devices. In *Proceedings of the 32nd ACM Conference on Human Factors in Computing Systems (CHI 2014)*. ACM Press: 2307-2316.

Pressure-sensitive auto-correct

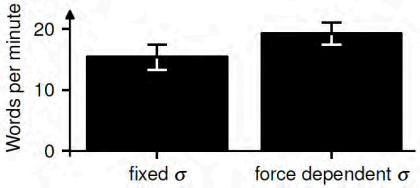


- Likelihood of a Gaussian with standard deviation regulated by pressure
- Standard deviation computed as C/ω_T, where C is a constant and ω_T is the pressure for touch T
- Tuned C so that the pressure of a typical touch had a standard deviation of half a key width

Weir, D., Pohl, H., Rogers, S., Vertanen, K. and Kristensson, P.O. 2014. Uncertain text entry on mobile devices. In *Proceedings of the 32nd ACM Conference on Human Factors in Computing Systems (CHI 2014)*. ACM Press: 2307-2316.

Results

- Enabling users to regulate their certainty by force resulted in a 10% percentage drop in active corrections (fixing a word by backspacing or retyping)
- This improved entry rate by 20%



Efficiency

Eye-typing

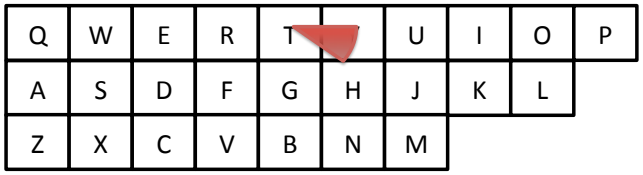
Q	W	E	R	T	Y	U	I	O	P
A	S	D	F	G	H	J	K	L	
Z	X	C	V	B	N	M			

Eye-typing

Q	W	E	R	T	Y	U	I	O	P
A	S	D	F	G	H	J	K	L	
Z	X	C	V	B	N	M			

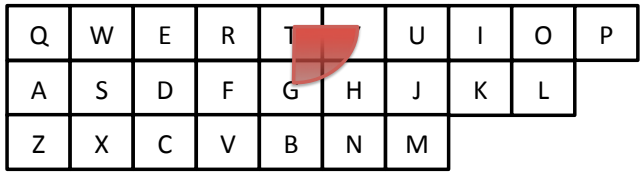
Eye-typing

125 ms



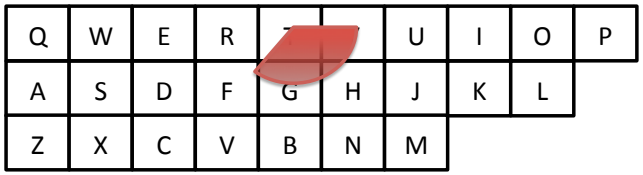
Eye-typing

250 ms



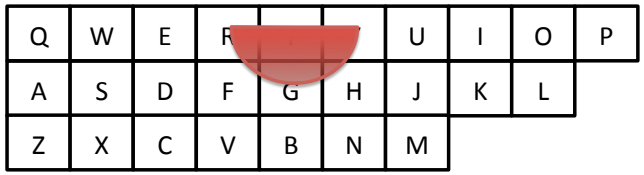
Eye-typing

375 ms



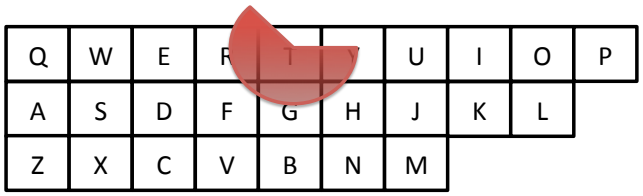
Eye-typing

500 ms



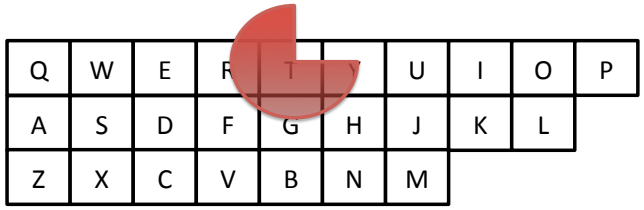
Eye-typing

625 ms



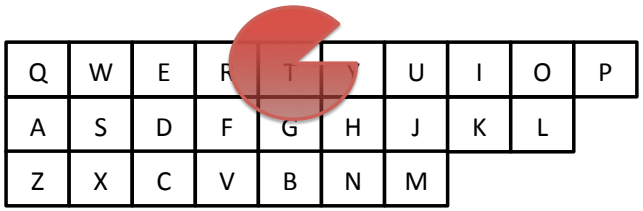
Eye-typing

750 ms



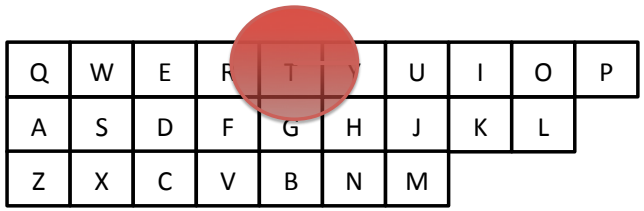
Eye-typing

875 ms



Eye-typing

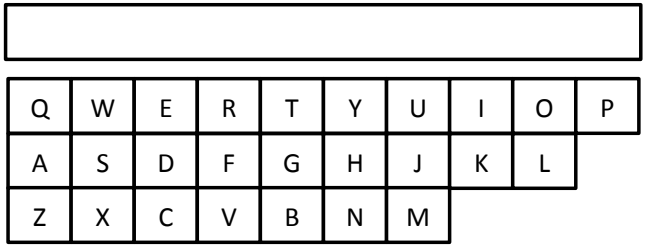
1000 ms



Record speeds achieved when writing by gaze

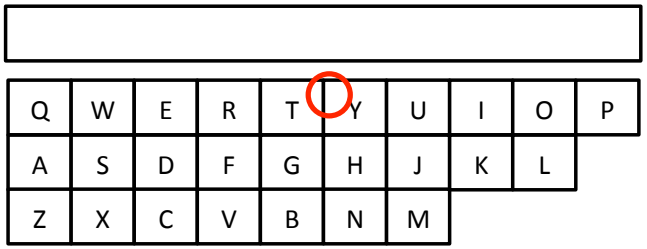
- **Eye-typing**
  - 5–10 wpm (Majaranta and Räihä 2002; Rough et al. 2014)
- **Eye-typing with adjustable-dwell**
  - 7-20 wpm (Majaranta et al. 2009; Räihä and Ovaska 2012; Rough et al. 2014)
- **Dasher**
  - 12–26 wpm (Tuisku et al. 2008; Ward and MacKay 2002; Rough et al. 2014)

Dwell-free eye-typing

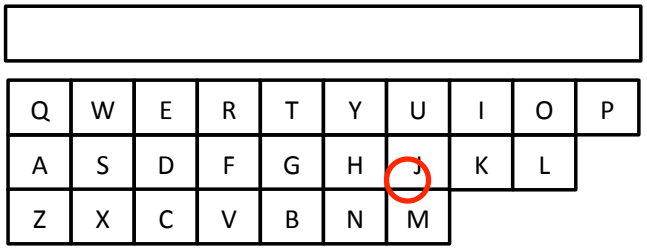


Kristensson, P.O. and Vertanen, K. 2012. The potential of dwell-free eye-typing for fast assistive gaze communication. In *Proceedings of the 7th ACM Symposium on Eye-Tracking Research & Applications (ETRA 2012)*. ACM Press: 241-244.

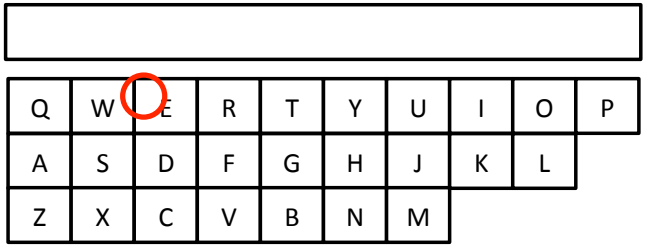
Dwell-free eye-typing



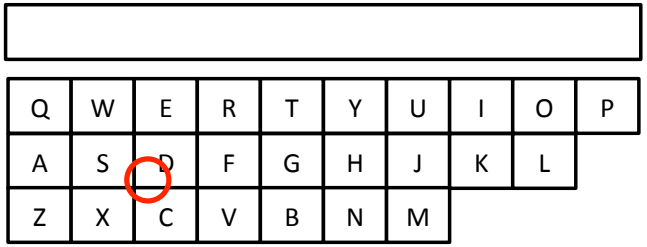
Dwell-free eye-typing



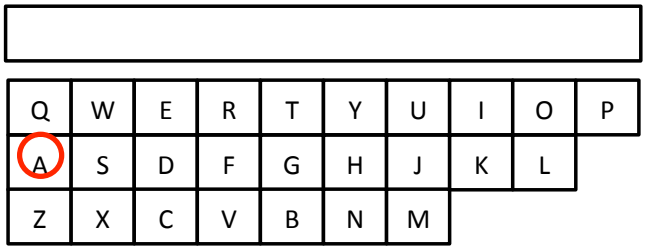
Dwell-free eye-typing



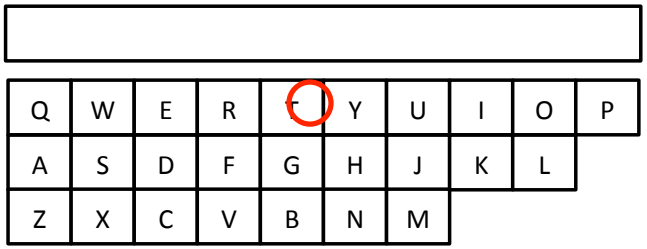
Dwell-free eye-typing



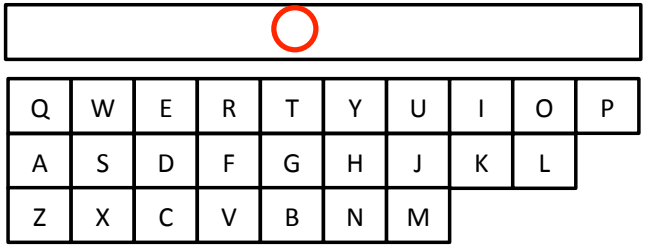
Dwell-free eye-typing



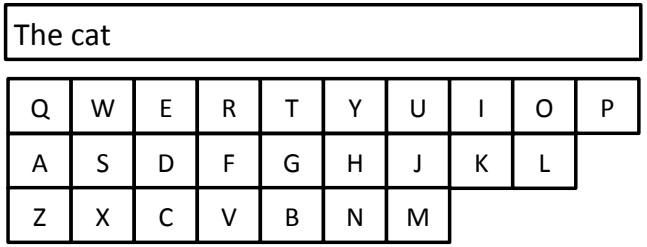
Dwell-free eye-typing



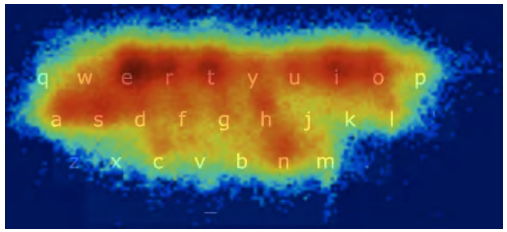
Dwell-free eye-typing



Dwell-free eye-typing

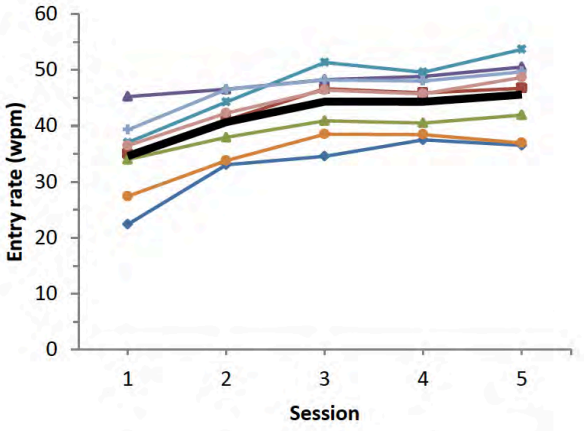


Human performance estimate of dwell-free eye-typing

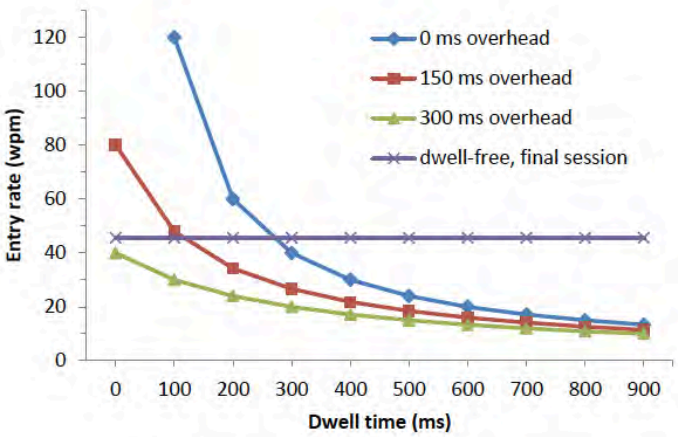


- Recorded 400 minutes of eye-trace data
- Participants entered a total of 2026 phrases
- Participants were prompted phrases and asked to copy them as quickly and as accurately as possible
- Our system knew what the user was supposed to write and verified that the user is gazing at the letter sequence corresponding to the stimulus

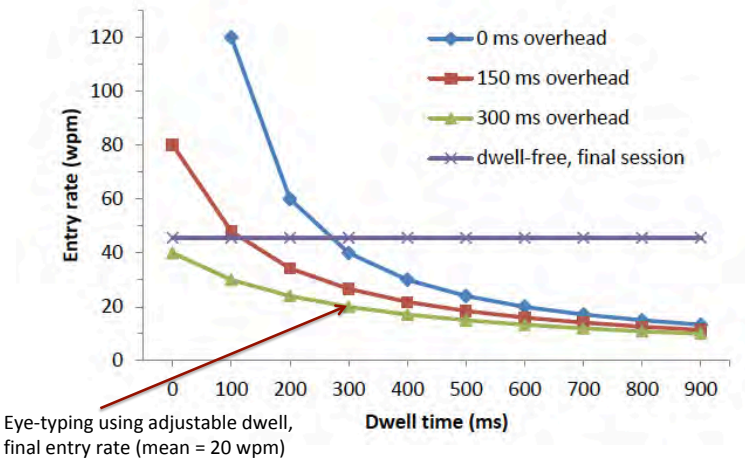
Entry rate



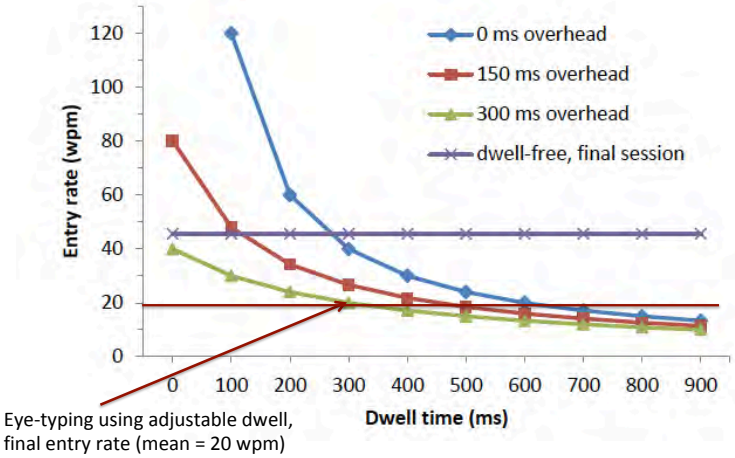
Human performance model



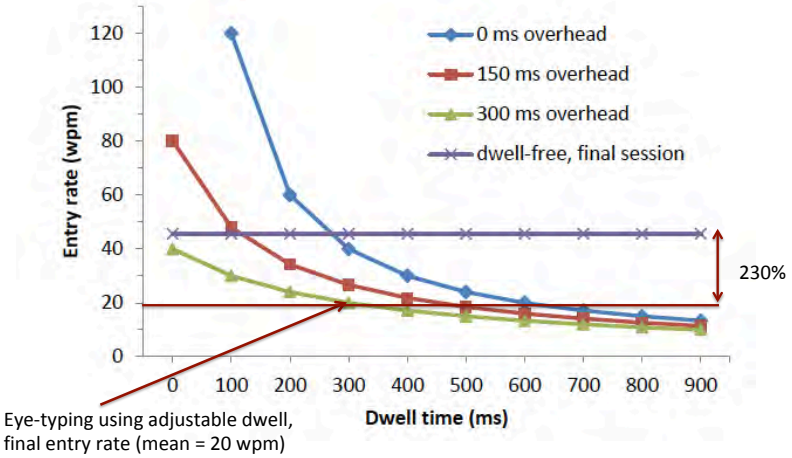
Human performance model



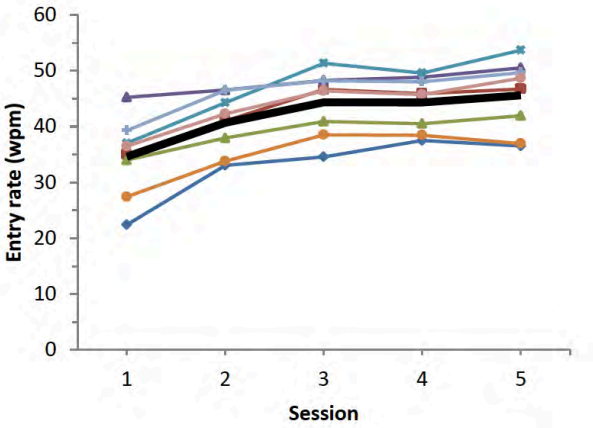
Human performance model



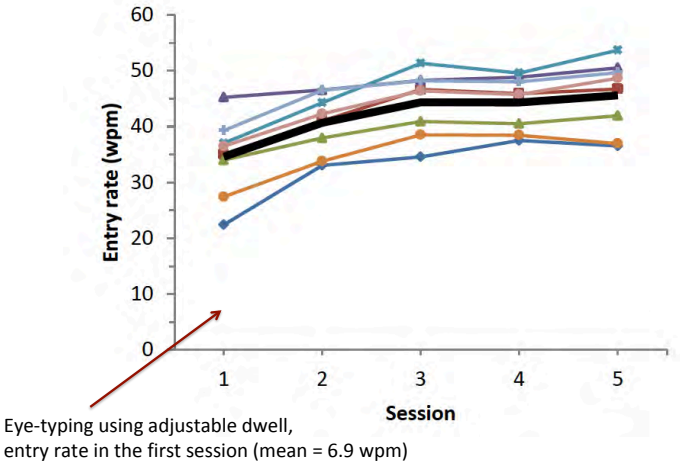
Human performance model



Entry rate, first 10-15 minutes

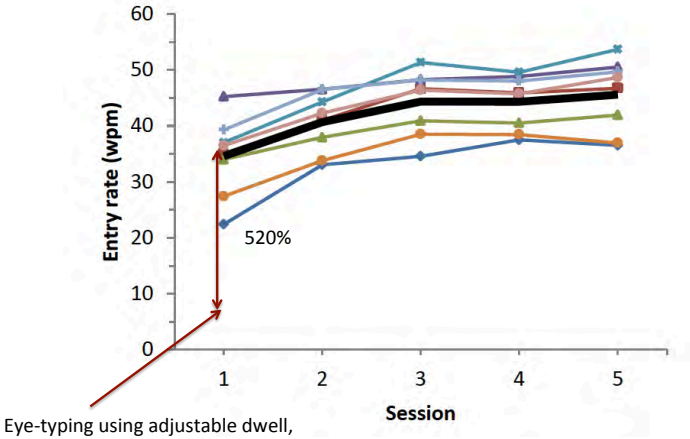


Entry rate, first 10-15 minutes



Eye-typing using adjustable dwell,
entry rate in the first session (mean = 6.9 wpm)

Entry rate, first 10-15 minutes



Eye-typing using adjustable dwell,
entry rate in the first session (mean = 6.9 wpm)

A step-change in gaze communication

- **Existing gaze communication solutions**
  - Limited to circa 20 wpm
- **Dwell-free eye-typing**
  - Empirically measured human performance potential: 46 wpm average
- Released as a product: Tobii-Dynavox I-Series+

Conclusions

- A text entry method likely to be adopted by users is probably similar to existing solutions and at least as fast
- It is still possible to make progress by using a few solution principles:
  - From closed to open-loop
  - Continuous novice-to-expert transition
  - Path dependency
  - Flexibility
  - Probabilistic error correction
  - Fluid regulation of uncertainty
  - Efficiency
- In general, these can be viewed as **solution principles for uncertain interaction**

Kristensson, P.O. 2015. Next-generation text entry. *IEEE Computer* **48**(7): 84-87.

Lecture 5: Designing efficient systems

Measuring and optimising human performance through quantitative experimental methods.

Overview of the course

- Theory driven approaches to HCI
- Design of visual displays
- Goal-oriented interaction
- Designing smart systems (guest lecturer)
- **Designing efficient systems**
- Designing meaningful systems (guest lecturer)
- Evaluating interactive system designs
- Designing complex systems

Lessons from text entry - recap

- It's possible to model human action
- It's possible (in part) to predict human action
- Efficiency can be predicted, and also measured
- A really fundamental trade-off:
  - Speed versus accuracy

Fitts' Law

User actions are information-constrained

How many bits of information to select one of these choices?

How many bits of information to select one of these choices?

The human neuromotor system is limited by information rate - size of target relative to movement

Demonstration of Fitts' Law

Fitts' Law – the only equation in HCI!

- How long does it take to point at something?

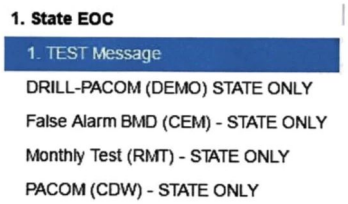
- Proportional to the **D**istance to target
- Inversely proportional to **W**idth of target
- Like most human performance (and most things in information theory), it's a log function:

- Time = k log (2D/W)

Speed-accuracy tradeoff

- Users are capable of doing things faster
- But making more mistakes as a result
- Did your application need speed, or accuracy?

By Anna Frodesiak - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=11443870



https://theoutline.com/post/2954/user-interface-designers-are-horrified-by-hawaii-s-missile-alert-system?zd=1

Hacking Fitt's Law: "semantic pointing"

Renaud Blanch, Yves Guiard and Michel Beaudouin-Lafon. **Semantic Pointing: Improving Target Acquisition with Control-Display Ratio Adaptation.** In *Proceedings of CHI 2004*, pages 519-526, Vienna - Austria, April 2004.

Small changes can have a big effect (1972)

Psychological Evaluation of Two Conditional Constructions Used in Computer Languages

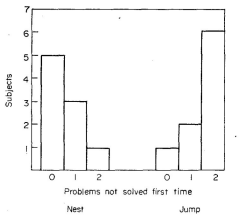
M. E. SIME, T. R. G. GREEN AND D. J. GUEST

```
NEST solution:
  IF JUICY THEN
    IF LEAFY THEN
      IF GREEN THEN GRILL
      OTHERWISE BOIL
    OTHERWISE FRY
  OTHERWISE
    IF HARD THEN ROAST
    OTHERWISE REJECT
```

vs

```
JUMP solution:
    IF JUICY GOTO L1
    IF HARD GOTO L2
    REJECT
L2  ROAST
L1  IF LEAFY GOTO L3
    FRY
L3  IF GREEN GOTO L4
    BOIL
L4  GRILL
```

=>



KLM/GOMS: Predicting time

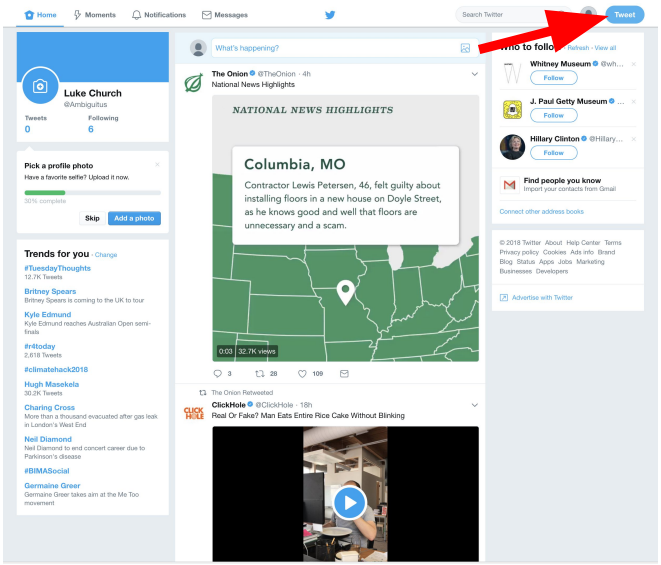
Keystroke Level Model (KLM)

Model an interaction as series of operators, to predict the time an expert takes to do something

Operator	Time/s	Description
K	0.2	Key or button press
P	1.1	Pointing
H	0.4	Homing, switching hand between keyboard/mouse
M	1.35	Mental preparation
R	?	System response time

Example

M (before command)
H (hand -> mouse)
P (point at "Tweet")
K (Click)
R (wait for response)



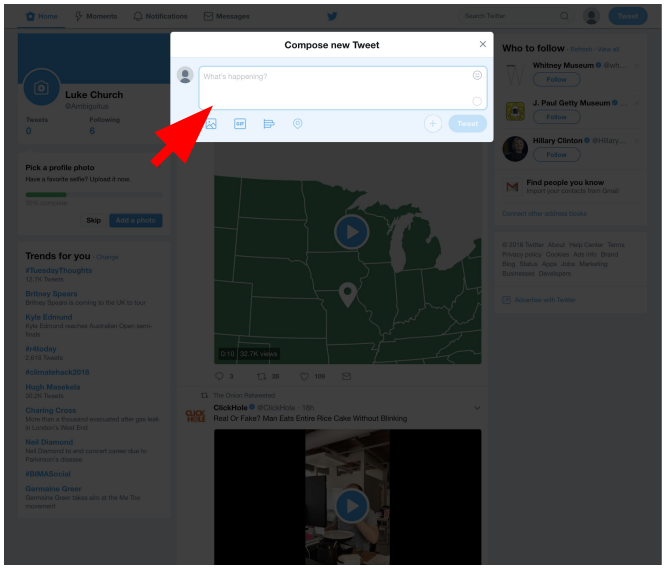
Keystroke Level Model (KLM)

Rules for when you should insert operators (NOT EXAMINABLE)

1. Insert Ms in front of Ks and Ps that select commands
2. Remove any Ms that are fully anticipated
3. Remove all by the first M from runs of MK that are a single cognitive unit
4. Remove any Ms where the K is a redundant terminator
5. Remove Ms from terminate constant strings

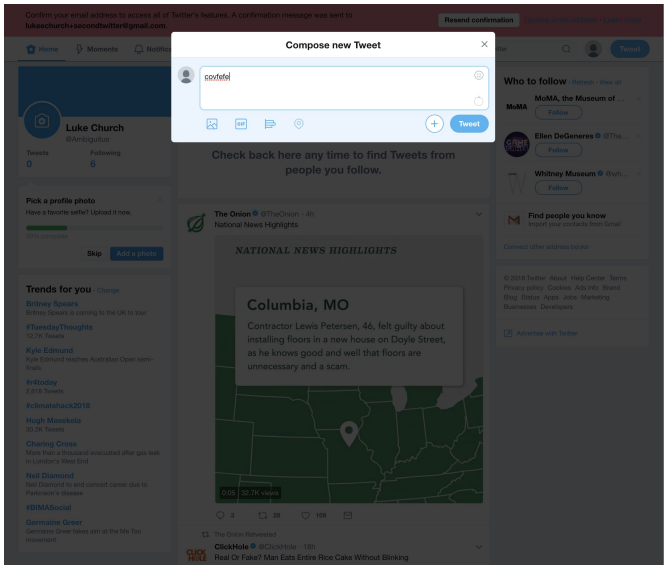
Example

M (before command)
P (point at "What's happening?")
K (Click)



Example

M (Prepare to type)
K
K
K
K
K
K
K
M (Prepare to click)
P (Point at “Tweet”)
K (Click)
R (Wait for response)

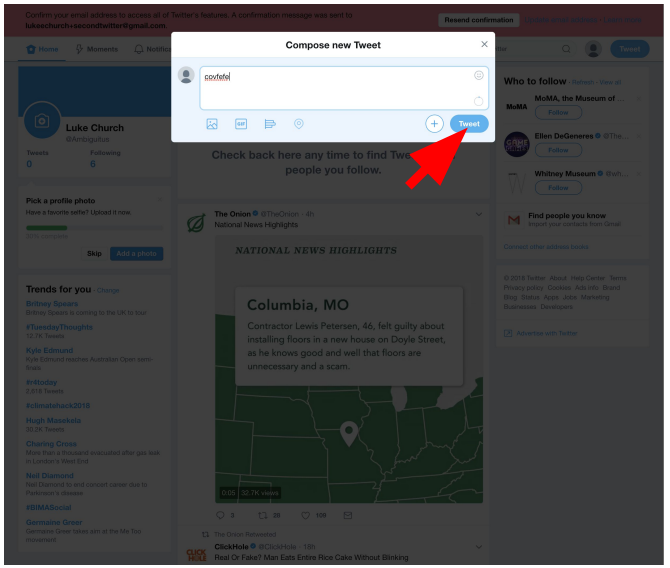


Example

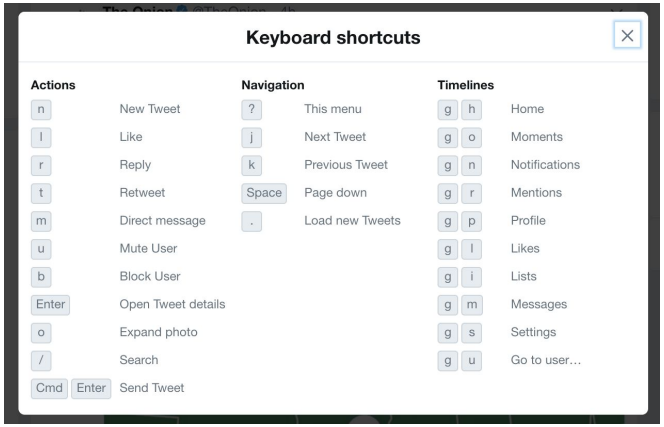
MHPKR
MPK
MKKKKKKKMPKR

1.35 + 0.4 + 1.1 + 0.2 + ~0.2
1.35 + 1.1 + 0.2
1.35 + 7*0.2 + 1.35 + 1.1 + 0.2 + ~0.2

= 11.5s

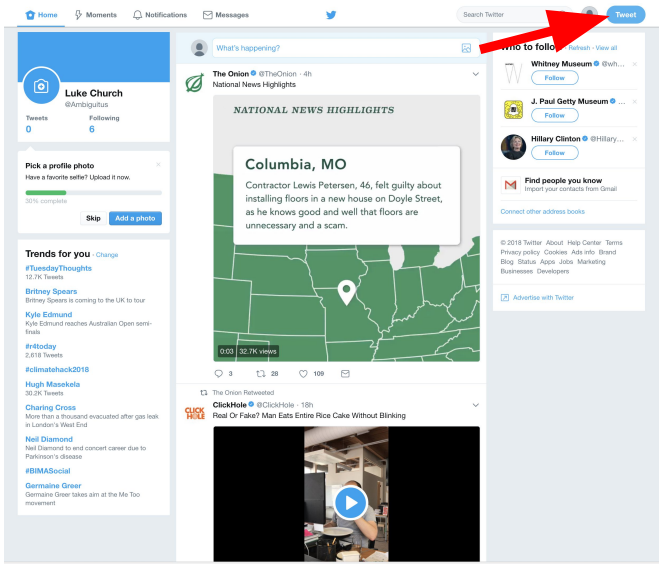


Keyboard shortcuts



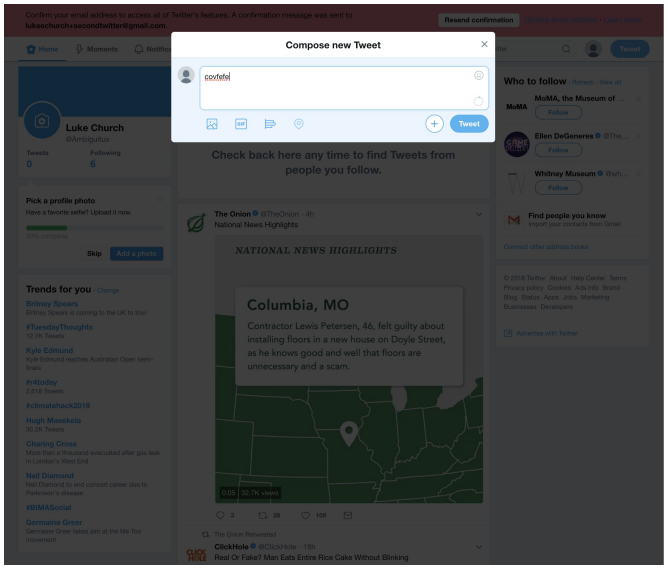
Example

M (become command)
K (‘n’)
R (wait for response)



Example

M (Prepare to type)
K
K
K
K
K
K
K
M (Prepare to click)
K (cmd)
K (enter)
R (Wait for response)



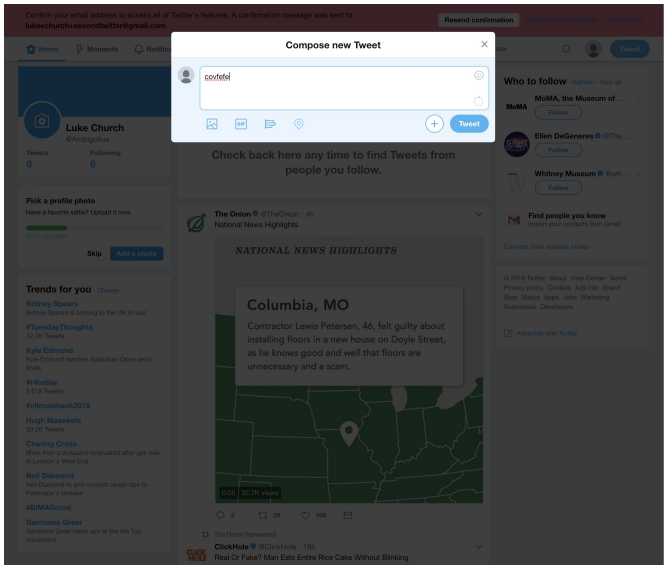
Example

MKR
MKKKKKKKMKKR

1.35 + 0.2 + ~0.2
1.35 + 7*0.2 + 1.35 + 0.2 + 0.2 + ~0.2

= 6.45s

(Compared to 11.5s before)



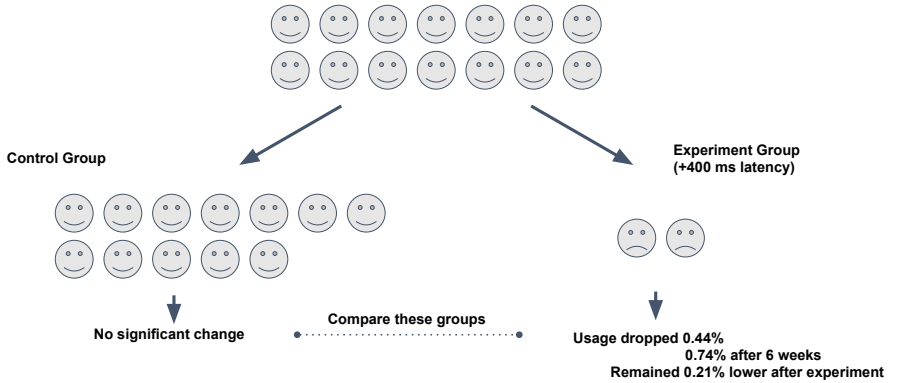
Experiments: Measuring time/usage

How many links should be on a search result page? (10, 20 or 30?)

- User studies: More is better
- When given 30, usage fell - why?
  - Analysis showed 400ms extra latency

Marissa Mayer, http://assets.en.oreilly.com/1/event/29/Keynote%20Presentation%202.pdf
https://www.youtube.com/watch?v=WFsQvcdmLxc&feature=channel

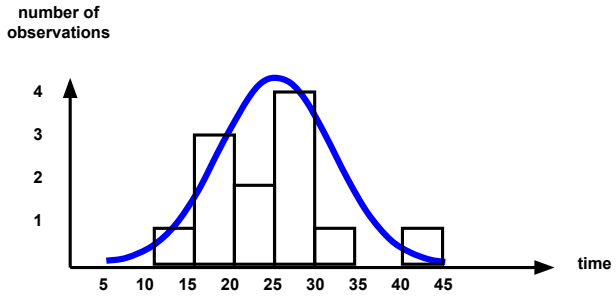
Latency experiment



Marissa Mayer, http://assets.en.oreilly.com/1/event/29/Keynote%20Presentation%202.pdf

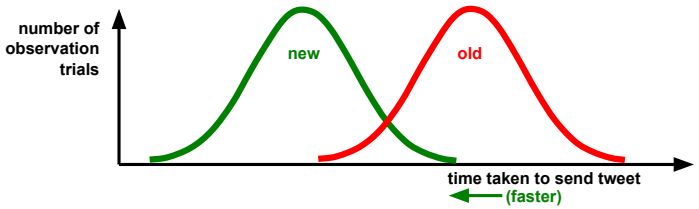
These are A/B experiments

(statistics: histograms & distributions)



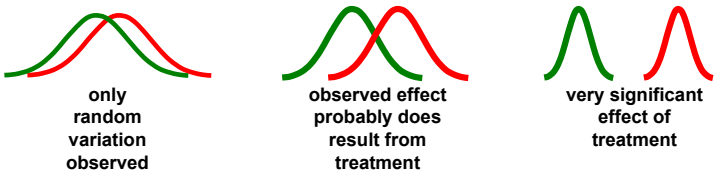
Experimental treatments

- A *treatment* is some modification that we expect to have an effect on usability:
  - How long does Donald take to send his tweet using this great new interface, compared to the crummy old one?
  - Expected answer: *usually* faster, but not *always*



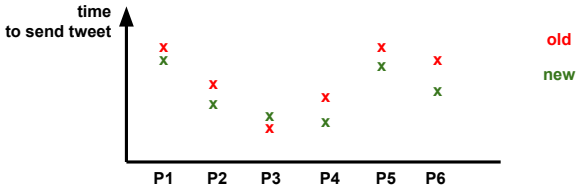
Hypothesis testing

- *Null hypothesis:*
  - What is the probability that this amount of difference in means could be random variation between samples?
  - Hopefully very low ($p < 0.01$, or 1%)
  - Use a statistical *significance test*, such as the *t-test*.



Sign tests

- In a within subjects experiment it's possible to compare the results
  - Explores the [null] hypothesis that the median of the pairs is zero
  - Means might not be significant, but the sign can be
  - This is a non-parametric test, so doesn't depend much on the data, but not very powerful (use a paired t-test, or Wilcoxon rank test instead)



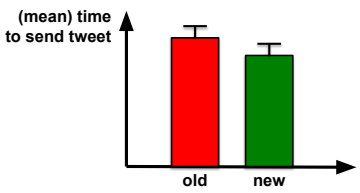
Experiment A: 'significant' but boring

Sources of variation

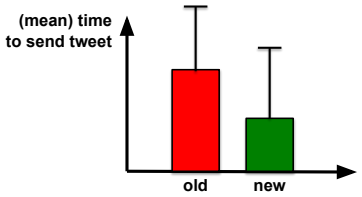
- People differ, so quantitative approaches to HCI must be statistical.
- We must distinguish sources of variation:
  - The effect of the treatment - what we want to measure.
  - Individual differences between subjects (e.g. IQ).
  - Distractions during the trial (e.g. sneezing).
  - Motivation of the subject (e.g. Mondays).
  - Accidental intervention by experimenter (e.g. hints).
  - Other random factors.
- Good experimental design and analysis isolates these.

Effect size – means and error bars

- Difference of two means may be statistically significant (if sample has low variance), without being very interesting.
  - But mean differences must ***always*** be reported with a confidence interval, or plotted with 'error bars'



Experiment A: 'significant' but boring



Experiment B: interesting, but treat with caution

Problems with controlled experiments

- Huge variation between people (~200%)
- Mistakes mean huge variation in accuracy (~1000%)
- Improvements are often small (~20%)
- … or even negative (because new & unfamiliar)
- … and may result from something unrelated to your design!

The Hawthorne Effect

- Studies on productivity in 1924-1932
  - Do lighting levels affect productivity?
  - Studies appeared to show improvements in both directions
  - Results show the motivational effect of being studied, not of the change

By Western Electric Company - Western Electric Company Photograph Album, 1925., Public Domain, https://commons.wikimedia.org/w/index.php?curid=37704076

Is efficiency always a design goal?

- What if you wanted to encourage thoughtfulness? Creativity?

Taylorism

- F.W. Taylor (1856-1915)
  - Engineer who invented scientific management
  - Measure workers as if parts in a machine
  - Optimise by measurement and correction
- Not so popular with trade unions!
  - Note that 2nd wave HCI (the turn from human factors to social science) involved working closely with trade unions, especially in Sweden and Denmark

Public Domain, https://commons.wikimedia.org/w/index.php?curid=4548998

Discretionary use systems

If you are not working to someone else's goal, you can decide whether or not to be efficient (or whether you want to use the system at all)

Simone Giertz: "Queen of Shitty Robots"

Efficient creativity?

- What if there isn't a good measure of productivity?
  - Maximise output of poetry-lines?
  - Maximise musical notes played per second?
  - Maximise Cambridge graduates per year?
- Optimum User Experience
  - What if you wanted people to enjoy what they did?

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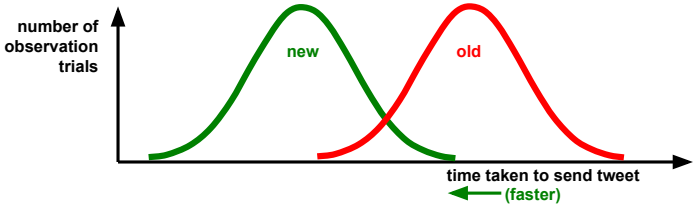
Lecture 7: Evaluating interactive systems

Approaches to evaluation in systems research and engineering

Overview of the course

- Theory driven approaches to HCI
- Design of visual displays
- Goal-oriented interaction
- Designing smart systems (guest lecturer)
- Designing efficient systems
- Designing meaningful systems (guest lecturer)
- **Evaluating interactive system designs**
- Designing complex systems

Reminder: Controlled experiments from Lecture 5



Randomised Control Trial (RCT)

- Commonly used in medicine e.g. drugs trials
- What you need to run an RCT:
  - A performance measure
  - A representative population sample + informed consent
  - A task
- Results
  - Effect size, correlations, significance measures
- Difficulties
  - Overcoming natural variation needs large samples
  - Little understanding as to why a change occurred
  - Does the effect generalise?
  - Number of studies/orthogonality of variables

Commercial product evaluation

- RCTs are little used for design research in commercial products
- Performance measure is usually profit maximisation
  - Sales/Profit are often hard to measure with useful latency
- Typically use proxy measures instead
  - 1 day active, 7 day active, 28 day active

Often used as *summative* evaluation

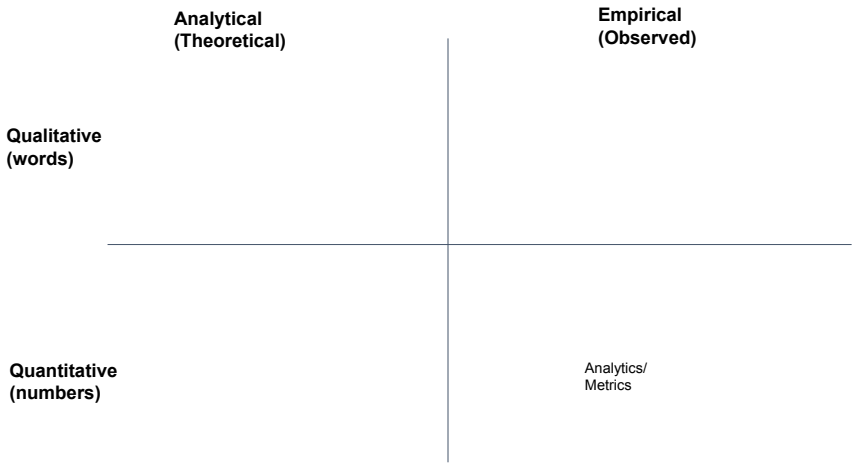
Internal vs External validity

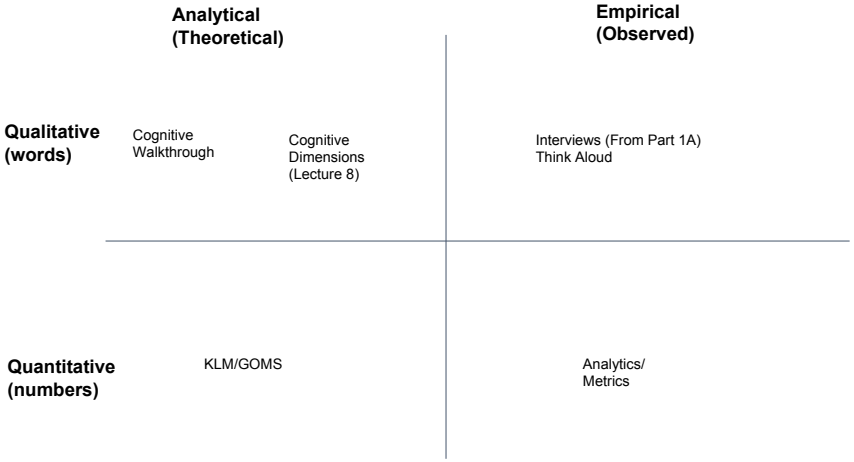
- Internal Validity
  - Reproducibility, Scientific integrity, Refutability
  - "Was the study done right?"

- External Validity
  - Generalisability
  - "Does the study tell us useful things?"

Formative vs Summative

- Formative
  - Evaluates and refines design ideas
- Summative
  - Tests and evaluates systems





Analysing qualitative data

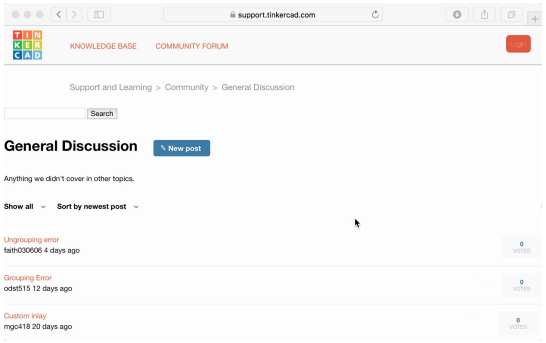
- Categorical coding (answers ‘closed’ questions)
  - Create a coding frame of expected categories of interest
  - Segment the text data
  - Assign each segment to a category
- Grounded theory (asks ‘open’ questions)
  - No prior expectation or theoretical assumption
  - Read data closely, looking for interesting stuff (‘open coding’)
  - Collect fragments, writing ‘memos’ to capture your own insights
  - Organise emerging themes using ‘axial coding’
  - Constantly compare memos, themes and findings to original data

Case study: Interpreting product feedback

Tinkercad Community Forum -> General Discussion

“Anything we didn't cover in other topics” (so could contain anything at all)

https://support.tinkercad.com/hc/en-us/community/topics/200160948-General-Discussion



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I created an account for my son and I received the email to "Approve". I clicked on approve however my son can not use the account. It appears there is a lag time from the time I approve???? My son has a work shop this evening and he is required to have a Tinkercad account. Can you manually approve?
Why is it that selecting objects in the tutorial other than the largest ones fails so often? The controls and instructions are incredible simple and easy, but 3 times out of 4, when i try to select an object, it just won't select it, no matter what angle i rotate the view to, or how far in or out i zoom it. This is especially true with objects moved inside orange guidelines.
Can Tinkercad be used to design simple 2D architecture style drafting for a remodel of my home?
Hi. I have used the group option a lot to give shape to many of the objects of my design. I've noticed all these changes are stored, so everytime I load the design or edit an object, it becomes slower and slower. Isn't there any way to make the program forget about all the objects used for cutting or adding shapes and expand the result as a definitive object? Thanx.
I used tinkercad quite some time ago for a school project and some other stuff and haven't logged in since. I think it must be about 2 years (or more) since I last logged in. I had some projects that I worked on but now they're all gone? Does anyone know why this could be and how to get them back (if possible) THanks in advance.
Whenever we try to print our design on our 3D printer it keeps messing up at the corners when it overlaps and then the nozzle pulls it from the bed. We have square corners not roundish corners. Its frustrating and we don't know if its the corners or the bed or something to do with the slicer.
Hi, i'm trying to create a lock for my tripod camera, i started the design but i'm not sure if it will works, i'm asking any help to review my design please. the image show the lock, and the diameter of the tripod is 26mm so i have designed the lock as 27mm. i will appreciate your help thanks
I'm trying to make a cookie cutter. I succeeded in converting the outline to an svg file and then importing into Tinkercad, but I can't seem to figure out how to increase the width of the actual outline. I was able to adjust the height of the cookie cutter, length and width...but not the thickness of it. It doesn't even tell me what the thickness is currently If i had to guess it's probably defaulted at 1mm...and this is fine for the part of the cutter that actually cuts into the cookie dough. But 1 mm is flimsy and would be difficult to keep its shape. So I have to make a duplicate copy of the shape, widen the thickness to 3 or 4 mm and put it on top of the cutter as a frame to give it more strength. I just can't figure out how to do it. I'm amazed I've gotten this far just googling because i have NO IDEA what I'm doing!
is it possible to integrate Thinkercad in a web site I'm creating as CAD tool with the output files stored on the server where the site is running? Is there a sort of engine plugin?
My students have been having difficulty with Tinkercad this week. They log in just fine, but the workplane will not load. We've tried Chrome and Explorer with no success. Anyone else experiencing this issue?
hello, is there a place that i can view my build log, or atleast see when the build began, other than a rough estimate of "a month ago" etc?
This has been frustrating for me. It's probably something so simple that no one describes how to do it. I've been trying to use Tinkercad on a laptop with a trackpad. I've been unable to pan around the screen. I could zoom to the center and back out but not actually move the point of zoom off of the center. I looked for the keyboard shortcuts but there's nothing there about panning. There were instructions for how to do it with a mouse but not for a trackpad. It turns out to pan on the trackpad you have to press and hold the shift key and then click and hold with two fingers and then scroll around. The instructions say to do that using the right mouse button. I've commonly used the two finger to click but never two finger click, hold, scroll. I probably should have figured it out sooner. If anyone else is having the same problem, maybe this will help.
Hello, I just validated my account using my email address, but when I log in, all my files are gone. I normally log in using my FB social media profile. How can I link accounts?
The only way I know to print -- on a 2D printer -- is to "share" which generates a .png. I would like to 2D print my projects with dimensions for all the pieces. What would be a good approach?
I'm working on a file that I found on Thingiverse. I'm just trying to customize it the way I want to use. The final shape is as in the STL file I'm going to share. But I'm also sharing an image file where I'm showing 3 different sides and on these sides, I marked some spots where I can't get rid of misalignement. No matter what I do here, It's never all straight. Can anybody help me? Would it be difficult for you to just open the file on tinkercad and try if you can fix those sides? I'd be very appreciated.
How would I scale a few complicated interlocking objects up or down by 17% for example? A cube I would just add 17% to the 3 dimensions.
I like making projects, but I can't figure out how to share my designs with others. It says there is a button, but I don't see one. Please help!
Please I need of Help! How to round the sharp edges of a non-standard detail,...Apple logo?
i was wondering if it was possible to animate the 3D creations you mak in tinkercad, and if it is possible if someone could explain it to me
We have a student who keeps getting a "Failed connecting. Please try again later" error when trying to log in. Using the same computer and browser, we are able to log in to Tinkercad with a different Google account. So the issue doesn't appear to be computer, browser, or filtering related. This is affecting this student's ability to continue with the lesson and is falling behind what the rest of the class is able to accomplish. We have tried logging in using this account on several different computers and browsers, all with the same error message. I have tried submitting a ticket to Support (four tickets actually), but now one has yet to respond after about two weeks.
Despite having checked the 'stay logged in' box, I keep getting logged out after a short period of inactivity. Very frustrating!
Hi. I would like to delete a Tinkercad project, but I can't find the option anywhere. How can I delete it?
With the new beta client I have had nothing but trouble importing stl and OBJ files. Even though the files fit within the limitations, anything over only a megabyte or two will cause the workspace to lockup with an infinite "import" process bar in the bottom corner. When I check task manager it says I am uploading, but after so long ,up to a hour sometimes I will get a error and the upload will cancel.
I create a shape in PS and it exports as an svg and goes right into Tinkercad. But when I have any kind of bitmap graphic and export it as an svg Tinkercad thinks about it for a minute or so and then just rejects the file. I'm trying to make this as simple as possible for my class, which means introducing Ai is not an option. We already use PS, so that is what I want.
Hello all, I'm trying to make a pillar for a project, this pillar in real life gets slimmer from bottom to top (Base is thick and half way up it starts getting slimmer). Is there anyway that I can replicate this in Tinkercad?
I would like to know how to export a TinkerCAD 3D object into an AutoCAD 3D solid? I tried with Reaconverter but in opening on AutoCAD it isn't a solid anymore.

Categorical coding

- Create a coding frame of expected categories of interest
  - Bugs
  - Feature requests
  - Permission requests
  - Other
- Segment the text data
- Assign each segment to a category

Segmentation

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Segmentation (and relevance filtering)

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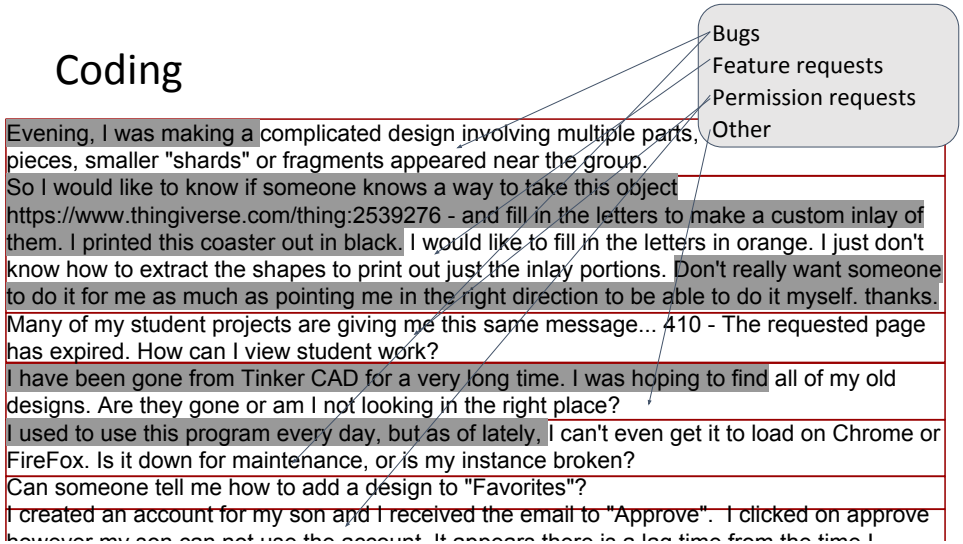
Coding



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Inter-rater reliability

- Two or more people make the coding decisions independently to avoid systematic bias or misinterpretation
- Compare how many decisions agree, relative to chance
  - Calculate a statistical measure such as Cohen's Kappa (for 2 people) or Fleiss' Kappa (for more), comparing to typical levels (0.6-0.8 is considered 'substantial agreement')
- May take account of how many decisions still disagreed after discussion
  - Which may involve refining the coding frame to resolve decision criteria
  - Can 'prototype' by discussing a sample before coding the main corpus

Grounded theory

- For research where you *don't know in advance* what you are looking for, but wanting to learn something from qualitative data

- Read data closely, looking for interesting stuff ('open coding')
- Collect fragments, writing 'memos' to capture your own insights
- Organise emerging themes using 'axial coding'
- Constantly compare memos, themes and findings to original data

Open Coding

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Memo: First time I've heard this term. Might be useful for future product documentation or features?

Open Coding

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Memo: Nice community spirit

Open Coding

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Memo: Time for an educator's forum?

Open Coding

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Memo: Institutional Permissions

Open Coding

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Memo: Alumni?

Open Coding

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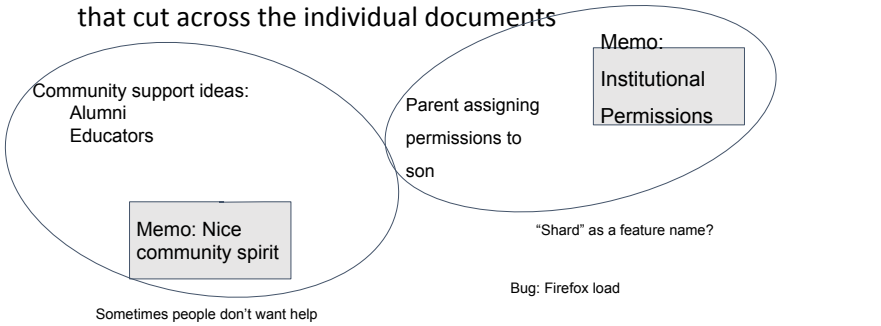
Memo: Community again

Axial coding

Review the codes and memos, organising them according to themes that cut across the individual documents



Reliability through constant comparison

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Help from community or self-sufficiency?

How to evaluate your Part II project

When HCI methods will be relevant

- Systems that a user will interact with
  - e.g. games, programming systems, VR
- Systems with perceptual goals
  - e.g. graphics, audio, affective computing
- Systems that you plan to deploy
  - e.g. apps, mobile sensing, software tools
- Systems that analyse social data
- In all these cases, you will be doing research with human participants - guidance is available & permission is necessary
  - https://www.tech.cam.ac.uk/Ethics_guidance

Thinking about evaluation (even if not HCI)

- Approach 'testing' as a scientific exercise, with intellectual outcomes
  - Define goals and hypotheses
  - Understand boundaries and performance limits by exploring them - failure is necessary!
- Should your evaluation be analytic (reasoning/argument) …
  - How consistent / well-structured is your analytic framework?
- … or empirical (measurement/observation)?
  - What are you measuring & why? Are the measurements compatible with your claims (*validity*)?
- Should your evaluation be formative or summative in nature?
  - If formative – couldn't you finish your project?
  - If summative – are the criteria internal (from some theory) or external (from some problem)?
- Is your data quantitative or qualitative?
  - Descriptive aspects of the system, or engineering performance data?
  - If qualitative, how will you establish objectivity (i.e. that this is not simply your own opinion)?

Summary of analytic options (analysing your design)

- Cognitive Walkthrough
  - Normally used in formative contexts – if you do have a working system, then why aren't you observing a real user (far more informative than simulating/imagining one)?
  - But Cognitive Walkthrough can be a valuable time-saving precaution before user studies start, to fix blatant usability bugs
- GOMS
  - unlikely you'll have alternative detailed UI designs in advance
  - If you have a working system, a controlled observation is superior
- Cognitive Dimensions (lecture 8)
  - better suited to less structured tasks than CW & GOMS, which rely on predefined user goal & task structure

Summary of empirical options (collecting data)

- Interviews/ethnography
  - could be useful in formative/preparation phase
- Think-aloud / Wizard of Oz
  - valuable for both paper prototypes and working systems
  - can uncover usability bugs if analysed rigorously using qualitative methods
    - It would be wise to make this clear in your dissertation, to avoid reasonable suspicion of bad techniques
- Controlled experiments
  - numbers sometimes appear more 'scientific', but only:
    - If you can measure the important attributes in a meaningful way
    - If you test significance and report confidence interval of observed means
- Questionnaires
  - be clear what you are measuring – is self-report accurate?
- Field Testing
  - controlled release (and data collection?) may be possible
- See human participants guidance for empirical methods

Surveys and questionnaires

- Standardised *psychometric instruments* can be used
  - To evaluate mental states such as fatigue, stress, confusion
  - To assess individual differences (IQ, introversion …)
- Alternatively, questionnaires can be used to collect *subjective* or *self-report* evaluation from users
  - as in market research / opinion polls
  - 'I like this system' (and my friend who made it)
  - 'I found it intuitive' (and I like my friend)
- This kind of data can be of limited value
  - Can be biased, and self-report is often inaccurate anyway
  - It's hard to design questionnaires to avoid these problems

Questionnaire design

- *Open* questions …
  - Capture richer qualitative information
  - But require a coding frame to structure & compare data (if hypotheses)
  - Or grounded theory methods (if you have broader questions)
- *Closed* questions …
  - Yes/No or *Likert* scale (opinion from 1 to 5)
  - Quantitative data is easier to compare, but limited insight
- Collecting survey data via interviews gives more insight but questionnaires are faster
  - Can collect data from a larger sample
  - Remember to test questionnaires with a pilot study, as it's easier to get them wrong than with interviews

Product field testing

- Brings advantages of task analysis/ethnography to assessment and testing phases of product cycle.
- Case study: Intuit Inc.'s Quicken product
  - originally based on interviews and observation
  - follow-me-home programme after product release:
    - random selection of shrink-wrap buyers;
    - observation while reading manuals, installing, using.
  - Quicken success was attributed to the programme:
    - survived predatory competition from Microsoft Money
    - later valued at $15 billion.

Bad evaluation techniques - don't use these!

- Purely *affective* reports: 20 subjects answered the question "Do you like this nice new user interface more than that ugly old one?"
  - Might apparently be empirical or quantitative (do you like it on a scale of 1 to 10)
  - But probably biased – if these are your friends, or trying to please (experimental demand)
- No testing at all: "It was deemed that more colours should be used in order to increase usability."
  - Apparently formative/analytic
  - But subjective – since the author is the subject
- Introspective reports made by a single subject (often the programmer, project manager or your project supervisor): "I find it far more intuitive to do it this way, and the users will too."
  - Might be apparently analytic or qualitative, for example drawing on folk wisdom
  - But is often both biased and subjective
  - Unfortunately common in industry - the HiPPO evaluation method (Highest-Paid Person's Opinion)

Lecture 8:
Designing complex systems

Case studies on applying theory to hard HCI problems

Overview of the course

- Theory driven approaches to HCI
- Design of visual displays
- Goal-oriented interaction
- Designing smart systems (guest lecturer)
- Designing efficient systems
- Designing meaningful systems (guest lecturer)
- Evaluating interactive system designs
- **Designing complex systems**

What are some things that make designs complex?

- How complex is the domain?
- How many different tasks might a user perform?
- How well defined are the outcomes? (Wicked problems, L3)
- How easy is it to understand each part?
- When the parts are put together how easy is to guess the behaviour?
- Does the system do things when the user isn't there? (Attention Investment from L3)

Designing tasks vs interaction spaces

Consider a (slightly silly) APIs for sending a message:

```
(1) sendTheRightMessage()
(2) sendMessage(Enum message)
(3) sendMessage(String message, Urgency status)
```

- Naive design would result (1). Complex systems tend to be built out of reusable components that the users configure (2,3)
- Building this kind of system involves discussing tradeoffs as well as detailed design decisions
- This is the kind of system that most of you will build: **Programming languages, APIs, AI systems**

Broad brush techniques

- Descriptions of specific actions result in a ‘death by detail’
- Don’t describe specific actions with an interface
  - Instead describe interaction with a level of *analytical distance* from the interface

- These techniques often give names to the patterns

Broad brush techniques

- Descriptions of specific actions result in a ‘death by detail’
- Don’t describe specific actions with an interface
  - Use an *analytical frame* which is a way of structuring a description of an interaction
  - Instead describe interaction with a level of *analytical distance* from the interface
  - The description can then be compared to an ideal for a domain to become a critical perspective (see Lecture 1)

Cognitive Dimensions of Notations (CDNs): Analytical Frame

A user

Performs an *activity*

Interface containing *notations,* described along a number of *dimensions*

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Performs an *activity*

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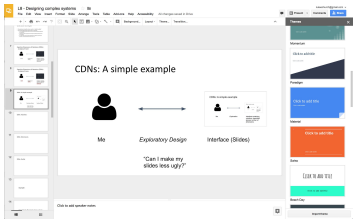
CDNs: A simple example



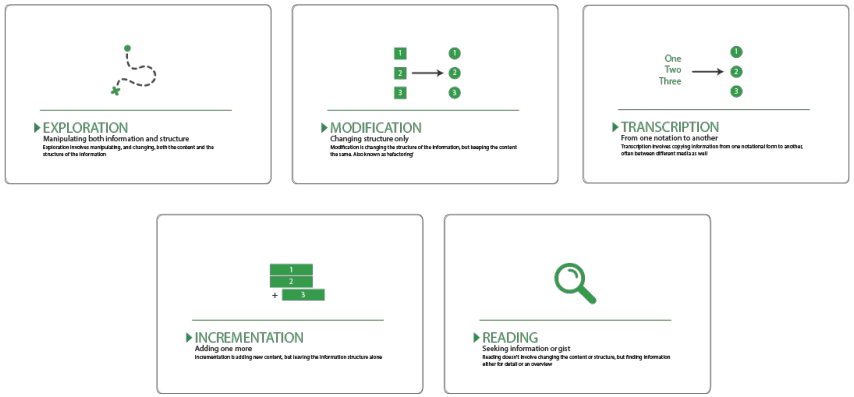
Me *Exploratory Design* Interface (Google Slides)

"Can I make my slides less ugly?"

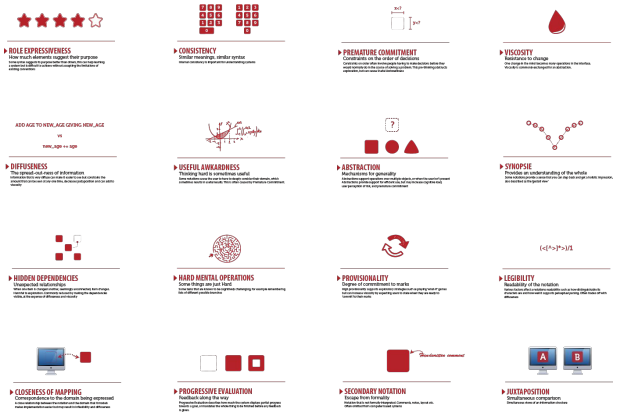
CDNs: A simple example (Demo)

- One described change "Make the font of the headings *Comic Sans*"
  - Select the first slide, change the font
  - Select the second slide, change the font
  - Yawn.
- This is repetition *Viscosity*, many operations to perform one change
- Design maneuver: Introduce an *Abstraction* (master slide), decreases *Viscosity*, but increases *Premature Commitment*
- NB: CDNs analysis is meaningless independent of an interface.

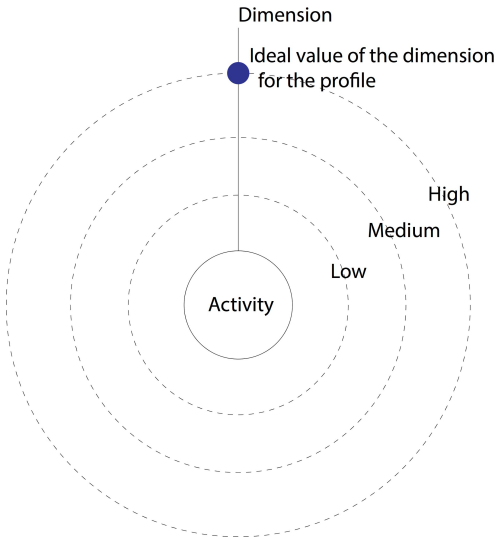
CDNs: Activities



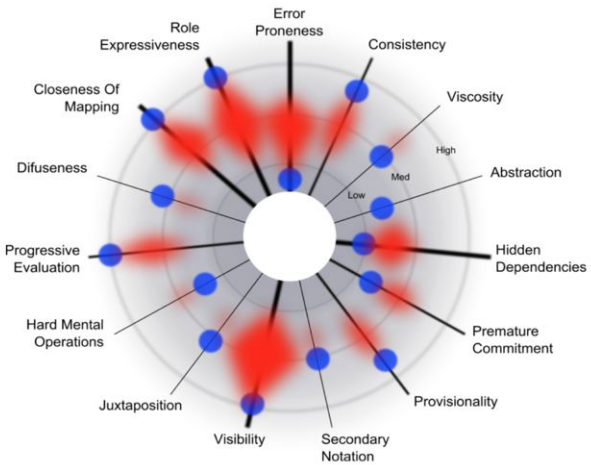
CDNs: Dimensions



CDNs: Profile



CDNs: Profile



Case Study: Dynamo's type system

Dynamo

- Language for exploring building designs
- Live Demo
- Includes a constructor **`Point(x, y, z)`** and array literal syntax [1,2]

Design question for discussion:

"What should **`Point([0, 1, 2], 10, 10)`** do?"

- What activities are important?
- How important: Viscosity? Premature commitment? Hidden Dependencies? Abstraction hunger?

Case Study: Interaction with Machine Learning

FlashFill for Excel

- From 2011 research by Sumit Gulwani at Microsoft Research
- “Synthesises a program from input-output examples”
  - How do you choose the examples?
  - How do you know what will happen?
-
- Live Demo (requires Excel 2013/16)
  - Paste a list of semi-structured text data into the left column
  - Type an example transform result in top cell to the right, then <Enter>
  - Press <Ctrl+E>

Some current research problems

Augmented reality is still a visual representation (remember metaphor?)

Microsoft Hololens

Programming, or direct manipulation?

- Many Internet of Things (IoT) devices have physical switches etc
  - But how do you define configuration, policy, future action?
  - Now we need a notation - or a programming language
- Remember behavioural economics and attention investment
  - Even around your house, bounded rationality happens

Philips Hue Light control

Conversational agents

- Do they build a user model, goal model or task model?
- Will this be more or less complex than FlashFill?
- How can you see it the model?
  - i.e. what is the notation?
- How could you modify the model?
  - … in response to errors (yours, or the system's)
  - … if you change your goals?
- Does having a 'body' help?
  - (remember metaphor)

Amazon Echo / Alexa agent

Human issues in machine learning

- Ethics and accountability
  - automating and/or justifying bias and prejudice
- Digital humanities
  - treating text and images as meaningful and sophisticated
  - (rather than just statistical fodder)
- Reward
  - who does the intellectual 'work' of providing training corpus content, data labelling, how are they paid, and where do the profits go?

Global challenges

- Is knowledge infrastructure built to …
  - … prioritise low income populations
  - … advance United Nations Sustainable Development Goals (human rights, education etc)?

Africa's Voices Foundation / Cambridge Global Challenges Initiative

Further interest...

- Part II: Project
- Part III: Interacting with Machine Learning
- Research Skills: Working with artists and designers