The Attentional Origins of Random Choice

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March, 2025

Motivation

- In many economic models, choice exhibits some degree of randomness
- Understanding, modeling and estimating how attention influences choice randomness is important:
  - Across individuals making a decision from the same menu.
  - Within one individual making a repeated decisions (e.g., across time).
  - Increasingly important in a digital "attention economy"
- Many intuitions for what drives choice randomness:
  - Heterogeneity in preferences across individuals
  - Utility shocks within individuals: Random Utility Models (RUM)
  - People look at different things at different times: Random Attention Models (RAM)
  - Individuals engage in search process
- Little work done to determine the relative importance of each of these intuitions

Questions

- What is the relationship between random choice and attention

1. How much of variation in choice can be explained by variation in attention?
   - about 86%
2. How does this relationship change with menu size?
   - attention explains more for large menus
3. How much of choice randomness is due to within-person shocks as opposed to across-person heterogeneity?
   - about 40% within-person
4. Is attention correlated with choice randomness?
   - no
5. IS more attention correlated with fewer mistakes?
   - no

Today's talk

- Experiment: individuals repeatedly choose gambles from menus
  - A gamble is a pair of pay-offs, e.g., (100,200)
  - 27 menus (sets of gambles)
  - Each individuals sees a given menu multiple times (5 or 10)
  - Menus vary in size (number of gambles): 2, 3, 6, 13, 14, 17
  - Menus partly overlap

- We track choice and attention (via eye-tracking):
  - What each subject chose from each menu.
  - What each subject looked at (extensive attention)
  - How long items were looked at (intensive attention)

Today's Talk

- Individual-Level Findings:
  - Extensive attention explains about 30% of overall choice randomness.
  - Conditional on extensive attention, intensive attention accounts for roughly 80% of the remaining randomness (total explained = 86%).

- Differences by Menu Size:
  - Small menus (sizes 2, 3, 6): Most options are viewed, so choice randomness seems mainly driven by (unobserved) utility shocks.
  - Large menus (sizes 13, 14, 17): Limited attention indicates a search-like process where subjects locate and choose a preferred option.
  - In large menus, extensive attention explains about 40% of choice randomness (vs. only about 10% in small menus).
  - Conditional on extensive attention, intensive attention explains approximately 85% of the residual randomness in large menus (vs 70% in small menus).

Today's talk

- Aggregate choice randomness is about 40% within-person shocks, and 60% between-person heterogeneity
- Although extensive and intensive attention are highly correlated at the individual level, both are uncorrelated with choice randomness
  - suggests individuals with fewer attentional constraints have more preference randomness
- Higher attention does not reduce choice mistakes (FOSD violations)
  - suggests endogenous attention: higher attention in settings where mistakes are more likely

Today's talk

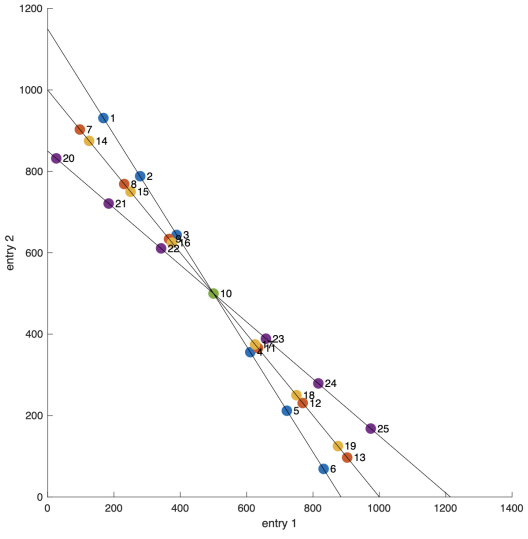
- Part of larger research agenda
- Will focus on "stylized facts"
  - Will refer to intuitions from formal models, but no direct testing
- Results can
  - Inform us about what models we should be empirically estimating
  - Guide development of new theories
  - Inform welfare analysis
- Caveats:
  - Stylized lab experiment $\rightarrow$ limits external validity
  - incentives were somewhat weak?

Experimental Design

Experimental Procedure

- 50 Subjects from the Ohio State University subject pool.
- Subjects make 180 choices from 27 menus of varying size
  - Menus of size 2, 3, 6, 13, 14, 17
- Payoff structure:
  - Subjects choose an option.
  - Each option consists of a pair of pay-offs, e.g., (100,200)
  - Two states of world, equally likely (e.g., payment of 100 if state is 1, 200 if state is 2)
- To construct gambles :
  - Begin with 3 budget lines, all intersecting at the same point
  - Select multiple points on each budget line
  - Allow for dominance relations between gambles
  - 25 gambles in total

menu


1200
1000
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entry 2
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entry 1
1
7
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20
2
8
15
21
3
16
22
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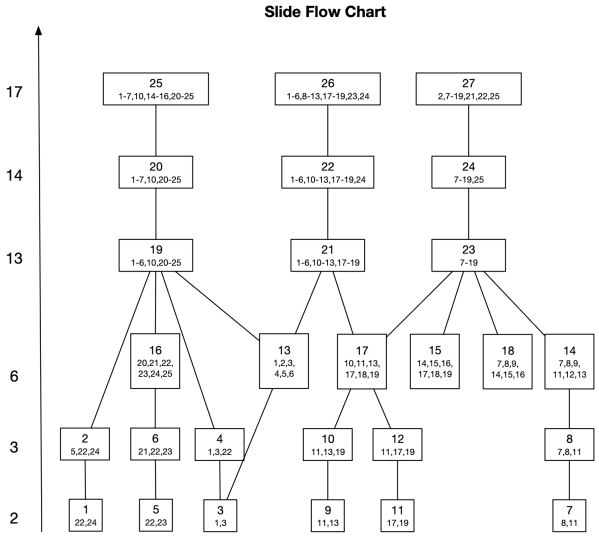
23
4
17
24
18
12
5
25
19
13
6

Experimental Procedure

- Construct menus using these 25 gambles
- Build sub-set/super-set relationships between menus
  - Generates "choice trees"
  - Why? most RUM and RAM models have predictions about what happens as the set of available options expands
- Allow for partial overlap across menus
- Goal: test for classical biases (attraction, compromise and default effects) - not detected

Choice Tree Visualization



Experimental Procedure

- Display menus on a 5×5 grid (25 squares)
- Some squares show "XXX,XXX", indicating an alternative "hidden" behind the square
- Gaze contingent design:
  - Look at square $\rightarrow$ uncovers the alternative
  - Look away $\rightarrow$ payoffs replaced by "XXX,XXX"
  - To make a choice: look + press a key
- No time constraint
- One menu randomly chosen to be paid; selected gamble paid
- Menus shown in random order to subject
- Location of the options is randomized
- Small (2, 3, 6) menus shown 5 times each
- Large (13, 14, 17) menus shown 10 times each
- Each individuals was shown multiple *instances* of each menu (to test choice randomness)
- (100,200) is a gamble between USD \$2 and \$4

Experimental Layout

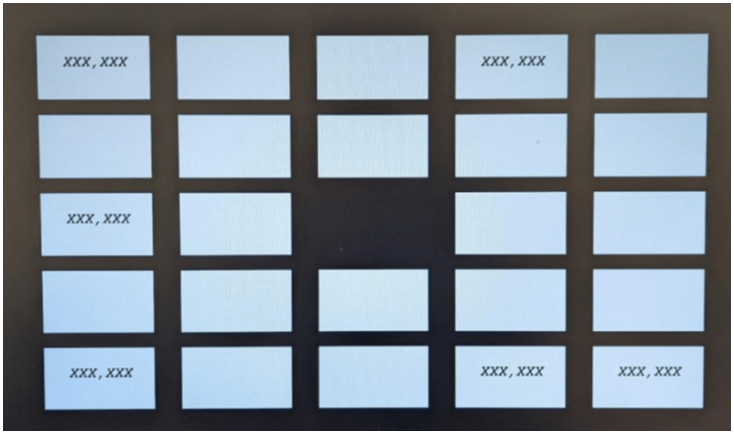


Figure: A sample menu when the subject is not looking at any of the gambles.

Looking at a different gamble

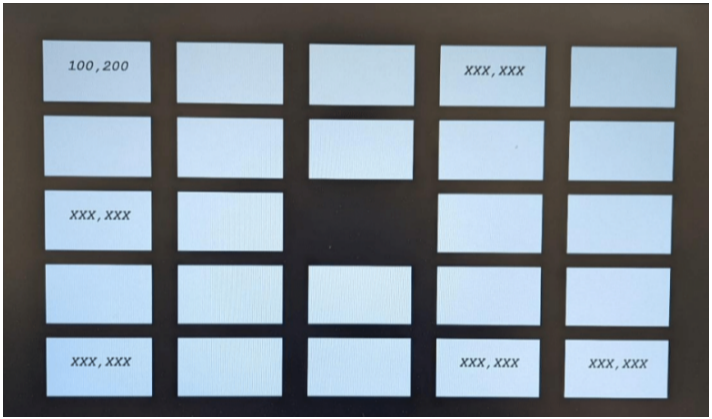


Figure: Here, the subject is looking at the top left option on the screen which shows the option (100,200).

▸ Link (Video)

Definitions and Summary Stats

Definitions of Choice Randomness: Choice Reversal

- Choice Reversal: for each individual i and menu m, across all pairs of instances j, j' of that menu, how often does choice not match
- n_m is menu size
- $\mathbb{I}_{i,m,j,j'} = 1$ iff choices made by individual i in instances j and j' of menu m are different

$$\text{Choice Reversal}_{im} = \frac{2 \sum_j \sum_{j' \neq j} \mathbb{I}_{i,m,j,j'}}{n_m(n_m - 1)} \in [0, 1]$$

Alternative Definitions of Choice Randomness

- Share of all options chosen across all instances of the menu
- Entropy of the distribution of choice probabilities

Choice Randomness: Correlation

- All measures highly correlated with one another.
- For this talk, focus on choice reversal.

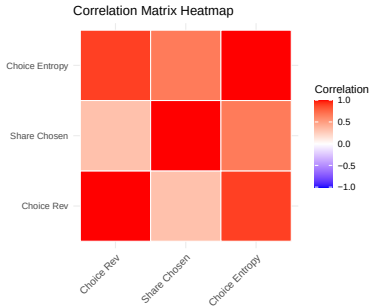


Figure: Correlation of Choice Measures

Individual vs Representative Agent Randomness

- We compute measures of choice randomness for each individual
- We also compute these measures as if a single individual had made all choices (i.e., shown many instances of each menu)
- Choice randomness by this "representative agent" includes heterogeneity in preferences across individuals
- The difference between these two measures tell us what share of choice randomness is due to inter-individual heterogeneity vs intra-individual utility or attention shocks

Choice Reversals

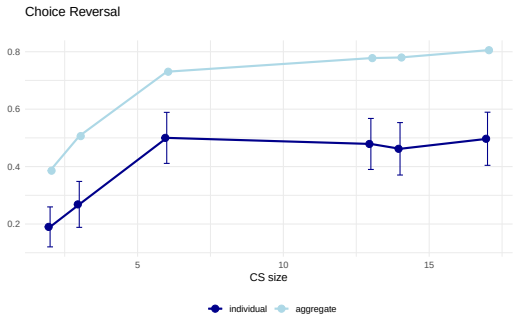


Figure: Choice Reversals by menu Size

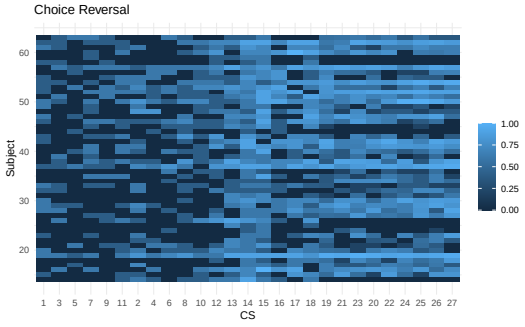


Figure: Choice Reversals by menu and Individual

How to define Attention?

- Extensive attention:
  - Shared Looked at: share of items looked at for a given menu, on average across instances
- Intensive attention:
  - Dwell Time Per Item: length of time looking at items, divided by number of items in menu, on average across instances
- Fixations:
  - How many times do you look at an item in a menu on average

Attention Summary Stats

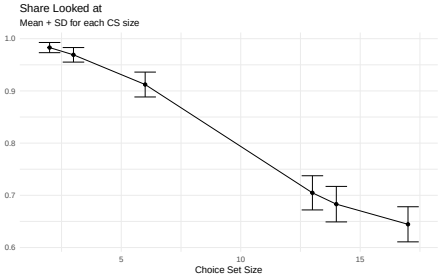


Figure: Shared Looked at by menu

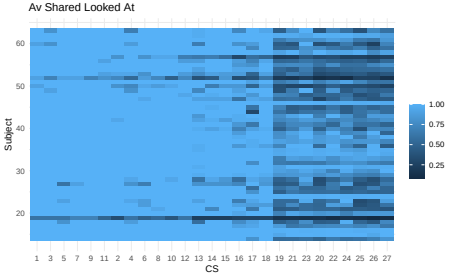


Figure: Shared Looked at by menu and Individual

Attention Summary Stats

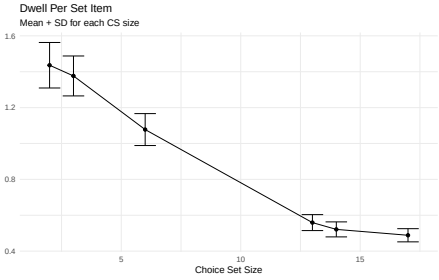


Figure: Dwell Time Per Item by menu

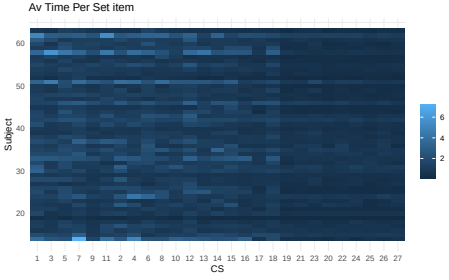


Figure: Dwell Time Per Item by menu and Individual

Baseline: Multinomial Logit (a RUM)

- Widely used approach to estimating preferences in presence of "choice randomness"
- What does the basic MNL model assume and predict?
  - Subjects always look at everything
  - No prediction about how long they look at anything
  - Gradual increase in choice randomness with menu size
  - Within and between-person randomness should be the same
  - Attention uncorrelated with randomness (trivially)
  - Allows for FOSD violations, but should not be reduced by controlling for attention

Results

Extensive Attention and Random Choice

- Question: can (extensive) attention rationalize choice randomness?

- Consider two instances j, j' of the same menu for individual i: call these $S_{i,j}$ and $S_{i,j'}$.
- Let the observed choices be $c(S_{i,j})$ and $c(S_{i,j'})$.

- 'Unconditional Reversal' (UR)
  - UR=1 iff $c(S_{i,j}) \neq c(S_{i,j'})$ (i.e., choices do not match across the two instances)

- Let the set of options looked at in a particular menu and instance S be $A(S)$.
- Define 'Cross-Attention' (CA)
  - CA $= 1$ iff j was looked at when j' was chosen and vice-versa (i.e., j, j' were both looked at in each instance)
  - Formally, $c(S_{i,j}) \in A(S_{i,j'})$ and $c(S_{i,j'}) \in A(S_{i,j})$
  - if CA $= 1$, (extensive) attention cannot not explain differences in choice

Extensive Attention and Random Choice

- If UR $= 1$, choices were inconsistent
- If CA $= 0$, then UR $= 1$
  - Individual chose from j from S_{ij}. If they didn't look at j in the second instance, they could not have chosen j.
- Suppose CA $= 1$ but UR $= 1$: extensive attention cannot explain the choice reversal.
  - Individual could have made the same option in both instances, but didnt
- Conditional Reversal (CR)
  - CR $= 1$ iff UR$=1$ and CA$=1$
- CR/UR is fraction of reversals that cannot be explained by extensive attention

Result 1: Attention and Randomness

Result 1(a): Extensive attention can rationalize around 30% of individual-level choice reversals across all menus. Attention explains more (about 38%) for large menus, and only about 12% for small menus.

Table: Extensive Attention and Choice Randomness

	UR	CR	Fraction Unexplained $\left(\frac{CR}{UR}\right)$
Individual Average			
Overall	0.4	0.29	0.73
Small menus	0.32	0.28	0.88
Large menus	0.52	0.30	0.58
representative-agent			
Overall	0.71	0.56	0.80
Small menus	0.54	0.50	0.93
Large menus	0.79	0.61	0.79

Intensive Attention and Random Choice

- What if we also include intensive measures of attention, can we explain some of the residual choice randomness?
- We now restrict to pairs of instances of a menu where there is a choice reversal, and both choices were looked at in each instance (i.e., where extensive attention cannot explain the choice reversal)
- Do subjects look at the choice from instance j more in instance j than the choice from instance j', and vice versa)?

Result 1: Attention and Randomness

Result 1(b): Intensive attention reversals are highly predictive of choice reversals

Table: Intensive Attention and Choice Reversals (Individual Average)

Instance j	**Instance** j'	
	Choice Dwelled Longer	Choice Dwelled Shorter
	Overall	
Choice Dwelled Longer	79.9%	9.4%
Choice Dwelled Shorter	9.7%	1.0%
	Small Menus	
Choice Dwelled Longer	70.7%	12.9%
Choice Dwelled Shorter	14.3%	2.1%
	Large Menus	
Choice Dwelled Longer	85.0%	7.4%
Choice Dwelled Shorter	7.1%	0.4%

Result 1: Attention and Randomness

- Extensive attention can rationalize up to 40% of choice reversals
- Conditional on extensive attention, intensive attention predicts choice reversal extremely well
- A combination of intensive and extensive measures of attention captures a lot: up to 90% of randomness in large menus.
- Currently no model capturing both intensive and extensive attention

Result 2: Small versus Large menus

Result 2: Choice randomness and attentional patterns are different for large menus relative to small menus

- Small menus:
  - Almost all individuals look at all option
  - Choice randomness seems due to preference "shocks"
- Large menus:
  - Greater randomness in choices
  - Shorter dwell times per item, and fewer fixations per item
  - Individuals not aware of all options — fewer items looked at (as fraction of total option
  - Consistent with sequential search with imperfect recall
- No models which predict change in choice and attention process as menu size changes (we'd like to do this)

Individual vs Aggregate Randomness

- Can measure choice randomness at the individual level
  - Randomness captures variation within individual across repeated instances of a menu
- Can also compute choice randomness as if as single individual had produced all the data (a "representative agent" approach)
  - This conflates randomness due to heterogeneity across individuals with randomness due to shocks within individuals
  - The difference in choice randomness between the two approach tells us how much of it is due to differences inter-individuals vs intra-individual shocks
- If aggregate and individual randomness are the same, then all individuals are the same
  - The more randomness at aggregate level the more across-person variation matters

Result 3: Individuals versus Aggregate Behavior

Result 3: About 55% ($\frac{0.4}{0.71}$) of aggregate choice randomness comes from individual randomness and 45% from differences across individuals. This is higher for large choice sets ($\frac{0.52}{0.79} \approx 65$ %)

Table: Extensive Attention and Choice Randomness

	UR	CR	Fraction Unexplained $\left(\frac{CR}{UR}\right)$
Individual Average			
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representative-agent			
Overall	0.71	0.56	0.80
Small menus	0.54	0.50	0.93
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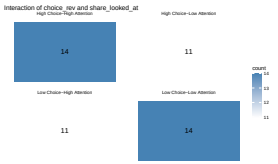
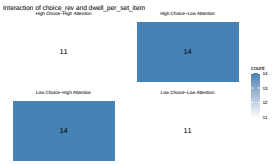
- Important to capture both within and across person variation

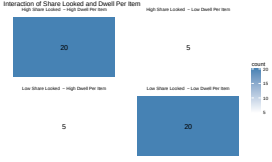
Result 4: Correlations



(a) Correlation of Choice Reversal and Extensive Attention (share looked at)



(b) Correlation of Choice Reversal and Intensive Attention (dwell time per item)



(c) Correlation of Extensive (share looked at) and Intensive (dwell time per item) Attention

Result 4: Correlations

- At individual level, extensive and intensive attention are highly correlated
- But Extensive and Intensive attention uncorrelated with randomness in choice
- Attention can rationalize choice randomness... but people who exhibit more attention seem to "compensate" with more post-attention choice randomness (i.e., attention seems be endogenous - more random individuals exhibit more attention)

Result 5: Value of Attention

- An individual's preferred gamble depends on their (unobserved) risk aversion
- We do not observe utilities
- But if individuals have utility increasing in money, violating FOSD implies a mistake
- We classify how often were FOSD violations observed, conditional on the number of possible violations in a menu (for some menus, few gambles are dominated; for other menus, many are)
- Then we ask : what is the unconditional probability of FOSD violations, and that probability conditional on having observed both the dominating and dominated gambles?
- We also consider "state-wise" dominance, a more obvious form of dominance

Result 5: Value of Attention

Table: FOSD Violations

	FOSD Vio.	Ratio	FOSD Vio. w/ Attention	Ratio w/ Attention
Aggregate menus	16.9%	931/5500	15.1%	710/4701
Small menus	9%	135/1500	7.75%	108/1394
Large menus	19.9%	796/4000	18.2%	602/3307

Table: Statewise Monotonicity Violations

	S-Mon. Vio.	Ratio	S-Mon. Vio. w/ Attention	Ratio w/ Attention
Aggregate menus	6.49%	292/4500	4.33%	154/3551
Small menus	5.8%	29/500	4.59%	22/469
Large menus	6.58%	263/4000	4.28%	132/3082

Result 5: Value of Attention

- Fewer statewise monotonicity violations
- Controlling for extensive attention barely reduces violations of FOSD or state-wise dominance
- Consistent with attention being endogenous: individuals exert more attention in menus where a mistake is more likely
- Maybe attention reduces errors, but because mistakes were already likely in menus with lots of attention, total effect is ≈ 0

Conclusion

- Lots of randomness in choice.
- We need models and empirical approach that allow for
  - Both intensive and extensive attention
  - Menu size to change choice and attention process
  - Both within and across person randomness
  - Attention is an endogenous process
- Suggests that at the very least one should be careful in attributing randomness only to "utility shocks" or only to "attentional shocks"

Additional Figures

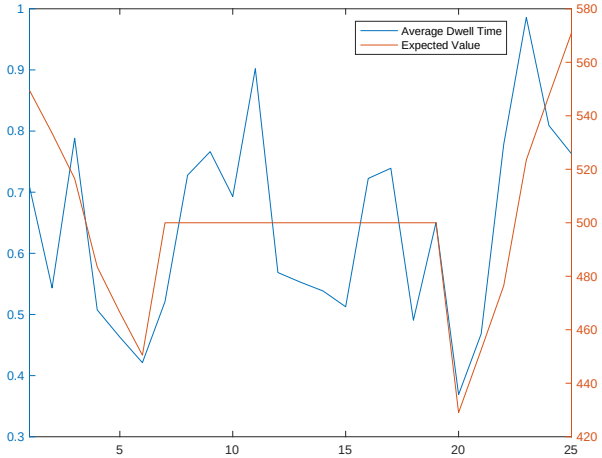


Figure: Correlation of Attention Measures

Additional Figures

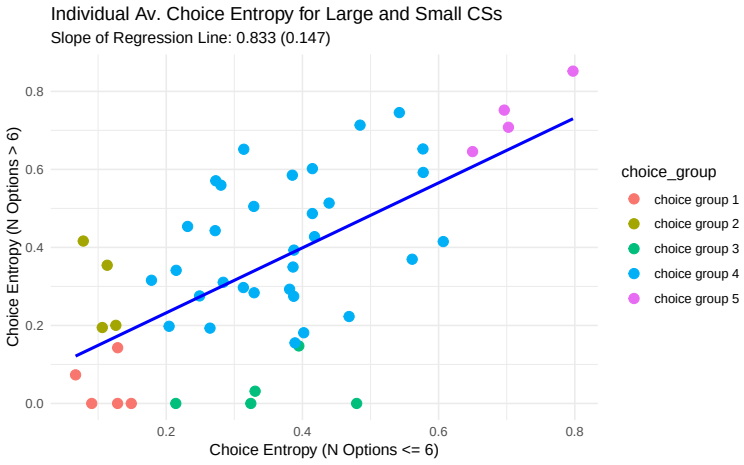


Figure: "Types" in Choice Reversals

Additional Figures

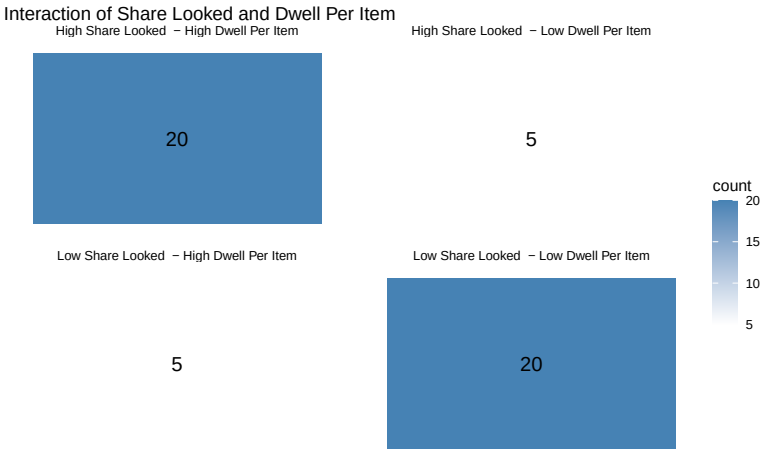


Figure: "Types" in Extensive Attention

Additional Figures