DISPUTES IN PIE CHARTS

STUDENT RESEARCHER

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Pie Chart Properties & Design Variations

AGENDA

- Introduction & Abstract
- Background & Experiment Overview
- Results & Next Steps

INTRODUCTION

- **Major:** Business Information Systems
- **Graduation Date:** May 2022
- **Post-Graduation Plans:** Financial Analyst, FDP Program at W.W. Grainger, July 2022
- **Why I chose to pursue this research?**
  - I wanted to explore further after my INFS360 course, with an interest in biometrics. This fellowship provided the resources to pursue this project and see what opportunities are available beyond my current career interests!
- **Fun Fact:** I can play guitar and am currently self-learning drums.

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FOR THE ONES WHO GET IT DONE

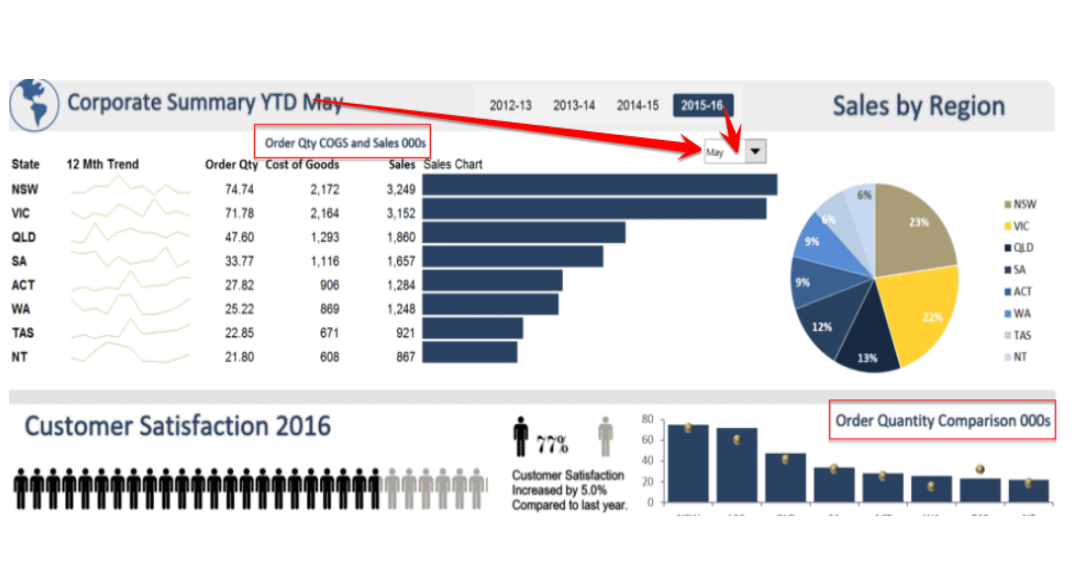
ABSTRACT

Pie charts are among some dominant ways to present information, especially in a business dashboard context. This has led to several studies attempting to assess the impact of pie chart use on decision speed, accuracy, and ease of information interpretation with inconclusive results.

Our research will explore some of the previous research studies' questions, As well as the impact of pie chart data representation on users by focusing on assessing users' cognitive effort and visual attention while employing novel eye-tracking technology. Our research will be focusing on one of Two questions that are centered around a difference in users' visual attention and cognitive effort between a pie chart and data representation alternative and visual properties.

The results we found showed a reliance on visual properties used to estimate the size of underlying data does impact user experience and performance. We found among our chosen design variations, the traditional 2-D pie chart outperforms the tested variations; in comparison, 3-D and donut charts had significant absolute error values (20% & 30%), which further amplifies our conclusions from experiment 1, suggesting a possible connection between accuracy and fixation duration.

Figure 1: Business Dashboard
(via Tableau/ The DataCrunch)



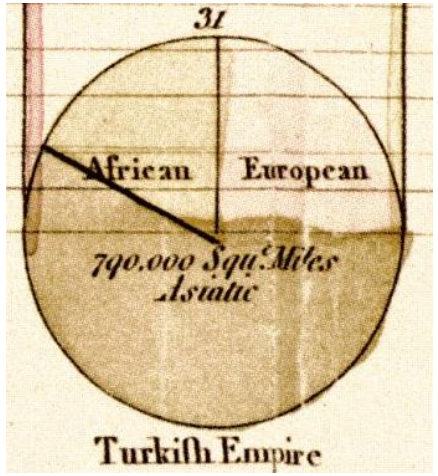


Figure 2: The First Pie Chart
(via William Playfair, 1801)

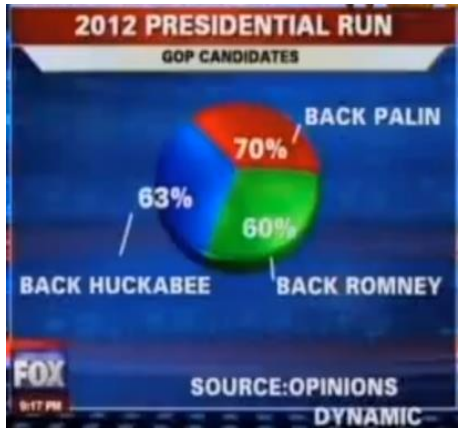


Figure 3: Pie Chart Misuse

BACKGROUND – PIE CHARTS & B.I.V

- GRAPHICAL INFORMATION HAS BEEN AROUND FOR THOUSANDS OF YEARS, BEGINNING WITH DISCOVERY OF HIEROGLYPHS IN CAVES
- PIE CHARTS BECAME POPULAR AFTER WILLIAM PLAYFAIR'S FIRST OFFICIAL RECORD OF THE GRAPHIC PUBLISHED IN 1801 (*STATISTICAL BREVIARY*)
- IN SIMPLE TERMS, A PIE CHART IS "A SIMPLE INFORMATION GRAPHIC WHOSE PRINCIPAL PURPOSE IS THE SHOW THE RELATIONSHIP OF A PART TO THE WHOLE"*
- BUSINESS INFORMATION VISUALIZATION (B.I.V) IS A "SUBFIELD IN DATA VISUALIZATION THAT ENCOMPASSES COMPUTER INTERACTIVE VISUAL REPRESENTATIONS OF BUSINESS DATA FOR BETTER DECISION-MAKING"***
- A SERIES OF STUDIES HAVE BEEN CONDUCTED TO TEST HOW USERS READ PIE CHARTS AND HOW DESIGN CHOICES IMPACT USER PERFORMANCE **

*Spence, I., & Lewandowsky, S. (1991). Displaying proportions and percentages. Applied Cognitive Psychology, 5(1), 61–77.

**Kosara, R., & Skau, D. (2016). Judgment Error in Pie Chart Variations. Proceedings of the Eurographics/IEEE VGTC Symposium on Visualization (EuroVis), 91–95.

*****Bačić, D., & Fadlalla, A. (2016). Business information visualization intellectual contributions: An integrative framework of visualization capabilities and dimensions of visual intelligence. *Decision Support Systems*, *89*(July), 77–86.

BACKGROUND- COGNITIVE EFFORT

- Cognitive effort has been defined broadly as "cognitive resources needed to complete a task"*
- A predominant way to measure cognitive effort has been through user perception
- More recently, advances have been made, and research found numerous ways to measure cognitive effort physiologically through fMRI, EEG, and eye-tracking.
- Eye-tracking is the most popular physiological sensing technology used in visual stimuli, and has been used widely to measure the distribution of visual attention
- Our measure of Performance: Accuracy, Time, Fixation duration/count
    - Fixation: eye movements that stabilize the retina over a stationary object of interest

*Cooper-Martin, E. (1994). Measures of cognitive effort. *Marketing Letters*, *5*(1), 43–56.

Figure 4: Example of Eye Tracking Device
(via YouTube//Tobii Eye Tracker 5 technology)

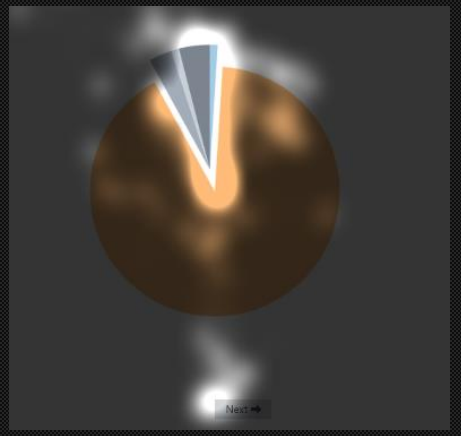


Figure 5: Gaze Heat Map

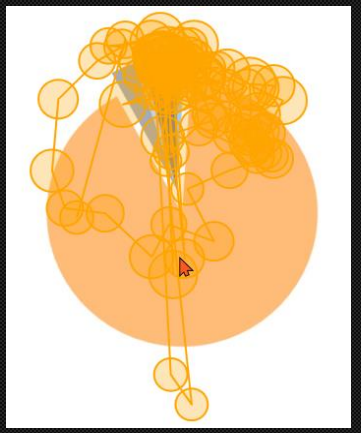
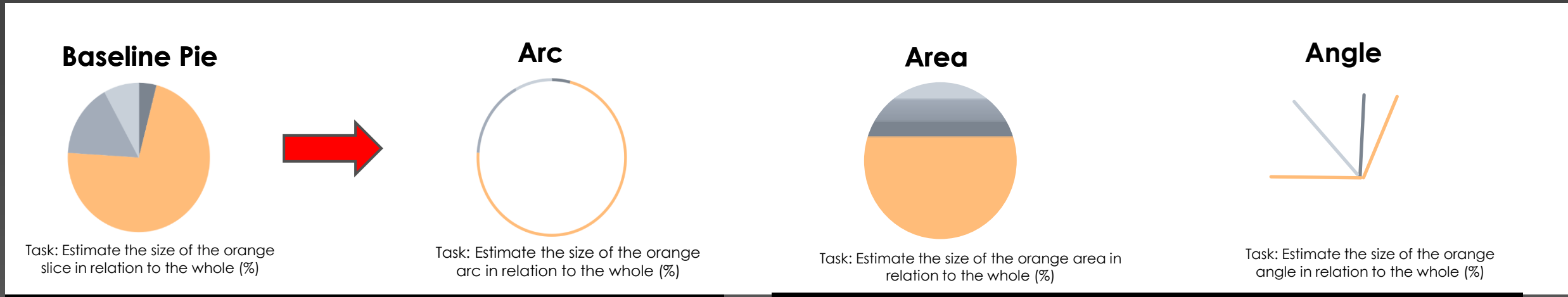


Figure 6: Fixation Count & Duration

EXPERIMENT 1: DO THE PIE CHART'S VISUAL PROPERTIES IMPACT USERS' VISUAL ATTENTION, PERFORMANCE, AND COGNITIVE EFFORT?

Figure 7: Stimuli in Experiment 1



WHAT ARE WE LOOKING AT?

- PIE CHART VISUAL PROPERTIES (ARC, AREA, ANGLE, REGULAR PIE)
- USER PERFORMANCE (TIME AND ACCURACY) AND EFFORT WERE MEASURED
- 30 PARTICIPANTS

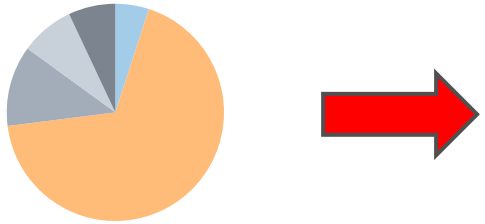
PROCEDURE

- 4 CHART TYPES, 4 VARIATIONS
  - A-D VARIATION CHOICES
- 4 DIFFERENT PERCENTAGE OF ORANGE SLICE DISPLAYED
  - 64%; 72%; 41%; 11%
- PARTICIPANTS WERE SHOWN ONE OF EACH CHART TYPE, ASKED TO MEASURE THE SIZE OF THE ORANGE SLICE
  - FIXED RANDOMIZATION
- BASELINE VS ANGLE, BASELINE VS ARC, BASELINE VS AREA

EXPERIMENT 2: DO PIE CHART DESIGN VARIATIONS IMPACT USERS' VISUAL ATTENTION, PERFORMANCE, AND COGNITIVE EFFORT?

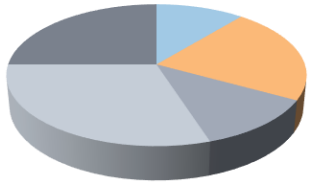
Figure 8: Stimuli in Experiment 2

Baseline 2-D Pie



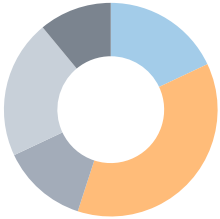
Task: Estimate the size of the orange slice in relation to the whole (%)

3-D Pie



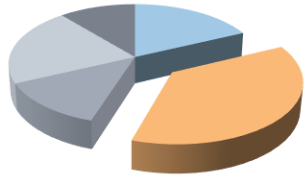
Task: Estimate the size of the orange slice in relation to the whole (%)

Donut



Task: Estimate the size of the orange slice in relation to the whole (%)

Exploding



Task: Estimate the size of the orange slice in relation to the whole (%)

WHAT ARE WE LOOKING AT?

- PIE CHART DESIGN VARIATIONS (3D, EXPLODING SLICE, DONUT, REGULAR PIE)
- IMPACT ON USER PERFORMANCE AND EFFORT IMPACT WAS MEASURED
- 30 PARTICIPANTS

PROCEDURE

- 4 CHART TYPES, 4 VARIATIONS
  - A-D VARIATION CHOICES
- 4 DIFFERENT PERCENTAGE OF ORANGE SLICE DISPLAYED
  - 64%; 72%; 41%; 11%
- PARTICIPANTS WERE SHOWN ONE OF EACH CHART TYPE, ASKED TO MEASURE THE SIZE OF THE ORANGE SLICE
  - FIXED RANDOMIZATION
- BASELINE VS 3D, BASELINE VS DONUT, BASELINE VS EXPLODING

EXPERIMENT PROCEDURES

1. Consent Form

CONSENT TO PARTICIPATE IN RESEARCH

Project Title: Disputes in Data Visualization: Pie Charts and their place in Business Information Visualization

Researcher(s): Ariana Krbanjevic

Faculty Sponsor: Dinko Bačić

Introduction:

You are being asked to take part in a research study being conducted by Ariana Krbanjevic for a thesis part of the Loyola University's Chicago Provost Fellowship program under the supervision of Dr. Dinko Bačić in the Department of Information Systems and Supply Chain Management at Loyola University of Chicago

You are being asked to participate because we are interested in assessing individuals' cognitive effort and visual attention while problem-solving through different data visualizations. Being a student in college, your problem-solving capacity makes you an ideal candidate for our research.

Please read this form carefully and ask any questions you may have before deciding whether to participate in the study.

2. Demographic Survey

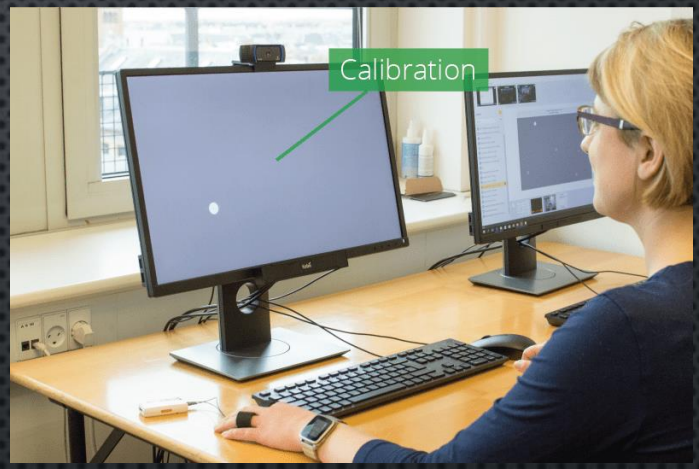
Please indicate your age:

- Under 18
- 18-22
- 23-44
- 45-65
- 65 and over

Please indicate your current school standing:

- Undegraduate Student
- Graduate Student
- Faculty
- Staff
- Not Applicable

3. Eye & Device Calibration



4. Data Collection

RESULTS: EXPERIMENT 1

	Accuracy/Error* ABS VAR %)	Time*** (seconds)	Fixation Count***	Fixation Duration**(m/s)
Area	11.54%	11.26	29.07	244.5208
Angle	19.37%	16.96	36.6	266.6606
Arc	10.73%	16.87	42.2	253.6674
Baseline	9.39%	16.05	39.1	265.4067
RM ANOVA	$F(3,87)=2.62$ p= 0.0559	$F(3,87)=6.35$ p=0.0006	$F(3,87)=4.98$ p=0.0031	$F(3,87)=2.709$ p=0.0942

*0.1 **0.05 ***0.001

Table 1: ANOVA Experiment 1

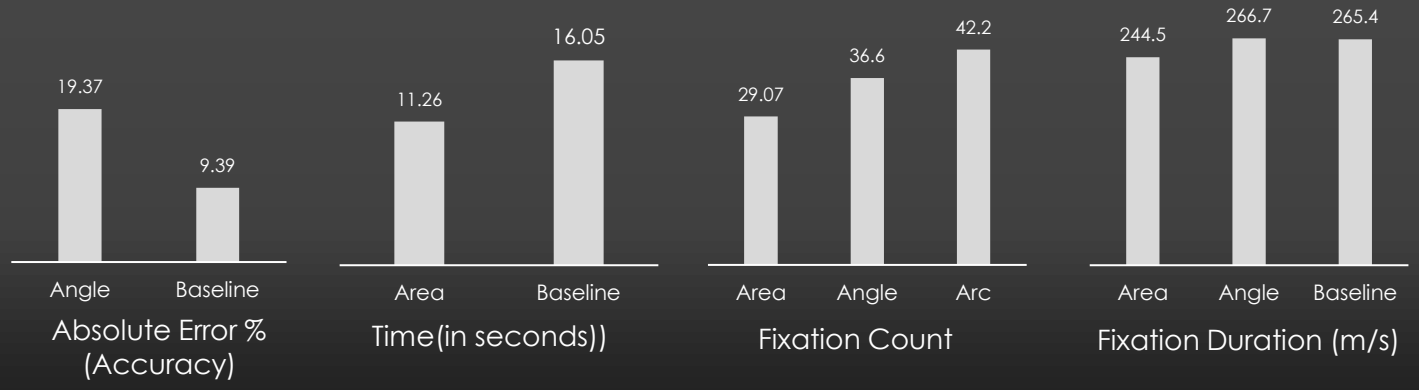


Figure 9: T-test (only for p<0.05)

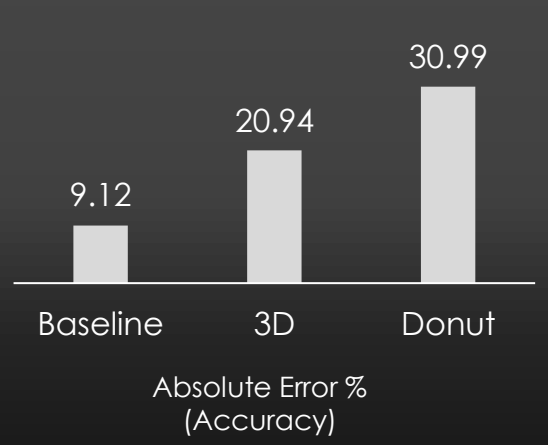
- ANOVA and T-Tests were conducted
  - ANOVA revealed there was significance based on stimuli properties
  - T-tests revealed which pairs were significant
- Most error was reported amongst angle charts
  - If people only use angle property, then their error rate doubles doubles relative to baseline pie chart
  - If area property is used alone, then overall time is reduced in task solving compared to baseline
  - Fixation Count & Duration
    - Number of fixations goes down if using area chart
    - Duration decreases from baseline pie to area chart
- Results indicate promise for further testing and exploration

RESULTS: EXPERIMENT 2

- ANOVA AND T-TESTS WERE CONDUCTED
  - ANOVA REVEALED THERE WAS SIGNIFICANT DIFFERENCE BASED ON STIMULI PROPERTIES FOR ACCURACY AND FIXATION DURATION ONLY
  - T-TESTS REVEALED WHICH PAIRS WERE SIGNIFICANT
- MOST ERROR WAS REPORTED AMONGST 3-D AND DONUT CHARTS
- ERROR RATE (ACCURACY) WAS HIGHEST AMONGST 3-D AND DONUT CHARTS, WITH 20% AND 30% VERSUS 9% ERROR RATE (ACCURACY) FOR BASELINE PIE
  - FIXATION DURATION RESULTED IN THE BASELINE PIE HAVING THE HIGHEST DURATION WHILE THE SHORTEST DURATION WAS DONUT CHART
- RESULTS INDICATE PROMISE FOR FURTHER TESTING AND EXPLORATION

	Accuracy		Time		Fixation Count		Fixation Duration	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2D (Baseline)	0.0912	0.0848	12.8684	8.0560	35.3684	24.2584	277.2788	65.1154
3D	0.2094	0.1852	12.7135	7.8682	34.1053	25.4185	255.9209	44.1099
	t(18)=(-2.7135), p=0.0071		t(18)=(0.0711), p=0.4720		t(18)=(0.1953), p=0.4237		t(18)=(1.6455), p=0.0586	
Donut	0.3099	0.4609	13.6429	7.2882	35.2105	19.9237	240.9337	40.2196
	t(18)=-1.9940, p=0.0308		t(18)=(-0.4487), p=0.3295		t(18)=(0.0353), p=0.4861		t(18)=(3.1114), p=0.0030	
Exploding	0.0544	0.0638	13.2277	7.8836	30.2632	20.3192	253.8778	47.0123
	t(18)=1.9891, p=0.03		t(18)=(-0.1676), p=0.4344		t(18)=(0.1883), p=0.1883		t(18)=(1.6455), p=0.0586	

Table 2: Experiment 2 T-Test Results



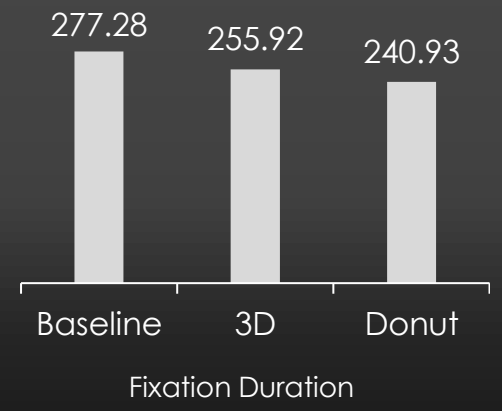


Figure 10: Experiment 2 Charts of Results

RECOMMENDATIONS & NEXT STEPS

- EXPAND POPULATION OF PARTICIPANTS FOR FURTHER ANALYSIS
- FIXED RANDOMIZATION WITHIN SOFTWARE
  - ENSURE EACH PARTICIPANT RECEIVES ONE TYPE OF EACH CHART AVAILABLE WITHOUT REPEATING IN A GIVEN SEQUENCE
- EXPLORE PIE CHART DIRECT COMPETITORS IN NEXT STUDY
- EXPLORE PIE CHART DESIGN OPTIONS
- FINDINGS DID HELP UNDERSTAND WHICH PIE CHARTS ARE MORE ACCURATE IN READING
  - CERTAIN VARIATIONS CREATE DIFFICULTY IN COMPREHENSION AND OVERALL MORE DISTRACTION

Figure 11: Pie chart competitors

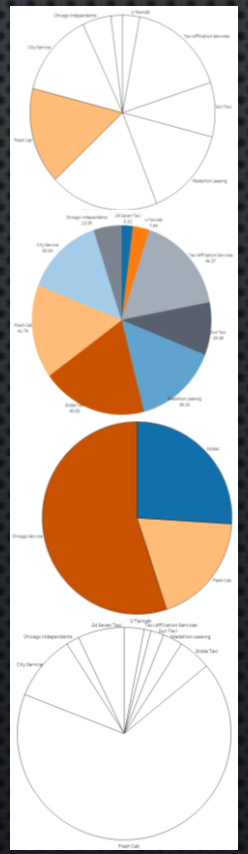


Figure 12: Pie chart Design Options

Summary & Conclusion

- These experiments revealed some promising results.
- The most accurate of charts was the 2-d baseline pie chart
  - 3-d pie chart, donut charts, and angle charts performed the worst
  - Reliance on visual properties exists!
- New question: what are users really evaluating when given area?
  - Area chart competitors- treemap, bar chart, etc
  - Do these types fare better and yield faster results than an area pie chart?