Regret Minimization, Path Dependence, and Attribute Non-attendance in Discrete Choice Experiments

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Introduction

- Discrete Choice Experiment (DCE) is increasingly used in nonmarket valuation, to elicit environmental preferences (Louiviere et al 2000, Kanninen 2007)
  - Several choice sets
  - Each choice set: multiple alternatives (policies, programs), including "opting out" or "status quo"
  - Each alternative: combinations of values of "attributes"
- Rational decision-making: utility maximization
  - Utility from an alternative: independent of other alternatives
- Limitations
  - Behavioral decision heuristics not incorporated
  - Incentive compatibility

Decision Heuristics

- Behavioral departures from rational decision-making
  - **Attributes processing:** Cancellation of shared attributes/Elimination by thresholds (e.g.,Tversky, 1972; Houston and Sherman, 1995; Layton and Hensher, 2010; Swait, 2001; Hensher and Rose, 2012)
  - **Reference dependent/Regret theory (**Tversky & Kahneman, 1981; Bell, 1982; Fishburn, 1982; Loomes and Sugden, 1982)
  - **Learning/adaptive heuristics** (Kahneman, Slovic & Tversky, 1982; Hart 2005)

- Existing literatures addressing behavioral decisions within DCE
  - ANA (Attribute Non-Attendance) (e.g., Hensher et al., 2005)
  - RM (Regret Minimization) (e.g., Chorus et al, 2008, 2010)

Random Regret Minimization (RRM)

- Chorus (2010): generalize anticipated regret to RRM in DCE
- Reference dependence: utility/regret from one alternative depends on other alternatives in the choice set:
  - Utility = f(own attributes, reference attributes), + max utility/min regret (RRM)
  - Utility = f(own attributes), + max utility (RUM)
- Regret of choosing program i for each attribute m::
  - Compare with *each* alternative $j \neq i$: $x_{jm} - x_{im}$
  - $x_{jm} - x_{im} < 0$ - rejoice (gain); $x_{jm} - x_{im} > 0$ - regret (loss)
- Decision: min anticipated regret + regret aversion

- Limitations
  - What are the reference points (current/previous choice sets, SQ experience)
  - Weights of multiple reference points

Attribute Non-Attendance (ANA)

- Attributes elimination through ignoring or no attending to them (Hensher et al., 2005) strategically/unconsciously
- ANA in DCE:
    - Stated ANA (e.g., Hensher et al., 2005)
    - Inferred ANA (e.g., Hensher &Greene, 2010)
    - Eyes tracking ANA (e.g., Spinks & Mortimer, 2015)
- Inferred ANA:
    - The Equality-Constrained Latent Class (ECLC) ANA (e.g., Scarpa et al., 2009)
    - Coeffs (ANA_attributes) = 0; Coeffs (other attributes) same across classes
- Limitations:
    - ANA or preference heterogeneity
    - ANA or other decision heuristics (e.g., eliminated by thresholds/references but not completely cancelled or ignored)
    - Pattern of ANA in repeated choices

What we do, and what we find

- Examine the interlinkage of ANA and RRM
  - Develop the RRM to account for different reference points
  - Incorporate two decision heuristics (RRM + ANA) within a single model
  - Question: Ignorance vs reference dependence regret min?
- Test the decision heuristics pattern in repeated choices
  - Account for path dependence
  - Separately test each model on each choice set + compare across choice sets
  - Questions: Consistent strategy vs adaptive pattern?

- Attributes are processed in a reference dependent manner
  - Reference dependent RM with multiple reference points with different weights
  - ANA no longer exists after *path dependence* is controlled
  - Adaptive decision heuristics over repeated choices

Note: This program is not expected to reduce corn yield with appropriate application rates
Expected N savings are based on average application rate of 170 lbs/acre with no practice adoption
The program chosen by the majority of respondents will be implemented immediately. If no program is implemented for now, you will be provided with ***new information*** *about N application and* ***given another chance to decide one year later****.*

Attributes	Program 1	Program 2	Do not participate
Fall application prohibited	Yes	No	**No**
Sidedress application required	No	Yes	**Yes** I would not
Winter cover crops required	Yes	Yes	**No** participate in these programs
Expected Nitrogen savings	25%	40%	**0**
Annual payment level	$180/acre	$180/acre	**0**
I would choose … **(check only one)**	☐	☐	☐

Yes: 1; No: 0

$\boldsymbol{\beta}$: preference par

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Winter cover crops required	Yes	Yes	I would not participate in these programs No
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I would choose … (check only one)	☐	☐	☐

Yes: 1; No: 0

$\boldsymbol{\beta}$: preference par

Strategy 1: utility max

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Winter cover crops required	Yes	Yes	No
Expected Nitrogen savings	25%	40%	0
Annual payment level	$180/acre	$180/acre	0
I would choose ... (check only one)	☐	☐	☐

I would not participate in these programs

Yes: 1; No: 0
$\boldsymbol{\beta}$: preference par

$\boldsymbol{\beta_f} \times \mathbf{1}$

$\boldsymbol{\beta_s} \times \mathbf{0}$

$\boldsymbol{\beta_w} \times \mathbf{1}$

$\boldsymbol{\beta_n} \times \mathbf{0.25}$

$\boldsymbol{\beta_p} \times \mathbf{180}$

Strategy 2: ignore "Fall": ANA (RUM)

Note: This program is not expected to reduce corn yield with appropriate application rates
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Attributes	Program 1	Program 2	Do not participate
[redacted]			
Sidedress application required	No	Yes	**Yes**
Winter cover crops required	Yes	Yes	**No** I would not participate in these programs
Expected Nitrogen savings	25%	40%	**0**
Annual payment level	$180/acre	$180/acre	**0**
I would choose ... (check only one)	☐	☐	☐

Yes: 1; No: 0
$\boldsymbol{\beta}$: preference par

$\boldsymbol{\beta}_s \times \mathbf{0}$

$\boldsymbol{\beta}_w \times \mathbf{1}$

$\boldsymbol{\beta}_n \times \mathbf{0.25}$

$\boldsymbol{\beta}_p \times \mathbf{180}$

Strategy 3: Regret Min

Note: This program is not expected to reduce corn yield with appropriate application rates
Expected N savings are based on average application rate of 170 lbs/acre with no practice adoption
*The program chosen by the majority of respondents will be implemented immediately. If no program is implemented for now, you will be provided with **new information** about N application and **given another chance to decide one year later**.*

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Sidedress application required	No	Yes	**Yes**
Winter cover crops required	Yes	Yes	**No** I would not participate in these programs
Expected Nitrogen savings	25%	40%	**0**
Annual payment level	$180/acre	$180/acre	**0**
I would choose ... **(check only one)**	☐	☐	☐

Yes: 1; No: 0
$\boldsymbol{\beta}$: preference par

Strategy 3: Regret Min

Note: This program is not expected to reduce corn yield with appropriate application rates
Expected N savings are based on average application rate of 170 lbs/acre with no practice adoption
*The program chosen by the majority of respondents will be implemented immediately. If no program is implemented for now, you will be provided with **new information** about N application and **given another chance to decide one year later**.*

Attributes	Program 1	Program 2	Do not participate
Fall application prohibited	Yes	No	No
Sidedress application required	No	Yes	Yes
Winter cover crops required	Yes	Yes	No
Expected Nitrogen savings	25%	40%	0
Annual payment level	$180/acre	$180/acre	0
I would choose ... (check only one)	☐	☐	☐

I would not participate in these programs

Yes: 1; No: 0
$\boldsymbol{\beta}$: preference par

$\beta_f \times (0 - 1)$

$\beta_s \times (1 - 0)$

$\beta_w \times (1 - 1)$

$\beta_n \times (0.4 - 0.25)$

$\beta_p \times (180 - 180)$

Strategy 3: Regret Min

Note: This program is not expected to reduce corn yield with appropriate application rates
Expected N savings are based on average application rate of 170 lbs/acre with no practice adoption
*The program chosen by the majority of respondents will be implemented immediately. If no program is implemented for now, you will be provided with **new information** about N application and **given another chance to decide one year later**.*

Attributes	Program 1	Program 2	Do not participate
Fall application prohibited	Yes	No	**No**
Sidedress application required	No	Yes	**Yes**
Winter cover crops required	Yes	Yes	**No** I would not participate in these programs
Expected Nitrogen savings	25%	40%	**0**
Annual payment level	$180/acre	$180/acre	**0**
I would choose ... (check only one)	☐	☐	☐

Yes: 1; No: 0
$\boldsymbol{\beta}$: preference par

$\boldsymbol{\beta_f} \times (\mathbf{0} - \mathbf{1})$

$\boldsymbol{\beta_s} \times (\mathbf{1} - \mathbf{0})$

$\boldsymbol{\beta_w} \times (\mathbf{0} - \mathbf{1})$

$\boldsymbol{\beta_n} \times (\mathbf{0} - \mathbf{0.25})$

$\boldsymbol{\beta_p} \times (\mathbf{0} - \mathbf{180})$

	Program 1	Program 2	Do not participate
Fall application prohibited	Yes	Yes	I would not participate in these programs
Sidedress application required	No	Yes	
Winter cover crops required	Yes	No	
Expected Nitrogen savings	25%	25%	
Annual payment level	$180/acre	$100/acre	
I would choose ... (check only one)	☐	☐	☐

...eld with appropriate application rates

...n rate of 170 lbs/acre with no practice

The program chosen by the majority of respondents will be implemented immediately. If no program is implemented for now, you will be provided with ***new information*** *about N application and* ***given another chance to decide one year later****.*

Attributes	Program 1	Program 2	Do not participate	Chosen alternative from last choice set
Fall application prohibited	Yes	No	No	Yes
Sidedress application required	No	Yes	Yes	Yes
Winter cover crops required	Yes	Yes	No	No
Expected Nitrogen savings	25%	40%	0	25%
Annual payment level	$180/acre	$180/acre	0	$100/acre
I would choose ... (check only one)	☐	☐	☐	

I would not participate in these programs

RRM: asymmetry in regret/rejoice

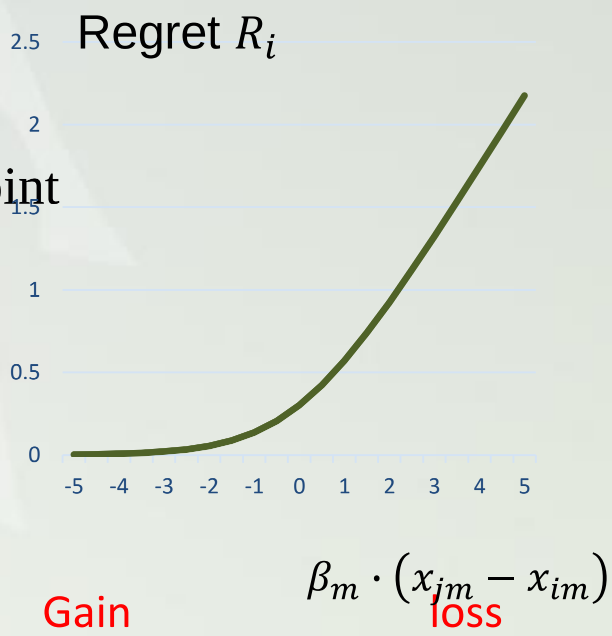
- RRM Log functional form (Chorus, 2010):

$$\mathrm{R_i} = \sum_{j \neq i}^{J} \sum_{\boldsymbol{m}} \ln(1 + \exp[\boldsymbol{\beta_m} \cdot (\boldsymbol{x_{jm}} - \boldsymbol{x_{im}})])$$

- RUM: $\mathrm{U_i} = \sum_m \boldsymbol{\beta_m} \cdot \boldsymbol{x_{im}}$
- Asymmetry of regret / rejoice:
  - More sensitive to regret than to rejoice
  - Sensitivity to regret increases as difference enlarges
  - Not loss aversion: payoff differentiable at reference point

- Estimation strategy is similar to RUM: $RR_i = R_i + \epsilon_i$.

  Extreme value distribution + $\max_{\mathrm{i}}(-RR_i)$→ Logit



Multiple reference points in RRM: LA-RRM

- Last Round and All Alternatives Referred Random Regret Minimization (LA-RRM)

$$RR_{isj} = R_{isj} + \varepsilon_{isj} =$$

$$\sum_{k \neq sq} \sum_{m} \ln\left(1 + exp\left[\beta_m^h \cdot \left(x_{iskm} - x_{isjm}\right)\right]\right) +$$

$$\sum_{m} ln\left(1 + exp\left[\beta_m^{sq} \cdot \left(x_{issqm} - x_{isjm}\right)\right]\right) +$$

$$\sum_{m} ln\left(1 + exp\left[\beta_m^{l} \cdot \left(x_{is-1\check{j}m} - x_{isjm}\right)\right]\right) +$$

$$\beta_0 \cdot sq_{isj} + \varepsilon_{isj}$$

- Reference points: β_m^h β_m^{sq} and β_m^l
- AA-RRM (Tian and Zhao, 2019) when β_m^l=0
- RRM (Chorus, 2010) when $\beta_m^h = \beta_m^{sq}$ and β_m^l=0

Equality Constrained Latent Class (ECLC) ANA model

- Q classes: heterogeneous attentions of attributes package
- Coeffs (ANA_attributes) = 0 & Coeffs (other attributes) same across classes
- $Pr\left(y_{isj} = 1\right) = \sum_{q=1}^{Q} Pr\left(y_{isj} = 1 \,\middle|\, class\ q\right) \times Pr\ (class\ q)$
  - $\Pr\ (class\ q) = \frac{\exp(s_q)}{\sum_{q=1}^{Q} \exp(s_q)}\ with\ s_Q = 0$
- $\Pr\left(y_{isj} = 1 \,\middle|\, class\ q\right) = \begin{cases} \frac{\exp(U_{isj}|class\ q)}{\sum_{j=1}^{J} \exp(U_{isj}|class\ q)} \text{ (RUM)} \\ \frac{\exp(-R_{isj}|class\ q)}{\sum_{j=1}^{J} \exp(-R_{isj}|class\ q)} \text{(RRM)} \end{cases}$

Survey and data

- NSF CNH grant to study nutrient management practices
- Mail survey in 2016: corn growers in Michigan, Iowa, and Indiana
- Random draw of farmer names from USDA Farm Service Agency (>100 acres)
- $2 “thank you”
- 1294 useable surveys, 27% response rate
- Cheap talk treatment
- Follow-up questions about past practices
- A Bayesian efficiency design using pretest data
- *4 choice sets, 3 alts, 5 attributes*

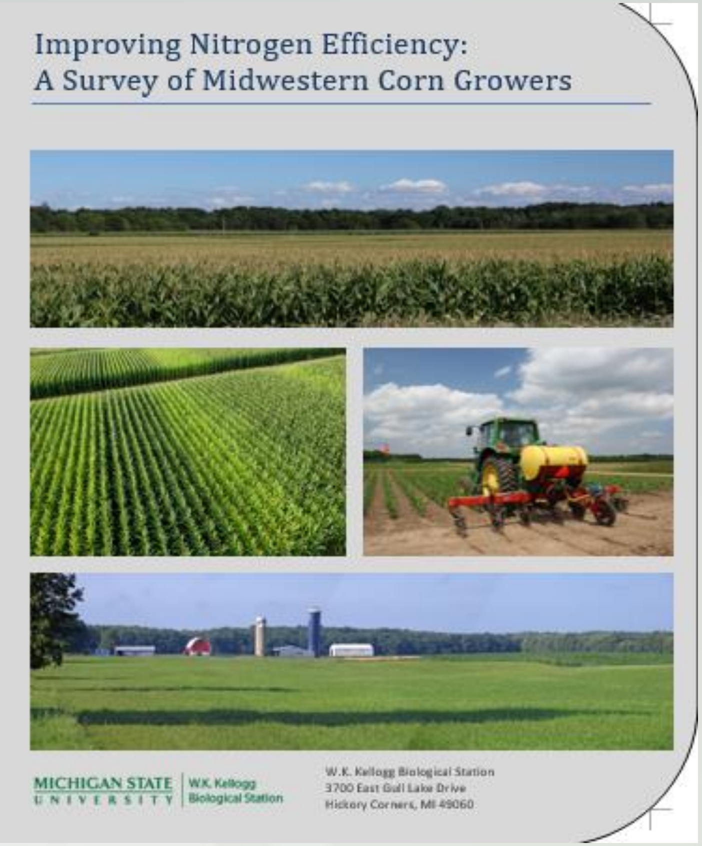


Table 1. Attributes and Levels Used in the Choice Design

Attributes	Levels
Winter Cover Crops Required	Yes, No
Fall Application of Fertilizer Prohibited	Yes, No
Fertilizer Sidedress Application Required	Yes, No
Expected Nitrogen Savings	0, 10%, 25%，40%，50%
Annual Payment/Acre	$0, $5, $20, $40, $100, $180

Table 2. RUM, AA-RRM, LA-RRM Estimation Results

	RUM		AA-RRM		LA-RRM	
Par	Est	S.d.	Est	S.d.	Est	S.d.
β_{winter}	-0.271*** [a]	0.0182				
β_{fall}	-0.0269*	0.0145				
β_{side}	-0.128***	0.0186				
$\beta_{nitrogen}$	0.78***	0.0947				
β_{pay}	0.00259***	0.000155				
β^{h}_{winter}			0.502***	0.102	0.184	0.141
β^{h}_{fall}			-0.112**	0.0518	0.928***	0.0962
β^{h}_{side}			0.484***	0.0768	0.0328	0.119
$\beta^{h}_{nitrogen}$			1.53***	0.227	0.00436	0.186
β^{h}_{pay}			0.00467***	0.000372	0.00335***	0.000568
β^{sq}_{winter}			-2.1***	0.143	-1.71***	0.202
β^{sq}_{fall}			0.028	0.0387	0.047	0.111
β^{sq}_{side}			-1.77***	0.118	1.4***	0.172
$\beta^{sq}_{nitrogen}$			5.84***	1.46	-1.55***	0.598
β^{sq}_{pay}			0.0344***	0.00361	6.29***	0.0472
β^{l}_{winter}					-2.22***	0.135
β^{l}_{fall}					-1.79***	0.133
β^{l}_{side}					-2.06***	0.126
$\beta^{l}_{nitrogen}$					5.89***	0.367
β^{l}_{pay}					0.0123***	0.00123
β_0	-1.15***	0.0695	-1.41***	0.103	-1.7***	0.0893
$\hat{\mathcal{L}}$	-4458.219		-4365.564		-2924.361	
AIC	8928.439		8753.129		5880.722	
BIC	8966.637		8823.159		5977.981	
No. obs	4300		4300		3225	

- RRM outperforms RUM → reference dependent
- Multiple RPs: $\beta^{h}_{m}, \beta^{sq}_{m}, \beta^{l}_{m}$ → across choice set dependent
- RPs are attributes specific (e.g., Fall, Pay refer hypo but no SQ)

Table 3. RUM, AA-RRM, LA-RRM ECLC ANA Estimation Results

	RUM		AA-RRM		LA-RRM	
Par	Est	S.d.	Est	S.d.	Est	S.d.
β_{winter}	-0.276***	0.0189				
β_{fall}	-3.82**	1.78				
β_{side}	-0.129***	0.0187				
$\beta_{nitrogen}$	0.798***	0.0977				
β_{pay}	0.00263***	0.00016				
β^{h}_{winter}			0.513***	0.102	1.34***	0.154
β^{h}_{fall}			-0.101**	0.0511	0.985***	0.0624
β^{h}_{side}			0.648***	0.166	0.142	0.108
$\beta^{h}_{nitrogen}$			1.51***	0.238	2.74***	0.401
β^{h}_{pay}			0.00478***	0.000381	0.00402***	0.000684
β^{sq}_{winter}			-2.15***	0.145	-1.56***	0.307
β^{sq}_{fall}			0.0171	0.0307	-0.0351	0.0977
β^{sq}_{side}			-3.84***	0.479	-1.41***	0.105
$\beta^{sq}_{nitrogen}$			5.39***	1.85	3.96***	0.724
β^{sq}_{pay}			0.0341***	0.00337	3.78***	0.0898
β^{l}_{winter}					-2.22***	0.137
β^{l}_{fall}					-1.83***	0.198
β^{l}_{side}					-2.15***	0.138
$\beta^{l}_{nitrogen}$					-4.95***	0.721
β^{l}_{pay}					0.0135***	0.0013
β_0	-1.17***	0.072	-1.37***	0.118	-1.9***	0.126
s_{winter}	-66.8	1.80e+308	44.6***	0.274	-83.1	1.80e+308
s_{fall}	3.23***	0.474	84.8	7.02e+005	-20.2***	0.625
s_{side}	-82.9	1.80e+308	38.3	1.80e+308	-100	1.80e+308
$s_{nitrogen}$	-100	1.80e+308	84.5	7.02e+005	-76.5***	23.8
$\hat{\mathcal{L}}$	-4457.536		-4360.525		-2938.85	
AIC	8935.072		8751.049		5917.7	
BIC	8998.736		8846.545		6039.273	
No. obs	4300		4300		3225	

Table 3. RUM, AA-RRM, LA-RRM ECLC ANA Estimation Results

	RUM		AA-RRM		LA-RRM	
Par	Est	S.d.	Est	S.d.	Est	S.d.
s_{winter}	-66.8	1.80e+308	44.6***	0.274	-83.1	1.80e+308
s_{fall}	3.23***	0.474	84.8	7.02e+005	-20.2***	0.625
s_{side}	-82.9	1.80e+308	38.3	1.80e+308	-100	1.80e+308
$s_{nitrogen}$	-100	1.80e+308	84.5	7.02e+005	-76.5***	23.8
$\hat{\mathcal{L}}$	-4457.536		-4360.525		-2938.85	
AIC	8935.072		8751.049		5917.7	
BIC	8998.736		8846.545		6039.273	
No. obs	4300		4300		3225	

$$\Pr(class\ q) = \frac{\exp(s_q)}{\sum_{q=1}^{Q} \exp(s_q)}\ with\ s_Q = 0\ (\text{Q=Full attention})$$

Table 4. Attribute Non-Attendance Class Probability

Class	RUM	AA-RRM	LA-RRM
Full attention	3.80%	0.0%	100.00%
Winter unattended	0.00%	0.0%***	0.00%
Fall unattended	96.2%***	57.4%	0.0%***
Side unattended	0.00%	0.0%	0.00%
Nitrogen unattended	0.00%	42.6%	0.0%***

- ANA behavior no longer significant after controlling for *cross choice sets dependence* behavior

Table 5. Attribute Non-Attendance Class Probability by Choice Set

Sample	All	S=1	S=2	S=3	S=4
Class			RUM-ANA		
Full attention	3.80%	100.00%	2.20%	0.00%	0.00%
Winter unattended	0.00%	0.0%***	0.0%***	0.0%***	0.00%
Fall unattended	96.2%***	0.00%	97.8%***	93.1%***	98.2%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	0.00%	0.0%***	0.00%	6.90%	1.8%***
Class			AA-RRM-ANA		
Full attention	0.00%	0.00%	0.00%	0.00%	0.00%
Winter unattended	0.0%***	20.80%	45.30%	0.0%***	0.0%***
Fall unattended	57.40%	51.10%	41.00%	21.4%***	57.4%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	42.60%	28.10%	13.70%	78.6%***	42.6%***
Sample	S=2, 3, 4		S=2	S=3	S=4
Class			LA-RRM		
Full attention	100.00%		78.10%	92.50%	0.00%
Winter unattended	0.00%		0.00%	0.00%	0.00%
Fall unattended	0.0%***		21.90%	0.0%***	0.00%
Side unattended	0.00%		0.00%	0.00%	0.00%
Nitrogen unattended	0.0%***		0.0%***	7.5%***	100.00%

- ANA exists but not from the beginning set: starts from set 2 (RUM) and set 3 (AA-RRM)→*Fatigue or Path dependence* with learning?

Table 5. Attribute Non-Attendance Class Probability by Choice Set

Sample	All	S=1	S=2	S=3	S=4
Class			RUM-ANA		
Full attention	3.80%	100.00%	2.20%	0.00%	0.00%
Winter unattended	0.00%	0.0%***	0.0%***	0.0%***	0.00%
Fall unattended	96.2%***	0.00%	97.8%***	93.1%***	98.2%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	0.00%	0.0%***	0.00%	6.90%	1.8%***
Class			AA-RRM-ANA		
Full attention	0.00%	0.00%	0.00%	0.00%	0.00%
Winter unattended	0.0%***	20.80%	45.30%	0.0%***	0.0%***
Fall unattended	57.40%	51.10%	41.00%	21.4%***	57.4%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	42.60%	28.10%	13.70%	78.6%***	42.6%***
Sample	S=2, 3, 4		S=2	S=3	S=4
Class			LA-RRM		
Full attention	100.00%		78.10%	92.50%	0.00%
Winter unattended	0.00%		0.00%	0.00%	0.00%
Fall unattended	0.0%***		21.90%	0.0%***	0.00%
Side unattended	0.00%		0.00%	0.00%	0.00%
Nitrogen unattended	0.0%***		0.0%***	7.5%***	100.00%

- ANA no longer exists after path dependence is controlled

Table 5. Attribute Non-Attendance Class Probability by Choice Set

Sample	All	S=1	S=2	S=3	S=4
Class			RUM-ANA		
Full attention	3.80%	100.00%	2.20%	0.00%	0.00%
Winter unattended	0.00%	0.0%***	0.0%***	0.0%***	0.00%
Fall unattended	96.2%***	0.00%	97.8%***	93.1%***	98.2%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	0.00%	0.0%***	0.00%	6.90%	1.8%***
Class			AA-RRM-ANA		
Full attention	0.00%	0.00%	0.00%	0.00%	0.00%
Winter unattended	0.0%***	20.80%	45.30%	0.0%***	0.0%***
Fall unattended	57.40%	51.10%	41.00%	21.4%***	57.4%***
Side unattended	0.00%	0.00%	0.00%	0.0%***	0.00%
Nitrogen unattended	42.60%	28.10%	13.70%	78.6%***	42.6%***
Sample	S=2, 3, 4		S=2	S=3	S=4
Class			LA-RRM		
Full attention	100.00%		78.10%	92.50%	0.00%
Winter unattended	0.00%		0.00%	0.00%	0.00%
Fall unattended	0.0%***		21.90%	0.0%***	0.00%
Side unattended	0.00%		0.00%	0.00%	0.00%
Nitrogen unattended	0.0%***		0.0%***	7.5%***	100.00%

- ANA exists but not from the beginning set: starts from set 2 (RUM) and set 3 (AA-RRM)→*Fatigue or Path dependence* with learning?
- ANA no longer exists after path dependence is controlled
- ANA behaviors inconsistent across models
  - RUM: ANA ↑ as S ↑ (Fall)
  - AA-RRM: ANA ↑ as S ↑ (Fall & Nitrogen)
  - LA-RRM: no ANA

Implication #1: Decision heuristics

- Attributes inferred as ANA are actually processed with alternative strategy
- Reference dependence RM is an essential strategy
- Alternatives in the current and previous sets are RPs
- RPs are attributes specific

Implication #2: Strategy pattern in repeated choices

- Reference points change after making the first choice
- Inferred ANA growing over choice sets is actually path dependence strategy
- More attributes, more choice sets to be checked

Implication #3. Regret minimization in DCE

- Behavior strategies (including ANA) are captured
- Better model performance
- Survey design should exactly mimic the real choice scenario to be incentive compatible

Thank you!

Contact to request the full paper:
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