INTERACTION DESIGN AND EVALUATION

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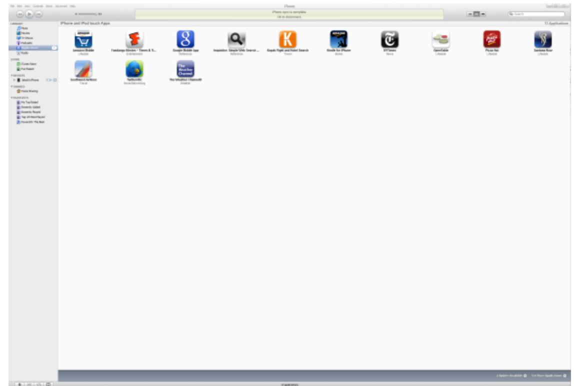

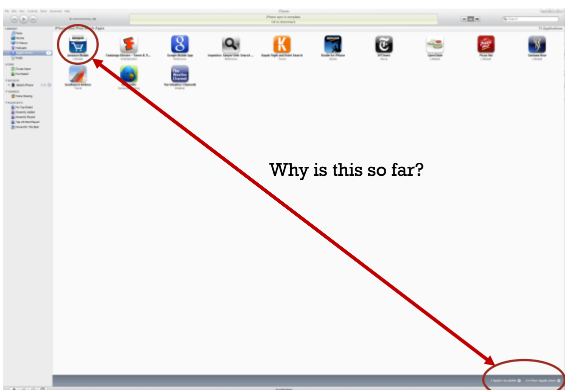

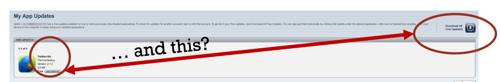

MOTIVATION

What about this game?

Is this interesting at all?
How difficult?

MOTIVATION

- Interaction Design and Evaluation:
  - Design User Interfaces
  - Measure/Predict performance
  - Design interaction

OBJECTIVES

- Understanding the fundamentals of basic interaction in UI
  - Hick-Hyman Law: Choice-Reaction Time
  - Fitts' Law: Pointing Time
  - Crossing and Steering Laws: Continuous Gestures
  - Guidelines for UI design and evaluation
  - Experiments to assess/evaluate interaction theories

INTERACTION DESIGN AND EVALUATION. SESSION 1

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OUTLINE

- Background
- Hick-Hyman Law: Measuring choice-reaction time
- Fitts Law: Measuring Pointing Time
- Typing & Keyboards

OUTLINE

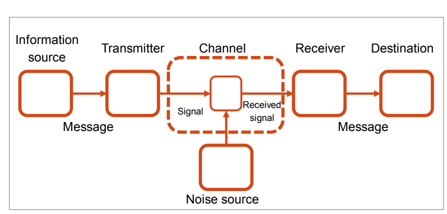
- **Background:**
  - Basics
  - Information Measures
- Hick-Hyman Law: Measuring choice-reaction time
- Fitts Law: Measuring Pointing Time
- Typing & Keyboards

BACKGROUND. BASICS

- Information Theory:
  - Due to Claude E. Shannon
  - *A Mathematical Theory of Communication* (1948)
  - Based on previous works by Nyquist and Hartley
  - Analysis of transmission of electrical signals for telegraphic communication
  - Shannon Entropy measures the amount of information to be transmitted by a message

BACKGROUND. BASICS

- Information Theory. Elements (telegraph):



BACKGROUND. BASICS

- Information Theory. Elements (telegraph):
  - **Information source:** The element that produces a message or sequences of message.
  - **Transmitter:** Operates on the message to make it transmissible through a medium.
  - **Channel:** The medium that transmits the message.
  - **Receiver:** The element that reconstruct the message to the destination.

BACKGROUND. INFORMATION MEASURES

- Let *d* be a device that produces symbols A, B, and C with the same probability
  - M = 3 is the total number of symbols
  - Each time a symbol is produced we are *uncertain* on which symbol is going to be generated
    - This uncertainty is not so big, since there are only three possibilities
  - The probability of a symbol to appear is 1/M
  - The uncertainty is $\log_2(3)$

BACKGROUND. INFORMATION MEASURES

- The uncertainty we have depends on the number M of symbols → log(M).
  - 3 symbols → uncertainty of log(3).
  - 2 symbols → uncertainty of log(2).
- Logarithms are commonly taken in base 2, and the units are bits.

BACKGROUND. INFORMATION MEASURES

- Let *d* be a device that produces one single symbol: C
  - M = 1 is the total number of symbols
    - We have no uncertainty ($\log_2(1) = 0$)
    - The probability of getting the symbol C is 1
    - We previously know which symbol will appear!

BACKGROUND. INFORMATION MEASURES

- We have two devices, one with outputs A, B, C, and the second with outputs 1, 2.
- We combine *words* by concatenating one symbol of device 1 and one with device 2.
- We will have 6 different words: A1, A2, B1, B2, C1, C2
  - 6 symbols → uncertainty of log(6) → log(2) + log(3) = log(6).

BACKGROUND. INFORMATION MEASURES

- M symbols with equal probability ➔ each symbol has probability P=1/M
  - Rewriting the surprise term

$$surprise = \log_2(M) = \log_2\left(\frac{1}{M}\right)^{-1} = \log_2(P^{-1}) = -\log_2(P)$$

  - *-log₂(P)* is called the surprise or *surprisal* of finding a certain symbol
  - We will use p_i from now on
- For M symbols that have different probabilities, we may have a different p_i for each, provided that

$$\sum_{i=1}^{M} p_i = 1$$

BACKGROUND. INFORMATION MEASURES

- Information is the ***reduction of uncertainty*** or ***average surprisal*** of a set of symbols
  - Measuring the surprise for an infinite set of symbols (produced by a device) the frequency of each symbol transforms to the probability.
  - Shannon Entropy measures the amount of information:

$$\mathrm{H} = \sum_{i=1}^{N} p_i \log_2\left(\frac{1}{p_i}\right) = -\sum_{i=1}^{N} p_i \log_2 p_i$$

    - *N* is the number of alternatives
    - p_i is the probability of the *i*th alternative.
    - *H* is the entropy of the message that is to be transmitted, the *amount of information* expected to be received (no noise).

BACKGROUND. INFORMATION MEASURES

- Information Theory. Shannon entropy:
  - There is interference: Not all information will reach the receiver
  - Average information faithfully transmitted (R):

$$R = \mathrm{H}(x) - \mathrm{H}_y(x)$$

    - $H_y(x)$ is the *equivocation* or conditional entropy of x when y is known

BACKGROUND. INFORMATION MEASURES

- Applications of Shannon entropy:
  - All types of signal transmission and storage:
    - Measuring information
    - Dictionary creation for compression
    - …

OUTLINE

- *Background*
- **Hick-Hyman Law: Measuring choice-reaction time**
  - Hick-Hyman Law
  - Experimental assessment
- Fitts Law: Measuring Pointing Time
- Typing & Keyboards

HICK-HYMAN LAW

- Hick-Hyman Law:
  - Initially stated by William E. Hick (1951)
  - It takes longer to respond to a stimulus when it belongs to a large set as opposed to a smaller set of stimuli
  - Describes human decision time as a function of the information content conveyed by a visual stimulus
  - Extended by Ray Hyman (1952)

HICK-HYMAN LAW

- Hick-Hyman Law:
  - Time to make a decision:

$$T = \mathrm{a} + \mathrm{b}\mathrm{H}_T$$

    - *a*, *b* constants
    - H_T transmitted information

HICK-HYMAN LAW

- Hick-Hyman Law:
  - Transmitted information:

$$H_T = \log_2(n+1)$$

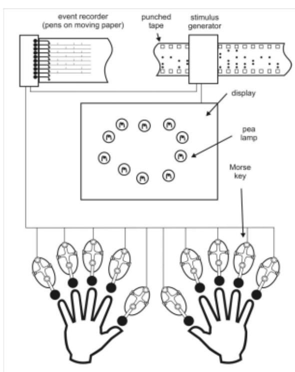
    - n equiprobable alternatives
    - H_T transmitted information
    - Original formulation did not have the "+1"
      - Attends for the uncertainty whether to respond or not
  - Time to answer. Reaction Time:

$$RT = \mathrm{a} + \mathrm{b}\log_2(n+1)$$

    - Reaction Time is a linear function of stimulus information

HICK-HYMAN LAW. EXPERIMENTAL ASSESSMENT

- Hick's initial experiment:
  - 10 pea lamps are arranged in an irregular circle
  - One random lamp is lit every 5 seconds
  - User has to press the correct key corresponding to the lamp that is lit
    - Stimulus and response encoded in a moving paper in binary code



HICK-HYMAN LAW. EXPERIMENTAL ASSESSMENT

- Time to answer. Reaction Time:

$$RT = \mathrm{a} + \mathrm{b}\log_2(n+1)$$

  - Reaction Time is a linear function of stimulus information
- Hyman [Hyman53] found that it also holds for not equiprobable alternatives
  - 8 lights (whose names were *Bun, Boo, Bee, Bore, By, Bix, Bev,* and *Bate*)
    - The users had to name the one lit
      - A microphone attached to the throat detected the voice and stopped the timer
    - First with equal probabilities
    - Then, with varying probabilities

HICK-HYMAN LAW. EXPERIMENTAL ASSESSMENT

- Evidences of Hick-Hyman Law
  - Novice users search linearly while experts decide upon item location and fit a Hick-Hyman curve [Cockburn2008]
  - Performance in hierarchical full-screen menu selections is well described by Hick-Hyman [Landauer85]
  - Selection times decay logarithmically with menu length for frequently selected items, but linearly with infrequent ones [Sears94].
    - Learnt locations (most frequent) fit Hick-Hyman decision times
    - Non-learnt locations fit a linear search

OUTLINE

- *Background*
- *Hick-Hyman Law: Measuring choice-reaction time*
- **Fitts Law: Measuring Pointing Time**
  - Original formulation
  - Variants
  - Experimental evidences
  - Extensions: 2D and Precision Pointing
  - Discussion
  - Assessed Results
- Typing & Keyboards

FITTS' LAW. ORIGINAL FORMULATION

- States a linear relationship between task difficulty and movement time (MT)
  - Formulation is also based on Information Theory
    - Human motor system is the communication *channel*
    - Amplitude of movement is the *signal*
    - Target width is the *noise*

FITTS' LAW. ORIGINAL FORMULATION

- Task difficulty:

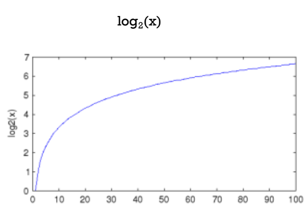
$$ID = \log_2\left(\frac{2A}{W}\right)$$

  - *ID*: Index of difficulty
  - *A*: Amplitude of movement
  - *W*: Target width

FITTS' LAW. ORIGINAL FORMULATION

- Task difficulty:

$$ID = \log_2\left(\frac{2A}{W}\right)$$



FITTS' LAW. ORIGINAL FORMULATION

- Task difficulty:

$$ID = \log_2\left(\frac{2A}{W}\right)$$

  - The larger the amplitude the higher the difficulty
  - The larger the target the lower the difficulty

FITTS' LAW. ORIGINAL FORMULATION

- Time to point a certain objective (target) is called Movement Time
  - Movement time:

$$MT = a + bID$$

    - *a* start/stop times in seconds
    - *b* inherent speed of the device

FITTS' LAW. VARIANTS

- Original formulation fits well to the original experiments
  - But it might fit better
- Other researchers have found different formulations that better model the experimental data
  - Including the experimental data by Fitts
- Welford [Welford68]:

$$MT = a + b\log_2\left(\frac{D + 0.5W}{W}\right)$$

    - D is the distance of movement
    - W is the width of the target

FITTS' LAW. VARIANTS

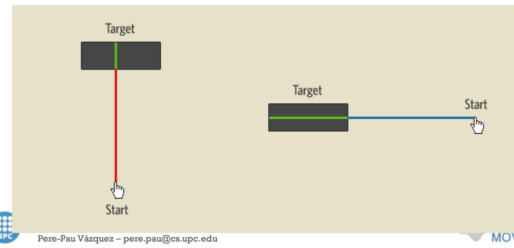
- MacKenzie's approach [MacKenzie92] is one of the most accepted:

$$MT = a + b\log_2\left(\frac{D}{W}+1\right)$$

  - D is the distance of movement
  - W is the width of the target

FITTS' LAW. VARIANTS

- Vertical and horizontal movements can be treated equally



FITTS LAW. EXPERIMENTAL EVIDENCES

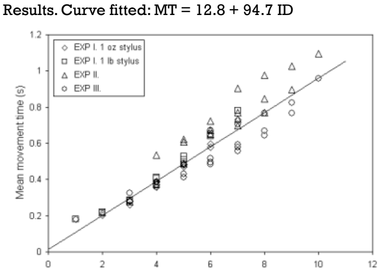
- Fitts Law. Original experiments:
  - Reciprocal tapping:
    - Participants used a metal-tipped stylus:
      - Two experiments with two different stylus: ~ 28.35 gr and 453.6 gr
    - Tap two strips of metallic targets of width from ~ 0.635 to 5.08 cm
    - At distance 5.08 to 40.64 cm
      - **Yes, original data is in ounces and inches!!!** ☺
    - Participants instructed to be accurate!

FITTS LAW. EXPERIMENTAL EVIDENCES

- Fitts Law. Original experiments:
  - Experiment 2: Disk transfer
    - Participants had to transfer stack round plastic disks (with holes drilled trough the middle) from one pin to another
    - Holes of different sizes and pins of different diameters used
  - Experiment 3: Pin transfer
    - Participants had to transfer pins of different diameters from a set of holes to another set of holes

FITTS LAW. EXPERIMENTAL EVIDENCES

- Fitts Law. Results. Curve fitted: MT = 12.8 + 94.7 ID



FITTS LAW. EXPERIMENTAL EVIDENCES

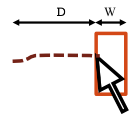
- Fitts Law. Results:
  - Experiment 1:
    - Average error negligible
    - Most difficult condition: Smaller W and largest A
    - Results show that there is a linear relationship between MT and ID

FITTS LAW. EXTENSIONS

- Main application of Fitts in HCI is evaluation/design of UI and interaction
- Today's interfaces are much more complex
  - Variety of sizes, 2D movements, use of fingers

FITTS LAW. EXTENSIONS

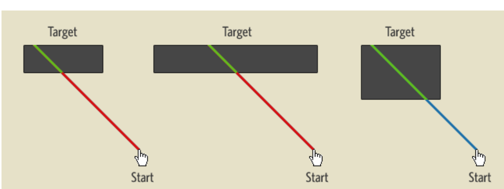
- Use in UI design or evaluation:



  - D is the distance the pointer (mouse) covers to reach the target (button)
  - W is the width of the target (button)

FITTS LAW. EXTENSIONS. 2D

- Vertical and horizontal movements can be treated equally… or not!



FITTS LAW. EXTENSIONS. 2D

- Fitts' Law is designed for 1D movements
  - Most movements in a UI are 2D
- Several extensions deal with 2D movements
  - Mimicking Fitts' Law, but changing some of the parameters
  - [Crossman83]: $MT = a + b\log_2\left(\frac{2D}{W}\right) + c\log_2\left(\frac{2D}{H}\right)$
  - [Accot97]: $MT = a + b\log_2\left(\sqrt{\left(\frac{D}{W}\right)^2 + \eta\left(\frac{D}{H}\right)^2} + 1\right)$

FITTS LAW. EXTENSIONS. PRECISION POINTING

- Fitts Law does not model properly very small targets:
  - Extra time devoted to fine adjustment
  - Increase of errors
  - …
- Very small targets yield a lower fit of the regression curve of the MT function
- Touchscreens also modifies the timing we require to point targets.

FITTS LAW. EXTENSIONS. PRECISION POINTING

- Extension of Fitts' Law by analyzing the behavior both in tactile screens and small targets ([Sears91]):
  - Named FFitts (Finger Fitts), also PPMT (Precision Pointing Movement Time) by some other authors :

$$FFits = a + bID + dID_2$$

$$FFitts = a + b\left[\log_2\left(\frac{cD}{W}\right)\right] + d\left[\log_2\left(\frac{e}{W}\right)\right]$$

FITTS LAW. EXTENSIONS. PRECISION POINTING

- FFitts:

$$FFitts = a + b\left[\log_2\left(\frac{cD}{W}\right)\right] + d\left[\log_2\left(\frac{e}{W}\right)\right]$$

  - the first logarithmic factor measures *the time to place the finger on the screen initially*
  - the second factor measures *the time to position the cursor*
  - *D* is the distance, measured in three dimensions, from the original hand location to the location of first contact
  - W is some measurement of target size
  - *a*, *b*, *c*, *d*, and *e* must be determined for each specific case

FITTS LAW. EXTENSIONS. PRECISION POINTING

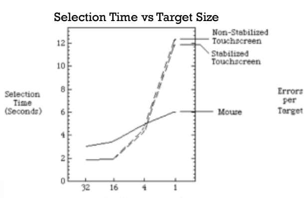
- FFitts:

$$FFitts = a + b\left[\log_2\left(\frac{cD}{W}\right)\right] + d\left[\log_2\left(\frac{e}{W}\right)\right]$$

  - If the task consists of iteratively clicking targets: *D* is the distance from one target to the next one

FITTS LAW. EXTENSIONS. PRECISION POINTING

- Ffitts' experiments:
  - Date from 1989!
    - Tactile screens of lower resolution than mouse interaction
      - Required on purpose stabilization software



FITTS LAW. DISCUSSION

- Fitting regression curves:
  - Validation of Fitts' Law may not extrapolate to outside values
    - Only valid for the experiments carried out
    - Has been demonstrated that very small values of ID do not fit properly
    - Limited number of target sizes (four in original Fitts' work)
    - The lack of precise distance measurements (from the user's hand to the target) makes analysis difficult
  - The higher number of freedom degrees, the easier to fit in a regression curve
    - Note that this sort of proves are partially done *a posteriori*

FITTS LAW. DISCUSSION

- Validation can be done in several ways:
  - Move from a control point to another in a fixed direction and fixed distance, target known
  - Move from a control point to another in a fixed direction and varying distance, target known
  - Move from a control point to another in random direction (e. g. left or right) and fixed/varying distance, target known
  - Move from one target to another in a succession, targets known
    - With all the previous variants
  - Move from one control point to another target that appears immediately after we click the control point
    - With all the previous variants (both directions and distances and discrete vs continuous target selection)

FITTS LAW. DISCUSSION

- Validity of Fitts experiments:
  - Each experimentation will be valid for the concrete specifications
  - The results of a successive target selection may not match the results of discrete selection
    - Constants will be different
    - Some formulations may yield to negative intercept values, which does not make sense
    - Some results must account for the movement preparation time

FITTS LAW. DISCUSSION

- Speed vs accuracy tradeoff:
  - Users can be *guided* through the experimentation:
    - Ask them to be precise
      - Showing error rates enforces correction
    - Ask them to be fast
  - We may skew the experiment depending on what we say, e.g.:
    - "This experiment is to demonstrate that larger targets are acquired easier than small targets"
      - Users might want to satisfy you!
      - …Or not!

FITTS LAW. ASSESSED RESULTS

- Fitts' Law has shown its validity in multiple setups and devices:
  - Mouse, joystick, finger, stylus…
  - Different screen types of varying sizes…
  - But the results cannot be extrapolate to data outside the experiment
    - Commonly the experiments evaluate a relatively small set of configurations (e. g. four button sizes, 6 distances…)
    - Precuing or not precuing may influence results
    - The device used may behave differently
      - External variables such as mouse acceleration must be taken into account
- Age may influence (adult vs children)
  - Fitts' law predicts the first time the children enter a target
  - But not the time of the final selection

FITTS LAW. ASSESSED RESULTS

- Fitts' Law has shown its validity in multiple setups and devices:
  - Mouse, joystick, finger, stylus…
  - Different screen types of varying sizes…
  - But the results cannot be extrapolate to data outside the experiment
- Precued targets lead to more efficient and precise pointing movements than for non-precued targets [Hertzum2013].
  - Most common case: we know the buttons' positions in advance.
  - The benefit of precuing is larger for the mouse than the touchpad
    - Maybe movement preparation is more effective if the device is more demanding
- The index finger alone does not perform as well as the wrist or forearm in pointing tasks
  - But the thumb and index fingers in coordination outperform all above cases [Balakrishnan97]

FITTS LAW. ASSESSED RESULTS

- Effective target width:
  - Some researchers suggest measuring the ID using the *effective target width* (or W_e), instead of the *nominal width* [Fitts64, Sourkoreff2004]
    - Users do not click on a fixed distance
      - But endpoints have certain variability
  - Effective widths remove biases in target utilization by enlarging error-prone targets and shrinking underutilized targets while leaving *MT*s intact [Chapuis2011].
    - Uncorrected widths seems useful to reliably assess actual user pointing times in user interfaces.
    - Effective widths instead useful to compare the performance of different input devices.

FITTS LAW. ASSESSED RESULTS

- Effective target width:
  - Not available without experimentation
    - Less useful than nominal value
  - Effective widths remove biases in target utilization by enlarging error-prone targets and shrinking underutilized targets while leaving *MT*s intact [Chapuis2011].
    - Uncorrected widths seems useful to reliably assess actual user pointing times in user interfaces.
    - Effective widths instead useful to compare the performance of different input devices.

OUTLINE

- *Background*
- *Hick-Hyman Law: Measuring choice-reaction time*
- *Fitts Law: Measuring Pointing Time*
- **Typing & Keyboards**
  - Layouts
  - Practical Issues
  - Mobile Layouts

TYPING & KEYBOARDS. LAYOUTS

- QWERTY keyboard layout:
  - Design by Christopher Latham Shole.
  - The placement of the keys reduces key jams.
    - Keys commonly typed together are placed at large physical distance
      - In a typing machine
      - Changing hands
      - Assuming language is English
    - Does not make sense with computers
    - Not everybody writes in English

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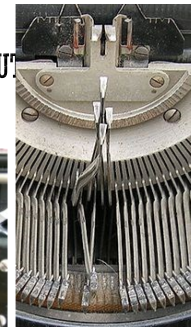
MOVING

TYPING & KEYBOARDS. LAYOUTS

- QWERTY keyboard layout:



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MOVING

TYPING & KEYBOARDS. LAYOUTS

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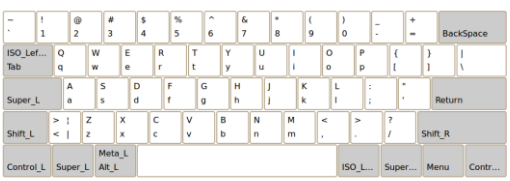

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MOVING

TYPING & KEYBOARDS. LAYOUTS

- Dvorak layout:
  - Invented with the objective of reducing travel distances
    - 10-finger typing
  - Improvements of up to 30%
    - Other researchers say 5-10%
  - Less errors
  - Also optimized for English
  - Low level of acceptance

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MOVING

TYPING & KEYBOARDS. LAYOUTS

- Dvorak layout:
  - Vowels in one hand
    - Combinations with consonants impose hand change
  - Most common letters at the places the fingers rest on the keyboard

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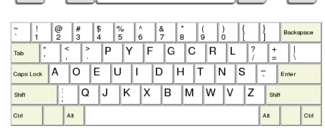
MOVING

TYPING & KEYBOARDS. LAYOUTS

- Keyboard layouts AZERTY vs Dvorak:



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MOVING

TYPING & KEYBOARDS. LAYOUTS

- Keyboard layouts
  - Dvorak proven more efficient
    - Reduces by an order of magnitude the finger travel distances
    - Reduces errors
    - Not acceptance
    - Typing Guinness world record held by a Barbara Blackburnwith a DVORAK keyboard in a typewriter for many years
      - 150 wpm for 50 minutes
  - Other ergonomic layouts

TYPING & KEYBOARDS. LAYOUTS

- Keyboard layouts
  - Improves posture and reduces tension
  - No proven advantage

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Touchable layouts
  - Size depends on screen size
    - Limited and occludes text
  - Require significant visual attention
    - No physical feedback
      - Sometimes sound
  - Distance from the keyboard to the insertion point
    - Especially on larger form factors
  - Errors: accidentally touching the screen
  - Touch and stylus based may be a good combination

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Fitts Law accurately predicts pointing movement
  - If improvement required, it can help us modify our UI
    - Change target width:
      - Increase size for faster reach
    - Change distance:
      - Move targets closer to reduce movement time
    - Change pointer movement:
      - Increase speed

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Designing virtual keyboards. Elements to consider:
  - Auto-correction
  - Auto-capitalization
  - Input data type & custom keyboards
  - Tabs
  - (Multiple-)Language support

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Auto-correction:
  - Only suitable if proper dictionaries:
    - Commonly, users do not notice the corrections
    - Some data such as address very prone to wrong correction
    - 92% sites do it wrong
  - Best practices:
    - Skip auto-correction for certain fields

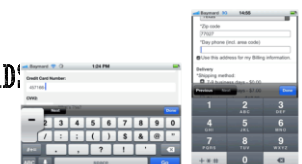
TYPING & KEYBOARDS. PRACTICAL ISSUES

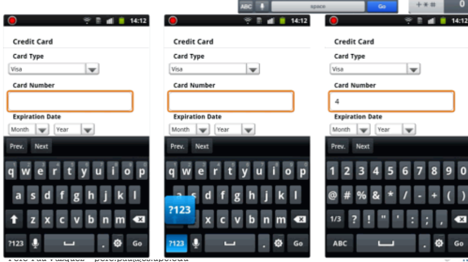
- Auto-capitalization:
  - In e-mail addresses, disable auto-capitalization
    - Even if correct, people tries to fix

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Appropriate layouts for the input data type:
  - Virtual keyboards are small
    - An iPhone 4 character (portrait) measures 4 × 5.9 mm
      - Minimum recommended clickable size is 6.85 × 6.85 mm
    - Increase typos, validation errors…
    - 60% top mobile websites do it wrong
  - Dedicated keyboards may increase the size enough (phone numbers, ZIP codes, currency…)
    - Invoke them, and **do it consistently**

TYPING & KEYBOARD



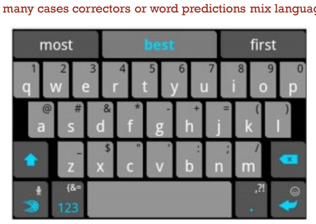


TYPING & KEYBOARDS. PRACTICAL ISSUES

- Tabs:
  - Buttons Next and Previous should act as we expect from a tabulator: Next/Previous field
    - Mobile keyboards often hide the rest of the fields
  - Provide a standardized way to change between them

TYPING & KEYBOARDS. PRACTICAL ISSUES

- (Multiple-)Language support:
  - Most custom keyboards provide the possibility of changing the language on demand
    - In many cases correctors or word predictions mix languages



TYPING & KEYBOARDS. PRACTICAL ISSUES

- Expert typing model [Bi2013]:
  - Time to move the tapping device with a single finger from one key (*i*) to another (*j*) depends on the distance and key width of the keys:

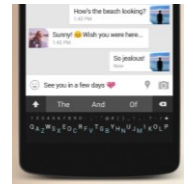
$$MT_{ij} = a + b\log_2\left(\frac{D_{ij}}{W_{ij}} + 1\right)$$

  - D_{ij} is the distance between keys *i* and *j*,
  - W_{ij} is the width of each key
  - Bi *et al.* also use the effective width

TYPING & KEYBOARDS. PRACTICAL ISSUES

- Improving mobile layouts:
  - Different parameters to take into account:
    - 10-finger typing? As of tablets
    - 2-thumb typing? Mobiles/tablets.
    - 1-finger typing? Most commonly mobile
- Optimize for the number of fingers
  - Tactile screen form factor
  - Maybe hand positions too

TYPING & KEYBOARDS. MOBILE LAYOUTS

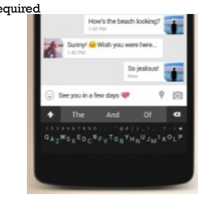




TYPING & KEYBOARDS. MOBILE LAYOUTS

- Proposed mobile layouts. KALQ:
  - Optimize layout for better **2 thumb typing**
  - Analyzed hand position, digram frequency, tablet orientation…

TYPING & KEYBOARDS. MOBILE LAYOUTS

- Proposed mobile layouts. Minuum:
  - **Two or one finger typing**
  - Compressing the three key rows into one
    - Reduction of distances (in vertical)
    - Larger targets (the whole region of e. g. QAZ)
    - Proficient word prediction/correction required
  - More room in your screen

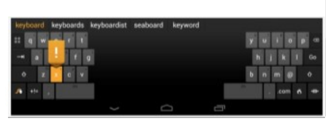


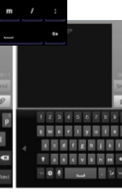
TYPING & KEYBOARDS. MOBILE LAYOUTS

- Minuum is intended to type everywhere:

TYPING & KEYBOARDS. MOBILE LAYOUTS

- Proposed mobile layouts. Split keyboard / size change:
  - **Two thumbs (left) one thumb on a large device (right)**



TYPING & KEYBOARDS. MOBILE LAYOUTS

- Digram-based layout for **single-finger typing** [Lewis99]:
  - Optimized distances
  - Up to 25 wpm (over the typical 20 wpm on a complete QWERTY)

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

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TYPING & KEYBOARDS. MOBILE LAYOUTS

- Keyboard arrangements should be designed so that:
  - Balance the loads on the right and left hands
  - Maximize the load on the home row
  - Maximize the frequency of alternating hand sequences
    - Alternating fingers avoids the need to wait for the end of the movement of the first finger before starting the second movement.
  - Minimizing the frequency of same finger typing

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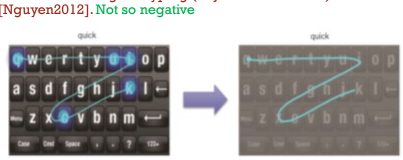
TYPING & KEYBOARDS. MOBILE LAYOUTS

- **Single finger** gesture typing [Kristensson2012, Zhai2012]
  - The finger traverses all the letters of a word without lifting off the screen
  - More comfortable (subjective evaluation) in tablets [Nguyen2012]
  - Not faster than regular typing (objective evaluation) in tablets [Nguyen2012]. Not so negative



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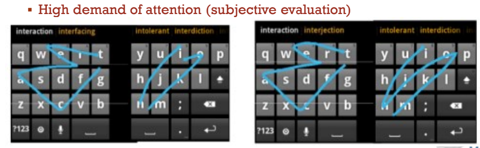
TYPING & KEYBOARDS. MOBILE LAYOUTS

- **Two finger** gesture typing [Bi2012]
  - The two thumbs swipe to compose a word
    - Lifting the finger when a part of the word belongs to the other thumb
    - Or with a continuous trace
  - Finger traveling shortened by 50%
  - Speed does not increase over one finger entry (objective evaluation). Not so negative
  - High demand of attention (subjective evaluation)



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INTERACTION DESIGN AND EVALUATION. SESSION 1

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INTERACTION DESIGN AND MEASURES

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