# Market User Interface Design

#### October 26<sup>th</sup>, 2011 ECON 1465 - Market Design, Brown University



Sven Seuken University of Zurich Department of Informatics

Joint work with:

- David C. Parkes (Harvard)
- Eric Horvitz (MSR)
- Kamal Jain (MSR)
- Mary Czerwinski (MSR)
- Desney Tan (MSR)

### **Cafeteria Design**



 Re-arranging cafeteria choices increases/decreases the consumption of food items by up to 25%

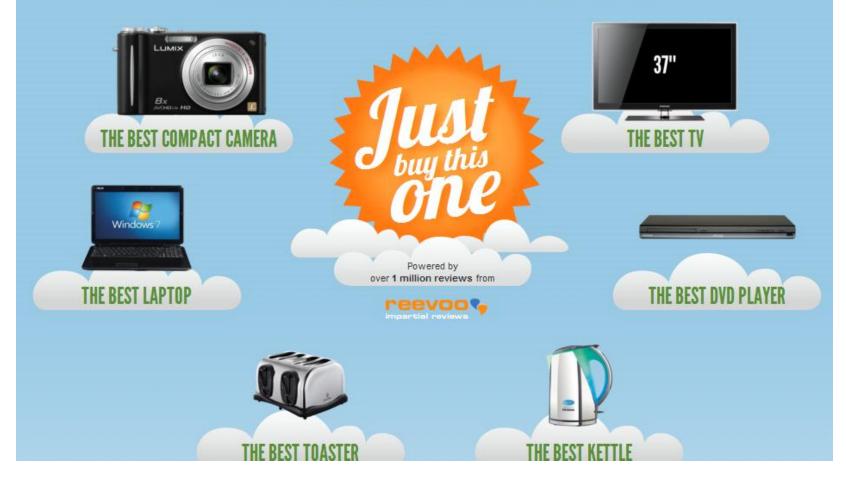
# 401(k) Plan Design

BrightScope Rating	0	Plan Details		0
Southwest Airlines Co.		Address	2702 Love Field Dr	
Plan: Southwest Airlines Pilots Retirement Savings Plan 🔻			Dallas, TX 75235	
lan: Southwest Airlines Fliots R	etirement savings Plan 📑	Industry	Air Transportation	
		Administrator	Richard Doherty	
	BrightScope Rating	Total Plan Assets	\$1,390,000,000	
	86	Active Participants	5,100	
_		Avg Account Balance	\$270,000	
Lowest Hotang	Average Rating Highest Kating	Top 3 Investment Hold	ings	
In Fear Croup	In Peer Group 55 86	1. Davis NY Venture		14%
	ulau haa tha hishaat	<ol> <li>American Funds Eur R5</li> </ol>	oPacific Growth Fund	149
rating in its peer grou	plan has the highest <sub>ion</sub>	<ol> <li>Ro</li> <li>3. Dodge &amp; Cox Balance</li> </ol>	ed Fund	91
& Help Improve This Plan	📌 Track This Plan			
	<u></u>	Other Companies in Po	eer Group	0
Plan Component Ratings	0	FedEx		82.1
Total Plan Cost	Averane	YRC Worldwide		59.5
Totarriancost	Areage	Con-way		55.8
Company Generosity	Great	Ryder System		45.8
CARLES IN	Beer Martine .	J.B. Hunt Transport Serv	ices	44.1
Investment Menu Quality	Great	Plan Service Providers		0
Participation Rate	Great	Auditor	Wagner, Eubank and	E.
			Nichols, LLP	
Deferral Rate	Great	Administration	The 401K Company	
Com nts Account Balances	Great	Consultant	Wurtz & Associates	
Add Comment (0)		Plan Data Vault		
	*	Please visit the	vault to keep your 401k	plan

 More choices in 401(k) plan selection leads to fewer employees enrolling.

# A new Way of Online Shopping

Millions of products. Thousands of shops. Too much choice. Why not stop shopping and start enjoying life?



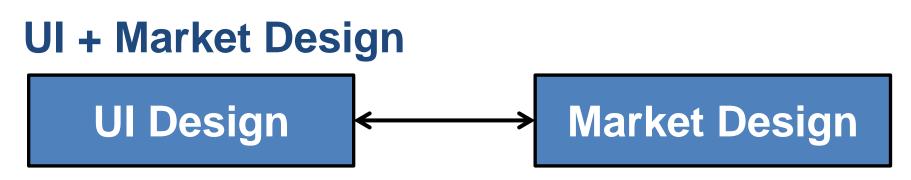
# Humans vs. Econs (Thaler & Sunstein)

### • Econs

- Perfectly rational
- Unlimited time to make a decision
- Unbounded computational resources for deliberation

### • Humans

- Cognitive costs
- Bounded time (opportunity costs)
- Bounded computational resources
- "Choice architecture" matters for humans!
- In electronic markets: many decisions of small value



- Why is UI design important:
  - 1<sup>st</sup> point of contact
  - UI design constrains the market design
  - UI defines how users express preferences
  - UI defines amount of "cognitive costs"

### **Trade-off: UI/Market Complexity vs. Expressiveness**

- Our earlier work: "Hidden Market Design"
  - *Hide* market complexities
  - Maintain high efficiency of the market

### Market User Interface Design

- Market User Interface:
  - 1. Which information is displayed to the user?
  - 2. What choices/how many choices are offered to the user?
- Research Questions:

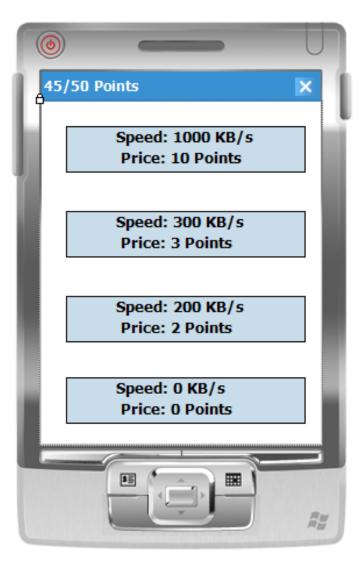
What is the optimal market user interface given that users have cognitive costs?

- Lab study with 53 users
- 53 users x 55 games x 6 time steps  $\approx$  17,500 data points

### Outline

- 1. Introduction: UI Design & Market Design
- 2. The 3G Bandwidth Allocation Game
- 3. Experiment Design and Results
- 4. Conclusion

### A Bandwidth Market User Interface



- What can we change about this market UI?
- We tested 4 UI Design Levers:
  - 1. # of choices
  - 2. Fixed vs. changing prices
  - 3. Fixed vs. situation-dependent choice sets
  - 4. UI optimized for optimal or behavioral play

### Game Demo

Time 59s/60s	Rounds Left 6/6	Tokens 30/30	Score \$0
Task Catego	my Importance		
Medium	Inportance		
	Speed: 900 l	KB/s	
	Value: \$1.2		
	Price: 9 Tok	tens	
	Speed: 300 l	KB/s	
	Value: \$0.3		
	Price: 3 Tok	tens	
	Speed: 100	KB/s	
	Value: - \$0.3		
	Price: 1 Tok	tens	
	Speed: 0 KB	/s	
	Value: - \$0.6		
	Price: 0 Tok	tens	

### Game Demo

Time 5s/7s	Rounds Left 4/6	Tokens 12/30	Score \$0.3
Task Cate			
mealum	Importance		
	Speed: 900 k	KB/s	
	Value: \$1.2		
	Price: 18 To	kens	
	Speed: 300 I	KB/s	
	Value: \$0.1		
	Price: 6 Tok	ens	
	Speed: 100 I	(B/s	
	Value: - \$0.1		
	Price: 2 Tok	ens	
	Speed: 0 KB	ls	
	Value: - \$1.0		
	Price: 0 Tok	ens	

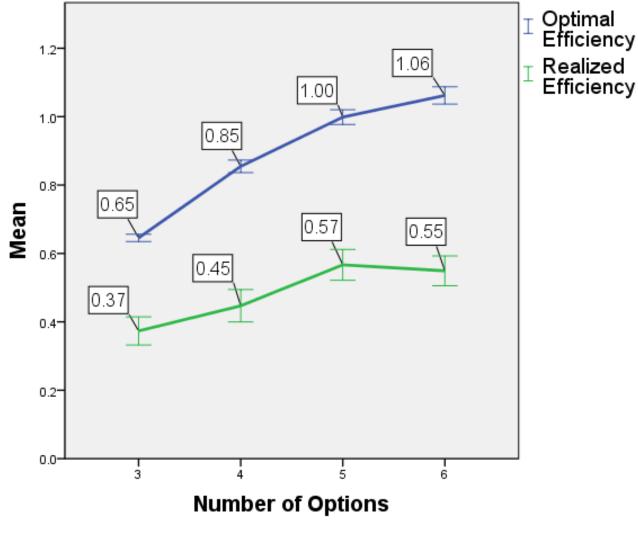
### **MDP Formulation of the Game**

- Formalize as a Markov Decision Process (MDP):
  - State space: Budget x Round x Values x Prices
  - Actions: Each affordable choice
  - Transitions: deterministic for budget/round, random for values/prices
- Solve the game optimally  $\rightarrow$  becomes gold standard
- Compute Q-values of each state-action pair: Q(s,a) = expected value from taking action a in state s, and following optimal policy afterwards

## **1. Design Lever: Number of Choices**

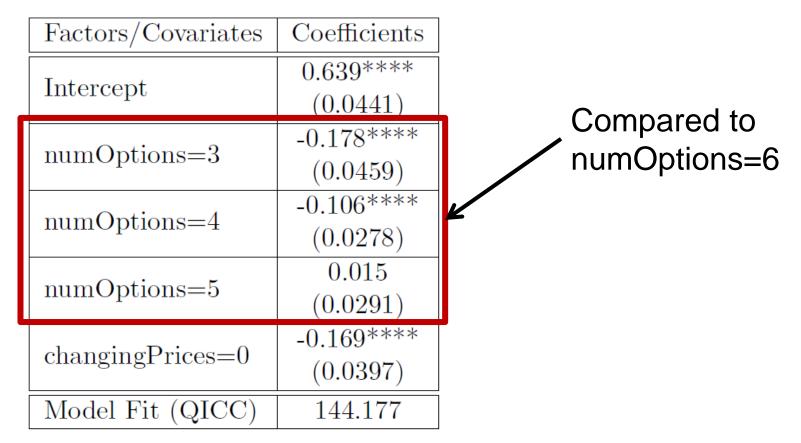
Time     Rounds L       4s/7s     6/6       Task Category	Time     Rounds L       5s/7s     6/6	Time 5s/7s	Rounds Left 6/6	Tokens 30/30	Time 4s/7s	Rounds Left 6/6	Tokens 30/30	Score \$0
High Importance	High Importance	Task Categ			- Task Categ	portance		
Speed: Value: Price: (	Speed: Value: Price:		Speed: 400 Value: - \$0.			Speed: 500	KB/s	
Speed: Value: :	Speed:		Price: 8 Tol			Value: \$0.9 Price: 10 To	okens	
Price: 4	Value: Price: 4		Speed: 300 Value: - \$0.1 Price: 6 Tol	2		Speed: 400 Value: \$0.6 Price: 8 Tol		
Value: - Price: (	Speed: Value: Price: 2		Speed: 200 Value: - \$0.3 Price: 4 Tol	3		Speed: 300 Value: \$0.3	KB/s	
	Speed: Value: - Price: (		Speed: 100 Value: - \$0. Price: 2 Tol	7		Price: 6 Tol Speed: 200 Value: \$0.3 Price: 4 Tol	KB/s	
			Speed: 0 KE Value: - \$0.9 Price: 0 Tol	9		Speed: 100 Value: \$0.0 Price: 2 Tol		
						Speed: 0 KB Value: - \$0.7 Price: 0 Tol	7	

### Number of Choices & Efficiency (1/2)



Error Bars: 95% CI

# Number of Choices & Efficiency (2/2)



• Repeated measures linear regression (using GEE) for the dependent variable Efficiency. The individual coefficient is statistically significant at the \*10% level, the \*\*5% level, the \*\*\*1% level, and at the \*\*\*\*0.1 % level.

# 2. Design Lever: Fixed vs. Changing Choices

- We don't know users' values  $\rightarrow$  learning:
  - Each choice is a signal from the user
  - Learn a mapping from context to value estimate
  - Present users with situation-dependent choices!

TimeRounds LeftTokensScore6s/10s6/630/30\$0	TimeRounds LeftTokensScore3s/10s6/630/30\$0	TimeRounds LeftTokensScore4s/10s6/630/30\$0
Task Category Low Importance	Task Category Medium Importance	Task Category High Importance
Speed: 400 KB/s Value: - \$0.1 Price: 8 Tokens	Speed: 600 KB/s     Speed: 1000 KB/s       Value: \$0.7     Value: \$1.8       Price: 12 Tokens     Price: 20 Tokens	
Speed: 200 KB/s	Speed: 200 KB/s	Speed: 400 KB/s
Value: - \$0.3	Value: \$0.0	Value: \$0.6
Price: 4 Tokens	Price: 4 Tokens	Price: 8 Tokens
Speed: 100 KB/s	Speed: 100 KB/s	Speed: 200 KB/s
Value: - \$0.5	Value: - \$0.1	Value: \$0.3
Price: 2 Tokens	Price: 2 Tokens	Price: 4 Tokens
Speed: 0 KB/s	Speed: 0 KB/s	Speed: 0 KB/s
Value: - \$0.7	Value: - \$0.6	Value: - \$1.2
Price: 0 Tokens	Price: 0 Tokens	Price: 0 Tokens

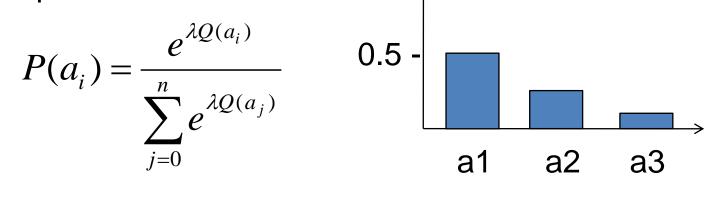
# **Changing Choices & Efficiency**

Factors/Covariates	Coefficients	
Intercept	$0.405^{****}$	
Intercept	(0.0410)	
changingChoices	$0.077^{**}$	
changingenoices	(0.0376)	
Model Fit (QICC)	106.552	

 Repeated measures linear regression (using GEE) for the dependent variable Efficiency. The individual coefficient is statistically significant at the \*10% level, the \*\*5% level, the \*\*\*1% level, and at the \*\*\*\*0.1 % level.

# 3. Design Lever: UI Optimization

Quantal-Response Model:



1.0 -

- 1. Learning + Model Building: Compute maximum likelihood estimate of  $\lambda$ .
- 2. UI Optimization: Search through design space, and select best UI (i.e., achieving highest expected efficiency)
  - a) Assuming optimal play
  - b) Assuming behavioral play (according to user model)
- **3. Experiment:** Compare the two resulting UIs

# **UI Optimization**

Time 3s/7s	Time Rounds Left Token 3s/7s 6/6 30/30				
Task Categ Medium	Importance				
	Speed: 900 F Value: \$1.1 Price: 27 To				
	Speed: 300 F Value: \$0.2 Price: 9 Tok				
	Speed: 100 K Value: - \$0.3 Price: 3 Tok	}			
	Speed: 0 KB Value: - \$1.0 Price: 0 Tok	)			

(a) Optimized for Optimal Play

Time 5s/7s	Fime Rounds Left Tokens s/7s 6/6 30/30				
Task Categ Medium	Importance				
	Speed: 400 F Value: \$0.4 Price: 12 To				
	Speed: 300 F Value: \$0.2 Price: 9 Tok				
	Speed: 100 F Value: - \$0.3 Price: 3 Tok	}			
	Speed: 0 KB Value: - \$1.0 Price: 0 Tok	)			

(b) Optimized for Behavioral Play

# **UI Optimization & Efficiency (1/3)**

Factors/Covariates	(1)
Intercept	0.462****
moropo	(0.0501)
changingChoices	$0.077^{**}$ (0.0376)
	-0.111****
optimizedForSubOpt	(0.0334)

### → **Lower** Efficiency with UI optimized for behavioral play

What happened?

# **UI Optimization & Efficiency (2/3)**

Factors/Covariates	(1)	(2)
Intercept	0.462****	0.004
шенере	(0.0501)	(0.0639)
changingChoices	$0.077^{**}$	0.08**
enangingenoices	(0.0376)	(0.0367)
optimizedForSubOpt	-0.111****	-0.119****
optimized of of the optimized of the opti	(0.0334)	(0.344)
Lambda		0.103****
Lambya		(0.0110)

 $\rightarrow$  The efficiency depends on users' "degree of rationality"

# **UI Optimization & Efficiency (3/3)**

Factors/Covariates	(1)	(2)	(3)
Intercept	0.462****	0.004	0.053
mercept	(0.0501)	(0.0639)	(0.1417)
changingChoices	0.077**	0.08**	0.080**
changing e horees	(0.0376)	(0.0367)	(0.0365)
optimizedForSubOpt	-0.111****	-0.119****	
optimized of Subopt	(0.0334)	(0.344)	
Lambda		$0.103^{****}$	$0.100^{****}$
Lumbua		(0.0110)	(0.0253)
SmallLambda=1			-0.065
			(0.0530)
OptimizedForSubOpt			-0.069
*smallLambda=1			(0.0500)
OptimizedForSubOpt			$-0.174^{****}$
*SmallLambda=0			(0.0391)

- Large Losses for "more rational" users
- No statistically significant difference for "less rational" users
- → Suggests: personalized market user interfaces (future work)

## **Statistical Analysis of Behavioral Effects**

- The UI-Optimization (based on quantal-reponse model) achieved lower instead of higher efficiency!
- $\rightarrow$  Question: which other behavioral effects are at play?
- Detailed statistical analysis of "Optimal Choice": which factors influence users' decision performance?

### **Q-Values: Optimal Choices?**

Factors	(1)		(2)	
	В	$\operatorname{Exp}(B)$	В	Exp(B)
Intercept	$-0.816^{****}$	$0.442^{****}$	$-1.529^{****}$	$0.217^{****}$
Intercept	(0.1408)		(0.1593)	
Lambda	$0.150^{****}$	$1.162^{****}$	$0.161^{****}$	$1.175^{****}$
	(0.0180)		(0.0197)	
QvalueDiff			$5.868^{****}$	353.713****
SvarueDiii			(0.4353)	

→ Users respond strongly to Q-value differences
 → are forward-looking in playing the MDP!

## **UI Complexity and Position Effects**

Factors/Covariates	(1)			
	В	Exp(B)		
Intercept	-0.341	0.711		
intercept	(0.2664)			
Lambda	0.150****	1.162****		
	(0.0189) 4.428****	00 741 ****		
QvalueDiff	(0.5060)	83.741****		
	-0.151**	0.860**		
female?	(0.0687)	0.000		
C1	-0.086*	.917*		
numChoices	(0.0486)			
optRelativeRank=5	-3.884****	$0.021^{****}$		
optiverativervank=5	(0.9824)			
optRelativeRank=4	-1.902****	$0.149^{****}$		
	(0.4482)	0.000****		
optRelativeRank=3	-1.205****	0.300****		
	(0.2692) -0.619**	0539**		
optRelativeRank=2	(0.2784)	0339		
	-0.169	0.845		
optRelativeRank=1	(0.2272)	0.0.10		
ant Dalation Dank 0	0	1		
optRelativeRank=0				
<u>,</u>	-			

### **Loss Aversion**

Factors/Covariates	(1)		(2)		(3)	
	В	Exp(B)	В	Exp(B)	В	Exp(B)
Intercept	-0.341	0.711	-0.339	0.713	-0.439*	0.645*
Intercept	(0.2664)		(0.2584)		(0.2558)	
Lambda	$0.150^{****}$	$1.162^{****}$	$0.150^{****}$	$1-162^{****}$	$0.145^{****}$	$1.156^{****}$
Lambda	(0.0189)		(0.0188)		(0.0197)	
QvalueDiff	4.428****	83.741****	4.427****	83.671****	4.599****	99.387****
	(0.5060)		(0.5039)		(0.4998)	
female?	-0.151**	$0.860^{**}$	-0.151**	0.860**	-0.166**	$0.847^{**}$
	(0.0687)		(0.0695)		(0.0734)	
numChoices	-0.086*	.917*	-0.087*	0.917*	-0.065	0.937
	(0.0486)		(0.0513)		(0.0584)	
optRelativeRank=5	-3.884****	$0.021^{****}$	-3.881****	0.021****	-4.068****	$0.017^{****}$
opereeration of the second sec	(0.9824)		(0.9925)		(1.0438)	
optRelativeRank=4	-1.902****	$0.149^{****}$	-1.900****	$0.150^{****}$	-1.853****	0.157****
operender er ann 1	(0.4482)		(0.4594)		(0.4948)	
optRelativeRank=3	$-1.205^{****}$	0.300****	$-1.203^{****}$	0.300****	$-1.183^{****}$	0.306****
opereorativeration of	(0.2692)		(0.2974)		(0.3372)	
optRelativeRank=2	-0.619**	0539**	-0.617**	$0.539^{**}$	-0.523	0.593
opercenterverunk-2	(0.2784)		(0.2967)		(0.3322)	
optRelativeRank=1	-0.169	0.845	-0.168	0.845	-0.178	0.837
operenter veranik-1	(0.2272)		(0.2358)		(0.2493)	
optRelativeRank=0	0	1	0	1	0	1
			-0.002	0.998	-1.314****	0.269****
optimalChoiceNegative?			(0.0896)		(0.2270)	
currentCategory=2					1.539	4.058
0					(0.2088)	
currentCategory=1					0.032	1.033
					(0.1282)	
currentCategory=0					0	1

# Conclusion

- Summary:
  - Introduced "market user interface design" paradigm
  - Analyzed 4 design levers (# choices, price dynamics, choice set composition, UI optimization)
  - Found many important behavioral factors
  - Significant differences between individual users
- Future work:
  - Personalized UIs, dependent on individual user's abilities
  - Iterative, real-time UI optimization
- Feedback very welcome: <a href="mailto:seuken@ifi.uzh.ch">seuken@ifi.uzh.ch</a>
- Thank you for your attention!

### Male vs. Female Users: Optimal Choices

Factors	(4)			
	B Exp(B)			
Intercept	$-1.398^{****}$	$0.247^{****}$		
Intercept	(0.1657)			
Lambda	$0.151^{****}$	$1.163^{****}$		
Lamoqa	(0.0176)			
QvalueDiff	$5.884^{****}$	359.392****		
g, and e D m	(0.4358)			
Age				
formals?	-0.130*	0.878*		
female?	(0.0716)			
Fit (QICC)	(3588.483)			

→ Female users miss the optimal choice more often, but...
...male users make more severe mistakes

## Male vs. Female Users: Value Loss (1/2)

Factors/Covariates	(1)		
	В	Beta	
Intercept	$0.138^{****}$		
	(0.0118)		
Lambda	$-0.11^{****}$	-0.141****	
Lambda	(0.0015)		
female?	-0.004	-0.018	
	(0.0032)		
Goodness of Fit (QICC)	36.302		
Cases Considered	All (N=2756)		

# Male vs. Female Users: Value Loss (2/2)

Factors/Covariates	(1)		(2)	
	В	$\operatorname{Beta}$	В	$\operatorname{Beta}$
Intercept	$0.138^{****}$		0.231****	
Intercept	(0.0118)		(0.0154)	
Lambda	$-0.11^{****}$	$-0.141^{****}$	-0.013****	-0.151****
Lambqa	(0.0015)		(0.0021)	
female?	-0.004	-0.018	- 0.016***	-0.066***
Termane.	(0.0032)		(0.0056)	
Goodness of Fit (QICC)	36.302		24.026	
Cases Considered	All $(N=2756)$		OptChoice= $0$ (N=1246)	

 $\rightarrow$  Male users make more severe mistakes

# Loss Aversion (1/2)

Factors/Covariates	(1)		(2)	
	В	Exp(B)	В	Exp(B)
Intercept	-0.341	0.711	-0.339	0.713
mercept	(0.2664)		(0.2584)	
Lambda	$0.150^{****}$	$1.162^{****}$	$0.150^{****}$	$1-162^{****}$
Lamoua	(0.0189)		(0.0188)	
QvalueDiff	4.428****	83.741****	4.427****	83.671****
al caracity in	(0.5060)		(0.5039)	
female?	$-0.151^{**}$	0.860**	$-0.151^{**}$	0.860**
Termine :	(0.0687)		(0.0695)	
numChoices	-0.086*	.917*	-0.087*	0.917*
numenoice	(0.0486)		(0.0513)	
optRelativeRank=5	-3.884****	0.021****	-3.881****	0.021****
opercenter of	(0.9824)		(0.9925)	
optRelativeRank=4	-1.902****	$0.149^{****}$	-1.900****	$0.150^{****}$
	(0.4482)		(0.4594)	
optRelativeRank=3	-1.205****	0.300****	-1.203****	0.300****
1	(0.2692)		(0.2974)	
optRelativeRank=2	-0.619**	0539**	-0.617**	0.539**
-F	(0.2784)		(0.2967)	
optRelativeRank=1	-0.169	0.845	-0.168	0.845
1	(0.2272)		(0.2358)	
optRelativeRank=0	0	1	0	1
optimalChoiceNegative?			-0.002	0.998
op and a choice regativer			(0.0896)	

### **Loss Aversion: Interaction Effect**

Factors/Covariates	(1)		
Intercept	-0.433*	0.648*	
Intercept	(0.2514)		
Lambda	$0.144^{****}$	$1.155^{****}$	
Lamoda	(0.0203)		
QvalueDiff	$4.605^{****}$	100.016****	
QvaldeDill	(0.4918)		
female?	$-0.174^{**}$	0.840**	
	(0.0763)		
numChoices	-0.066	0.936	
numenoices	(0.0581)		
optRelativeRank=5	$-4.086^{****}$	$0.017^{****}$	
optitelativertalik=5	(1.0302)		
optRelativeRank=4	$-1.846^{****}$	$0.158^{****}$	
optitelativertalik=4	(0.4798)		
optRelativeRank=3	$-1.186^{****}$	0.305****	
optitelati vertalik=5	(0.3292)		
optRelativeRank=2	-0.531	0.588	
optitelati vertalik—2	(0.3342)		
optRelativeRank=1	-0.186	0.831	
optitelativertalik=1	(0.2476)		
optRelativeRank=0	0	1	
$[optimalChoiceNegative=1 \times$	0.248**	1.281**	
oneHigherNegative= $1 \times \text{currentCategory}=2$	(0.1255)		
[optimalChoiceNegative=1 ×	0.070	1.073	
oneHigherNegative= $0 \times \text{currentCategory}=2$	(0.4076)		
[optimalChoiceNegative=0 ×	-1.199	0.301	
oneHigherNegative=0 × currentCategory=2]	(1.7347)		
$[optimalChoiceNegative=1 \times$	-1.038***	$0.354^{***}$	
oneHigherNegative= $1 \times \text{currentCategory}=1$ ]	(0.4043)		
$[optimalChoiceNegative=1 \times$	-1.575****	0.207****	
oneHigherNegative= $0 \times \text{currentCategory}=1$ ]	(0.3256)		
$optimalChoiceNegative=0 \times$	0.066	1.068	
oneHigherNegative= $0 \times \text{currentCategory}=1$ ]	(0.1327)		
[optimalChoiceNegative=1 $\times$	-0.322	0.725	
oneHigherNegative= $0 \times \text{currentCategory}=0$ ]	(0.6351)		
$[optimalChoiceNegative=0 \times$	0	1	
oneHigherNegative= $0 \times \text{currentCategory}=0$ ]			