

# Decision conflict in the newsvendor game

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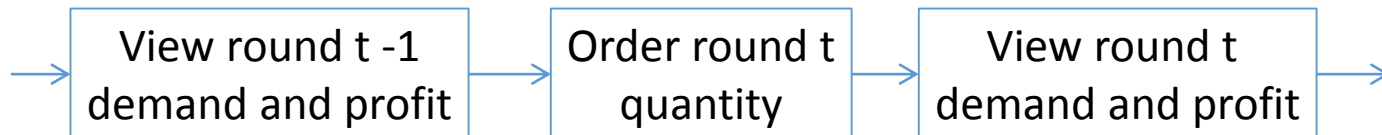
- Background on the newsvendor game
- Decision conflict
- Description of the experiment and results

# Newsvendor game

- Workhorse model in operations management, especially in *behavioural operations*

# Newsvendor game

- Agent maintains inventory selling a single product
- Orders stock  $q$  before demand  $x$  is realized
- Stock is worthless after the selling season: both **overage** and **underage** incur profit losses
- Normative solution  $q^* \neq \underline{x}$
- Usually repeated with a stable demand distribution



# Pull to center bias

- Subjects choose between  $q^*$  and  $\underline{x}$
- Overordering in low margin and underordering in high margin conditions
- Observed in various subject pools (students, managers), incentive mechanisms, etc.
- Repetition decreases the bias but does not completely abolish it

# Pull to center bias

(Moritz, Hill, Donohue 2011)

<b>Study</b>		<b>High Margin: % above mean</b>	<b>Low Margin: % below mean</b>
Schweitzer and Cachon (2000)	Study 1	18%	10.60%
	Study 2a	25%	5%
	Study 2b	4%	2.70%
Bostian <i>et al.</i> (2008)	Study 1	32%	22%
	Study 2	22%	12%
Bolton and Katok (2008)	Study 1	22%	12%
Kremer <i>et al.</i> (2010)	Study 1	11%	7%
	Study 2	18%	10%

# Pull to center bias: behavioral explanations

- Anchoring on  $x_{t-1}$  (Schweitzer and Cachon 2000)
- Preference to minimize ex-post inventory error  $|x - q|$
- Decision errors (noise) (Su 2008)
- Bounded rationality (Ockenfels and Selten 2014)
- Overconfidence in order variation estimation (Ren and Croson 2013)
- Framing effects (Kremer et al. 2010)

# Pecuniary and nonpecuniary motives

- Literature on behavioural economics shows that people care about nonpecuniary motives even without material consequences for selfish decisions (dictator games)
- Newsvendor game is often **framed** as maintaining inventory in order to satisfy customer demand: *both* share the damage caused by underage
- Compare to a **dictator game** where one decides about a resource allocation for oneself and another player who does not have a say on the decision



$$\max_q p \min(x, q) - cq$$

$$\min f(x - q)$$



# Conjecture

- *Decision conflict between pecuniary and non-pecuniary motives determines behaviour in the Newsvendor game*

# Decision conflict

- Human decision makers overcome decision conflict by cognitive regulation
  - The more there is conflict between the decision alternatives, the higher is the need for cognitive regulation
  - I.e. impulsive and quick decisions are more likely to occur in low-conflict situations
- Evidence accumulation models predict that **decision time** increases in decision conflict (e.g. Krajbich & Rangel 2011)
- Therefore we can use decision time as a process measure to indicate conflictedness

# Decision conflict

- The exact definition is context-dependent
- In many decision situations the conflict is between selfish and social motives
- Often associated with *cognitive dissonance*
  - Inconsistency with behaviours or values
  - E.g. a smoker who knows that smoking is bad but still smokes because he finds it pleasurable

# Example: Decision conflict in a social dilemma

	<b>Cooperate</b>	<b>Defect</b>	<b>Punish</b>
<b>Cooperate</b>	1 , 1	-2 , 2	-5 , 1
<b>Defect</b>	2 , -2	0 , 0	-3 , -2
<b>Punish</b>	1 , -5	-2 , -3	-5 , -5

(Dreber, Rand, Fudenberg, Nowak 2008)

# Example: Decision conflict in a social dilemma

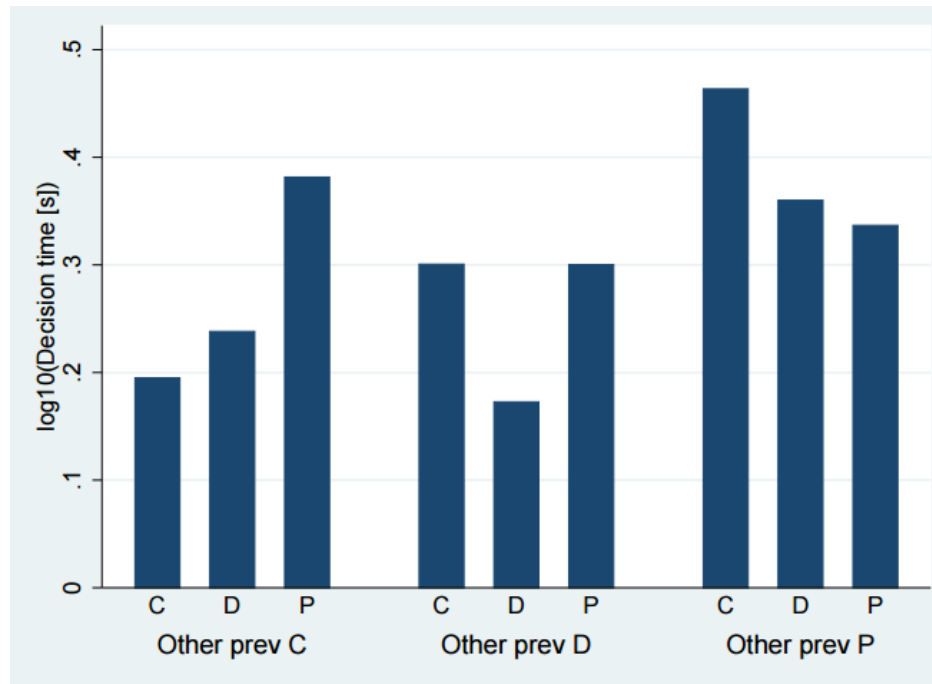
- When other (row player) defects,
  - Responding in kind by “Defect” is least conflicted
  - Forgiving and escalating are more conflicted

	<b>Cooperate</b>	<b>Defect</b>	<b>Punish</b>
<b>Cooperate</b>	1 , 1	-2 , 2	-5 , 1
<b>Defect</b>	2 , -2	0 , 0	-3 , -2
<b>Punish</b>	1 , -5	-2 , -3	-5 , -5

(Dreber, Rand, Fudenberg, Nowak 2008)

# Example: Decision conflict in a social dilemma

- When other (row player) defects,
  - Responding in kind by “Defect” is fastest
  - Forgiving and escalating are more slower




(Courtesy of Dave Rand)

# Social value orientation (SVO)

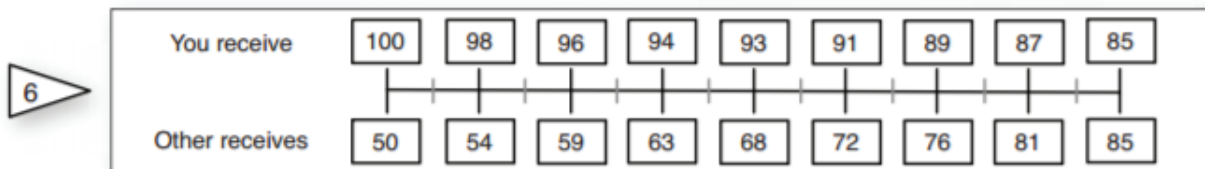
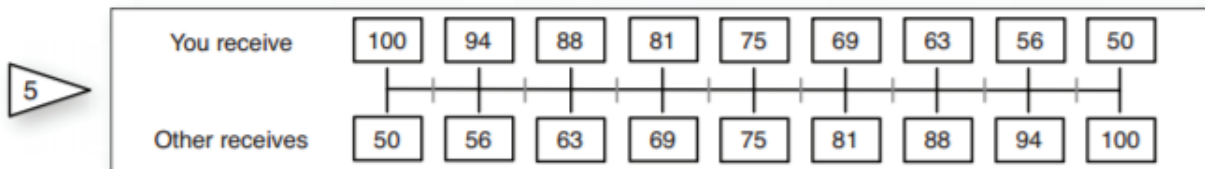
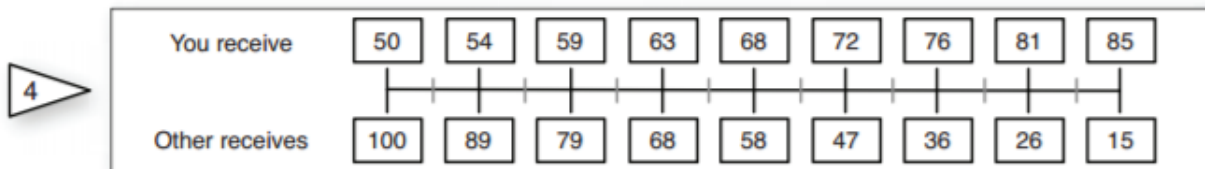
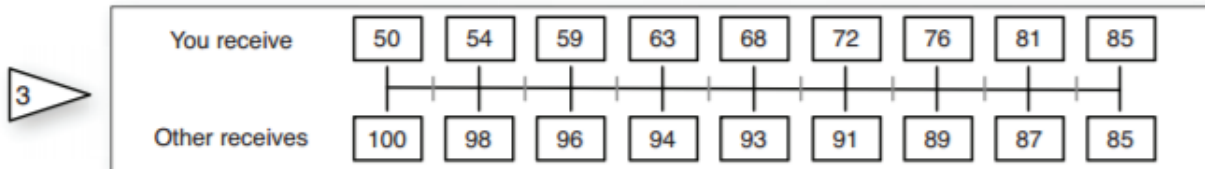
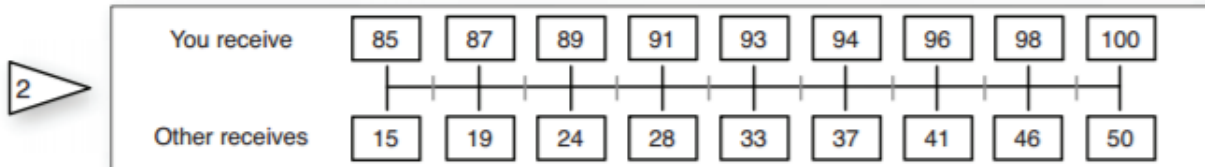
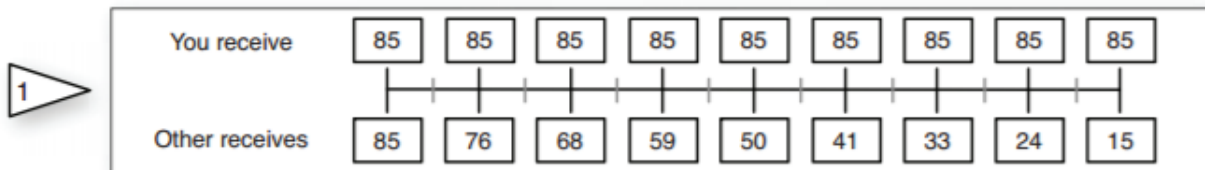
- A continuous measure of social preferences (Murphy et al. 2011)
- 6 dictator game allocations
- Provides information about **individual predispositions** to value nonpecuniary motives

Option 1	Option 2
85 to me	100 to me
85 to the other	50 to the other

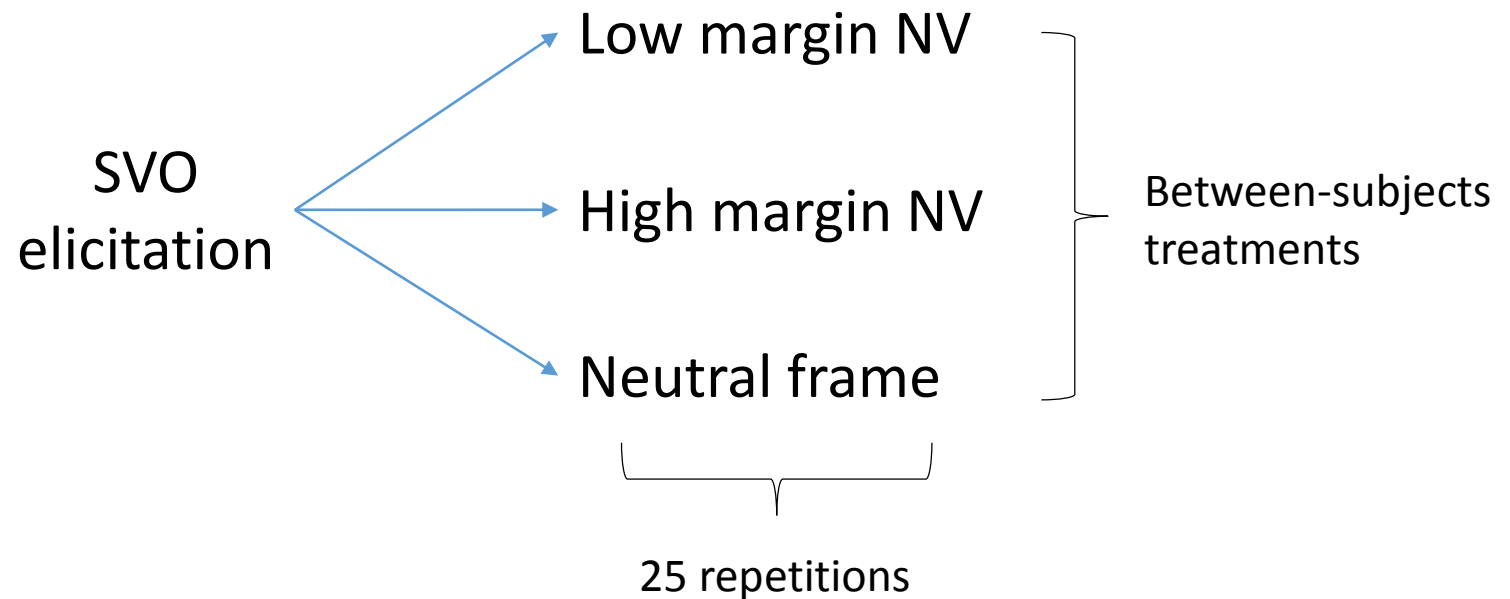
About 65%  
choose this







# Experimental study



- 330 incentivised international participants from Prolific Academic

# Experimental study

- High margin profit table

Order	Demand						
	300	400	500	600	700	800	900
	1/7	1/7	1/7	1/7	1/7	1/7	1/7
<b>300</b>	420	420	420	420	420	420	420
<b>400</b>	382	560	560	560	560	560	560
<b>500</b>	344	522	700	700	700	700	700
<b>600</b>	306	484	662	840	840	840	840
<b>700</b>	268	446	624	802	980	980	980
<b>800</b>	230	408	586	764	942	1120	1120
<b>900</b>	192	370	548	726	904	1082	1260

# Experimental study

- Low margin profit table

Order	Demand						
	500	550	600	650	700	750	800
	1/7	1/7	1/7	1/7	1/7	1/7	1/7
500	780	780	780	780	780	780	780
550	494	858	858	858	858	858	858
600	208	572	936	936	936	936	936
650	-78	286	650	1014	1014	1014	1014
700	-364	0	364	728	1092	1092	1092
750	-650	-286	78	442	806	1170	1170
800	-936	-572	-208	156	520	884	1248

# Experimental study

- Neutral framing profit table

Decision	State of the world						
	S1	S2	S3	S4	S5	S6	S7
	1/7	1/7	1/7	1/7	1/7	1/7	1/7
A	780	780	780	780	780	780	780
B	494	858	858	858	858	858	858
C	208	572	936	936	936	936	936
D	-78	286	650	1014	1014	1014	1014
E	-364	0	364	728	1092	1092	1092
F	-650	-286	78	442	806	1170	1170
G	-936	-572	-208	156	520	884	1248

# Hypotheses

- **Intermediate** situation: neither demand is satisfied nor order quantity is at the normative level
- **Extreme** situation: either demand is satisfied or order quantity is at the normative level
  
- **H1:** Extreme and intermediate situations in round  $t-1$  lead to different decision times in round  $t$
- **H2:** Intermediate situations in round  $t-1$  lead to higher quantity in round  $t$  than extreme situations

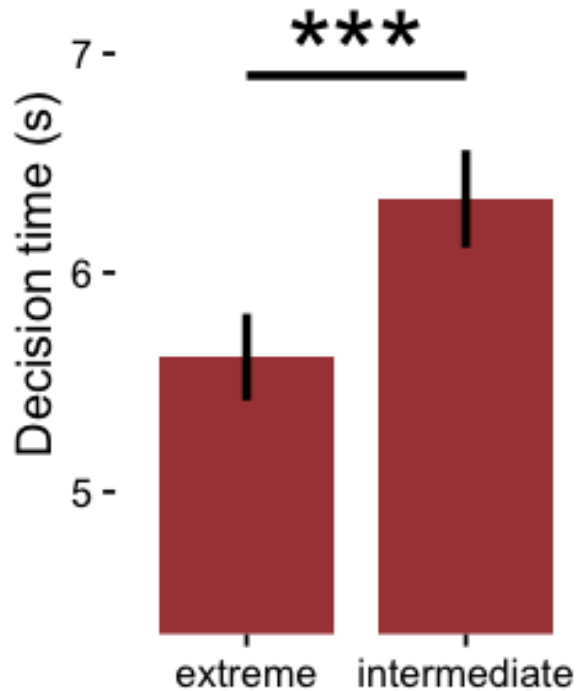
# Results

- Pull-to-center pattern is replicated
- Demand anchoring:  $q_t$  depends on  $x_{t-1}$  in low and high treatments but not in neutral treatment
- In 11.3% of rounds subjects choose  $q^*$  in low margin and in 16.4% in high margin as opposed to 25% in the neutral treatment
- SVO does not directly affect order quantity

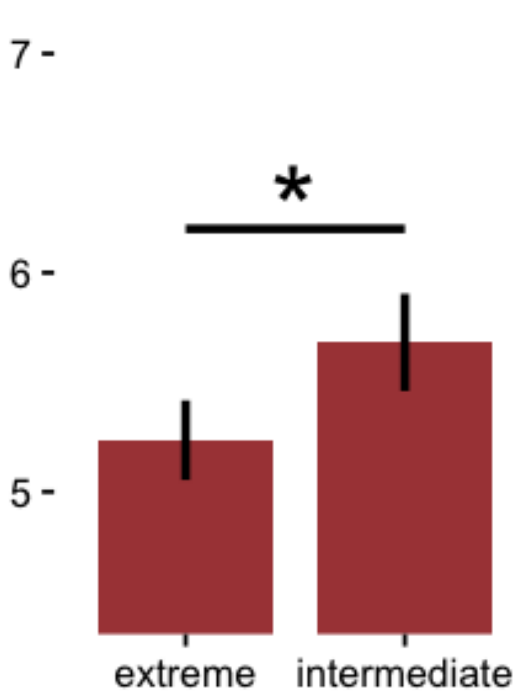
	Mean q (SD)		Mean profit	$q^*$	$\bar{x}$
Low	633.25	(66.25)	613.08	550	650
High	655.81	(147.96)	631.13	800	600
Neutral	596.74	(68.51)	686.87	550	650

# Results: H1 is supported

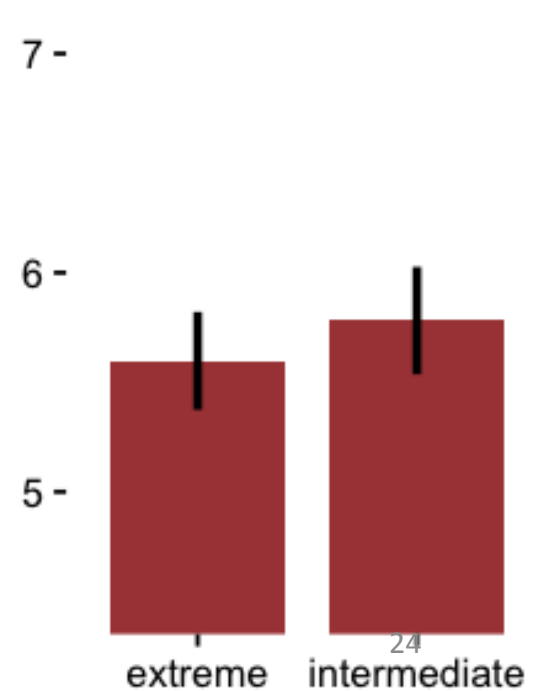
Low margin



High margin



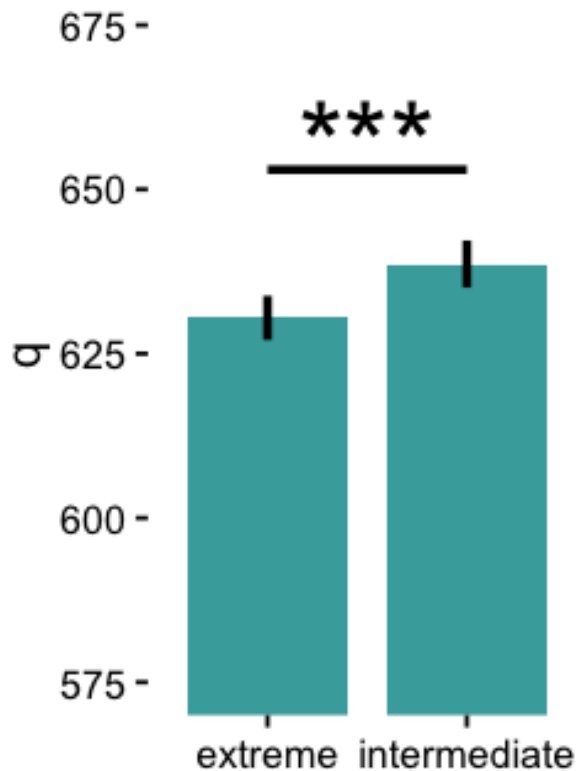
Neutral



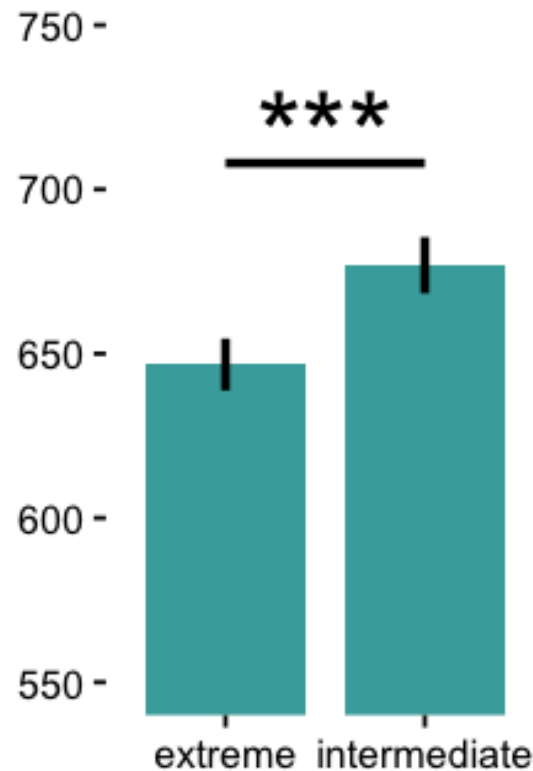


# Results: H2 is supported

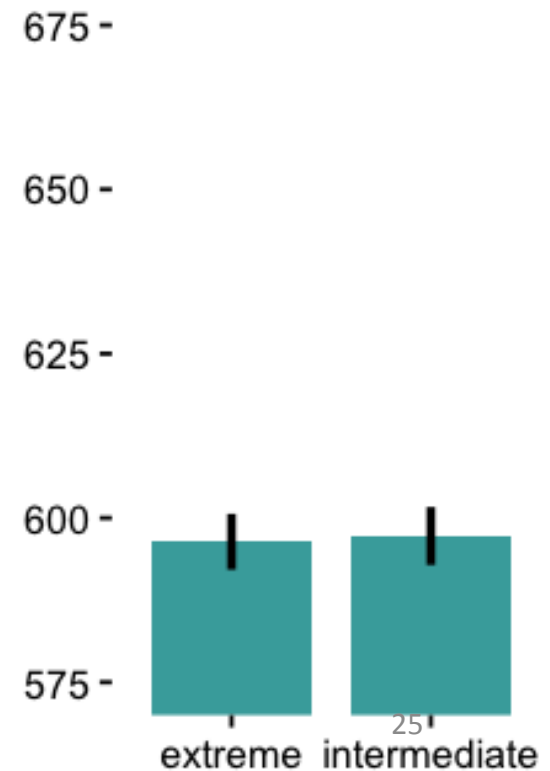
Low margin



High margin



Neutral



# Another source of conflict?

- Conflict may arise not only from extreme/intermediate situations but **also when choosing  $q^*$**  (effective only in low treatment)
- Logit regression shows that probability of choosing  $q^*$  in round  $t$  is not affected by decision time

	Low	High	Neutral
	Estimate (SEM)	Estimate (SEM)	Estimate (SEM)
Intercept	-2.42 (0.13) ***	-1.86 (0.12) ***	-1.5 (0.18) ***
Decision time	0.0021 (0.012)	-0.022 (0.014)	-0.011 (0.01)
SVO	-0.0031 (0.01)	0.0061 (0.0084)	0.013 (0.014)
Decision time x SVO	0.00082 (0.00097)	0.0024 (0.00092) **	-0.00026 (0.00077)

(Dependent variable: whether  $q=q^*$  or not)

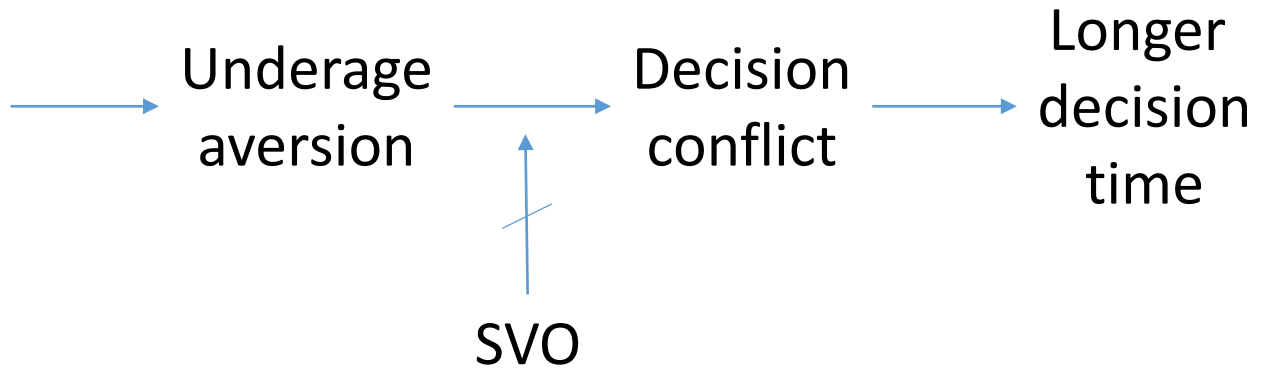
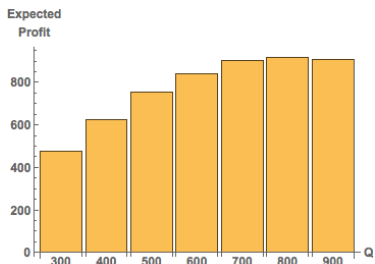
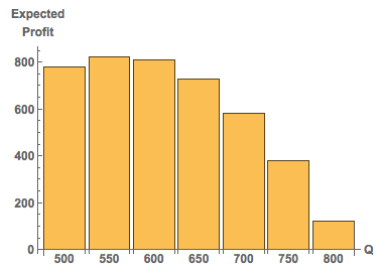
# Profits wrt. decision time

- In low margin profit decreases in decision time
- In high margin profit increases in decision time
- Neutral framing: no dependence

	Low		High		Neutral	
	Estimate	(SEM)	Estimate	(SEM)	Estimate	(SEM)
Intercept	606.29	(9.83) ***	629.88	(4.45) ***	680.16	(8.94) ***
Decision time	-6.05	(1.79) ***	3.56	(0.87) ***	-0.96	(1.02)
SVO	0.18	(0.75)	0.085	(0.32)	1.19	(0.66)
Decision time x SVO	0.19	(0.13)	-0.09	(0.058)	0.09	(0.079)

(Dependent variable: profit)

# Conclusions



- Krajbich, I. and Rangel, A., 2011. Multialternative drift-diffusion model predicts the relationship between visual fixations and choice in value-based decisions. *PNAS* 108(33), pp. 13852-57.
- Kremer, M., Minner, S. and Van Wassenhove, L.N., 2010. Do random errors explain newsvendor behavior? *Manufacturing & Service Operations Management*, 12(4), pp. 673-681.
- Murphy, R.O., Ackermann, K.A. and Handgraaf, M., 2011. Measuring social value orientation. *Judgment and Decision Making*, 6(8), pp. 771-781.
- Ockenfels, A. and Selten, R., 2014. Impulse balance in the newsvendor game. *Games and Economic Behavior*, 86, pp. 237-247.
- Ren, Y. and Croson, R., 2013. Overconfidence in newsvendor orders: An experimental study. *Management Science*, 59(11), pp. 2502-2517.
- Schweitzer, M.E. and Cachon, G.P., 2000. Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence. *Management Science*, 46(3), pp. 404-420.
- Su, X., 2008. Bounded rationality in newsvendor models. *Manufacturing & Service Operations Management*, 10(4), pp. 566-589.