

#### Empirical Research Methods for Human-Computer Interaction

I. Scott MacKenzie<sup>1</sup> Janet R. Read<sup>2</sup> Matt Horton<sup>2</sup>



<sup>1</sup>York University Toronto, Canada



<sup>2</sup>U. Of Central Lancashire Preston, UK

Copyright is held by the author/owner(s). CHI2023, April 23-28, 2023, Hamburg, Germany. ACM 2023/04.



#### Presenter

**Scott MacKenzie**'s research is in HCI with an emphasis on human performance measurement and modeling, experimental methods and evaluation, interaction devices and techniques, alphanumeric entry, language modeling, and mobile computing. Scott is a member of the SIGCHI Academy. He has more than 200 HCI publications (including 50 from the SIGCHI conference and two HCI books) and has given numerous invited talks over the past 25 years. Since 1999, he has been Associate Professor of Electrical Engineering and Computer Science at York University, Canada.

Home page: <u>http://www.yorku.ca/mack/</u>

**Janet Read** and **Matt Horton** have previously delivered courses at CHI on Child Computer Interaction. For the last 15 years Janet has been teaching a course on research methods and Matt has been teaching an advanced level course in user studies in HCI.

Full details: <u>https://chici.org/about/</u>



#### Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



## What is...Research

(three dictionary definitions)

1. Careful or diligent search

- 2. Collecting information about a subject
- 3. Investigation or experimentation aimed at the discovery and interpretation of facts









#### Definition #4 (not in dictionary)

• Research → *a* word added to give weight to baseless assertions intended to deceive the public

T.



#### Example (Definition #4)

• "Independent research proves our Internet service is the fatter and most reliated proves out Internet service is the fatter

Rogers Communications, Inc.



#### What is... Empresedarch

- vs. theoretical research
- Properties of empirical research:
  - Based on observation or experience
  - Relying on observation or experience alone without due regard for system or theory (i.e., not blinded by pre-conceptions)
  - Capable of verification or disproval by observation or experiment
- In HCI...
  - "observation or experience" is of humans interacting with computers (or technology of some sort)



#### Why do... Empirical Research

- We conduct empirical research to...
  - Answer (and raise!) questions about new or existing user interface designs or interaction techniques
  - Find *cause-and-effect* relationships
  - Transform baseless opinions into informed opinions supported by evidence
  - Develop or test models that *describe* or *predict* behavior (of humans interacting with computers)



#### How do we do... Empirical Research

- Through a program of inquiry conforming to the *scientific method*
- The scientific method involves...
  - The recognition and formulation of a problem
  - The formulation and testing of hypotheses
  - The collection of data through observation and experiment
- In HCI...
  - The methodology is often a *user study* (an experiment with human participants)



## Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



#### **Group Participation**

- At this point in the course, attendees are divided into groups of two to participate in a real user study
- A two-page handout is distributed to each group (see next slide)
- Read the instructions on the first page and discuss the procedure with your partner
- The instructors will provide additional information



#### Handout (2 pages)

	Instru	ction	s and	App	aratus				Log Sheet		
Study and memorize the planes below. Enter it by tapping with a non-making stylus on the performed many. Proceed as quickly as possible while trying nor to make mirrature. Don't					Participan Ishid	r 54	n: Male Fe	nale Apr			
ape to up SPACE between words. Your partner will time you with a watch. Begin when				la English your first lauruses" Yes No							
en you tap the last	character (the '	1.11	dog?)	Equ	t fire times	sing Method A, then	Houn of compute	er une per der:			
time using Met	hod B. Then re	ritch re	148.91	th your	partne.		Do you regulatly	use a mobile phone?	Yes	204	
or partner should	d do Method 1	Hint,	Metho	d.Ase	cend.		Do you send text	managas on a mobile;	phone? Yes	200	
							H'ye", how man	ty messages per day.			
		Me	thod	'A'			1000	dial disc		Mathead	E' Decisión
		_	_				Trial	Time		Triel	Time
	9 7	U	м	¢	K Z		1			1	
	49414	0	τ	н	-		2			2	
	1	-	-				3			3	
					W LA			_		4	
	8 8	-	-	-			4	-			
	B B B	1	25	D	space		4			3	
he quick	B B space J 7 brown f	1 V tox	N G Jun	D L ps c	space T T	e lazy dog	4 3 Participan Initial	±=====================================	n: Male Fe	5	
the quick	B S space J P brown 1	I V fox Me	G Jun thod	D L ps (	space T T T T T T	e lazy dog	4 9 articipaer laintid la English your d Noun of compute Do you send wer If "you", how man	a: Se er language" e uespe day: uesemblagbene" menugie on ambilie ty mesugie per day:	n Male Fe Yes Yes phone? Yes	3 No No No	_
te quick	B S space J P brown 1 brown 1	I V Cox Me	Jun fhod	D L P.8 0 -8"	pasa T Dreg ti	e lazy dog	4 3 Participan Initial Is English your di Bisma of comparis Do you send tear IP 'you", how can Martine	x Se ni lagrage" ni uni per dej uni a mobila ploner" menugio di a mobila ty masage per dej: (%) perend)	n: Male Fe Yes Yes phone" Yes	3 No No No	8' diss)
te guick	B S space J P brown 1	I V Cox	B G Jun thod	D L ps c 		e lazy dog P	4 3 Participan faithi la English your 6 Biswa foregon De you septian De you septian De you septian De you septian De you septian De you septian Trai	iz Se cr: Language" ware molt-lapbone" meauges as mobile; y meauges per day: (%) become Time	n Male Fe Yes Yes phone" Yes	5 No No No Teal	B' (fini) Tipe
te quick [ ]	8 8 space 3 P brown 1 0 W E A S D 2 X (	I I V Cox R R F V	G Jun hod T B	D L ps ( 1 H N	<b>R</b> ace <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	e lazy dog P	4 3 9 erticipen facilità 1a English your 6 Bisson of compute De your send sen 17 'yes', how man 7 tradi 1 1 trad 1	iz 5e or language" e ver pe day: use mehčeptone" mesage on a mehčey y mesage pe day: (%) (pecad) Time	n: Male Per Yes Yes phone? Yes	5 No No No No Teal	B'(Sec) Tipe
te guick	8 8 7 7 7 7 7 7 7 7 7 7 7 7 7 7	I V Cox R P V	2 3 6 1 1 0 1 8 10 10 10 10 10 10 10 10 10 10 10 10 10	D L ps (U H N	<b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b> <b>\$</b>	e lazy dog P	4 5 Participan Initial Is English your di Binan of company Do you engladay Do	ir: Se rr language <sup>1</sup> www.pw.doy: www.ex.mbhlog.bone <sup>2</sup> manage or.a.mobile yr manage per doy: <u>'W' Decend</u> <u>Time</u>	n Male Fer Yes Yes phone" Yes	5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	B'(Shec) Tipe
te guick	8 8 9400 3 7 5 brown 1 5 2 2 5 2 2 5 2 5	I I V Cox R P V	2 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4	D L P 7 U N N	T OVER TO	e lazy dog	4 3 Participan Initial Is English your di Bisma of compute Do you septi sent ID your spect sent ID your is how sant Tanal 1 2 3	x Se ex lagrage? ex use per dey: use s mith deplore? message ou s mobile, y manages per dey: Time Time	n Mas Fe Ye Ye phote" Ye	5 55 359 359 359 359 359 359 359 359 359	S' (fext) Tipe
te guick [ ] te guick	B B space 2 P brown 1 2 X 4 S D 2 X 4 5 brown 1	I V Cox R F V Cox	2 6 Jun 7 1 0 3 8 9400	D L Pa ( N Pa (	page T T T T T T T T T T T T T	e lazy dog P ] e lazy dog	4 3 Participan Initial Is Inglish your 6 Biswa do compute De you seal ser If 'you', how and De you seal ser If 'you', how and Initial 1 2 3 4 4	iz 54 or language? was anoble phone? manager on a mobile y manager on a mobile y manager on a mobile Time Time	n Mais Fe Ye Ye phons" Ye	5 5 50 50 50 50 50 50 50 50 50 50 50 50	R'(Sec) Tipe

Full-size copies of the handout pages will be distributed during the course. The pages are also available on the course web site.



• Remember:

# The second person to do the task needs to do *Method B first*, followed by Method A



#### Do the Experiment

- The experiment is performed
- This takes about 25 minutes
- Assistants transcribe the tabulated data into a ready-made spreadsheet
- Results are presented in Session Two



## Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



#### Observations and Measurements

- Observations are gathered...
  - Manually (human observers)
  - Automatically (computers, software, cameras, sensors, etc.)
- A measurement is a recorded observation



#### Scales of Measurement<sup>1</sup>



T I



#### Scales of Measurement

- Nominal -
- Ordinal
- Interval
- Ratio

- (aka *categorical data*) arbitrary codes assigned to attributes; e.g.,
  - M = male, F = female
  - 1 = audio feedback, 2 = vibrotactile feedback
- Stats:
  - equivalence, greater/less than, mean, ratio
- Usually, it is the count that is important
  - "Are females or males more likely to..."
- Example:

Gender	Mobile Pl	hone Usage	Total	0/	
	Not Using	Using	Total	70	
Male	683	98	781	51.1%	
Female	644	102	746	48.9%	
Total	1327	200	1527	100	6
%	86.9%	13.1%	Γ	DAR VEL	

Note: The counts (grey) are ratio scale measurements



Nominal

Ordinal

Interval

Ratio

#### Scales of Measurement

- Associates a rank to an attribute
- The attribute is any characteristic of interest, for example
  - Users try three different GPS systems, then rank them: 1st, 2nd, 3rd choice
- Stats:
  - equivalence, greater/less than, mean, ratio
- Example:

What is your weekly time playing computer games? 1. 0 hr 2. 1 - 5 hr 3. 5 - 20 hr 4. 20 - 40 hr 5. More than 40 hr



#### Scales of Measurement

- Equal distances between adjacent values
  - No absolute zero (ratios not possible)
- Classic example: temperature (°F, °C)
- Stats:
  - equivalence, greater/less than, mean, ratio
- Example: Likert scale questionnaire responses

ndicate your level of agreement with the following statement:						
	Strongly disagre	y e			Strongly agree	
It is safe to talk on a mobile phone while driving.	1	2	3	4	5	

- Nominal
- Ordinal
- Interval
- Ratio



#### Scales of Measurement

- Nominal
- Ordinal
- Interval
- Ratio

- (aka *continuous data*) most sophisticated of the four scales of measurement
- Preferred scale of measurement
- Stats:
  - equivalence, greater/less than, mean, ratio
- Absolute zero, therefore many calculations possible
- Often, ratio data are counts; e.g.,
  - "time" the number of seconds to complete a task
  - "DEL presses" the number of times the delete key was pressed
- Example: (next slide)



Ratio Data Example in HCI<sup>1</sup>



<sup>1</sup> MacKenzie, I. S., & Isokoski, P. (2008). Fitts' throughput and the speed-accuracy tradeoff. *Proc CHI 2008*, pp. 1633-1636.

T. T



## Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



#### Allen Newell (1927-1992)

- ACM Turing Award (1975)
- With Stuart Card and Tom Moran, author of *The Psychology of Human-Computer Interaction* (1983)



"Science is method. Everything else is commentary."



#### **Research Methods**





#### **Observational Method**

- Example techniques:
  - Interviews, field investigations, contextual inquiries, case studies, field studies, focus groups, think aloud protocols, story telling, walkthroughs, cultural probes, etc.
- Focus on *qualitative* assessments (vs. quantitative)
- Relevance vs. precision
  - High in relevance (behaviours studied in a natural setting)
  - Low in precision (lacks control available in a laboratory)
- Goal: discover and explain reasons underlying human behaviour (*why* or *how*, as opposed to *what*, *where*, or *when*)



#### **Experimental Method**

- Controlled experiment conducted in lab setting
- In HCI, this is typically called a *user study*
- Focus on *quantitative* assessments (vs. qualitative)
- Relevance vs. precision
  - Low in relevance (artificial environment)
  - High in precision (extraneous behaviours easy to control)
- At least two variables:
  - Manipulated variable (aka independent variable)
  - *Response variable* (aka *dependent variable*)
- Cause-and-effect conclusions possible



#### **Correlational Method**

- Look for relationships between variables
- Observations made, data collected
  - Example: Are users' privacy settings while social networking related to their age, gender, level of education, employment status, income, shoe size, number of tattoos, etc.
- Non-experimental
  - Interviews, on-line surveys, questionnaires, etc.
- Balance between relevance and precision
- Predictions possible
- Cause-and-effect conclusions not possible



#### **Research Methods**

#### Observational



- Real-world setting
- No variables per se
- Broad, qualitative questions:
  - What's going on?
- High-level inquiry

#### Correlational



#### Experimental



- Controlled setting (lab)
- IVs, DVs, etc.
- Narrow, quantitative questions:
  - How fast? How accurate?
- Low-level inquiry



#### Relevance vs. Precision





### Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



#### Experiment Terminology (Part 1)

- Terms to know
  - Participant
  - Independent variable (test conditions)
  - Dependent variable (measured behaviors)
  - Control variable, random variable
  - Confounding variable
  - Within subjects vs. between subjects
  - Counterbalancing
  - Latin square

T m



#### Participant

- The people participating in an experiment are referred to as *participants* (the term *subjects* is also acceptable<sup>1</sup>)
- When referring specifically to the experiment, use *participants* 
  - "all participants exhibited a high error rate..."
- When discussing the problem generally or drawing conclusions, use other terms
  - "these results suggest that users are less likely to ... "
- Report the selection criteria and give relevant demographic information or related experience



#### How Many Participants

- Use the same number of participants as used in similar research<sup>1</sup>
- Too many participants...
  - Statistically significant results for differences of no *practical* significance
- Too few participants...
  - No statistically significant results when there really is an inherent difference between the test conditions



#### How Many Participants (Part 2)

- User researchers in industry use about five participants when testing a new system... Why?
- Useful for exploratory testing of a UI
  - Five participants will discover most of the problems<sup>1</sup>
  - Using more than five results in diminishing returns<sup>1</sup>
- Not practical for an evaluative study comparing two or more interaction techniques
- Not publishable as a research paper at CHI

<sup>1</sup> Nielsen et al. (1993). "A mathematical model of the finding of usability problems," *Proc. ACM INTERCHI'93*, pp. 206-213



#### Independent Variable

- *Independent variable* a circumstance that is manipulated through the design of the experiment
- It is "independent" because it is independent of participant behavior (i.e., there is nothing a participant can do to influence an independent variable)
- Examples
  - Interface, device, feedback mode, button layout, visual layout, gender, age, expertise, etc.
- The terms *independent variable* and *factor* are synonymous


#### **Test Conditions**

- The levels, values, or settings for an independent variable are the *test conditions*
- Provide a names for both the *independent variable* and its *levels* (*test conditions*)
- Use these names consistently throughout a research paper
- Examples

Independent Variable	Test Conditions (Levels)
Device	mouse, touchpad, pointing stick
Feedback mode	audio, tactile, none
Task	pointing, dragging
Visualization	2D, 3D, animated
Search interface	Google, Bing



#### **Dependent Variable**

- *Dependent variable* a measurable aspect of the interaction involving an independent variable
- Examples
  - Task completion time, speed, accuracy, error rate, throughput, target re-entries, task retries, presses of backspace, etc.
- Give a name to the dependent variable, separate from its units, for example...
  - "entry speed" in "words per minute"
  - "task completion time" in "seconds"
- Clearly define all dependent variables (research must be reproducible!)



#### **Control Variable**

- *Control variable* a circumstance (not under investigation) that is held constant
- Upside: helps internal validity (better chance of obtaining statistical significance)
- Downside: hinders external validity (results are less generalizable to other people and other situations)
- Typical examples
  - Lighting
  - Room
  - Room temperature
  - Participant position (e.g., sitting)
  - Device location (e.g., on a desk)



#### Random Variable

- *Random variable* a circumstance that is allowed to vary randomly
- Upside: aides external validity (results are more generalizable)
- Downside: hinders internal validity (more variability is introduced in the measures)
- Typical examples
  - Time since last meal
  - Coffee consumption prior to testing
  - Time of day for testing (e.g., morning, afternoon, evening)
  - Participants' field of study or work
  - Participants' socio-economic background



#### Tradeoff

#### (control variable vs. random variable)

• There is a trade-off which can be examined in terms of internal validity and external validity (see below)

Variable	Advantage	Disadvantage
Random	Improves external validity by using a variety of situations and people.	Compromises internal validity by introducing additional variability in the measured behaviours.
Control	Improves internal validity since variability due to a controlled circumstance is eliminated	Compromises external validity by limiting responses to specific situations and people.



- *Confounding variable* a circumstance that varies systematically with an independent variable
- Upside: none!
- Downside: results misleading, even wrong
- Example: a study investigates "camera distance" in an eye tracking task
  - Independent variable: *camera distance* with levels *near* and *far* 
    - Near setup: small camera mounted on eye glasses
    - Far setup: commercial eye tracker mounted below display
  - *Hardware* is a confounding variable
  - Are the differences observed due to camera distance or to the different hardware or software drivers?
  - No reliable conclusions are possible



## Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



#### Experiment Design

- *Experiment design* the process of deciding
  - What variables to use
  - What tasks and procedures to use
  - How many participants to use and how to solicit them
  - Etc.
- Let's continue with some terminology...



## Experiment Terminology (Part 2)

- Terms to know
  - Participant
  - Independent variable (test conditions)
  - Dependent variable (measured behaviors)
  - Control variable, random variable
  - Confounding variable
  - Within subjects vs. between subjects
  - Counterbalancing
  - Latin square



#### Within-subjects, Between-subjects

- Two ways to assign conditions to participants:
  - *Within-subjects* → each participant is tested on each condition (aka *repeated measures*)
  - Between-subjects → each participant is tested on one condition only
  - Examples:

#### Within-subjects

Participant	Test Condition				
1	А	В	С		
2	А	В	С		

#### **Between-subjects**

Participant	Test Condition
1	A
2	A
3	В
4	В
5	С
6	С



# Within-subjects

- Advantages
  - Fewer participants (easier to recruit, schedule, etc.)
  - Less "variation due to participants"
  - No need to balance groups (because there is only one group!)
- Disadvantage
  - Order effects (i.e., interference between conditions)

### **Between-subjects**

- Disadvantages
  - More participants (harder to recruit, schedule, etc.)
  - More "variation due to participants"
  - Need to balance groups (to ensure they are more or less the same)
- Advantage
  - No order effects (i.e., no interference between conditions)





## Within-subjects, Between-subjects (2)

- Sometimes...
  - A factor must be assigned within-subjects
    - Examples: block, session (if learning is the IV)
  - A factor must be assigned between-subjects
    - Examples: gender, handedness
  - There is a choice
    - In this case, the balance tips to within-subjects (see previous slide)
- With two factors, there are three possibilities:
  - both factors within-subjects
  - both factors between-subjects
  - one factor within-subjects + one factor between-subjects (this is a *mixed design*)



#### Counterbalancing

- Only applies to within-subjects designs:
  - Participants may benefit from the 1<sup>st</sup> condition and thereby perform better on the 2<sup>nd</sup> condition
  - This is a problem (results are misleading)
- To compensate, *counterbalancing* is used:
  - Participants are divided into *groups*, and a different testing order is used for each group
- The testing order is best governed by a *Latin Square* (next slide)
- *Group*, then, is a between-subjects factor
  - Was there an effect for group? Hopefully not!



## Latin Square

- The defining characteristic of a Latin Square is that each condition occurs only once in each row and column
- Examples:



Note: In a *balanced Latin Square* each condition both precedes and follows each other condition an equal number of times



#### Succinct Statement of Design

#### • "3 x 2 within-subjects design"

- An experiment with two factors, having *three levels* on the first, and *two levels* on the second
- There are *six test conditions* in total
- Both factors are repeated measures, meaning all participants were tested on all conditions
- A mixed design is also possible
  - The levels for one factor are administered to all participants (within subjects), while the levels for another factor are administered to separate groups of participants (between subjects)



## Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



### Answering Research Questions

- We want to know if the measured performance on a dependent variable (e.g., entry speed) is different between test conditions, so...
- We conduct a user study and measure the performance on each test condition with a group of participants
- For each test condition, we compute the mean score over the group of participants
- Then what?



## Answering Research Questions (2)

- 1. Is there a difference?
  - Some difference is likely
- 2. Is the difference large or small?
  - Statistics can't help (Is a 5% difference large or small?)
- 3. Is the difference of practical significance?
  - Statistics can't help (Is a 5% difference useful? People resist change!)
- 4. Is the difference real? (Is it statistically significant or is it due to chance?)
  - Statistics can help!
  - The statistical tool is the analysis of variance (ANOVA)



## Null Hypothesis

- Formally speaking, a research question is not a question. It is a statement called the *null hypothesis*.
- Example:

There is no difference in entry speed between Method A and Method B.

- Assumption of "no difference"
- Research usually seeks to reject the null hypothesis
- Please bear in mind, with experimental research...
  - We gather and test evidence
  - We do not prove things



### Analysis of Variance

- It is interesting that the test is called an analysis of *variance*, yet it is used to determine if there is a significant difference between the *means*.
- How is this?





"Significant" implies that in all likelihood the difference observed is due to the test conditions (Method A vs. Method B).



#### Method

"Not significant" implies that the difference observed is likely due to chance.



#### Example #1 - Details





#### ANOVA Table for Task Completion Time (s)





There was a significant effect of input method on entry speed ( $F_{1,9} = 9.796$ , p < .05).

- Notice in the parentheses
  - Uppercase for *F*
  - Lowercase for *p*
  - Italics for *F* and *p*
  - Space both sides of equal sign
  - Space after comma
  - Space on both sides of less-than sign
  - Degrees of freedom are subscript, plain, smaller font
  - Three (maybe four) significant figures for F statistic
  - No zero before the decimal point in the *p* statistic



#### Example #2 - Details



Example #2					
Participant	Met	hod			
Fanticipant	А	В			
1	2.4	6.9			
2	2.7	7.2			
3	3.4	2.6			
4	6.1	1.8			
5	6.4	7.8			
6	5.4	9.2			
7	7.9	4.4			
8	1.2	6.6			
9	9 3.0				
10	6.6	3.1			
Mean	4.5	5.5			
SD	2.23	2.45			



#### Example #2 – ANOVA

#### ANOVA Table for Task Completion Time (s)

	DF	Sum of Squares	Mean Square	F-Value	P-	-Value	Lambda	Pow er
Subject	9	37.372	4.152					
Method	1	4.324	4.324	.626	•	.4491	.626	.107
Method * Subject	9	62. <b>1</b> 40	6.904					

Probability of obtaining the observed data if the null hypothesis is true





• Helpful to mention both the independent variable and the dependent variable:

"The effect of *independent\_variable* on *dependent\_variable* was statistically significant (F-statistic)."

• Example on next slide



Figure 4. A participant performing the experimental task

#### RESULTS AND DISCUSSION

#### Throughput

Touch interaction yielded a higher throughput compared to the mouse. The overall mean throughput for touch interaction was 5.52 bps, which was 41.1% higher than the 3.83 bps observed for the mouse. The effect of input technique on throughput was statistically significant ( $F_{1,11} = 35.51$ , p < .0001). Although not as high as the throughput reported by Forlines et al. (2007) for touch input (discussed earlier), our throughput values were computed using a direct

The effect of <u>input technique</u> on <u>throughput</u> was statistically significant ( $F_{1,11} = 35.51$ , p < .0001).

> Independent variable: Input technique

Dependent variable: Throughput

Sasangohar, F., MacKenzie, I. S., & Scott, S. D. (2009). Evaluation of mouse and touch input for a tabletop display using Fitts' reciprocal tapping task. *Proc HFES 2009*, pp. 839-843.



#### Other Designs and Procedures

• 1 factor with 4 levels  $\rightarrow$ 



• With ost hoc tests  $\rightarrow$ 



• Two-factor design  $\rightarrow$ 



Īm



**ANOVA Demos** 



- *StatView* (now sold as JMP, <u>http://jmp.com</u>)
  - Commercial statistics package
  - Input data shown on the right
- GoStats
  - Java program and its API are freely available via the URL on the last slide
  - Input file (same data as on the right): anova-ex1.txt

Example 1 data					
Method A	Method B				
5.3	5.7				
3.6	4.8				
5.2	5.1				
3.5	4.5				
4.6	6.0				
4.1	6.8				
4.0	6.0				
4.8	4.6				
5.2	5.5				
5.1	5.6				



## ANOVA Demos (2)

ANOVA Table for Task Completion Time (s)							
	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Outlinet			For the second		1 1 4 140		
Subject	9	5.080	.564				
Method	1	4.232	4.232	9.796	.0121	9.796	.804
Method * Subject	9	3.888	.432				

ANOVA_table					GoSta
Effect	df	SS	MS	F	p
Participant	9	5.080	0.564		
F1	1	4.232	4.232	9.796	0.0121
F1_x_Par	9	3.888	0.432		
Data_file: anova-e	x1.txt				

**s**ê



# GoStats (1)

- Suite of free stats tools available via the URL on the last slide
- Includes tools for:
  - ANOVA
  - Post Hoc
  - Other statistical tests conducted in HCI research
- Also includes an API with example experiments and input files

🛓 GoStats			×
Welcome	to G	oStats	;
What would	you lik	e to do	?
ANOVA			
O Post Ho	c		
🔿 Chi Squ	are		
○ Friedma	an		
🔾 Kruskal	Wallis		
⊖ Wilcoxe	n Signed-I	Rank	
O Mann V	/hitney U		
🔿 Normali	ty test		
Go	Exit		



#### GoStats (2)

🛃 AnovaGUI

|--|

Arguments			
Data file			
Open Er	ntrySpeed.txt		View
Design			
Number	r of participants:	24	
Within-subjects factors	s	Between-subjects f	actors
F1 levels: 2		F5 levels:	2
F2 levels: 5		F6 levels:	
F3 levels:		F7 levels:	
F4 levels:			
Output options			
	OVA table		Effect sizes
Mai	n effect means		Verbose
🗹 Sun	nmary statements		
	View API in	n Browser	
	Analyse	Back	

#### ANOVA\_table\_for\_Entry speed (wpm)

ffect	df	SS	MS	F	р
Froup	1	73.737	73.737	0.618	0.4401
Participant(group)	22	2624.205	119.282		
ayout	1	29664.381	29664.381	533.785	0.0000
ayout_x_Group	1	80.007	80.007	1.440	0.2430
ayout_x_P(group)	22	1222.620	55.574		
rial	4	1298.277	324.569	78.825	0.0000
rial_x_Group	4	2.688	0.672	0.163	0.9564
rial_x_P(group)	88	362.348	4.118		
ayout_x_Trial	4	172.752	43.188	10.706	0.0000
ayout_x_Trial_x_Group	4	10.887	2.722	0.675	0.6113
ayout_x_Trial_x_P(group)	88	354.997	4.034		

Data file: EntrySpeed.txt

#### Summary statements:

The effect of group on entry speed was not statistically significant (F(1, 22) = 0.618, ns). The effect of layout on entry speed was statistically significant (F(1, 22) = 533.785, p < .0001). The layout\_x\_group interaction effect was not statistically significant (F(1, 22) = 1.440, p > .05). The effect of trial on entry speed was statistically significant (F(4, 88) = 78.825, p < .0001). The trial\_x\_group interaction effect was not statistically significant (F(4, 88) = 0.163, ns). The layout\_x\_trial interaction effect was statistically significant (F(4, 88) = 10.706, p < .0001).

Clear Save



## **Group Participation Results**

- Results will be presented in class for the experiment conducted before the break
- The following results are from another run of the same experiment



Entry Time (seconds)												
Darticipant	Initiala	Opti (A)					QWERTY (B)					
Panticipant	initials	1	2	3	4	5	1	2	3	4	5	Group
P1	al	92.0	94.0	84.0	68.0	93.0	23.0	19.0	17.0	17.0	15.0	1
P2	ig	65.0	63.0	55.0	49.0	41.0	18.0	15.0	14.0	14.0	13.0	1
P3	ma	54.0	44.0	38.0	38.0	32.0	19.0	17.0	17.0	15.0	19.0	1
P4	kw	65.0	71.0	57.0	61.0	51.0	23.0	19.0	19.0	19.0	18.0	1
P5	ja	40.0	33.0	31.0	29.0	28.0	19.0	17.0	19.0	17.0	16.0	1
P6	ej	66.0	65.0	47.0	52.0	46.0	20.0	17.0	17.0	15.0	14.0	1
P7	ml	50.0	49.0	40.0	36.0	31.0	22.0	18.0	16.0	16.0	14.0	1
P8	ра	68.0	47.0	46.0	35.0	34.0	17.0	13.0	12.0	16.0	12.0	1
P9	ul	86.0	83.0	56.0	46.0	45.0	29.0	19.0	18.0	17.0	15.0	1
P10	em	72.0	67.0	51.0	45.0	49.0	18.0	15.0	13.0	12.0	14.0	1
P11	pl	49.0	48.0	53.0	39.0	39.0	19.0	18.0	17.0	15.0	18.0	1
P12	bc	39.0	43.0	34.0	33.0	32.0	14.0	12.0	13.0	12.0	12.0	1
P13	as	54.0	44.0	41.0	38.0	41.0	17.0	14.0	12.0	13.0	13.0	2
P14	jj	75.0	65.0	55.0	71.0	53.0	21.0	17.0	17.0	19.0	16.0	2
P15	al	83.0	80.0	52.0	67.0	63.0	23.0	22.0	22.0	19.0	18.0	2
P16	sk	60.0	52.0	43.0	39.0	36.0	17.0	19.0	16.0	15.0	15.0	2
P17	jo	84.0	66.0	57.0	40.0	54.0	15.0	13.0	13.0	13.0	12.0	2
P18	hk	74.0	57.0	49.0	45.0	39.0	21.0	20.0	17.0	17.0	16.0	2
P19	mb	58.0	50.0	68.0	51.0	46.0	24.0	18.0	18.0	14.0	14.0	2
P20	jk	64.0	47.0	42.0	41.0	42.0	14.0	14.0	13.0	13.0	12.0	2
P21	ct	60.0	50.0	40.0	39.0	33.0	14.0	12.0	12.0	12.0	11.0	2
P22	hha	62.0	46.0	45.0	40.0	45.0	23.0	18.0	18.0	17.0	16.0	2
P23	SS	37.0	37.0	31.0	31.0	23.0	18.0	14.0	12.0	11.0	11.0	2
P24	ma	49.0	45.0	52.0	43.0	33.0	16.0	13.0	13.0	12.0	12.0	2



$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Entry Speed (wpm)												
Pailocpant initials 1 2 3 4 5 1 2 3 4 5 Group   P1 al 5.61 5.49 6.14 7.59 5.55 22.43 27.16 30.35 30.40 1   P2 ig 7.94 8.19 9.38 10.53 12.59 28.67 34.40 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 1 1   P4 kw 7.94 7.27 9.05 8.46 10.12 22.43 27.16 30.35 34.40 28.67 1   P6 ej 7.84 10.98 9.92 11.22 25.80 30.35 30.43 36.86 1 1   P6 ej 7.59 10.98 11.22 14.74 15.18 30.35 39.69 43.00 32.25 43.00 1   P9 ul 6.00 6.22 9.21 11.22 <td< td=""><td>Participant</td><td>Initiale</td><td colspan="5">Opti (A)</td><td colspan="5">QWERTY (B)</td><td></td></td<>	Participant	Initiale	Opti (A)					QWERTY (B)					
P1 al 5.61 5.49 6.14 7.59 5.55 22.43 27.16 30.35 30.35 34.40 1   P2 ig 7.94 8.19 9.38 10.53 12.59 28.67 34.40 36.86 36.86 39.69 1   P3 ma 9.56 11.73 13.58 13.58 16.13 27.16 30.35 34.40 27.16 1   P4 kw 7.94 7.27 9.05 8.46 10.12 22.43 27.16 30.35 34.40 28.67 1   P5 ja 12.90 15.64 16.65 17.79 18.43 27.16 30.35 34.40 36.86 1   P6 ej 7.82 7.94 10.98 19.22 11.22 25.80 30.35 34.40 36.86 1   P7 ml 10.32 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67	r anticipant initia	muais	1	2	3	4	5	1	2	3	4	5	Group
P2 ig 7.94 8.19 9.38 10.53 12.59 28.67 34.40 36.86 36.86 39.69 1   P3 ma 9.56 11.73 13.58 13.58 16.13 27.16 30.35 30.35 34.40 27.16 1   P4 kw 7.94 7.27 9.05 8.46 10.12 22.43 27.16 27.16 27.16 28.67 1   P5 ja 12.90 15.64 16.65 17.79 18.43 27.16 30.35 30.35 34.40 36.86 1   P6 ej 7.82 7.94 10.98 9.92 11.22 58.67 32.25 32.25 36.86 1   P7 ml 10.32 10.53 12.90 14.33 16.65 23.45 28.67 32.25 32.25 43.00 1   P10 em 7.17 7.70 10.12 11.47 17.79 27.16 28.67 30.35 <td>P1</td> <td>al</td> <td>5.61</td> <td>5.49</td> <td>6.14</td> <td>7.59</td> <td>5.55</td> <td>22.43</td> <td>27.16</td> <td>30.35</td> <td>30.35</td> <td>34.40</td> <td>1</td>	P1	al	5.61	5.49	6.14	7.59	5.55	22.43	27.16	30.35	30.35	34.40	1
P3 ma 9.56 11.73 13.58 13.58 16.13 27.16 30.35 34.40 27.16 1   P4 kw 7.94 7.27 9.05 8.46 10.12 22.43 27.16 27.16 27.16 27.16 27.16 28.67 1   P5 ja 12.90 15.64 16.65 17.79 18.43 27.16 30.35 32.40 36.66 1   P6 ej 7.82 7.94 10.98 9.92 11.22 25.80 30.35 30.40 36.66 1   P7 ml 0.32 10.53 12.90 14.33 16.65 23.45 28.67 30.35 34.40 36.66 1   P9 ul 6.00 6.22 9.21 11.22 14.47 17.79 27.16 28.67 30.35 34.40 36.66 1   P10 em 7.17 7.70 10.12 11.47 10.53 36.86 43.00	P2	ig	7.94	8.19	9.38	10.53	12.59	28.67	34.40	36.86	36.86	39.69	1
P4 kw 7.94 7.27 9.05 8.46 10.12 22.43 27.16 27.16 27.16 28.67 1   P5 ja 12.90 15.64 16.65 17.79 18.43 27.16 30.35 27.16 30.35 32.25 1   P6 ej 7.82 7.94 10.98 9.92 11.22 25.80 30.35 30.40 36.66 1   P7 ml 10.32 10.53 12.90 14.33 16.65 23.45 28.67 30.25 32.25 43.00 1   P8 pa 7.59 10.98 11.22 11.47 17.79 27.16 28.67 30.35 34.40 36.66 1   P10 em 7.17 7.70 10.12 11.47 10.53 28.67 34.40 39.69 43.00 30.65 34.40 28.67 1   P11 pl 10.53 10.75 9.74 13.23 12.59 30.35<	P3	ma	9.56	11.73	13.58	13.58	16.13	27.16	30.35	30.35	34.40	27.16	1
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	P4	kw	7.94	7.27	9.05	8.46	10.12	22.43	27.16	27.16	27.16	28.67	1
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	P5	ja	12.90	15.64	16.65	17.79	18.43	27.16	30.35	27.16	30.35	32.25	1
P7 ml 10.32 10.53 12.90 14.33 16.65 23.45 28.67 32.25 32.25 36.86 1   P8 pa 7.59 10.98 11.22 14.74 15.18 30.35 39.69 43.00 32.25 43.00 1   P9 ul 6.00 6.22 9.21 11.22 11.47 17.79 27.16 28.67 30.35 34.40 1   P10 em 7.17 7.70 10.12 11.47 10.53 28.67 34.40 39.69 43.00 36.86 1   P11 pl 10.53 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67 1   P12 bc 13.23 12.09 13.58 12.59 30.35 36.86 43.00 39.69 39.69 22 2 2 1 2 2 2 2 2 2 2 2 2	P6	ej	7.82	7.94	10.98	9.92	11.22	25.80	30.35	30.35	34.40	36.86	1
P8 pa 7.59 10.98 11.22 14.74 15.18 30.35 39.69 43.00 32.25 43.00 1   P9 ul 6.00 6.22 9.21 11.22 11.47 17.79 27.16 28.67 30.35 34.40 1   P10 em 7.17 7.70 10.12 11.47 10.53 28.67 34.40 39.69 43.00 36.86 1   P11 pl 10.53 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67 1   P12 bc 13.23 12.00 15.18 15.64 16.13 36.86 43.00 39.69 43.00 43.00 1   P13 as 9.56 11.73 12.59 13.58 12.59 30.35 36.86 43.00 39.69 39.69 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35	P7	ml	10.32	10.53	12.90	14.33	16.65	23.45	28.67	32.25	32.25	36.86	1
P9 ul 6.00 6.22 9.21 11.22 11.47 17.79 27.16 28.67 30.35 34.40 1   P10 em 7.17 7.70 10.12 11.47 10.53 28.67 34.40 39.69 43.00 36.86 1   P11 pl 10.53 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67 1   P12 bc 13.23 12.00 15.18 15.64 16.13 36.86 43.00 39.69 43.00 43.00 1   P13 as 9.56 11.73 12.59 13.58 12.59 30.35 30.35 30.35 27.16 32.25 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 <td>P8</td> <td>ра</td> <td>7.59</td> <td>10.98</td> <td>11.22</td> <td>14.74</td> <td>15.18</td> <td>30.35</td> <td>39.69</td> <td>43.00</td> <td>32.25</td> <td>43.00</td> <td>1</td>	P8	ра	7.59	10.98	11.22	14.74	15.18	30.35	39.69	43.00	32.25	43.00	1
P10 em 7.17 7.70 10.12 11.47 10.53 28.67 34.40 39.69 43.00 36.86 1   P11 pl 10.53 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67 1   P12 bc 13.23 12.00 15.18 15.64 16.13 36.86 43.00 39.69 43.00 43.00 1   P13 as 9.56 11.73 12.59 13.58 12.59 30.35 36.86 43.00 39.69 39.69 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 23.45 27.16 32.25 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 30.55<	P9	ul	6.00	6.22	9.21	11.22	11.47	17.79	27.16	28.67	30.35	34.40	1
P11 pl 10.53 10.75 9.74 13.23 13.23 27.16 28.67 30.35 34.40 28.67 1   P12 bc 13.23 12.00 15.18 15.64 16.13 36.86 43.00 39.69 43.00 43.00 1   P13 as 9.56 11.73 12.59 13.58 12.59 30.35 36.86 43.00 39.69 39.69 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P16 sk 8.60 9.92 7.70 8.19 22.43 23.45 23.45 27.16 28.67 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 </td <td>P10</td> <td>em</td> <td>7.17</td> <td>7.70</td> <td>10.12</td> <td>11.47</td> <td>10.53</td> <td>28.67</td> <td>34.40</td> <td>39.69</td> <td>43.00</td> <td>36.86</td> <td>1</td>	P10	em	7.17	7.70	10.12	11.47	10.53	28.67	34.40	39.69	43.00	36.86	1
P12 bc 13.23 12.00 15.18 15.64 16.13 36.86 43.00 39.69 43.00 43.00 1   P13 as 9.56 11.73 12.59 13.58 12.59 30.35 36.86 43.00 39.69 39.69 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 23.45 27.16 28.67 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 43.00 2   P17 jo 6.14 7.82 9.05 10.53 11.47 13.23 24.57 25.80	P11	pl	10.53	10.75	9.74	13.23	13.23	27.16	28.67	30.35	34.40	28.67	1
P13 as 9.56 11.73 12.59 13.58 12.59 30.35 36.86 43.00 39.69 39.69 2   P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 23.45 27.16 38.67 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 43.00 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 43.00 2   P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 28.67 36.86 36.86	P12	bc	13.23	12.00	15.18	15.64	16.13	36.86	43.00	39.69	43.00	43.00	1
P14 jj 6.88 7.94 9.38 7.27 9.74 24.57 30.35 30.35 27.16 32.25 2   P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 23.45 27.16 28.67 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 43.00 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 43.00 2   P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 25.80 30.35 30.35 32.25 2   P19 mb 8.90 10.32 12.99 12.59 12.29 36.86 36.86 39.69 43.00	P13	as	9.56	11.73	12.59	13.58	12.59	30.35	36.86	43.00	39.69	39.69	2
P15 al 6.22 6.45 9.92 7.70 8.19 22.43 23.45 23.45 27.16 28.67 2   P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 39.69 43.00 2   P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 25.80 30.35 30.35 32.25 2   P19 mb 8.90 10.32 7.59 10.12 11.22 21.50 28.67 28.67 36.86 36.86 2   P20 jk 8.06 10.98 12.29 12.29 36.86 36.86 39.69 43.00 2   P21 ct 8.60 10.32 12.90 11.47 22.43 28.67 30.35 32.25 2	P14	jj	6.88	7.94	9.38	7.27	9.74	24.57	30.35	30.35	27.16	32.25	2
P16 sk 8.60 9.92 12.00 13.23 14.33 30.35 27.16 32.25 34.40 34.40 2   P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 39.69 43.00 2   P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 25.80 30.35 30.35 32.25 2   P19 mb 8.90 10.32 7.59 10.12 11.22 21.50 28.67 28.67 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 36.86 30.00 43.00 46.91 2   P20 jk 8.60 10.32 12.90 13.23 15.64 36.86 43.00 43.00 46.91 2   P21 ct 8.60 10.32 12.90 11.47	P15	al	6.22	6.45	9.92	7.70	8.19	22.43	23.45	23.45	27.16	28.67	2
P17 jo 6.14 7.82 9.05 12.90 9.56 34.40 39.69 39.69 39.69 43.00 2   P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 25.80 30.35 30.35 32.25 2   P19 mb 8.90 10.32 7.59 10.12 11.22 21.50 28.67 28.67 36.86 36.86 2   P20 jk 8.06 10.98 12.29 12.29 36.86 36.86 39.69 39.69 43.00 2   P20 jk 8.06 10.98 12.29 12.29 36.86 36.86 39.69 39.69 43.00 2   P21 ct 8.60 10.32 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 36.86 43.00 4	P16	sk	8.60	9.92	12.00	13.23	14.33	30.35	27.16	32.25	34.40	34.40	2
P18 hk 6.97 9.05 10.53 11.47 13.23 24.57 25.80 30.35 30.35 32.25 2   P19 mb 8.90 10.32 7.59 10.12 11.22 21.50 28.67 28.67 36.86 36.86 2   P20 jk 8.06 10.98 12.29 12.59 12.29 36.86 36.86 39.69 43.00 2   P21 ct 8.60 10.32 12.90 13.23 15.64 36.86 43.00 43.00 46.91 2   P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P23 ss 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 <	P17	jo	6.14	7.82	9.05	12.90	9.56	34.40	39.69	39.69	39.69	43.00	2
P19 mb 8.90 10.32 7.59 10.12 11.22 21.50 28.67 28.67 36.86 36.86 2   P20 jk 8.06 10.98 12.29 12.59 12.29 36.86 36.86 39.69 39.69 43.00 2   P21 ct 8.60 10.32 12.90 13.23 15.64 36.86 43.00 43.00 43.00 46.91 2   P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P23 ss 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69	P18	hk	6.97	9.05	10.53	11.47	13.23	24.57	25.80	30.35	30.35	32.25	2
P20 jk 8.06 10.98 12.29 12.59 12.29 36.86 36.86 39.69 39.69 43.00 2   P21 ct 8.60 10.32 12.90 13.23 15.64 36.86 43.00 43.00 46.91 2   P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P23 ss 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   Mean 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29	P19	mb	8.90	10.32	7.59	10.12	11.22	21.50	28.67	28.67	36.86	36.86	2
P21 ct 8.60 10.32 12.90 13.23 15.64 36.86 43.00 43.00 43.00 46.91 2   P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P23 ss 13.95 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 2   P23 ss 13.95 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 20   P24 ma 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29 36.71   SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82	P20	jk	8.06	10.98	12.29	12.59	12.29	36.86	36.86	39.69	39.69	43.00	2
P22 hha 8.32 11.22 11.47 12.90 11.47 22.43 28.67 28.67 30.35 32.25 2   P23 ss 13.95 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   Mean 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29 36.71   SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82 5.91   Min 5.49 Max 22.43 46.91 46.91 46.91	P21	ct	8.60	10.32	12.90	13.23	15.64	36.86	43.00	43.00	43.00	46.91	2
P23 ss 13.95 13.95 16.65 16.65 22.43 28.67 36.86 43.00 46.91 46.91 2   P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   Mean 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29 36.71   SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82 5.91   Min 5.49 Max 22.43 4.01 5.49 5.74 6.15 5.82 5.91	P22	hha	8.32	11.22	11.47	12.90	11.47	22.43	28.67	28.67	30.35	32.25	2
P24 ma 10.53 11.47 9.92 12.00 15.64 32.25 39.69 39.69 43.00 43.00 2   Mean 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29 36.71   SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82 5.91   Min 5.49 Min 5.49 Max 22.43  Min 17.79	P23	SS	13.95	13.95	16.65	16.65	22.43	28.67	36.86	43.00	46.91	46.91	2
Mean 8.72 9.82 11.18 12.17 13.06 27.63 32.43 34.07 35.29 36.71   SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82 5.91   Min 5.49 Max 22.43 Max 46.91	P24	ma	10.53	11.47	9.92	12.00	15.64	32.25	39.69	39.69	43.00	43.00	2
SD 2.27 2.47 2.60 2.77 3.61 5.24 5.74 6.15 5.82 5.91   Min 5.49 Min 5.49 Min 17.79   Max 22.43 Max 46.91		Mean	8.72	9.82	11.18	12.17	13.06	27.63	32.43	34.07	35.29	36.71	
Min 5.49 Min 17.79   Max 22.43 Max 46.91		SD	2.27	2.47	2.60	2.77	3.61	5.24	5.74	6.15	5.82	5.91	r
Max 22.43 Max 46.91						Min	5.49				Min	17.79	
						Max	22.43				Max	46.91	




Note: A *bar chart* is appropriate here because the data along the x-axis are categorical (i.e., nominal scale).





Note: A *line chart* is appropriate here because the data along the x-axis are continuous (i.e., ratio scale).

T m



#### Created using GoStats

Effect	df	SS	MS	F	р
Group	1	73.737	73.737	0.618	0.4401
Participant(group)	22	2624.205	119.282		
Layout	1	29664.381	29664.381	533.785	0.0000
Layout_x_Group	1	80.007	80.007	1.440	0.2430
Layout_x_P(group)	22	1222.620	55.574		
Trial	4	1298.277	324.569	78.825	0.0000
Trial_x_Group	4	2.688	0.672	0.163	0.9564
Trial_x_P(group)	88	362.348	4.118		
Layout_x_Trial	4	172.752	43.188	10.706	0.0000
Layout_x_Trial_x_Group	4	10.887	2.722	0.675	0.6113
Layout x Trial x P(group)	88	354.997	4.034		

- Layout effect is significant ( $F_{1,22} = 533.8, p < .0001$ )
- Trial effect is significant ( $F_{4,88} = 78.8, p < .0001$ )
- Layout by trial interaction effect is significant ( $F_{4,88} = 10.7, p < .0001$ )
- Group effect is not significant ( $F_{1,22} = 0.62$ , *ns*)



Participant	Initials	Sex	Age	English as 1st language	Hours of computer use per day?	Do you regularly use a mobile phone?	Do you send text messages on a mobile phone?	If yes, how many messages per day?
P1	al	Male	43	No	10.0	Yes	Yes	8.0
P2	ig		35		7.0	Yes	n	0.0
P3	ma	female		Yes	8.0	Yes	Yes	5.0
P4	kw	female	33	No	8.0	Yes	Yes	2.5
P5	ja	Male	31	No	10.0	Yes	Yes	20.0
P6	ej	Male	42	Yes	10.0	Yes	Yes	20.0
P7	ml	female	41	No	8.0	Yes	Yes	5.0
P8	ра	Male	39	No	12.0	Yes	Yes	1.0
P9	ul	Male	36	No	10.0	Yes	Yes	3.0
P10	em	Male	45	Yes	8.0	Yes	Yes	5.0
P11	pl	Male	31	No	8.0	Yes	Yes	4.0
P12	bc	female	40	Yes	10.0	Yes	Yes	100.0
P13	as	Male	25	No	8.0	Yes	n	0.0
P14	jj	Male	45	No	6.0	Yes	Yes	5.0
P15	al	Male	51	No	10.0	Yes	Yes	5.0
P16	sk	Male	32	No	8.0	Yes	Yes	10.0
P17	jo	Male	31	No	10.0	Yes	Yes	5.0
P18	hk	female	33	No	10.0	Yes	Yes	20.0
P19	mb	Male	37	No	16.0	Yes	Yes	25.0
P20	jk	female	29	No	8.0	Yes	Yes	1.0
P21	ct	Male	33	Yes	10.0	Yes	Yes	8.0
P22	hha	female	36	No	9.0	n	n	0.0
P23	SS	Male	35	Yes	10.0	Yes	Yes	4.0
P24	ma	female	36	Yes	10.0	Yes	Yes	100.0
Respon	ses	23	23	23	24	24	24	24
Tally		15	839	7	224	23	21	357
Resu	lt	65.2%	36.5	30.4%	9.3	95.8%	87.5%	14.9
Units	5	Male	Years	English	Hours per day	Yes	Yes	Messages per day



# Topics

- The what, why, and how
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper



## **Research Paper**

• Research is not finished until the results are published!



<u>i a constante de la constante</u>



### Example Publication<sup>†</sup>



<sup>†</sup> Kumar, C., Hedeshy, R., MacKenzie, I. S., & Staab, S. (2020). TAGSwipe: Touch assisted gaze swipe for text entry. *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing System – CHI 2020*, pp. 190:1-190:12. New York, ACM. doi:10.1145/3313831.3376317.



## Title, Author(s), Affiliation(s)

TAGSwipe: Touch Assisted Gaze Swipe for Text Entry	CH 100 Paye	TAG	Swipe: Touch	Assisted Gaz	ze Swipe for T	ext Entry	
<text><text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text></text>	A set of the set of th	Chandan Kumar University of Koblenz-Landau Koblenz, Germany kumar@uni-koblenz.de			Ramin Hede University of Koble Koblenz, Gerr hedeshy@uni-ko	e <b>shy</b> nz-Landau nany blenz.de	
Title • Every word	tells.	Dep	I Scott MacKenzie York University ot of EE and Computer S Toronto, Canada mack@cse.yorku.ca	U Science Univ	<b>Steffen Staab</b> Universität Stuttgart, Stuttgart, Germany & University of Southampton, Southampton, UK s.r.staab@soton.ac.uk		
<figure><figure><text><text><text><text><text><text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text></text></text></text></text></text></figure></figure>	<text><text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text></text>	<section-header><text><text><text><section-header><page-footer></page-footer></section-header></text></text></text></section-header>	<text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text>	<text><text><text><text><text><text><text><text><text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text></text></text></text></text></text></text></text></text>	<list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item>	<list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item><list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item></list-item>	



## Abstract



#### Abstract

- Write last.
- Not an introduction!
- State what you did and what you found!
- Give the most salient finding(s).

#### ABSTRACT

The conventional dwell-based methods for text entry by gaze are typically slow and uncomfortable. A swipe-based method that maps gaze path into words offers an alternative. However, it requires the user to explicitly indicate the beginning and ending of a word, which is typically achieved by tedious gazeonly selection. This paper introduces TAGSwipe, a bi-modal method that combines the simplicity of touch with the speed of gaze for swiping through a word. The result is an efficient and comfortable dwell-free text entry method. In the lab study TAGSwipe achieved an average text entry rate of 15.46 wpm and significantly outperformed conventional swipe-based and dwell-based methods in efficacy and user satisfaction.

### ref = 1 ref = 1



## Keywords



#### **Author Keywords**

Eye typing; multimodal interaction; touch input; dwell-free typing; word-level text entry; swipe; eye tracking

#### **CCS Concepts**

•Human-centered computing → Text input; *Interaction devices; Accessibility technologies;* Interaction paradigms;

### Keywords

- Used for database indexing and searching.
- Use ACM classification scheme (for ACM publications).

		ore anon, epon amore, mult. Robolula, RI, USA				
11				CHI 2020, ADV 25-00, 2020, HOROLUL, HI, USA	Con July Page	CH 2020, April 25-20, 2020, HOROLUL, HL USA
	text entry rate in a formul experiment. Therefore, to confirm	physical modulities; however a formal study with more par-	Mondels Riscard Monto. 2017. Toward evendar gam	Computing Systems (CAY '76), ACM, New York,	(27) These Pfeidles 2018. Gase-based assistes technologies,	1911 Kovik Semparts, Ratharl Menary, Chandre Komar, and
	the pre-minence of TACEnipe, we conducted a small-scale	surpants is required to confirm the hypothesis. This is also	input Accuracy and precision of eye tracking and	1985-1996 MEL	In Smoot Technologies: Breakhroughs in Research and	Sarties Stade 2012 Impact of variable positioning of
	study with four participants (four sendors each) comparing	aligned with our future work, which is to investigate the feasi-	implications for design. In Proceedings of the ACM	http://ile.doi.org/10.1105/2010016_2050005	Practice. IGE Global. 44-66.	test prediction is pare-based test only. In Precondings
	DUPWER with fourbottany. As expected, the results indu-	peak of EVOpeche in refrictant ice onto pe bodie war	MOCHE COMPOSE OF BARAN FACOUR COMPANY	1181 Lhost MacKenzie and R William Instorett. 2003.	CNI Key Pleyfler, Jusia Alexander, and Ham Cellenera.	of the 1718 ACM Supportant of Ess Pracking Research
	card that he ansate it gate and start with an optimized	a motor impacted a no percent oper on a privace oper	New York (CAS 177), ACM, New York, 1110-1139, 1921	Phrase sets for evaluating wat eastly techniques. In	2013. Gape + truch vs. truch: What's the task-off when	A Appropriatizzan 195 AUM, New York, Achee
	many. TAGEning achieved 10% faster text entry part than	area, and a resta, and plan, pysick, or manner.	angereta, and angeret. Date worker, weaper	Executed Aburracci of the ACM INGONI Conference on	using pare to extend would to remote deplace? In	have the del second matching marries
	TomboCase. Average erior rate was 1 17th with EMD/wide.	Considering the practical applications, there are a wide variety	[7] M Masteo Fitchel, THE, Marquesposts do calon	Human Factors in Computing Fotoms (CHI '07). ALM,	Proceedings of the IPIP Conference on	
	and 2.64% with Exach-Gain. All four participants approci-	of user groups operating fourts-series tablets with the gate	International Administration of the second second	New 9108, 754-135	Human Computer Distraction (INTERNET '15)	[79] R. William Soukond? and L Scott Macketern. 2003.
	and the astomated word-level support in TWE8wipe compared	a lost entry mechanism in such even and back employed as	Parried Control Party 22, 1 (1996), 1-12	[79] Pairci Majameta. 2012. Communication and text-metry by	New City and annual Internet a line lines of the	and KNIC and a new section starting in
	to the manual effort required in Touch+Gase to select each	percention. For trading to hadron is continuench each in-	[1] John Panha Hamen, Anders Sciences Adamses,	gase. In Gase interaction and applications of the		Presentative of the SPOCHI Conference on Manual
	Constant.	for mobile devices. If provine tracking is provible, and users	2003. Commond without a click: Deall time insise he	Parally, Append a manufacture of the control	(7) Ant Pearley, range Alexandry, and Hall Generate.	Factors in Computing Scitions (CMF VII); ACM, New
	For sud-world diployment of TMGBwipe, it is found in have	can use the pass rwipe protony, and confirm it with a simple	means and max adjusticate. In Proceedings of		and tauch for our source and inh important for	York, 113-120.2021
	Trach-Gape as a fail-back option for character-level input	touch in the corner of the methile screen. Gate and touch	Namos-Compace Interaction-INTERICT Springer,	[30] Pitri Majarana, Ulla Kaija Ahria, and Greg Spakov.	Proceedings of the 2016 CBI Conference on Human	Mrsp., Cda., doi:
	when now wreat its his appear in the canonical for. Once	repairs are and conversion or visual many and apprendic many	Bofka, 121-128.	These is an a first of the second sec	Factors in Computing Streams (CHU 16): ACM, New	5414 Keith Tmka, John McCaw, Debra Yamington,
	the dictioners for future conductor structures. However, it	intraction can be attrifted	[9] Anhe Backnof and Marin Urbins. 2007. Garing with	Factory in Computing Sciaron (CBP 505) ACM, New	York, 2843-2836, 8601	Kalidoon P McCoy, and Christopher Pressugion. 2009.
	is notworthy that for other word-level dwell free methods.	653600000000000000000000000000000000000	pEXE: New concepts in spergping. In Proceedings of	York, 337-390.0011	10000-100-000-000-000-000-000000	uses another south was word production. The effects of
	such as EyeSwipe and Filteryodying the only fall-back option	ACKNOWLEDOMENTS	the 4th Tanponton on Applied Perception in Graphics	http://ike.doi.org/18.1140/1518781.0008758	[30] Ken Pleathy and Hans-Gellenen. 2016. Gare and teach	Company (73/CC230) 1, 3 (2009), 17.
	nor new women common to the Dwick method for character level install which would be a different interaction, and extended	we would the to math our concepter Rephart Menges (Uni-	147-147, p011	[21] Yagesh Kamar Moons, Habert Cecotti, K Wong-Lin,	supervision on tablets. In Proceedings of the 20th Annual Supervision on Unit American Software and Ecological	1411 Chei Tandar Phini Mananty Baila balanki and
	configure.	the intelementation phone. We would also like to these of	https://dx.doil.org/10.1015/071010.027018	and Girtysh Prasal. 2018. A novel multimodal	ATTENDED AND NEW YORK, NO., 113, 1011	Kath Stake, Fishi, 2015, New Tasher' Dash mut-
		the participants for their effort, time, and trodback during the	1110 July Kardman, 2015 Grande 19900 cardish (2015)	gare-controlled high virtual keyboard for doubled anes.	http://ite.dei.org/10.105/2584511.200424	longitudinal study of fast test entry by eye pare. In
	CONCLUSIONS AND FUTURE WORK	experiment.	the second	Max and Coherentees (1987) The IEEE New York	111 Onder Educat, Advantances and Early Mark, 2017	Proceedings of the 2008 Europeatum on Eur Tracking
	rectornance, knowing, and tangar source and the maper ob-		[11] PETTA ADDRESSOR and KEIN VEHAND, 2012, The potential of dwalfs first one-doning for first societies state.	3688-3685	Test must be motor-impained acousts. Conversal Access	Research & Applications (ETRA '06): ACM, New York,
	method. We argue that a maltimodal approach combining gase	111 Suprement Also and Condenk Lee, 2013 Game assigned	communication. In Proceedings of the ACM Supportant	1711 Richard Monroe, Chapter Komer, and Section Scott	in the Information Society 16, 1 (2017), 51-32.	19-24
	with teach makes the interaction more natural and potentially	Traine for anot choose in Proceedings of the I/M	on Eye Tracking Research and Applications (ETRA '12)	2020 Interview per exercise of the Industry band	1121 Also Paris and Lindon J Bull. 2006. For tracking in	[42] Marie H Urbina and Anke Huckauf. 2010. Alternatives
	faster. Hence, there is a need to investigate here best to com-	Symposium on Ever Interface Software and Robustage	ACM, New York, 241-244.	surraction: Introspecting and adapting interfaces. ACM	HCI and mubility strength. In Excerciptule of human	to angle character entry and dwell time selection on eye
	buse gave with truch for shore efficient heat entry. However,	(LEST '19), ACM, New York, 877-858, 0011	[12] Per-Ola Katarasson and Shamin Zhai. 2024. SHARK 2:	Bransactions on Computer Mamon Peeraction 26, 6,	compaint Attornations. Rid Global, 211-219.	For Frederic Records Antonio (FTFA 11)
	currently more an to opposize approaches or terma exper-	M70/274X-442-349/34-3345/3112343-354/943	a large vocabulary shorthand writing spokens for	Article 37 (Nov. 2019), 4b pages, DCC (	1331 Area Roman, 2013, Mantala ability to type, uniper-	Association for Computing Machinery, New York,
	wal carp	[2] Tanya René Beelders and Pieter J Ellignan, 2012.	pen-based computers. In Proceedings of the ACM	and the set with a the second	point with hand weakness in ALS. (Nov 2017)	318-322.0001
	In the surgery was been also in the fille stars a second second second as	Measuring the performance of gare and speech for text	Superior of Cor Sector Subsect and Echlerry	1214 Carlos H. Morimote and Araon Amir. 2010. Commit.	1141 David Kendy Keth Versney, and Dr Che Keinemann.	http://ika.doi.org/iki.tist/chabit.thaifa
	method that combines the simplicity and accuracy of tench	input, in Proceedings of the ACM Symposium on Fise	1171 Charles Knows Restored Million Restored Manager	Anticipations in Proceedings of the 2010 Englands on	2014. An evaluation of Dashey with a high performance	[43] Keith Verlagen and David J C MacKay. 2016 Speech
	with the speed of national ape moreosent for word-level text	New York, 377-343	Scott MacKenzie, and Series Study 2019	Exe-Ducking Research Applications (ETRA '19).	largeage model as a gate communication method, in	dasher: Fast writing using speech and gara. In
	entry. In TAOliwipe, the eyes look from the first through	and the second se	TrachCasePath: Multimodal interaction with teach and	Ameriation for Computing Machinery, New York, NY,	Proceedings of the Jood International Periods	Proceedings of the SPLACED Conference on Manual
	last letters of a word on the virtual keyboard, with manual	[1] Alexandri G. Laca, Konan Weile, and Healt Debts. 2007. Ecological of our pairs interaction methods for	gase puth for secure yet efficient PIN costs, its 2019	USA, 271-254, 8601	Yest Mb. (75	195.006
	processing on a source where we are a first the	security enhanced PIN errors in Proceedings of the 19th	International Conference on Makimodal Interaction	Public on the reliance of the		
	similared block and entry see that the popular marchaed	Assinglesian Conference on Computer Human	(ICM: '19) ACM, New York, 329–338. ECC.	[34] Carlos H. Morimons, Jose A. T. Leyva, and Amonio	[15] II. Saloe and S. Chiba, 1978. Dynamic programming international systems in the second systems of the systems of the systems of the system of the sys	[44] Rod Vologan. 2008. A File: faw comparison of eye-
	wat entry approach of Dwell, and the same such-based word-	Internation (OCOB VP) ACM, New York, 199-202.	and the second of the second s	Diar-Tafa. 2018. Connext switching over typing using	1955 Temperature or Acceptive Terral and Terral	trained. In Proceedings of the Vill committee of
	level approach of EyeSinipe. Participants fromd EMOSwipe	THE SHERE YOU ALL AND SK THEY LOOKE. THEY	[14] Chandia Karsar, Raphas Merges, and Series Sourt.	Residence Comparing Lagree, in Proceedings of the	Processing 36, 1 (Pohesara 1976), 43-49, 8001	conference on Multimodel Interfaces. ACM, New York,
	cuty to sue, achieving 14 wpen in the first session. TAGEwipe	[4] Antonio Diaz-Tafa and Carlos H. Morimote. 2015.	interaction (EEE WebBedie 21, 4 (Der 2006), 6, 13.	(COGAD) '241 ACM, New York, Article 6.9 pages.	http://ike.doi.org/10.100/1850-2558.1163015	241-248.
	was the performed choice of participants and stormed higher	Anylizy: Increasing Everal throughput in eye typing	DOE INFORT CHILL AND LODGED AT MICH. MICH. 10	DOI TETTE (Vide del Jorg/18, 1141/1396(34), 1396(34)	1911 Securi Securi Presed Paerus and Table Oraleshore.	1671 Alex Walted and Kat Full.co.(Eds.), 1993. Readings in
		with augmented keys, to Precondings of the ACM	1151 Manu Kashar, 2007 & SER DATERDAY'S DESIGN May	1151 Marker P. Mart. Share Williams. Jacob O Welthered.	2013. Eye K: An officiant double free over pare-based text	Speech Recognition: Morgan Kaufmann Publishow Inc.
	We showcased the potential of word-tool test pairs using eye	Systems (CRF '16), ACM, New York, 2333-3544, 2021	(300)	and Meredah Ringel Marris, 2017, Impriving	entry system. In Proceedings of the 17th Axis Phylic	San Prancisco, CA, USA.
	gate and trace spec, more 40. He appreciating or \$50,58 pc	http://dx.doi.org/14.1105/1818616.2018147	110 Man Former Andrew Rounds, Terry Warsard and	dwith-based gate typing with-dynamic, calcading dwell	Corporate or Computer Aluman Interaction, ACM,	[41] Jacob O Webbesck, Junes Robinstein, Machael W
	our experiments. The underheing action is to assist gam swipe	151 Bella Deners and Alberth Scheidt 2000 The	from Wiscopial, 2007. EvolVoist, practical extention and	times. In Proceedings of the ACM CM Conference on	Pere Fill, JLP-228	Sawyer, and Andrew T Dischowski. 2006. Longmannal
	via manual continuation, which can be performed by other	MAGIC touch: Combining MMOR posining with a	winction using gate and keyboard. In Proceedings of the	New York, 2458, 2459	[17] ROOK Neugopia, Raphael Mengos, Chandas Ramar, and Buillin Fault. 2017. Cont Tarking: International Interna-	evaluation of discrete consecutive gase genues for text
	means of physical movement or trigger devices. Foot based	touch sensitive mouse. In WIP Conference on	ACM MOCHU Conference on Manual Factors in	THE THE LOW LOW	interest study per Concretency interaction areas to	For Tending Research & Intelections (TER) (W)
	interaction course to a natural extension of Twillowipe. This	Human Computer Intervention Springer, Berlin,	Comparing Systems (CMP VP) ACM, New York,	[26] Daugo Pedrosa, Marta di Uraça Pinemiel, and Khan N. Tarana. 2013. Etheranderica: A cheeff first star former.	PUT Composition, George A. Papadopositos, Troi Kaffik,	ACM, New York, 11-18.
	since with TM Swine what prior the fact rating for some	411.425	-1	automate in Ferradad Alexandra of the ACM WOVEN	Fang Chen, Carlos Duarte, and Wai-Tat Pac (Eds.): ACM,	101 Dennis Their rad the On Kampung 2013 The
	experimental senspi for the teach function. The participant	[6] Anna Maria Feit, Shane Williams, Astaro Toledo, Ann	[17] Andrew Kusunshi, Wennin Peng, Agen Joshi, Carlos	Conference on Munice Factors in Computing Romany	New York, 121-124, and conduction and default	word-arotae herboard. Brimestates Leyboard
	addressed an average owicy rule of 14.6 septe with 2.5% among	Paradoo, Haroh Kutharin, Musin Kale, and	Providence, and pulping fields, 2016. Epictropic Decilities with entry units user ratio. In Preconduct	(CBF '77); ACM, New York, 303-306, DEE (	hig/hid/HCN: Mal/hop-profile10	Internations. Commun. ACM 35, 9 (2012), 90-101.
	This indicates the feasibility of using EAG/Swipe with other	Surger/www.subicidenees.com/products	of the ACM 3DOCH Conference on Busine Factors in	Map.OB.dol.sep10.104y176043.073548		
	Farmer 189	Face 12	From 100	Page 11	Fune 10	Face 12



## Introduction



• It's your story to tell!

## Method





## Method - Participants

#### **Participants**

<section-header><text><text><text><text><text><text>

Ciri (193) Paper

Every precision of the second of the second

Twelve participants (5 males and 7 females; aged 21 to 36, mean = 28.83, SD = 4.26) were recruited. All were university students. Vision was normal (uncorrected) for seven participants, while one wore glasses and four used contact lenses. Four participants had previously participated in studies with eye tracking, but these studies were not related to text entry. The other eight participants had never used an eye tracker. All participants were familiar with the QWERTY keyboard (mean = 6, SD = 1.12, on the Likert scale from 1 = not familiar to 7 = very familiar) and were proficient in English (mean = 6.08, SD = 0.9, from 1 = very bad to 7 = very good) according to self-reported measures. The participants were paid 25 euros for participating in the study. To motivate participants, we informed them that the participant with the best performance (measured by both speed and accuracy of all three methods together) would recei



### Participants

- State the number of participants and how they were selected.
- Give demographic information, such as age, gender, relevant experience.



## Method - Apparatus

#### Apparatus



Testing employed a laptop (3.70 GHz CPU, 16GB RAM) running Windows 7 connected to a 24" LCD monitor (1600  $\times$  900 pixels). Eye movements were tracked using a SMI REDn scientific eye tracker with tracking frequency of 60 Hz. The eye tracker was placed at the lower edge of the screen. See Figure 4. No chin rest was used. The eye tracker headbox as reported by the manufacturer is 50 cm  $\times$  30 cm (at 65 cm).



Figure 4: Experimental setup: A participant performing the experiment using TAGSwipe on a laptop computer equipped with an eye tracker and touch-screen mobile device.

#### Apparatus

- Describe the hardware and software.
- Use screen snaps or photos, if helpful.

phrase set [18]. The dwell-time for Dwell method was 600 ms, following Hansen et al. [8]. Selection of suggestion/letter was confirmed by filling the key area, no audio/tactile feedback was included.





### Method - Procedure

#### **Procedure**

tionnaire to accuracy,

questions v

for each pa





The study was conducted in a university lab with artificial illumination and no direct sunlight. Figure 4 shows the experimental setup. Each participant visited the lab on three days. To minimize learning or fatigue bias, only one input method was tested each day. Upon arrival, each participant was greeted and given an information letter as part of the experimental protocol. The participant was then given a pre-experiment questionnaire soliciting demographic information. Before testing, the eye tracker was calibrated.

For each method, participants first transcribed five practice phrases to explore and gain familiarity with the input method. The phrases were randomly sampled from the MacKenzie and Soukoreff phrase set [18] and shown above the keyboard. After transcribing a phrase, participants pressed the "Space" key to end the trial.

For formal testing, participants transcribed 25 phrases, five phrases in each of five sessions. They were allowed a short break between sessions. The instructions were to type fast and accurately, at a

#### After com **Procedure**

- Specify exactly what happened with each participant. the accurac
- scale. The • State the instructions given, and indicate if provement experiment demonstration or practice was used, etc.





## Method - Design

#### Design



<page-header><text><figure><figure><figure><section-header><section-header><section-header><section-header><section-header><text><text><text><text><text>

The experiment was a  $3 \times 5$  within-subjects design with the following independent variables and levels:

- Input Method (TAGSwipe, EyeSwipe, Dwell)
- Sessions (1, 2, 3, 4, 5)

The variable Session was included to capture the participants' improvement with practice.

The dependent variables were entry rate (wpm), error rate (%), and backspace usage (number of backspace events / number of characters in a phrase). Error rate was measured using the

#### MSV text Design

To

terb

a L dep

assi

The

- Give the independent variables (factors and levels) and dependent variables (measures and units).
- State the order of administering conditions, etc.
- Be thorough and clear! It's important that your research is reproducible.

input methous × 5 sessions × 5 utais/session).



#### **Results and Discussion**

- Use subsections as appropriate.
- If there were outliers or problems in the data collection, state this up-front.
- Organize results by the dependent measures, moving from overall means to finer details across conditions.
- Use statistical tests, charts, tables, 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.
- Discuss the results. State what is interesting.
- Explain the differences across conditions.
- Compare with results from other studies.
- 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).





## Conclusion



#### Conclusion

- Summarize what you did.
- Restate the important findings.
- State (restate) the contribution.
- Identify topics for future work.
- Do not develop any new ideas in the conclusion.

#### **CONCLUSIONS AND FUTURE WORK**

Performance, learning, and fatigue issues are the major obstacles in making eye tracking a widely accepted text entry method. We argue that a multimodal approach combining gaze with touch makes the interaction more natural and potentially faster. Hence, there is a need to investigate how best to combine gaze with touch for more efficient text entry. However, currently there are no optimized approaches or formal experiments to quantify multimodal gaze and touch efficiency for text entry.

In this paper, we presented TAGSwipe, a novel multimodal method that combines the simplicity and accuracy of touch with the speed of natural eye movement for word-level text entry. In TAGSwipe, the eyes look from the first through last letters of a word on the virtual keyboard, with manual press-release on a touch device demarking the word. The evaluation demonstrated that TAGSwipe is fast and achieves significantly higher text entry rate than the popular gaze-based



12120. April 25-38, 2020. Honolulu, M. USA	CHI 2019 Paper				
Computing Jonason (CAV '76), ACM, New York, 1952–1996, 2002 - 1996 - CH, doi, and Th. 1997 (2018) (2018)	[27] Thirs Philles. 2018. Gase-based anticities technologies. Benchmarks in Research Processor. Kill Chelod. 44:46.				
Koot MacKeneire and R William Jondonett. 2003. Patient on for trobusting KLL taky schlingen. In Standard Manuera of the ACM BioD2010 Conference on Familie Resourt in Computing Journes (CRU '00), ACM. New York, 375–355.	[78] Kon Plordler, Jusin Alvander, and Han Orderwei. 2013. Gan S visids vs. mod. v. mod. Which Y de Under of the Principal gans in created works in second displays. In Principal Computer Internation (OVERNIC '15): Neurosci. Respirator Detectoristic (OVERNIC '15): Neurosci. Respirator. 2015; 2015)				
Pairs Majazanta. 2012. Communication and text entry by pairs. In Case tolerancian and applications of epe mailtary. Advances in assistive reclandegies, ICE Child, 1777	Integration. And Angel 94, 1985 (1978) 3: 120-12468 (2,27) (29) Keen Plipatiley, Jacob Alexander, and Hans Geldeners				
Next Majarawas, Ulla Kaija Alerin, and Oleg Bpaless. 2008. Fast gaot spiray with an adjustable dwell time. In Proceedings of the ACM INFOCH Conference on Plansan Instant in Computing Systems (CIM' 509). ACM, New	and starts for put, some, and lisk intervention. In Proceedings of the 2019 CRI Conference on Ideau Acarons to Comparing Systems (CRI '56, ACM), N York, 28(2), 2018, 1001 Intervention, and and the 2019 CRI Intervention Intervention, and any IA, 1001 CRI INTERV				
Finds, 2019, 5000 (2011) - 5000 (2018/06), 5000/500 Finguesh Keenner Morens, Hishener Corcotts, K. Wong Lin, and Christoph Prysical 2016. A neurol meditimedial part-circumstitud histophytophytophytophytophytophytophytophy	[50] Kan Plorefin and Hane-Geltonen. 2016. Gure and intermediation on tables. In Proceedings of the 20th An Symposium on User Awardson Systems and Euclidea (IEET '915. ACM, Stein York, S65–511. DOI: 107101'08.aciorg/10.1105/008113.200014				
Ban, and Coherentia's (2007-716). BEEL New York, 6409-5005) Reghted Monges, Chardian Komur, and Section Staab. 2007. Represent over experiment of exp tracking based mercelines. Interspecting and adapting interdices. ACM Distanciation on Computer Maxime Description 18, 6,	[11] Onderj Polacek, Adam J Speeka, and Parel Marik. Test input for meteo-impained people. Colorestal Ac- in the Information Systems 16, 1 (2017) 14, 73.				
	[12] Alan Paole and Lindex J Ball. 2006. Fpr tracking in HCL and multility searanch. In <i>Decomposite of Inter-</i> computer Hornaction, EOI Okobal, 201–219.				
And a second sec	[15] Any Roman, 2013. Mentain ability to type, owipe point with hand weakness in ALS, (Nov 2017).				
Lindon H., Moreneous and Annon Annie. 2010. Comment fourishing for Plant Kay, Selections in First Energy Opplications. In: <i>Proceedings of the 2010 Economics on</i> <i>Control Science Research Opplementation (EPRA '19)</i> . Neuroistance Control (Epravision) (EPRA '19). Neuroistance Control (Epravision) (EPRA '19).	[14] Daniel Rough, Korin Womann, and Per Olis Krimer 2014. An evolution of Double with a high perform language model in a spare construction method. <i>Proceedings of the 2014 International Working Conference on Advanced Neural Development, SCM</i> , 1 York, 109–175.				
Tarkin H. Martinetti, Jone A. T. Leyvy, and Antonio Data Tuli. 2018. Contact with bing two sping using the static equivalent spin. The Proceedings of the fieldings on Communication by Gaze Internation COLMN '21, ACM. New York, Article 6: A range.	[15] B. Salow and S. Chiha, 1978. Dynamic programm algorithm optimization for spekers word recognition (2027) Distanciance on Accounting, Speech and Xipp Processing 26, 1 dynamy 1976a, 43–43, 1002. https://dx.ads.arg/th.10071309.1005.100401				
001 sterg code dei ang/m trat/sterion.tomore Marer I: Man, Shane William, Jacob O Wabbrock, and Mercolik Risoget Merco. 2011. September heiß-hand gaste typing with dynamic, cancading dwell merco he de code code code code code code of	[36] Saryan Saryan, Penirek Panerar, and Tahin Chakeshu. 2013. Eys K: An efficient dwell frair our pare hand onty system. In Proceedings of the 14th Acts Phile Conference on Computer Aluman Internation. ACM New York, 215–223.				
Barran Factors in Computing Systems (CBF 17): ACM, Son York, 2558–2550	[17] Korok Sengupta, Raphari Mengos, Chandan Kumar Stellers Studi. 2017. GareTheKey: Interactive keys interactive word methatisms. for usur based to a stress				
Enoug 2015. Filesy-edging: A dwell-line eye typing	PUT Composition, George A. Papadopoulos, Trvi Ka Pang Chen, Carlos Disarte, and Was-Tat Par (Eds.). J				



### Acknowledgment





## References



#### References

- Include a list of references, formatted as per the submission requirements of the conference or journal.
- Only include items cited in the body of the paper.

#### REFERENCES

- [1] Sunggeun Ahn and Geehyuk Lee. 2019. Gaze-assisted typing for smart glasses. In *Proceedings of the ACM Symposium on User Interface Software and Technology* (*UIST '19*). ACM, New York, 857–869. DOI: http://dx.doi.org/10.1145/3332165.3347883
- [2] Tanya René Beelders and Pieter J Blignaut. 2012. Measuring the performance of gaze and speech for text input. In *Proceedings of the ACM Symposium on Eye Tracking Research and Applications (ETRA '12)*. ACM, New York, 337–340.





## Summary

- The what, why, and how of empirical research
- Group participation in a real experiment
- Observations and measurements
- Research methods (and their properties)
- Experiment terminology
- Experiment design
- ANOVA statistics and experiment results
- Parts of a research paper

# Thank you

https://www.yorku.ca/mack/CHI2023/



## **Course Survey**

### https://fr.surveymonkey.com/r/6CK8CSD

Select course code (C12) and title at top



### For the complete story, see Scott's book:



http://www.yorku.ca/mack/HCIbook