

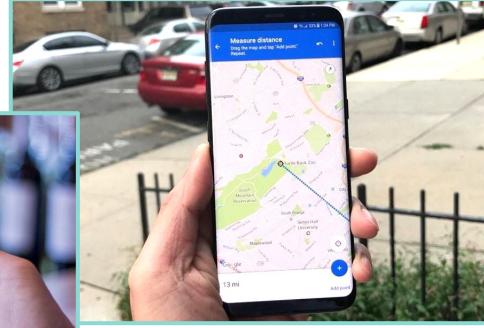
A Performance Comparison Between Hamburger Menu & Full Radial Menu for Mobile

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Welcome to the World of Mobile



We use our smartphones to order food, travel, find a mate, stay in touch, learn new skills, track our health, purchase goods, navigate the roads, and much more.



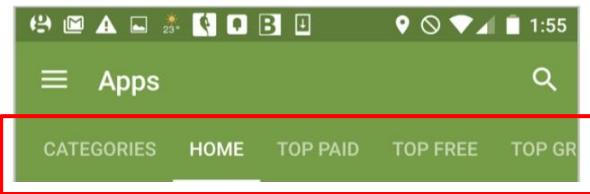
Welcome to the World of Mobile



The terms “mobile first” (Shields, 2011), “mobile friendly” or responsive” started to be adopted in order to make the usability of mobile websites and apps easier, **while maintaining optimal use of screen space as the highest priority.**

Transition into “Mobile-First”

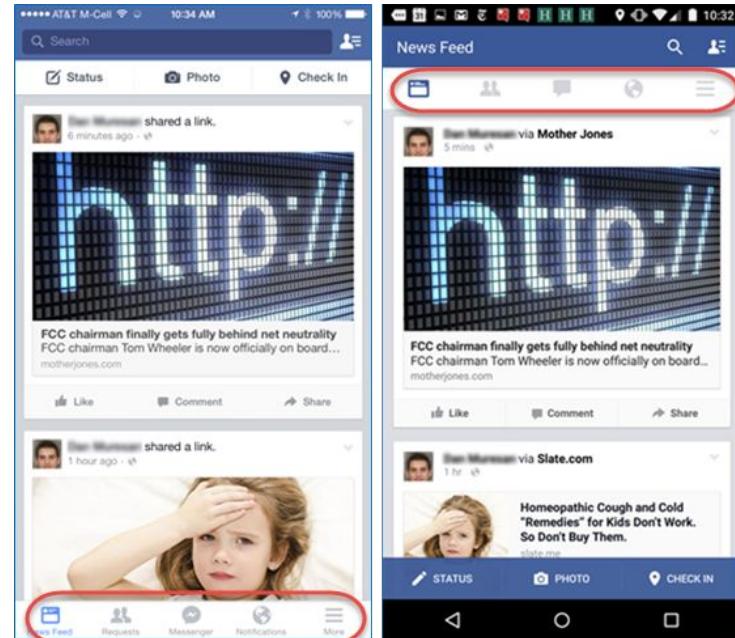
Top Navigation Bar



The Top Navigation Bar is most similar to **traditional desktop methods**. It has mobile advancements such as hide feature upon scroll down, and sticky method reintroduces upon scroll up.

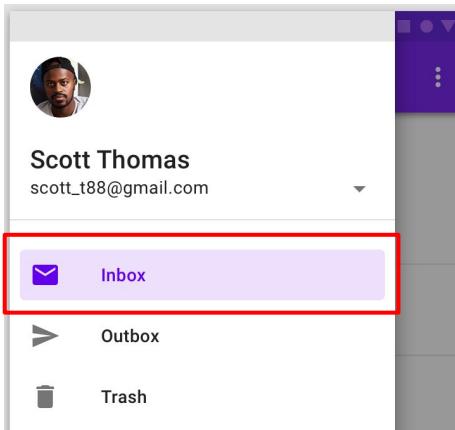
The Tab Bar is an **evolution** of the menu, displaying **text with icons**, but also icons only. It is **permanent** on the mobile phone, which may be a **disadvantage** as it takes up mobile screen space.

Tab Bar



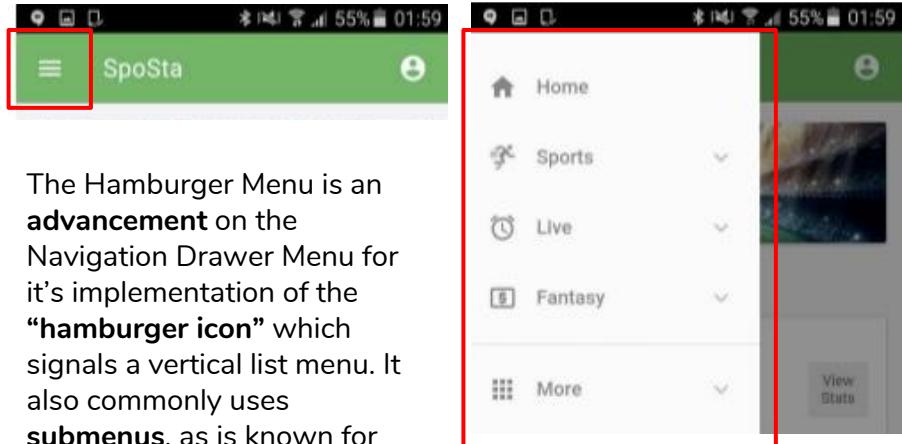
“Mobile First”

Navigation Drawer Menu



The Navigation Drawer was designed to use across devices sizes for a **consistent navigation experience**. Also **full touch-target icon and text** enhances mobile usability.

Hamburger Menu

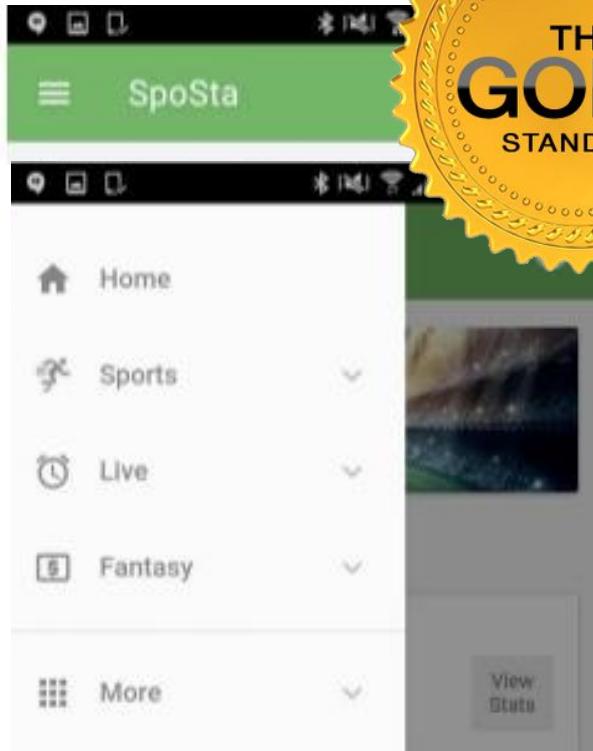


The Hamburger Menu is an **advancement** on the Navigation Drawer Menu for it's implementation of the **“hamburger icon”** which signals a vertical list menu. It also commonly uses **submenus**, as is known for allowing a **large number of menu items**.

The Gold Standard

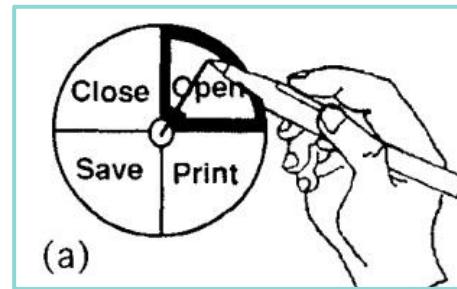
The hamburger menu appeared on **mobile first** and became popular in the design of websites as well.

Yet, the ubiquitous hamburger menu design is a prime example of wide adoption with **lack of empirical evidence**.

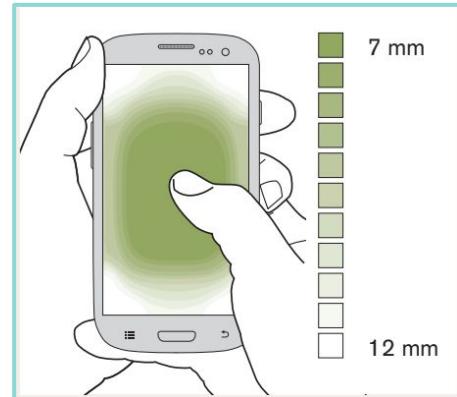


Alternative to Problem

- Marking menus are radial or pie menus.
(Kurtenback et al., 1994)
- According to study by Hoober (2015) revealed most users prefer to touch and view the **center of the screen**, whereas the hamburger menu is on the side of the screen.



[1]



[2]

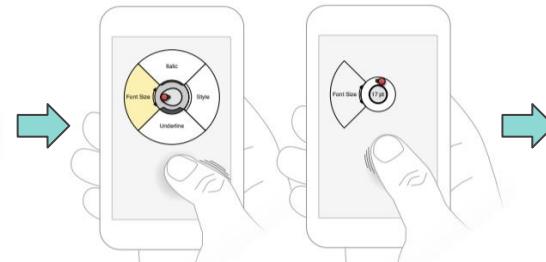


Radial Menus

Wavelet Menu
(Francone et al., 2009)



Swiss Army Menu (SAM)
(Bonnet et al., 2011)



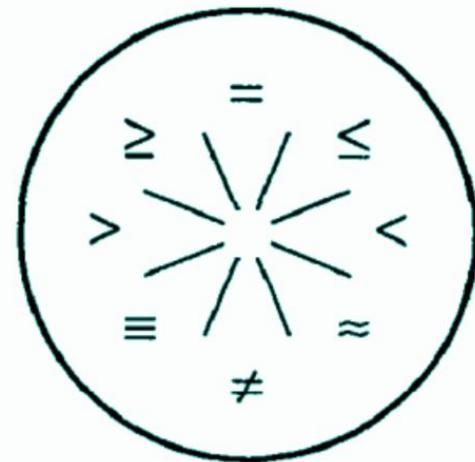
X-O Arch Menu
(Thalmann et al., 2014)



The Wavelet menu developed by Francone et al (2010) is a hierarchical marking menu designed to **address the limitations of large linear menus on mobile phones**, which seems promising as the hamburger menu is a large menu model.

Basis for our Study

Furthermore, the time to reach elements within a **radial menu is equal distance** (Callahan et al., 1998), and suggests higher performance over a vertical list menu since the distance between menu items is not equal.



These reasons led to the basis of our exploration to compare the gold standard of linear menu designs — the hamburger menu — with a radial display.

EXPLORATORY STUDY

Experiment 1: Half Radial Menu vs. Full Radial Menu

Experiment Goal

Will a half radial menu or full radial menu with different amounts of menu items have a better task completion time, and have increased performance in terms of errors?

Independent Variables:

Type of Radial Menu



Number of Menu Items



Dependent Variables:

Time
(sec.)



Errors
(per trial)



Methods



Participants

- 18 participants, age 18-37 years
- Private university campus
- Primarily English speakers
- Education level greater than high school
- Majority had corrected vision
- **83% iPhone users**
- 95% specified English for mobile device language settings
- **Majority check phones for 2-3 per day**
- Majority hold phone in right hand
- Majority are avid mobile phone users





Apparatus

- iPhone X, IOS version 11.2
- Menu prototypes via Proto.io app
- Video recording via DU Recorder and iPhone built-in screen recording
- Two stopwatches on smartphones



Experiment Design

- Within-subjects design, 6x6 Latin square
 - 18 participants x 4 tasks x 6 menu versions = 432 trials

Moderator	Participant	Trial #	Condition /Menu	Set	#Task	Instructions
CONSENT FORM PRE QUESTIONNAIRE		START RECORDER				
Deb	P1	1	A : 4-Half	4	Wifi	You want to automatically join wifi networks in your area
Deb	P1	2	A : 4-Half	4	Mail	You want to turn off loading remote images in your email messages.
Deb	P1	3	A : 4-Half	4	Battery	You want to check your battery's health.
Deb	P1	4	A : 4-Half	4	Sounds	You want to turn off the clicking sound of your keyboard
SURVEY A						
Deb	P1	5	B : 4-Full	6	Battery	You notice your phone's power is low so you want to set your battery to low power mode
Deb	P1	6	B : 4-Full	6	Wifi	You want to download photos but your connection is slow so you check your wifi status
Deb	P1	7	B : 4-Full	6	Sounds	Your phone went off during class, so you adjust your sound settings.
Deb	P1	8	B : 4-Full	6	Mail	You want to compose a new email.
SURVEY B						
Deb	P1	9	C : 8-Half	2	Battery	You want to know your remaining battery percentage.
Deb	P1	10	C : 8-Half	2	Mail	You want to change your default mail account.
Deb	P1	11	C : 8-Half	2	Sounds	You always miss your friends' calls, so you want to set your phone vibrate when ringing
Deb	P1	12	C : 8-Half	2	Wifi	Your instagram feed won't refresh so you go to check your wifi.
SURVEY C HALFWAY POINT						
Deb	P1	13	D : 8-Full	5	Mail	You are awaiting an important email, so you check your inbox.
Deb	P1	14	D : 8-Full	5	Sounds	You want to change your reminder alerts, so you need to change your sound settings
Deb	P1	15	D : 8-Full	5	Battery	You want to know which app is using up a lot of power, so you check your battery usage.
Deb	P1	16	D : 8-Full	5	Wifi	You need to upload files to Dropbox but you can't connect so you check your wifi status
SURVEY D						
Deb	P1	17	E : 12-Half	1	Wifi	Your web page isn't loading. So you need check your wifi status.
Deb	P1	18	E : 12-Half	1	Sounds	You are in a meeting and you need to set your phone in silent mode
Deb	P1	19	E : 12-Half	1	Battery	You want to know your battery usage details.
Deb	P1	20	E : 12-Half	1	Mail	You want to turn off your mail notifications.
SURVEY E						
Deb	P1	21	F : 12-Full	3	Mail	You want to add a new signature to your outgoing mail.
Deb	P1	22	F : 12-Full	3	Battery	Your want to know how much time you have left on phone use, so you check your battery status.
Deb	P1	23	F : 12-Full	3	Sounds	You are waiting for an important call, so you need to raise your phone's volume
Deb	P1	24	F : 12-Full	3	Wifi	You need catch an Uber but your app won't load so you need to check your wifi status
SURVEY F POST QUESTIONNAIRE		STOP RECORDER				

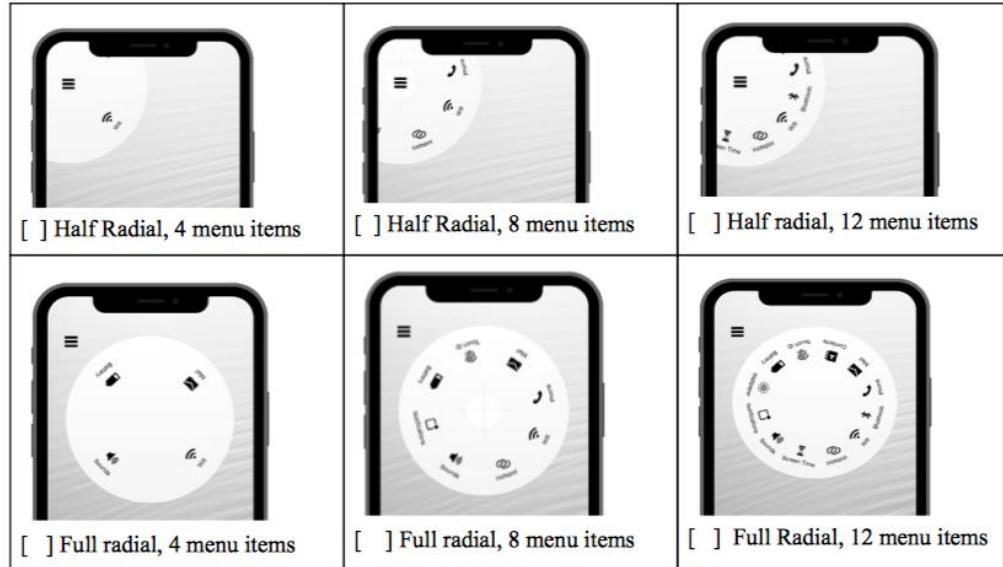
Experiment Design

- Context of an iPhone settings menu
- One task in each quadrant of radial menu



Prototype Design

- Touch target size 10mm or 38px x 38 px
- Equal radial distances from center (Callahan, 1988)
- Type 11px, “San Francisco UI Text Regular”, 0.06 tracking
- Color not used





Procedure

- Consent form
- Demographics questionnaire
- Instructions:
 - “Proceed as quickly and accurately as possible, but at a pace that is comfortable.”
 - Hold phone in hands, not resting upon the table.
(Tsiodouos, 2016)
 - Remain in provided screen at all times, not interact with device features, i.e. sound buttons or homepage of phone.
- Menu prototypes alternated between menu versions
A, B, C, D, E, or F with 4 tasks per block, Latin sq. design
- After each menu version, Likert scale survey (4 pt.)
- Post-study questionnaire for most and least liked menu

University of Miami - Questionnaire

P#: ____ [for moderator only]

Preliminary Information. Please put an 'x' before the answer you would like to choose.

Date: October ____ 2018

1. What is your gender? Female Male

2. What is your age? _____

3. What is your highest level of education? If applicable, specify what field.

High School Diploma Associate's Degree Bachelor's Degree

Master's Degree Doctorate Degree

4. What is your primary language?

English Spanish Chinese Other: _____

5. Do you have corrected vision? Please specify.

None Contact Lenses Glasses Lasik Other: _____

6. Which kind of mobile phone do you use?

Android iPhone Other: _____

7. What is the language setting on your phone?

English Spanish Chinese Other: _____

8. Which hand do you write with?

9. How often over

> 30 minutes

4 hrs - 5 hrs

10. How often do you

> 5 times

University of Miami - Questionnaire

P#: ____ [for moderator only]

MENU A - Participant Feedback

Please circle your answer on the scale.

1. This menu is easy to use. (Please note: "ease of use" is the degree to which a menu can be used to achieve quantified objectives with effectiveness, efficiency, and satisfaction.)



2. This menu is easy to learn. (Please note: "easy to learn" is the capability of a menu product to enable the desire and ability to quickly grow and adapt the user's skill set — in order to stay relevant and succeed.)



3. This menu is easy to memorize the locations of the menu items.



4. This menu is easy to reach the locations of the menu items.



Please put an 'x' before the answer you would like to choose.

5. The task that was easiest to complete on this menu was:

Wi-Fi Battery Sound Mail

[1]

[2]

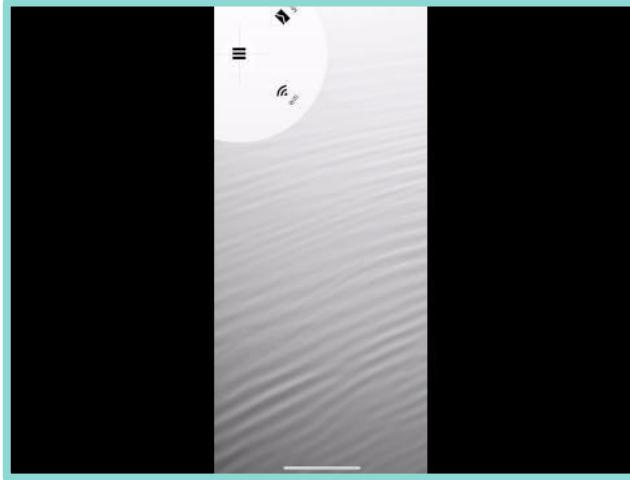
Procedure



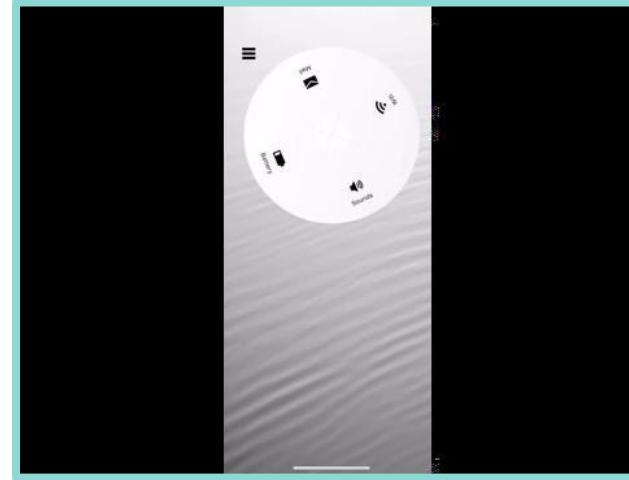
Prototypes (Radial Menus)



Menu A & B - 04 Menu Items



Half-Radial Menu, 4 Menu Items



Full-Radial Menu, 4 Menu Items



Menu C & D -

08

Menu Items



Half-Radial Menu, 8 Menu Items



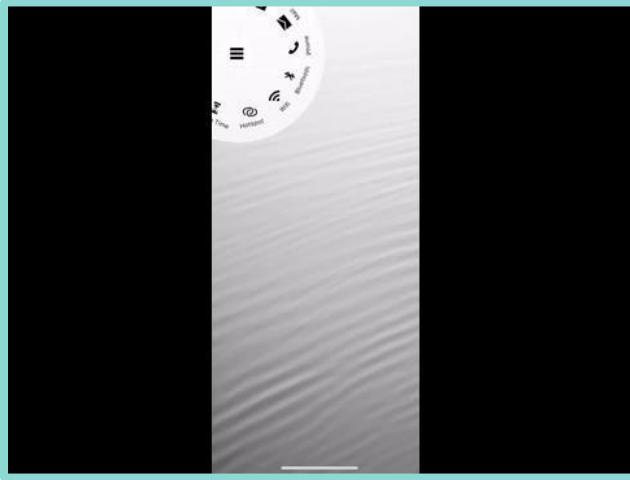
Full-Radial Menu, 8 Menu Items



Menu E & F -



Menu Items



Half-Radial Menu, 12 Menu Items

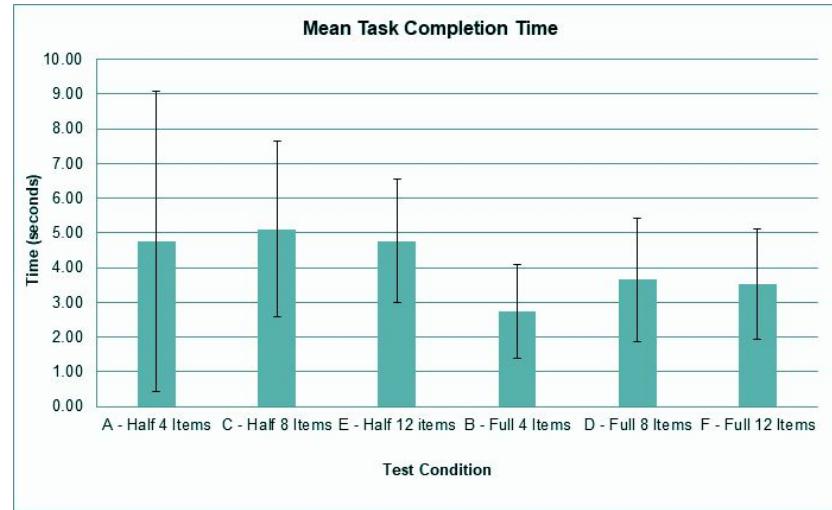


Full-Radial Menu, 12 Menu Items

Experiment 1 Results

Results - Significant

- **Fastest:** Full Radial (4 items) was fastest (2.74 sec.)
- **Slowest:** Half Radial with 8 menu items (5.11 sec.)



SIGNIFICANT. Full Radial menus had a faster task completion time than Half Radial.
A 2-way analysis of variance ANOVA shows that the main effect of menu type was statistically significant ($F=16.601$, $p < .05$).



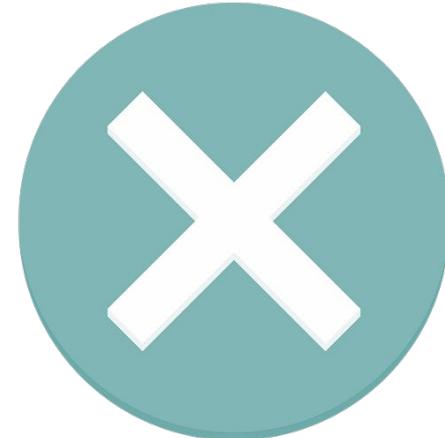
More Results

No impact in TASK COMPLETION TIME for...

- number of items from 4, 8 and 12. ($F=0.662$, ns)
- type of menu vs number of items.

No impact in ERROR RATE for...

- type of menu, Half Radial and Full Radial
- number of items from 4, 8 and 12
- type of menu vs number of items.



The results of errors showed that 1.85% of all trials were errors.

Subjective Data

LIKERT SCALE (4 pt, 0-3) post-menu questionnaires analyzed by post hoc analysis with Wilcoxon signed-rank tests conducted with a Bonferroni correction applied.

- **Ease of Use:** Full Radial Menu with 4 items is perceived to be easier to use than Half Radial Menus with 4, 8, or 12 items.
- **Memorization:** These results indicate that in menus with 12 items, regardless of menu type, were perceived to be difficult to memorize.
- **Easy to Learn** and **Easy to Reach** results failed to show any significant difference.



Most and Least Liked

MULTIPLE CHOICE and OPEN ENDED QUESTION

post-test questionnaire analyzed by the McNemar's test.

MOST

- The **Full Radial Menu with 4 items (Menu B)**, is the most preferred (11 of 18, $p < .05$), which was also the menu with significance in task completion time.



LEAST

- The Half Radial Menu with 12 items (Menu E) is the least preferred (11 of 18, $p < .05$)





Limitations & Discussion

- **TASK WORDING:** 13 out of 19 total errors were a result of task wording, which resulted in having to disregard the data in our final results
- **INTERACTION TOUCH POINTS:** menu buttons in prototypes required several taps by some participants to make the selection, which lead to increased time, and the need to increase target size in next experiment
- **ROTATION:** participants didn't realize half radial menu could rotate to see more options, which results in rotation considerations for experiment 2



Limitations & Discussion

- **CONTEXT:** prototype lacked a real-world context, and had a generic gray background, which may have influenced preference of full radial due to occlusion factor
- **VIDEO DATA:** tried to record, but glitches with the recording programs led to recordings to stop mid-session, however the data recordings did come in handy for specific cases that we needed to reference
- **HANDEDNESS:** we did not investigate which hand or finger participants used to select the menu items, as it was difficult to track along with time and errors; we observed many participants continuously changed their hands and fingers upon each selection, which was interesting



Conclusion

A **full radial menu with 4 menu items** is the winning design, as is **fastest in task completion** time among all menus, and the type of menu or number of menu items doesn't have an impact on performance in terms of errors.

Highlights indicate possible preference for menus that are easy to take in **at-a-glance**, especially important for **novice users**.



EXPERIMENTAL STUDY

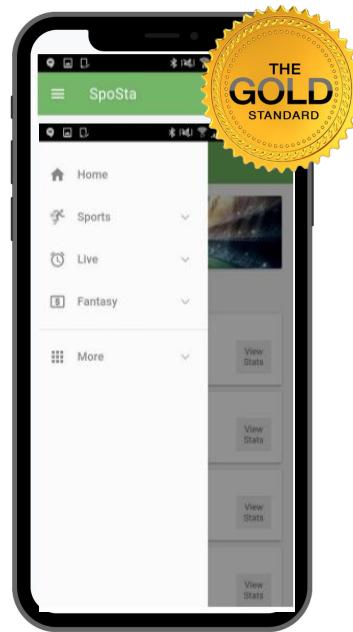
Experiment 2: Hamburger Menu vs. Full Radial Menu

The Exploration Continues...

With the winning 4-Item Full Radial Menu and participant preference for a low amount of menu items, we approach the probability that the winning design could present an increased performance when compared to the Gold Standard Hamburger Menu.



Full radial with 4 items
(Experiment 1)



Hamburger menu
(example)

Experiment Goal

Will a hamburger menu or radial menu with different amounts of menu items have a better task completion time, and have increased performance in terms of errors?

Independent Variables:

Type of Menu



Hamburger



Radial

Number of Menu Items



Dependent Variables:

Time
(sec.)



Errors
(per trial)



Methods



Participants (highlighted differences)

EXP. 2

vs.

EXP. 1

- 16 participants, age 18-30 years
 - Only 4 English speakers
 - 68.8% iPhone users
 - 62.5% specified English for mobile language settings
 - Majority check phones more than 3 hours per day
- 18 participants, age 18-37 years
 - Primarily English speakers
 - 83% iPhone users
 - 95% specified English for mobile language settings
 - Majority check phones for 2-3 per day





Apparatus

- These tools used are control variables in our study, and as such are the same apparatuses as experiment 1.



Experiment Design

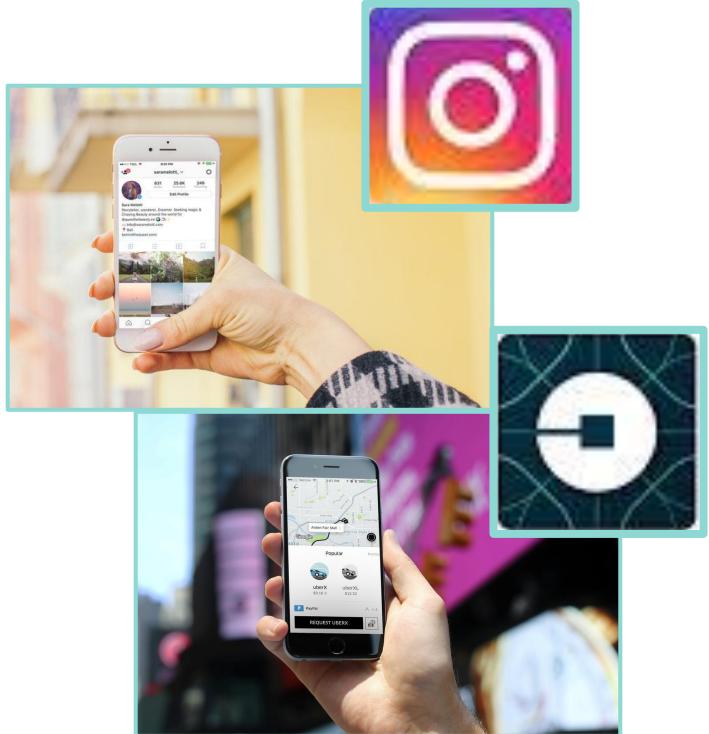
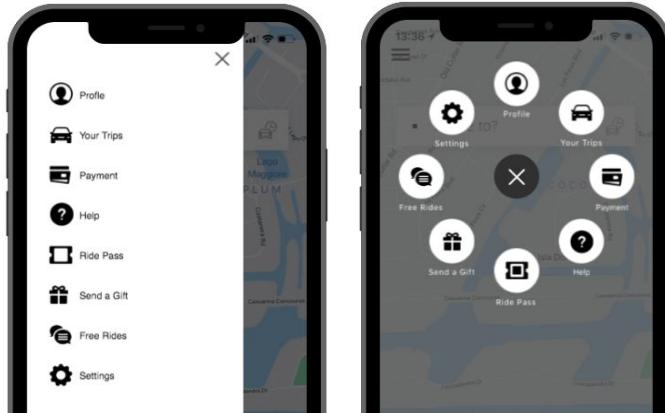
- Within-subjects design, 4x4 Latin square
 - 16 participants x 4 tasks x 4 menu versions = 256 trials

Moderator	Participant	Trial #	Condition /Menu	Set	#Task	Instructions
CONSENT FORM PRE QUESTIONNAIRE						
			START RECORDER			
Deb	P1	1	A : radial-Ins	I1	Nametag	You want a new friend to get your nametag on Instagram.
Deb	P1	2	A : radial-Ins	I1	Saved	You want to see your saved posts in Instagram.
Deb	P1	3	A : radial-Ins	I1	Facebook	You want to connect to your Facebook profile.
Deb	P1	4	A : radial-Ins	I1	Discover	You want to find people to follow.
SURVEY A						
Deb	P1	5	B : ham-Ins	I2	Facebook	You want to post on your Facebook profile.
Deb	P1	6	B : ham-Ins	I2	Nametag	You want to share your Instagram nametag with a new friend.
Deb	P1	7	B : ham-Ins	I2	Discover	You want to connect your contacts to instagram and choose who to follow.
Deb	P1	8	B : ham-Ins	I2	Saved	You want to find a recent post that you bookmarked.
SURVEY B HALFWAY POINT						
Deb	P1	9	C : radial-Uber	U1	Gift	You want to pay for a ride for a friend, so you send them a gift card.
Deb	P1	10	C : radial-Uber	U1	Help	You can't find the options you're looking for, so you seek assistance.
Deb	P1	11	C : radial-Uber	U1	Settings	You want to set your favorite address in settings.
Deb	P1	12	C : radial-Uber	U1	Your Trips	You want to view a recent trip.
SURVEY C						
Deb	P1	13	D : ham-uber	U2	Help	You need to report an issue with this trip, so you seek help.
Deb	P1	14	D : ham-uber	U2	Settings	You want to manage your trusted contacts in settings.
Deb	P1	15	D : ham-uber	U2	Gift	You'd like to send a digital gift card to thank a friend.
Deb	P1	16	D : ham-uber	U2	Your Trips	You want to see your history of trips.
SURVEY D POST QUESTIONNAIRE			STOP RECORDER			



Experiment Design

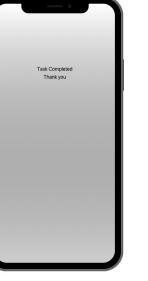
- Real world context of the actual hamburger menus in Instagram and Uber
- One task in each quadrant or section distributed equally through radial and hamburger menus





Prototype Design

- Touch target size 62px x 81px (full-radial) and 290px x 50px (hamburger)
- Equal radial distances from center for full-radial menu (Callahan, 1988)
- Type 13px, “San Francisco UI Text Regular”, 0.06 tracking
- Color not used

 <p>Main Screen (Based on Instagram)</p>	 <p>Hamburger Menu, 4 Menu Items</p>	 <p>Full Radial, 4 Menu Items</p>	 <p>Task Completed Screen</p>
 <p>Main Screen (Based on Uber)</p>	 <p>Hamburger Menu, 8 Menu Items</p>	 <p>Full Radial, 8 Menu Items</p>	 <p>Task Completed Screen</p>



Real World Context - Instagram



Main Screen
(Based on Instagram)



Hamburger Menu,
4 Menu Items

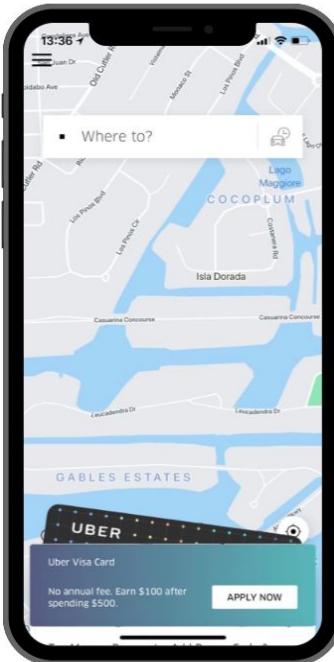


Full Radial,
4 Menu Items

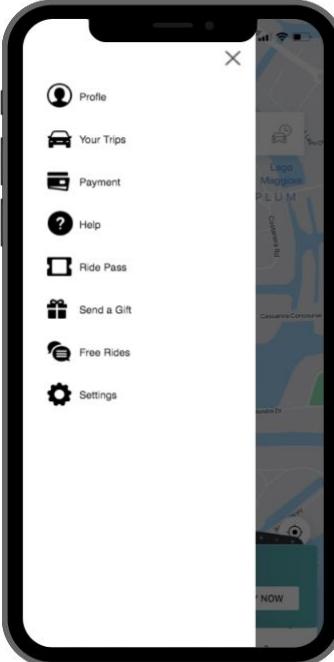


Task Completed Screen

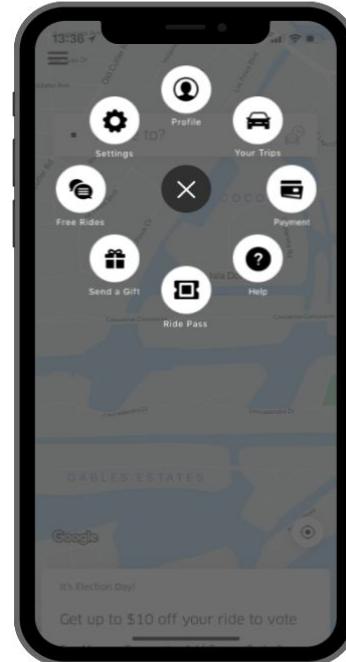
Real World Context - Uber



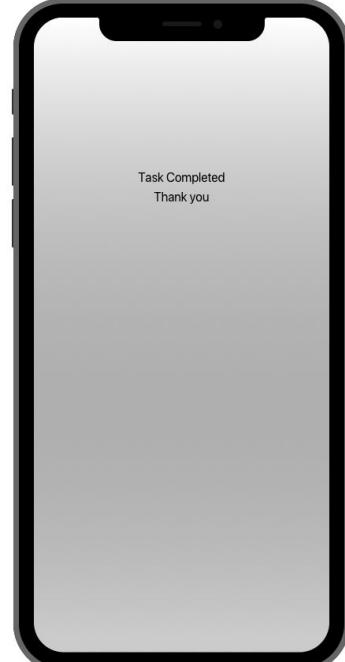
Main Screen
(Based on Instagram)



Hamburger Menu,
8 Menu Items



Full Radial,
8 Menu Items



Task Completed Screen

Procedure

- Demographics questionnaire and Instructions are the same as Experiment 1.
 - Consent form slight updates to disclose the purpose of the experiment.
 - Menu prototypes alternated between menu versions A, B, C or D with 4 tasks per block, Latin sq. design
 - After each block, Likert scale survey (updated to 6 pt.)
 - Post-study questionnaire for most and least liked menu

University of Miami - Questionnaire

Pt. ____ [for moderator only]

MENU A - Participant Feedback

Please circle your answer on the scale.

1. This menu is easy to use. (Please note: "ease of use" is the degree to which a menu can be used to achieve quantified objectives with effectiveness, efficiency, and satisfaction.)

1	2	3	4	5	6
<i>Strongly disagree</i>	<i>Disagree</i>	<i>Slightly Disagree</i>	<i>Slightly Agree</i>	<i>Agree</i>	<i>Strongly Agree</i>

2. This menu is easy to learn. (Please note: "easy to learn" is the capability of a menu product to enable the desire and ability to quickly grow and adapt the user's skill set — in order to stay relevant and succeed.)

1	2	3	4	5	6
<i>Strongly disagree</i>	<i>Disagree</i>	<i>Slightly Disagree</i>	<i>Slightly Agree</i>	<i>Agree</i>	<i>Strongly Agree</i>

3. This menu is easy to memorize the locations of the menu items.

1	2	3	4	5	6
<i>Strongly disagree</i>	<i>Disagree</i>	<i>Slightly Disagree</i>	<i>Slightly Agree</i>	<i>Agree</i>	<i>Strongly Agree</i>

[1]

4. This menu is eas

l

Strongly disagree

University of Miami - Questionnaire

PF: ___ [for moderator only]

Which menu do you like the least?

The image displays four smartphones arranged horizontally, each showing a different menu design. The first smartphone on the left shows a 'Hamburger Menu, 4 menu items' with a list of four items: 'Home', 'About', 'Contact', and 'Logout'. The second smartphone shows a 'Full Radial, 4 menu items' with a circular radial menu containing four icons. The third smartphone shows a 'Hamburger Menu, 8 menu items' with a list of eight items: 'Home', 'About', 'Contact', 'Logout', 'Help', 'FAQ', 'Feedback', and 'Logout'. The fourth smartphone shows a 'Full Radial, 8 menu items' with a circular radial menu containing eight icons. Each smartphone has a radio button below it for selecting the least preferred menu.

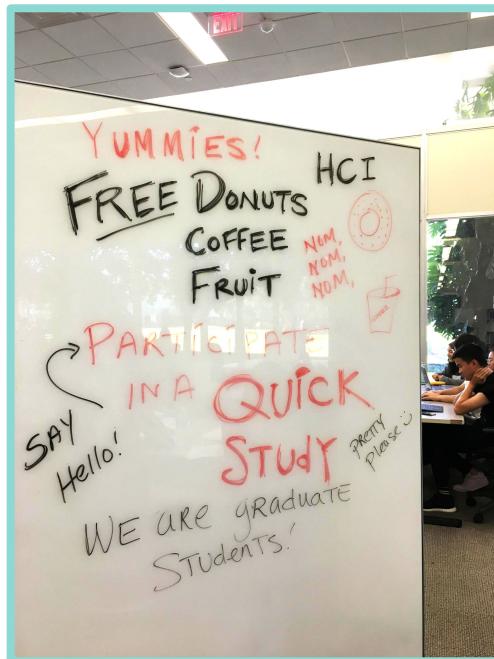
Please explain the reason why you selected the best and least preferred menus.

THIS STUDY IS NOW COMPLETE.
THANK YOU FOR YOUR PARTICIPATION!

[2]

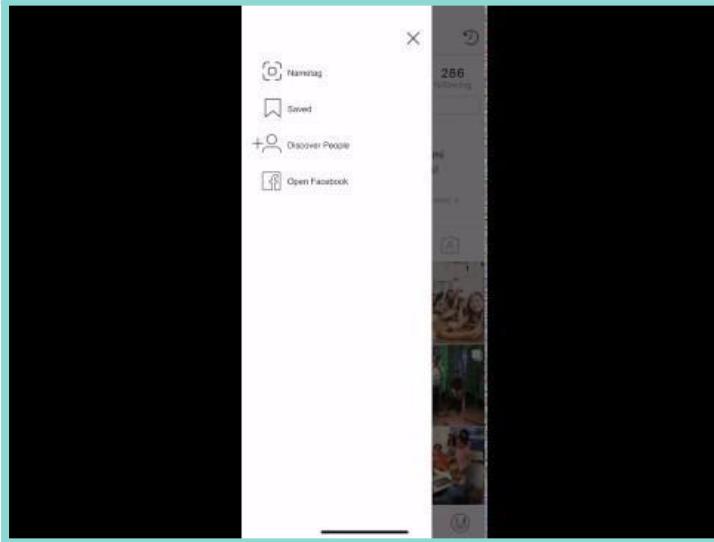


Procedure

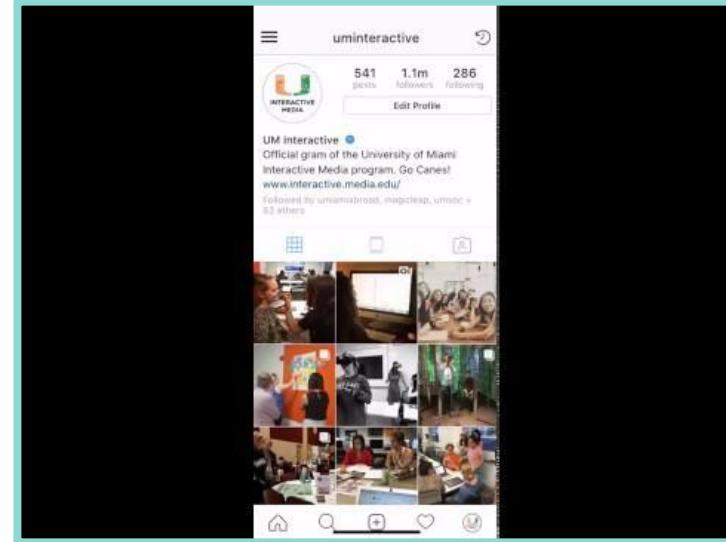


Prototypes (Hamburger vs. Radial)

Menu A & B - 04 Menu Items

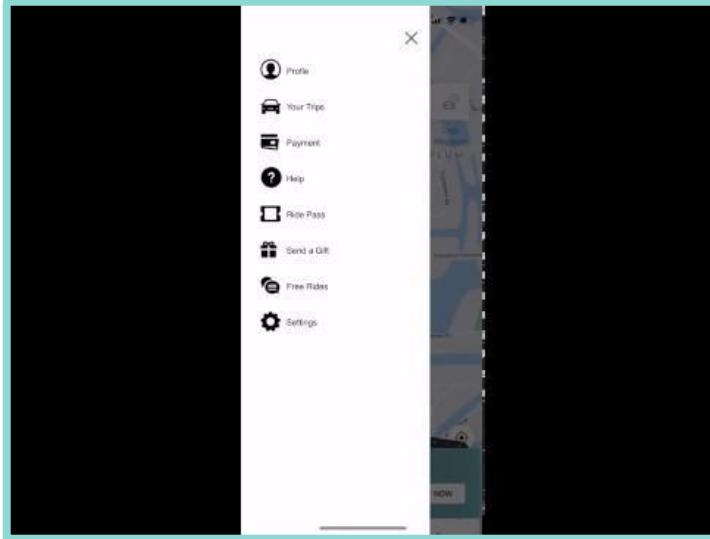


Hamburger Menu, 4 Menu Items

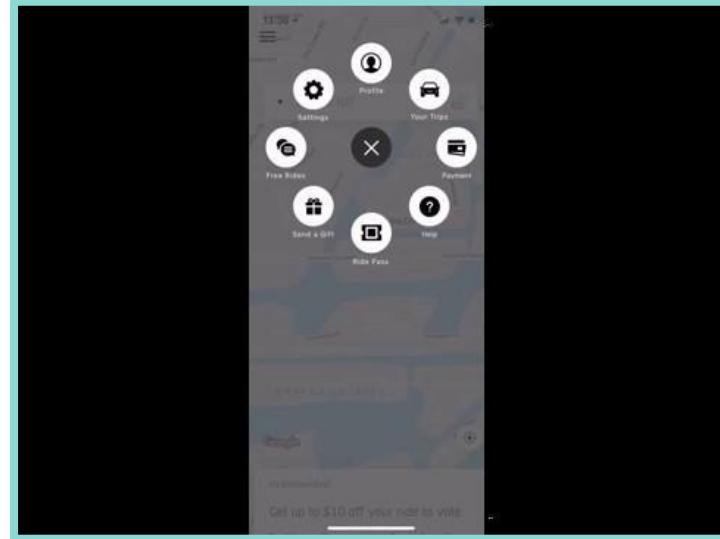


Full-Radial Menu, 4 Menu Items

Menu C & D - 08 Menu Items



Hamburger Menu, 8 Menu Items



Full-Radial Menu, 8 Menu Items

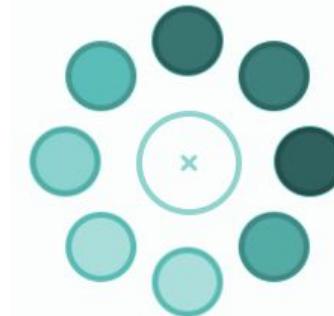
Experiment 2 Results



Results

Time

- **Fastest:** Full radial (4 items) = 2.98 sec.
- **Slowest:** Full radial (8 menu) = 3.68 sec.



Errors

- **Highest:** Hamburger menu (8 items) = 0.10%





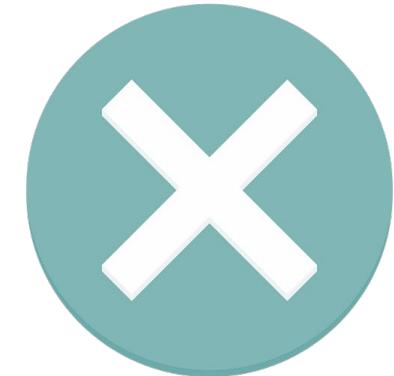
Results

No impact in **TASK COMPLETION TIME** for...

- type of menu, Hamburger and Full Radial. ($F=0.005$, ns)
- number of items between 4 and 8. ($F=1.817$, $p> .05$)
- type of menu vs number of items. ($F=1.001$, $p> .05$)

No impact in **ERROR RATE** for...

- type of menu, Hamburger and Full Radial. ($F=0.584$, ns)
- number of items between 4 and 8. ($F=1.311$, $p> .05$)
- type of menu vs number of items. ($F=0.135$, ns)



The results of errors showed that 4.3% of all trials were errors.



Subjective Data

LIKERT SCALE (6 pt, 1-6) post-menu questionnaires analyzed by post hoc analysis with Wilcoxon signed-rank tests conducted with a Bonferroni correction applied.

- **Memorization:** These results indicate that in menus with 8 items were perceived to be more difficult to memorize than menus with 4 items, regardless of menu type.
- **Easy to Learn, Ease of Use** and **Easy to Reach** results failed to show any significant difference.



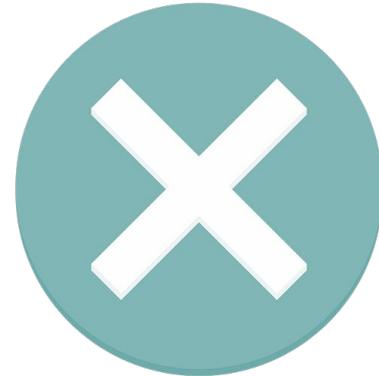


Most and Least Liked

MULTIPLE CHOICE and OPEN ENDED QUESTION

post-test questionnaire analyzed by the McNemar's test.

- There is no statistically significant difference in the most and least preferred menu designs.





Limitations & Discussion

- **PARTICIPANTS:** most of the participants were not native speakers of English, many international Chinese participants, which led to some confusion by the task instructions which required translation to understand the task.
- **PROTOTYPE DESIGN:** Similar and repetitive type of interactions — tap icon task — may cause no significant difference. Factors that the participants are so familiar with Uber and Instagram should also be taken into account, and study may have been affected by their real life expectations of the applications. I.e. “You need to report an issue with your trip, so you seek help” is not the selection option in real life.
- **RESEARCH QUESTIONS:** Based on our findings and our evaluation of the experiments, we also believe that our research questions are too broad to see a clear difference.



Highlights of Study

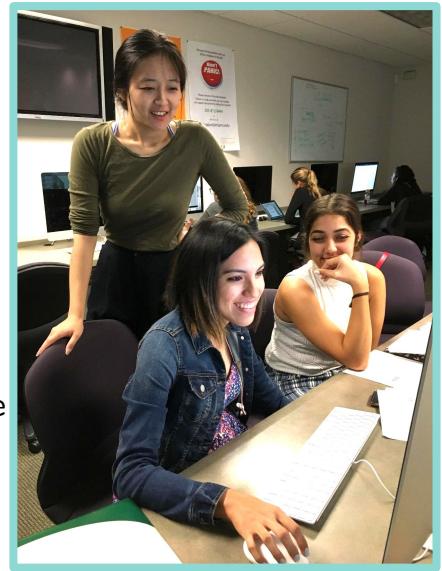
Full Radial fastest time over Half Radial (sig.) and Hamburger Menu (ns).

RADIAL

- **Less menu items** (4) preferred over more menu items (12).
- Subjective preference comments showed **rotation to not be preferred**, as discoverability is critical.

HAMBURGER

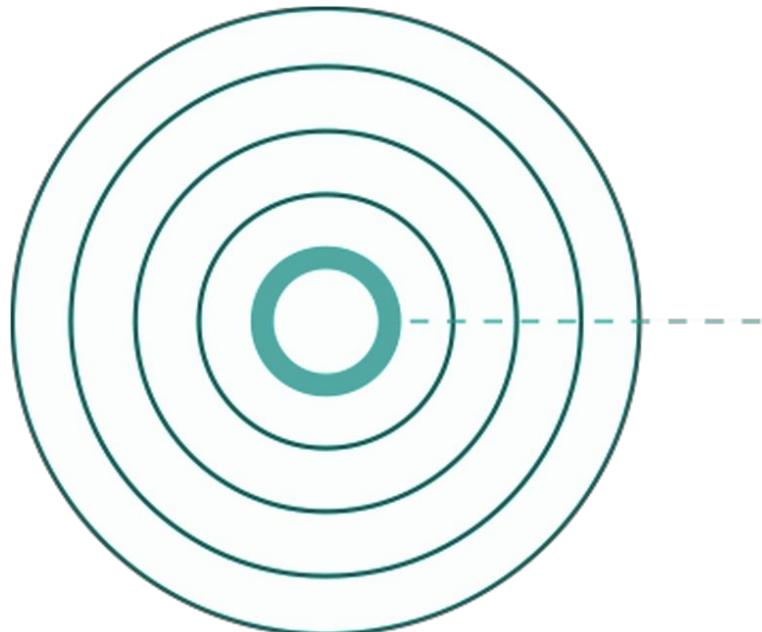
- Hamburger menu (8 items) had **highest errors**.
- Subjective preference comments revealed:
 - Difficulty accessing hamburger menu with one hand.
 - “The different position of the menu item [radial] (rather than in one list, from top to bottom helps me remember the items.”





Overall Take-Away

- With **no clear overall winner**, we conclude the subjective data suggests the possibility of **a larger sample size and more focused research question** in future comparisons.
- Additionally, the study's **experimental design** may have been **too simple** in terms of **level of depth being only one level**.
- **Future work** would be to compare a **hierarchical radial menu** with a **deeper hamburger menu**, exploring **submenus**.



**Thank
You!**