Using Fitts' Law to Model Key Repeat Time in Text Entry Models

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Abstract

- While Fitts' law provides a robust and accepted means to model rapid aimed movements, it should not be used for modelling key repeat times (zero-amplitude movements) that arise in text entry models.

Text Entry Modelling

- Predicts theoretical maximum typing speed for a keyboard arrangement given a language and Fitts' law models.
- Fitts' law is a relation derived from information theory used to model human movement. Text entry modelling uses Fitts' law to predict movement times for fingers, thumbs or styli, between keys on a keyboard.
- Inter-key movement times are calculated with:

$$MT_{ij} = a + b \times \log_2\left(\frac{A_{ij}}{W_j} + 1\right)$$

where:

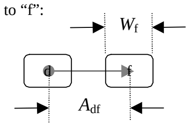
MT_{ij} = Time to move from key i to j (seconds)

A_{ij} = Distance from key i to j (metres)

W_j = Width of j key (metres)

a, b = Fitts' law constants, found through experimentation and linear regression.

  - Note that the $\log_2(\bullet)$ term is referred to as the Index of Difficulty (*ID*); it is a measure of the relative difficulty of the movement, and has units of *bits*.
- For Example, the Fitts amplitude and width when moving from key "d" to "f":



Key Repeat Time

- Key repeat occurs when one types the second of two identical consecutive characters (like the second "o" in "look").
- The purpose of Fitts' law is to model rapid aimed movements, but there is no Fitts' movement for repeat keypresses, so Fitts' law does not apply.
- For repeat keys, the Fitts' law devolves to the intercept:

$$MT_{ii} = a + b \times \log_2\left(\frac{A_{ii}}{W_i} + 1\right) = a + b \times 0 = a$$

but does a accurately represent repeat time? No!

Participants

- We found nine volunteers (four females, five males).
- They ranged in age from 25 to 32, with an average age of 29.7 years.
- Eight were right-handed; one was left-handed (as reported by the subjects).

Apparatus

- A modified Sharp EL-6053 pocket organiser was used.
- A PIC micro-controller (Microchip Technology, `www.microchip.com`) was interfaced to the keyboard hardware of the EL-6053, and programmed to emit ASCII characters in real time as keys were typed on the keyboard.
- The ASCII characters from the PIC micro-controller were transmitted through a serial cable at 1200 baud to a 400MHz Pentium II computer.
- A Java program on the Pentium computer time-stamped and recorded the ASCII characters.
- Particular attention was paid to lag, to ensure the accuracy of the final time-stamps.

Procedure

- The subjects were instructed to use each thumb to perform a series of artificial (non-English) typing tasks.
- The tasks were to enter repeating pairs of characters. The key patterns used for generating the left and right hand Fitts' law models were:

ID (bits) ‡	Left Hand Pattern	Right Hand Pattern
0	D	J
1.60	D-E	J-I
1.73	D-F	J-H
2.12	E-X	I-M
2.50	D-G	H-K
2.99	S-G	H-L
3.12	T-Z	M-T
3.71	Q-B	P-V

‡ Note that the target widths were taken to be 5 mm (the key height); the amplitudes were measured directly from the keyboard.

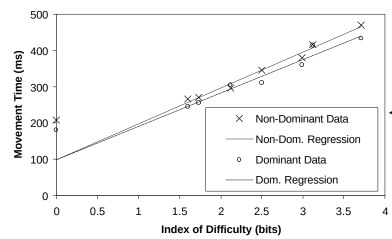
- Each condition lasted ten seconds.
- For example, to measure the time to complete the left-hand, 1.60-bit task, subjects entered "DEDEDE..." as quickly as they could for ten seconds. For the 0-bit tasks, subjects repeatedly pressed the respective single key.
- The specific instructions given to subjects were to enter the repeating pattern of characters as fast as possible without making any errors, but to ignore any errors they did make.
- The conditions were presented to the subjects in a random (not counter balanced) order.

Results

- Average movement times for each condition were calculated for each subject. Results from the subjects were averaged, and linear regression was used to generate the following Fitts' law models and key repeat times.
- The Fitts' law models:

Model	Intercept (ms)	Slope (ms/bit)	*n*	*r*
Dominant:	98.53	92.02	7	0.976
including *ID* = 0:	153.14	72.11	8	0.962
Non-Dominant:	98.62	98.79	7	0.993
including *ID* = 0:	170.73	72.50	8	0.956

  - Note the greyed intercept values, 98.53 and 98.62 ms. These are the *a* values in the Fitts' law models. How will these compare to actual key repeat times?
  - Note that the correlations (*r* values) are highest (indicating best fit) when the *ID* = 0 data points are not included.
- The averaged data and the Fitts' law models calculated without including the *ID* = 0 data points appear below:



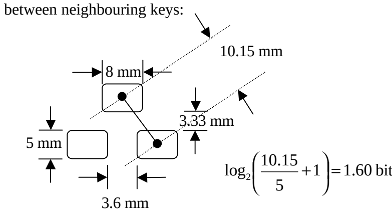
- The results of directly measuring key repeat time:

Thumb	Repeat Time (ms)	Standard Deviation
Dominant	181.57	23.74
Non-Dominant	208.28	31.88
Average	194.93	-

  - Note the greyed repeat times, 181.57 and 208.28 ms. These values are much greater than the intercepts of the Fitts' law models.

Discussion

- The regression models match the data well for index of difficulty values greater than or equal to 1.60 bits (particularly when the *ID* = 0 data points are not included in the linear regression), and a separately measured repeat value provides the best prediction for the *ID* = 0 value.
- The Fitts' law intercepts obtained when the *ID* = 0 data points are not included in the linear regression (98.53 and 98.62 ms) are approximately half of the measured repeat values (181.57 and 208.28 ms). This indicates that the Fitts' law intercept values are far too small to model key repeat.
- One could consider using the intercept values calculated including the *ID* = 0 data points, but the correlations suffer, and the intercept values obtained are still too small.
- We conclude that when constructing or using text entry models, Fitts' law (calculated without the *ID* = 0 data points) should be employed for inter-key movement times (with *ID* > 0 bits). However, a separate repeat value should be used for key repeat times (*ID* = 0 bits).
- We hypothesise that the effect we have observed is due to the distribution of *ID* values encountered. Notice that there is a large gap in *ID* values between 0 and 1.60 bits. This is due to the physical geometry of the keys. Notice the large spaces between neighbouring keys:



Other than the key repeat case (*ID* = 0), the smallest *ID* value possible is 1.60 bits.

- The effect of the distribution of *ID* values is visible in the Fitts' law graph. We're using values that are a long way to the right of the *y*-axis, to predict the *y*-intercept value.
- We lack data points near the *y*-axis, and so there is a lack of confidence in the *y*-intercept prediction. Hence, it is more accurate to separately measure the key repeat time, and use it instead of Fitts' law, for the key repeat case.