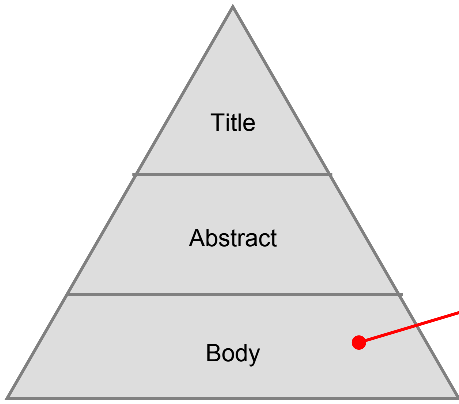
Writing a Research Paper

I. Scott MacKenzie

Research Paper

- The final step
- Research is not finished until the results are published!

Organization of a Research Paper



Main sections…
- Introduction
- Method
  - Participants
  - Apparatus
  - Procedure
  - Design
- Results and Discussion
- Conclusions

A Comparison of Input Devices in Elemental Pointing and Dragging Tas[k]

I. Scott MacKenzie[1], Abigail Sellen[2] and William Buxton[2]

[1]Ontario Institute for Studies in Education
University of Toronto
Toronto, Ontario, Canada M4S 1V6

[1]Seneca College of Applied Arts and Technology
Toronto, Ontario, Canada M2J 2X5

[2]Dynamic Graphics Project, Computer Systems Research Institute
University of Toronto
Toronto, Ontario Canada M5S 1A4

Abstract
An experiment is described comparing three devices (a mouse, a trackball, and a stylus with tablet) in the performance of pointing and dragging tasks. During pointing, movement times were shorter and error rates were lower than during dragging. It is shown that Fitts' law can model both tasks, and that within device the index of performance is higher when pointing than when dragging. Device differences also appeared. The stylus displayed a higher rate of information processing than the mouse during pointing but not during dragging. The trackball ranked third for both tasks.

Keywords: Input devices, input tasks, performance modeling.

Introduction – context for the research. State why it is interesting and relevant. Identify a problem as it currently exists. Give an overview of the contents of the entire paper.

INTRODUCTION

The actions of *pointing* and *dragging* are fundamental, low-level operations in direct manipulation interfaces. While pointing tasks have been studied extensively (see, for surveys by Milner, 1988 and Greenstein & Arnaut, 1988), the same is not true for dr present study addresses this imbalance. It is driven by a belief that the human factors range of direct manipulation tasks must be better understood. With such understandi the ability to develop better predictive and analytic models, for example by extending Keystroke-Level Model of Card, Moran, and Newell (1980) to handle this mode of in

This paper has two main contributions. First, it shows that dragging is a variation of and consequently, that Fitts' law can be applied to it. Second, it establishes that the p of input devices in *each* of these two tasks should be considered in characterizing th human-factors of devices.

We present an experiment comparing three devices (a mouse, a tablet, and a trackbal pointing and a dragging task. Each is modelled after Fitts' reciprocal tapping task (Fit

Use subsections as appropriate to provide the background and rationale for the research.

Fitts' Law: An Overview

Pointing (target acquisition) tasks have been studied extensively. Much of this work a robust model of human movement known as *Fitts' law* (Fitts, 1954). The law pred time to acquire a target is logarithmically related to the distance over the target size. More formally, the time *(MT)* to move to a target of width *W* which lies at distance (or amplitude) *A* is

$$MT = a + b \log_2(2A / W) \qquad (1)$$

where *a* and *b* are empirical constants determined through linear regression. A variation proposed by Welford (1968) is also widely used:

Number equations consecutively throughout manuscript

$$MT = a + b \log_2(A / W + 0.5). \qquad (2)$$

The log term is called the index of difficulty (*ID*) and carries the units "bits" (because the "2"). The reciprocal of *b* is the index of performance (*IP*) in bits/s. This is purportedly th human rate of information processing for the movement task under investigation. Card, E and Burr (1978) found *IP* = 10.4 bits/s for the mouse in a text selection task. This is sim values obtained by Fitts (1954) but is higher than usual. For example, ten devices were te studies by Epps (1986), Jagacinski and Monk (1985), and Kantowitz and Elvers (1988). Performance indices ranged from 1.1 to 5.0 bits/s.

Give and assess findings from prior research. Cite as appropriate.

There is recent evidence that the following formulation is more theoretically sound and yi better fit with empirical data (MacKenzie, 1989):

$$MT = a + b \log_2(A / W + 1). \qquad (3)$$

In an analysis of data from Fitts' (1954) experiments, Equation 3 was shown to yield high correlations than those obtained using the Fitts or Welford formulation. Another benefit of Equation 3 is that the index of difficulty cannot be negative, unlike the log term in Equation 1 or 2. Studies by Card et al. (1978), Gillan, Holden, Adam, Rudisill, and Magee (1990), and Ware and Mikaelian (1987), for example, yielded a negative index of difficulty under some conditions. Typically this results when wide, short targets (viz., words) are approached from above or below at close range. Under such conditions, *A* is small, *W* is large, and the index of difficulty, computed using Equation 1 or 2, is often negative. A negative index is theoretically unsound and diminishes some of the potential benefits of the model.

Fitts' original experiments used reciprocal tapping tasks where one alternately tapped on two rectangular targets. The controlled variables were target width and the distance between targets; however, the motion was one dimensional (back and forth). Extending the model to two dimensions (which better fits pointing tasks in computer usage) has been discussed by Card et al. (1978) and Jagacinski and Monk (1985), among others.

Use sub-subsections as appropriate (It's your story to tell.)

Dragging

There is little in the literature addressing human performance in dragging tasks. One exception is the study by Gillan et al. (1990). Like them, we extend Fitts' law to dragging. However, their study deals with text selection and is confounded on issues such as approach angle. Our work is at a lower level, and pays closer attention to device performance in the respective tasks and to the formulation of the mathematical model.

Using Fitts' law to model dragging is best explained using an example. Consider the case of deleting a file on the Apple Macintosh. First, the user acquires the icon for the file in question. This point/select operation is a classic two-dimensional target acquisition task. Then, while holding the mouse button down, the icon is dragged to the trashcan. This also is a target acquisition task. One is really just acquiring the trashcan icon. In this case, however, the task is performed with the mouse button depressed.

Use figures with captions as appropriate

From the perspective of motor performance, the only difference is whether the tasks are performed with the mouse button released or held down. (In both cases, the target is an icon of approximately the same size.) These classes of action are characterized as *State 1* and *State 2* by Buxton (1990), as illustrated in Figure 1.

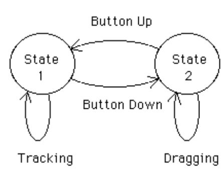


Figure 1. Simple 2-state interaction . In State 1, mouse motion moves the tracking symbol. Pressing and releasing the mouse button over an icon selects the icon and leaves the user in State 1. Depressing the mouse button over an icon and moving the mouse drags the icon. This is a State 2 action. Releasing the mouse button returns to the tracking state, State 1 (from Buxton, 1990).

State 2 motion on most input devices requires active maintenance of the state (e.g., by h down a button), generally restricting the freedom of movement.[1] Given the frequency 2 actions in direct manipulation systems, we feel the following are important:

- to evaluate devices in *both* State 1 and State 2 tasks (unlike prior emphasis on the former), and
- to show that an established model (i.e., Fitts' law) can apply to this additional, State 2, case.

Achieving these two goals was our main motivation. Mean movement time, error rate, and Fitts' law were used to compare performance on three input devices in both State 1 and State 2 tasks.

Objectives – good lead-in to the methodology that follows

Method

Subjects

Twelve computer literate subjects (11 male, 1 female) from a local college served as pa volunteers. Subjects used their preferred hand.

Equipment

Tasks were performed on an Apple Macintosh II using three input devices:

- Macintosh mouse
- Wacom tablet and stylus
- Kensington trackball

Method – tell the reader what you did and how you did it

Participants – state the number of participants. Give demographic information, such as age, gender, relevant experience. State how they were chosen. (Note: The term "Subjects" is now obsolete.)

Apparatus – describe the hardware and software.

Procedure – specify exactly what happened with each participant.

Use screen snaps of software if appropriate

Procedure

Pointing Task: Two targets appeared on each side of the screen (see Figure 2) with an
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Dragging Task: The dragging task was similar except an "object" (see Figure
pressing and holding down the button (on the mouse and trackball) or mainta
the stylus to "drag" the object to the other target. The object was dropped by
or pressure. The new object to be selected appeared immediately in the centr
which the old object was just dropped.

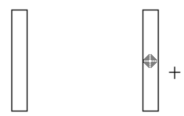

Figure 3. State 2 dragging task. By placing the cross over the> object inside the target, the object could be acquired and dragged to the other> target. State 2 was maintained by holding the mouse button down.

The dragging task can be likened to an inside-out pointing task: During pointing, movement occurred with the mouse button up and a down-up action terminated a move (and initiated the next); during dragging, movement occurred with the mouse button down and an up-down action terminated a move (and initiated the next).

Although instructed to move as quickly and accurately as possible, performance feedback was not provided. Subjects were told that an error rate of one miss in every 25 trials was optimal.

11

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Design – factors and levels, order of administering conditions, etc.

Be thorough and clear! It's important that your research is reproducible.

Design

Both tasks used four target amplitudes (A = 8, 16, 32, or 64 units; 1 unit = 8 pixels) fully
crossed with four target widths (W = 1, 2, 4, or 8 units). Each A-W combination initiated
block of ten trials, each being one pointing or dragging task. Sixteen randomized blocks
constituted one session. Five sessions were completed for each device for each task.

The task and device factors were within-subjects -- each subject performed both pointing
dragging on all three devices. Ordering of devices was counterbalanced. Within devices,
random process determined the initial task (dragging or pointing) and tasks alternated for
session thereafter.

Prior to each new device-task condition, subjects were given a practice block. Breaks were allowed between blocks and sessions, but subjects completed all ten sessions on each device in a single sitting. Three sittings over three days, for a total of about three hours, were necessary to complete all conditions.

12

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Results and Discussion

Use subsections as appropriate

If there were outliers or problems in the data collection, state this up-front.

Results

Adjustment of Data

Subjects were observed to occasionally "drop" the object during the dragging task, not th
normal motor variability, but because of difficulty in sustaining State 2 motion. (This was
particularly evident with the trackball.) Thus "dropping errors" were distinguished from n
variability errors. Examining the distribution of "hits" (the *X* coordinates) confirmed this s
of error. Figure 4 shows a sample distribution of responses around the target for one sub
during dragging. The data reveal deviate responses at very short movement distances dist
from the normal variability expected.

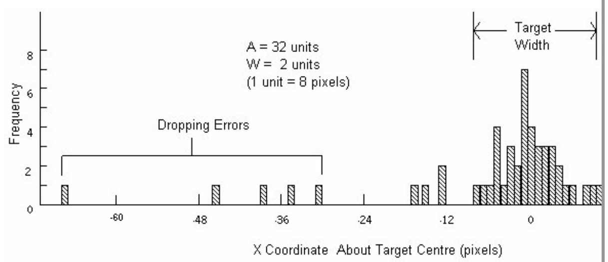

Figure 4. Dropping errors. The distribution of X coordinates for one subject showing deviate responses classified as "dropping errors". Shown are 50 trials for the trackball during dragging with A= 32 and W = 2.

13

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Organize results by the dependent measures. Give means across conditions. Use statistical tests as appropriate (e.g., analysis of variance). Again… It's your story to tell.

Movement Time

Mean movement times for the mouse, tablet, and trackball respectively were 674,
during pointing and 916, 802, and 1284 ms during dragging. There was a significar
task, with pointing faster than dragging ($F_{1,11}$ = 72.4, $p < .001$). This is shown in F
also differed in movement time ($F_{2,22}$ = 264.0, $p < .001$). The trackball was the sl
pointing and dragging; however, there was a significant task-by-device interaction (
.05). While the mouse and tablet were comparable for pointing, performance was
the mouse than for the tablet or trackball when the task changed to dragging. Adju
errors had minimal effect on movement time.

Use charts, tables, etc., as appropriate.

Don't overdo it! Giving too many charts or too much data means you can't distinguish what is important from what is not important. Give the results that are important, no more, no less.

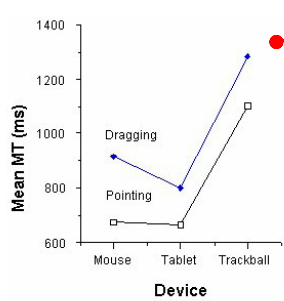

Figure 5. Mean movement time by device and task

14

Don't Give the Same Results Twice

[5]. The average of each of these measures across all trials is shown in Table 2 and Figure 9. All devices were significantly different from all others for each of the three metrics ($p < 0.002$ for all comparisons).

Device	Movement Time (ms)	Error Rate	Throughput–bps (std. d
Mouse	628	4.34%	[illegible]
SmartBoard	473	1.94%	11.80
Laser Pointer	930	6.26%	5.08 (1.47)
Semantic Snarfing	562	8.44%	13.13 (5.99)

Table 2 Results of Experiment 2

Same information

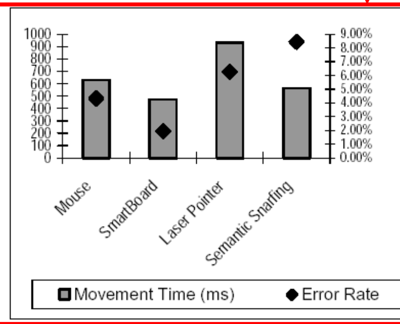

Figure 9. Results from the Experiment 2 for movement time and errors

From…

Myers, B. A., Bhatnagar, R., Nichols, J., Peck, C. H., Kong, D., Miller, R., & Long, A. C. (2002). Interacting at a distance: Measuring the performance of laser pointers and other devices. *Proceedings of CHI 2002*, 33-40. New York: ACM.

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Discuss the results. State what is interesting in the results. Explain the differences across conditions. Compare with results from other studies.

Errors

An error was defined as selecting outside the target while pointing, or relinquishing the target while dragging. Unadjusted error rates for pointing were in the desired r means of drag the tabl

Figure unadjus errors t of devic shown rate acr with the

Adjusting for errors, not surprisingly, had a profound effect on draggin errors occur in the pointing task; however, the same criterion was applied for consistency. If valid, not as many errors would be eliminated in the pointing task. As evident in Figure 6, this was the case.

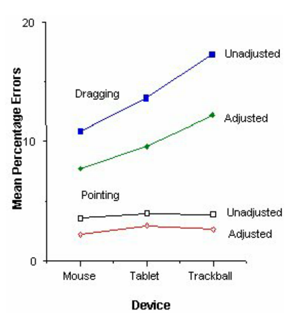

Figure 6. Mean percentage errors by device and task

Provide additional analysis, as appropriate, such as fine grain analyses on types of errors or linear regression or correlation analyses for models of interaction (such as Fitts' law).

Fit of the Model

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Five of the intercepts were close to the origin (within 135 ms); howev appeared for the trackball-dragging combination (-349 ms). With a n of a negative predicted movement time looms. However, the chance is remote because of the large slope coefficients. For example, under prediction would only occur for $ID < 0.5$ bits.

Device	r[a]	Intercept, a (ms)	Slope, b (ms/bit)	IP (bits/s)[b]
*** Pointing ***				
Mouse	.990	-107	223	4.5
Tablet	.988	-55	204	4.9
Trackball	.981	75	300	3.3
*** Dragging ***				
Mouse	.992	135	249	4.0
Tablet	.992	-27	276	3.6
Trackball	.923	-349	688	1.5

(Regression Coefficients)

[a] $n = 16$, $p < .001$

[b] IP (index of performance) = $1/b$

Figure 7. Fitts' law models. A regression analysis for each device-task combination shows the correlation (r), intercept (a), slope (b), and index of performance ($IP = 1 / b$). Prediction equations are of the form $MT = a + b\ ID$, where $ID = \log_2(A / W + 1)$.

17

Conclusions – sum up what you did, restating the important findings. Restate the contribution. Restate any problems noted earlier. Identify topics for future work.

Do not develop any new ideas in the conclusion.

Conclusion

This experiment confirmed the Card et al. (1978) finding of the superb performanc pointing tasks, although the performance was comparable using a stylus and tablet

The experiment showed a clear difference with devices in performing State 1 (poi (dragging) tasks. For State 2 tasks, movement times are longer and error rates are degradation between states differs across devices.

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The experiment also showed that Fitts' law can model both dragging ar performance indices within devices were higher while pointing. Overall, bits/s, somewhat less than the values found by Card et al. (1978) but comparable to values in other studies.

Of the devices tested, the highest index of performance was for the tablet during pointing and for the mouse during dragging. It is felt that a stylus, despite the requirement of additional, non-standard hardware, has the potential to perform as well as the mouse in direct manipulation systems, and may out-perform the mouse when user activities include, for example, drawing or gesture recognition.

Clearly, the work is not complete, and issues such as extending Fitts' law to accommodate approach angle need further investigation.

18

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Acknowledgements

We would like to acknowledge the contribution of Pavel Rozalski who wrote the s
members of the Input Research Group at the University of Toronto.

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19

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References – formatted as per the submission requirements of the conference or journal

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MacKenzie, I. S. (1989). A note on the information-theoretic basis for Fitts' law. *Journal of Motor Behavior*,*21*, 323-330.

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Ware, C., & Mikaelian, H. H. (1987). An evaluation of an eye tracker as a device for computer input. *Proceedings of the CHI + GI '87 Conference on Human Factors in Computing Systems and Graphics Interface*, 183-188. New York: ACM.

Welford, A. T. (1968). *The fundamentals of skill*. London: Methuen.

20

Writing Style

- Four tips
  1. Be concise
  2. Avoid superfluous words or phrases
  3. Use the active voice, not the passive voice
  4. (we'll get to this shortly)

The Abstract

- The abstract should state...
  - What you did
  - What you found
- The abstract is…
  - the most important section of the research paper (It is often the only part that is read. The abstract is read to determine if the rest of the paper should be read.)
- If the abstract is poorly written, the entire paper is poorly written

Abstract Example #1 – Content

- An example from CHI[1]

Next slide

[1] Karat, C. M., Halverson, C., Karat, J., & Horn, D. (1999). Patterns of entry and correction in large vocabulary continuous speech recognition systems, *Proceedings of ACM Conference on Human Factors in Computing Systems -- CHI '99* (pp. 568-575): New York: ACM...

Last slide on Feb 2

States *what they did*

Abstract

A study was conducted to evaluate user performance and satisfaction in completion of a set of text creation tasks using three commercially available continuous speech recognition systems. The study also compared user performance on similar tasks using keyboard input. One part of the study (Initial Use) involved 24 users who enrolled, received training and carried out practice tasks, and then completed a set of transcription and composition tasks in a single session. In a parallel effort (Extended Use), four researchers used speech recognition to carry out real work tasks over 10 sessions with each of the three speech recognition software products. This paper presents results from the Initial Use phase of the study along with some preliminary results from the Extended Use phase. We present details of the kinds of usability and system design problems likely in current systems and several common patterns of error correction that we found.

Nothing about what they found

Abstract Example #2 – Writing Style

- An example from UIST [1]
- We'll try to revise it, to find room for improvement

[1] Lee, J. C., Forlizzi, J., & Hudson, S. E. (2002). The kinetic typography engine: An extensible system for animating expressive text. *Proceedings of the ACM Symposium on User Interface Software and Technology -- UIST 2002*, pp. 81-90. New York: ACM.

Original

Kinetic typography – text that uses movement or other temporal change – has recently emerged as a new form of communication. As we hope to illustrate in this paper, kinetic typography can be seen as bringing some of the expressive powers of film – such as its ability to convey emotion, portray compelling characters, and visually direct attention – to the strong communicative powers of text. Although kinetic typography offers promise for expressive communication, it has not been widely exploited outside a few limited application areas (most notably in TV advertising). One of the reasons for this has been the lack of tools directly supporting it, and the accompanying difficulty in creating dynamic text. This paper presents a first step in remedying this situation – an extensible robust system for animating text in a wide variety of forms. By supporting an appropriate set of carefully factored abstractions, this engine provides a relatively small set of components that can be plugged together to create a wide range of different expressions. It provides new techniques for animating text used in traditional cartoon animation, and provides specific support for typographical manipulations.

Revision

Kinetic typography – text that moves or otherwise changes – is a new form of communication. As we illustrate, kinetic typography brings the expressive power of film – the ability to convey emotion, portray compelling characters, and direct attention – to the world of text. Although kinetic typography offers promise, it is not widely exploited outside areas such as TV advertising. Reasons include the lack of support tools and the difficulty in creating dynamic text. Our remedy is an extensible robust system for animating text. Through a set of abstractions, the engine provides a small set of pluggable components to create a range of expressions. It provides new techniques for animating text and supports typographical manipulations.

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Compare

Kinetic typography – text that uses movement or other temporal change … expressive powers of film – such as its ability to convey emotion, portray compelling characters, and visually direct attention – to the strong communicative powers of text. …

183 words

Kinetic typography – text that moves or otherwise changes – is a new form … typography offers promise, it is not widely exploited outside areas such as TV advertising. Reasons include the lack of …

112 words

1. Be concise

Original: *text that uses movement or other temporal change*
Revision: *text that moves or otherwise changes*

2. Avoid superfluous words or phrases

Original: *As we hope to illustrate in this paper…*
Revision: *As we illustrate…*

3. Use the active voice

Original: *it has not been widely exploited…*
Revision: *it is not widely exploited…*

Abstract Deconstructed (1)

Original	#	Revised
Kinetic typography – text that uses movement or other temporal change – has recently emerged as a new form of communication.	1	Kinetic typography – text that moves or otherwise changes – is a new form of communication.
As we hope to illustrate in this paper, kinetic typography can be seen as bringing some of the expressive powers of film – such as its ability to convey emotion, portray compelling characters, and visually direct attention – to the strong communicative powers of text.	2	As we illustrate, kinetic typography brings the expressive power of film – the ability to convey emotion, portray compelling characters, and direct attention – to the world of text.

Abstract Deconstructed (2)

Original	#	Revised
Although kinetic typography offers promise for expressive communication, it has not been widely exploited outside a few limited application areas (most notably in TV advertising).	3	Although kinetic typography offers promise, it is not widely exploited outside areas such as TV advertising
One of the reasons for this has been the lack of tools directly supporting it, and the accompanying difficulty in creating dynamic text.	4	Reasons include the lack of support tools and the difficulty in creating dynamic text.

Abstract Deconstructed (3)

This paper presents a first step in remedying this situation – an extensible robust system for animating text in a wide variety of forms.	5	Our remedy is an extensible robust system for animating text.
By supporting an appropriate set of carefully factored abstractions, this engine provides a relatively small set of components that can be plugged together to create a wide range of different expressions.	6	Through a set of abstractions, the engine provides a small set of pluggable components to create a range of expressions.

Abstract Deconstructed (4)

It provides new techniques for animating text used in traditional cartoon animation, and provides specific support for typographical manipulations.	7	It provides new techniques for animating text and supports typographical manipulations.

Tip #4

- "Get the little book"[1]

1. Strunk, Jr., W., and White, E. B. (2000). *The elements of style* (4th ed.). London: Allyn and Bacon.

Available online at...
http://www.bartleby.com/141/

Thank You