A Window of Cognition: Eyetracking the Decision-Making Process in Graphical Beauty Contest Games

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Focus

- Most theories only make predictions on choices. Most experiments only verify theories by observing choices.
  - We propose a new set of games, the Graphical Beauty Contest Games.
  - Using eyetracking, we base on a Level-k model to analyze subjects' choices and lookups in these games.

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- Since lookups are observed, our study is different from most experiments where only choices are analyzed.
- Moreover, due to the graphical nature of the games, the way lookups are used in our study has a very natural interpretation based on the sequence of best-responding of a Level-k model.

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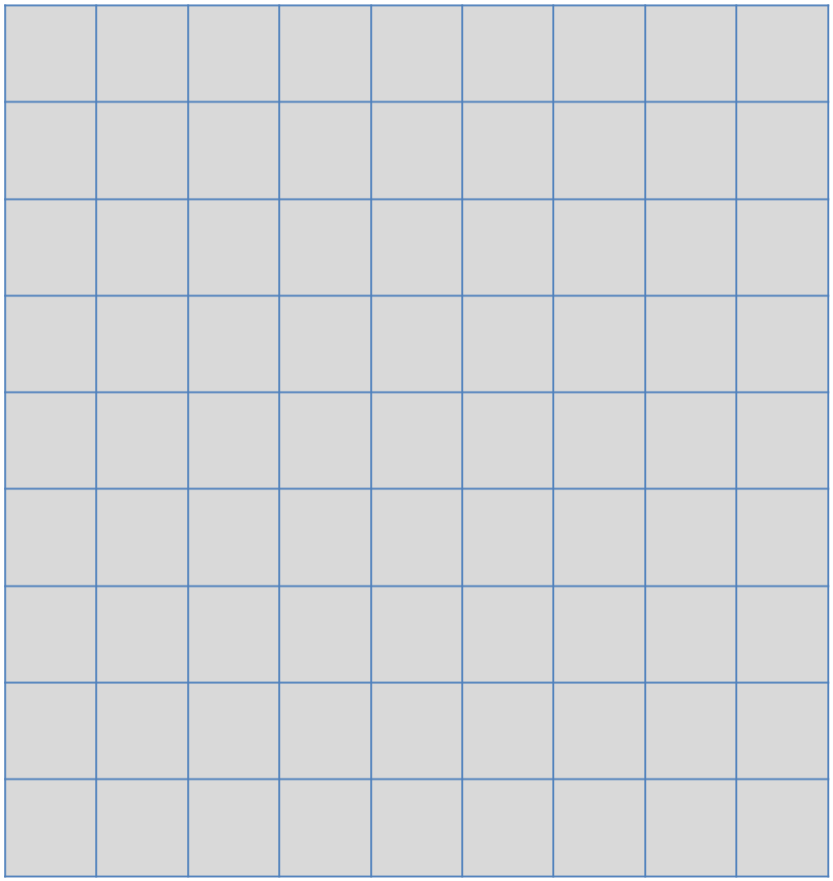
- Moreover, due to the graphical nature of the games, the way lookups are used in our study has a very natural interpretation based on the sequence of best-responding of a Level-k model.

Graphical Beauty Contest Game

Member A
LEFT 2

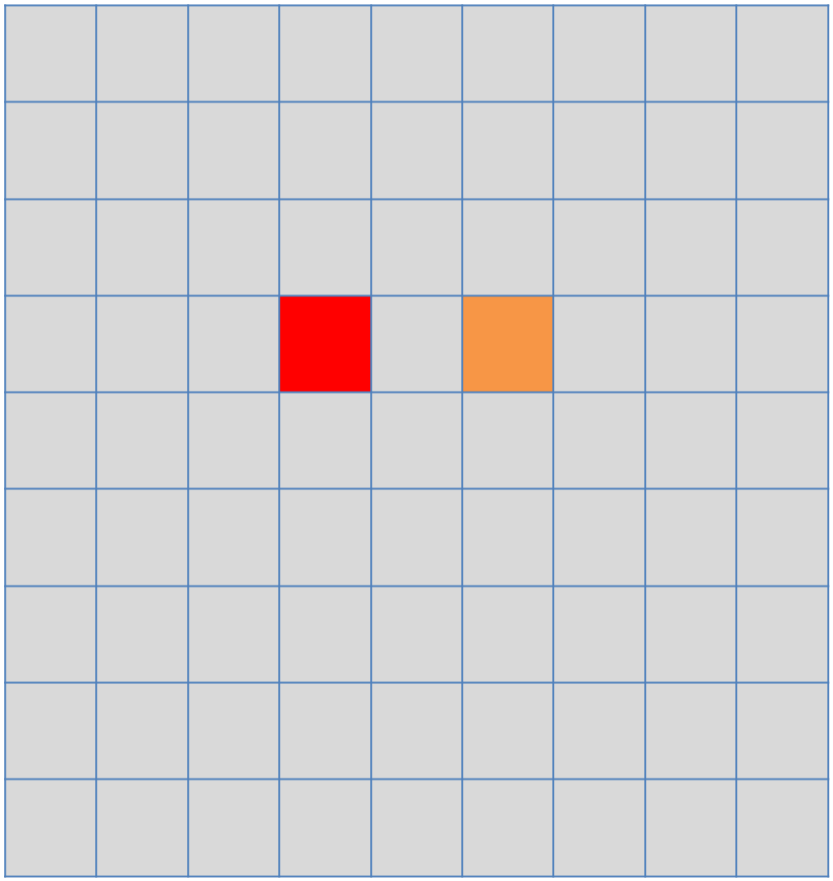


Member B
BELOW 4

Graphical Beauty Contest Game

Member A

LEFT 2



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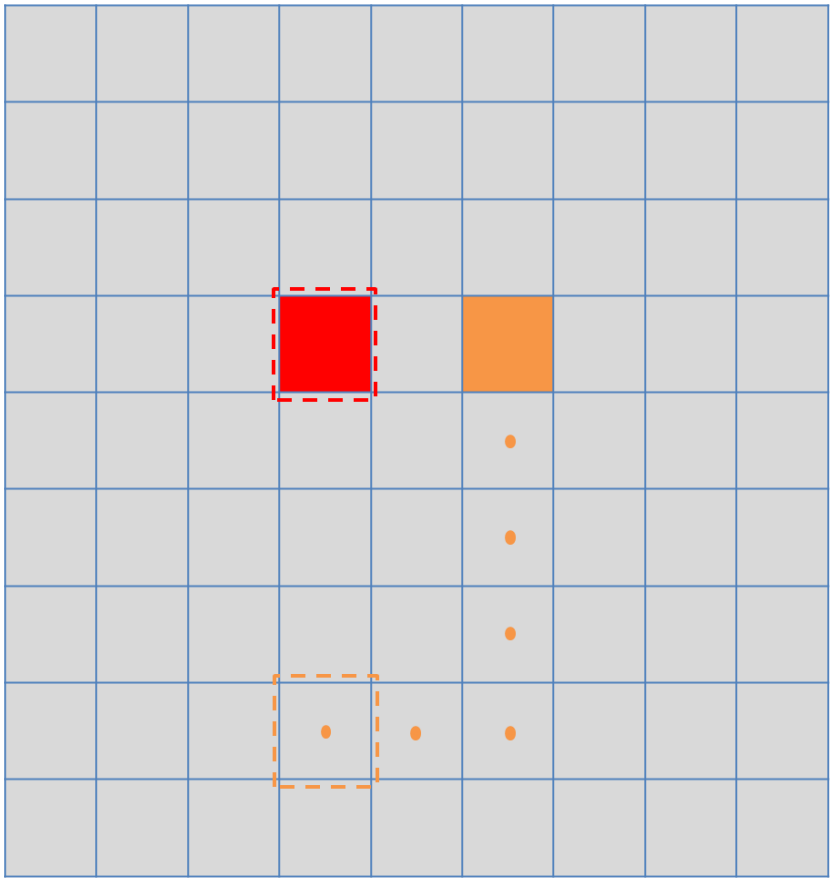

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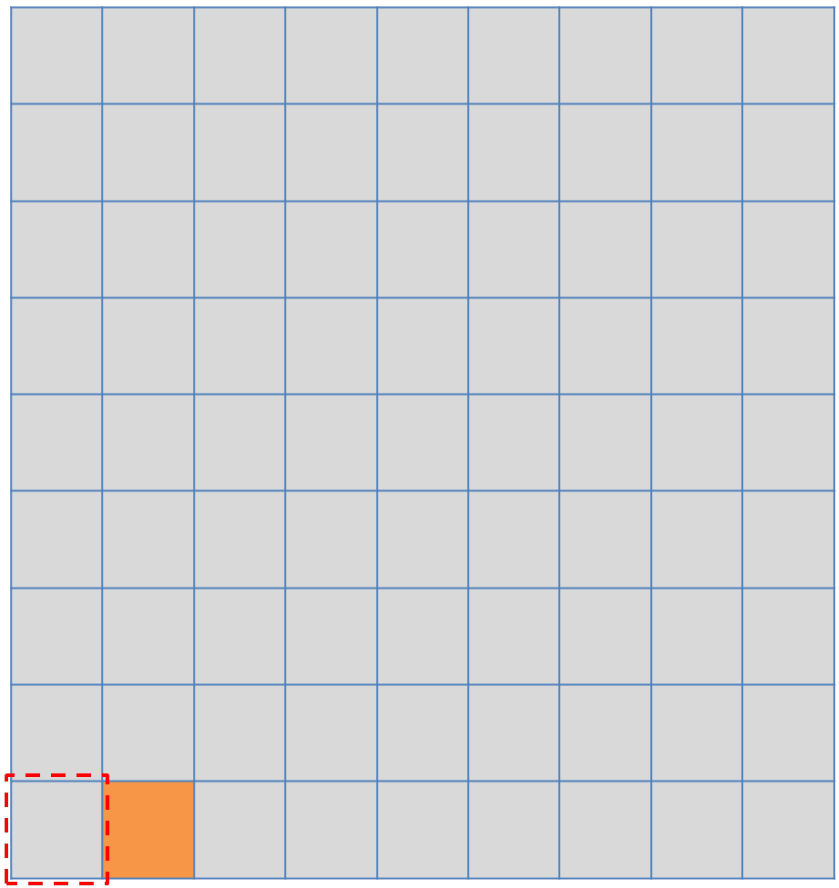

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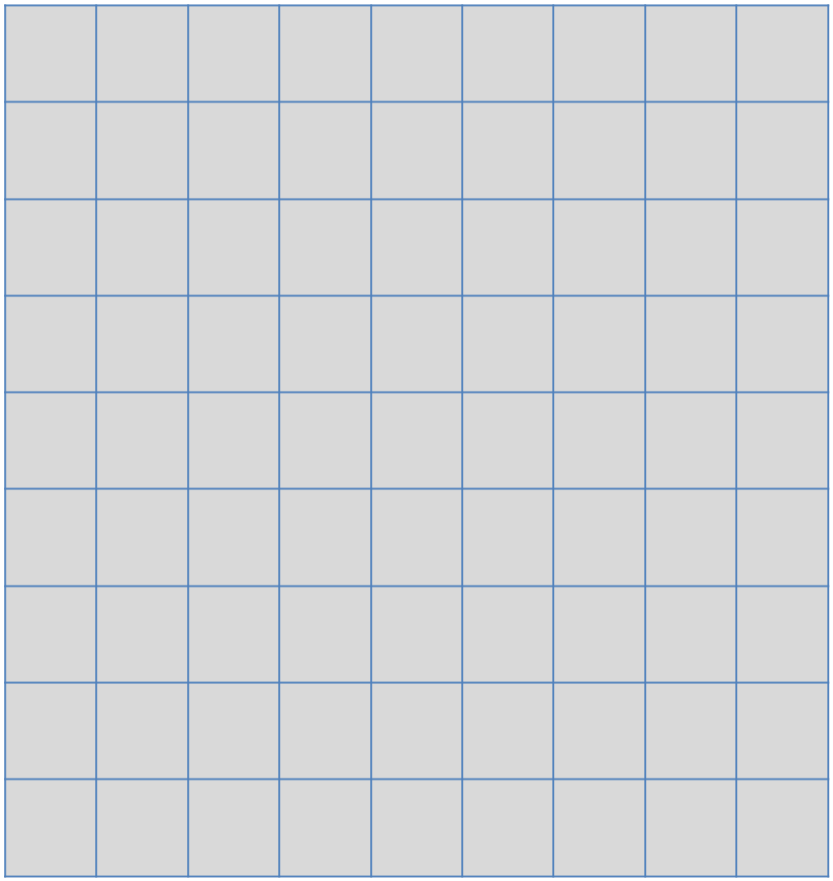
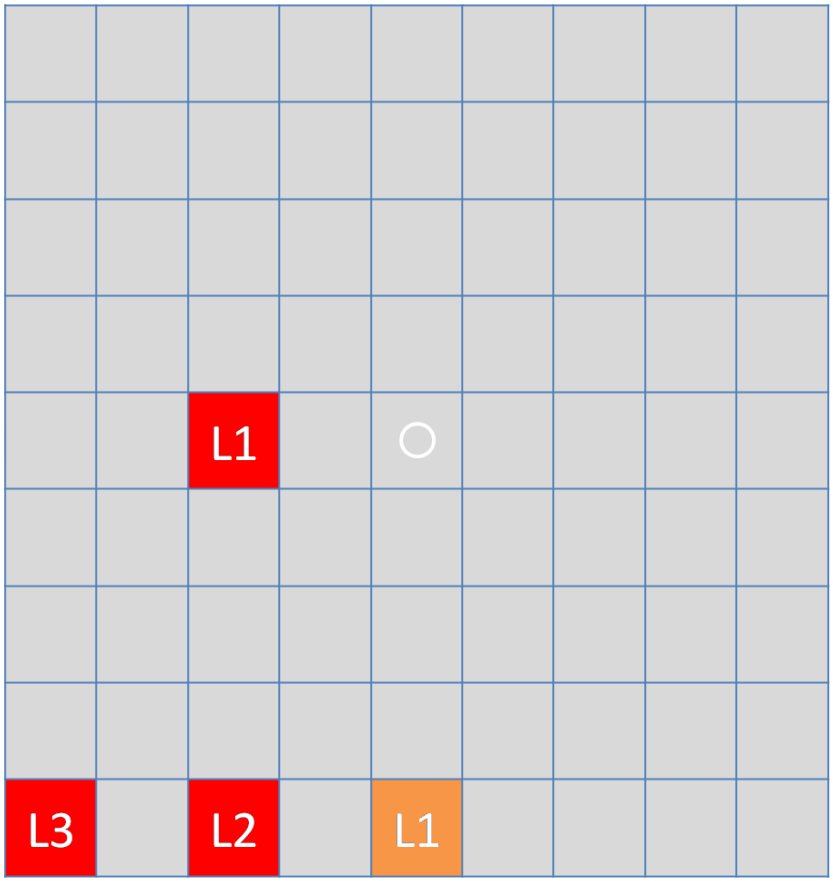


Member B
BELOW 4

Level-k classification

Member A

LEFT 2



Member B

BELOW 4

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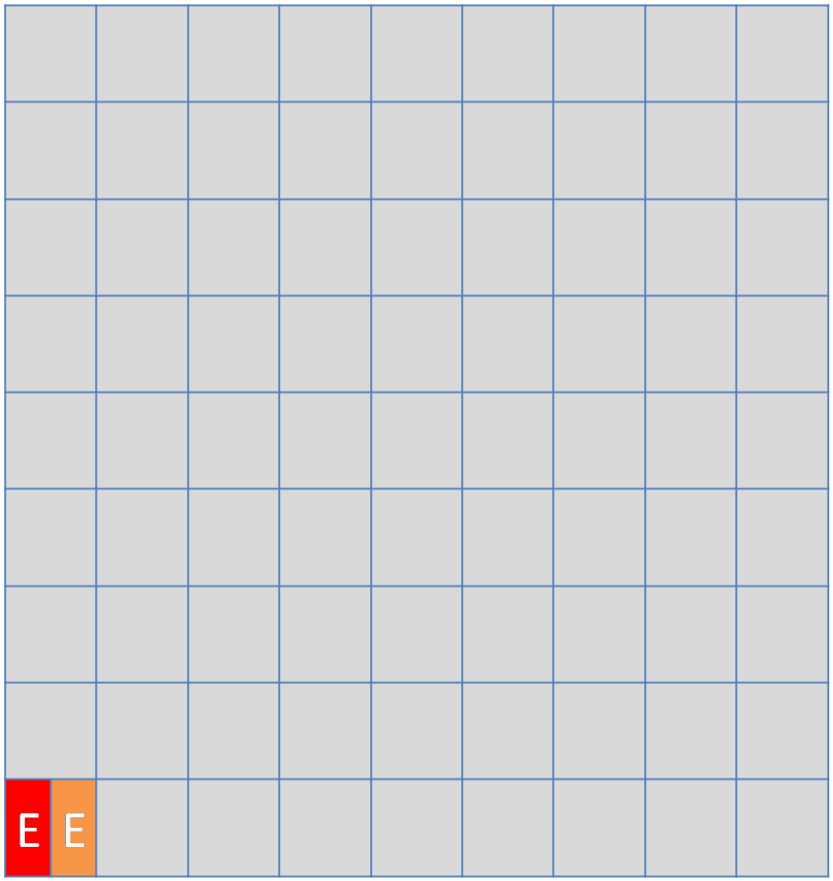


Member B

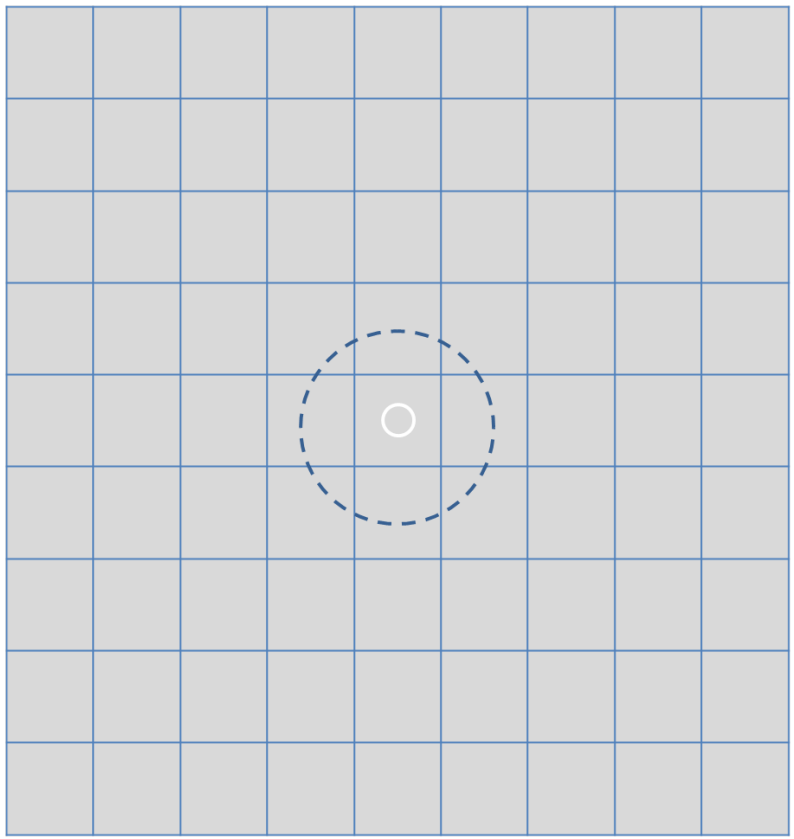
BELOW 4

Lookup behavior assumption

- Lookups will follow the sequence of best-responding implied by a Level-k model.

Level 0's Lookup behavior (central point)

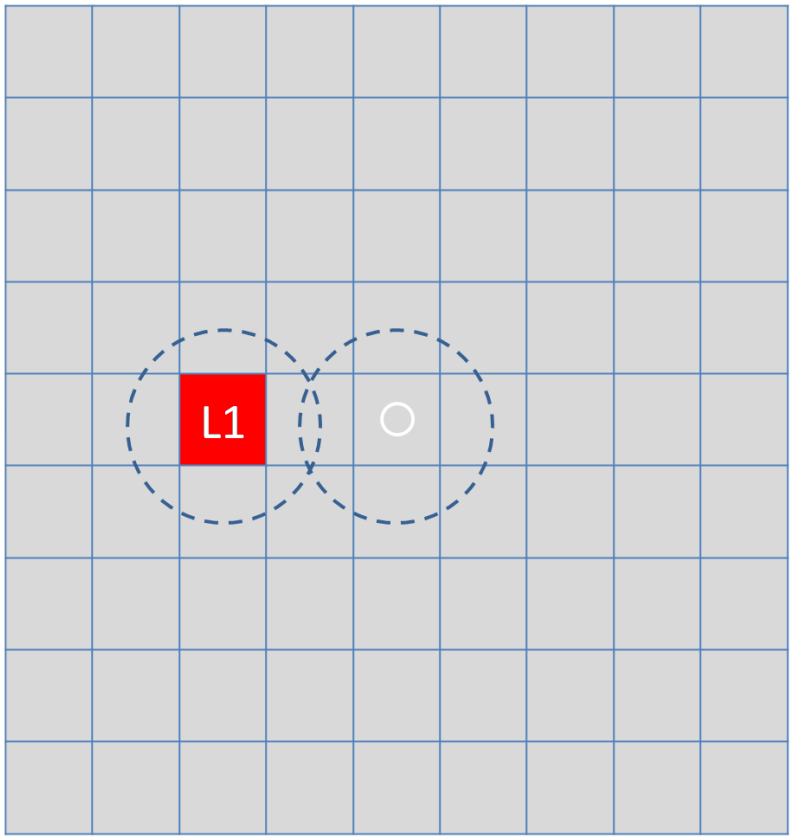
Member A
LEFT 2



Member B
BELOW 4

Level 1's Lookup behavior

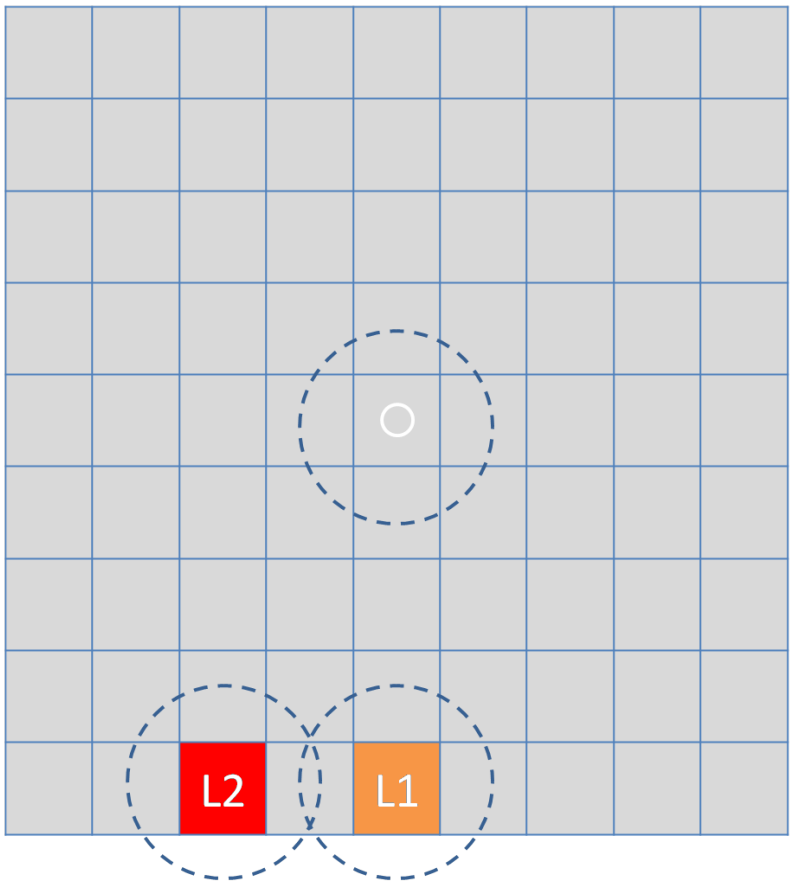
Member A
LEFT 2



Member B
BELOW 4

Level 2's Lookup behavior

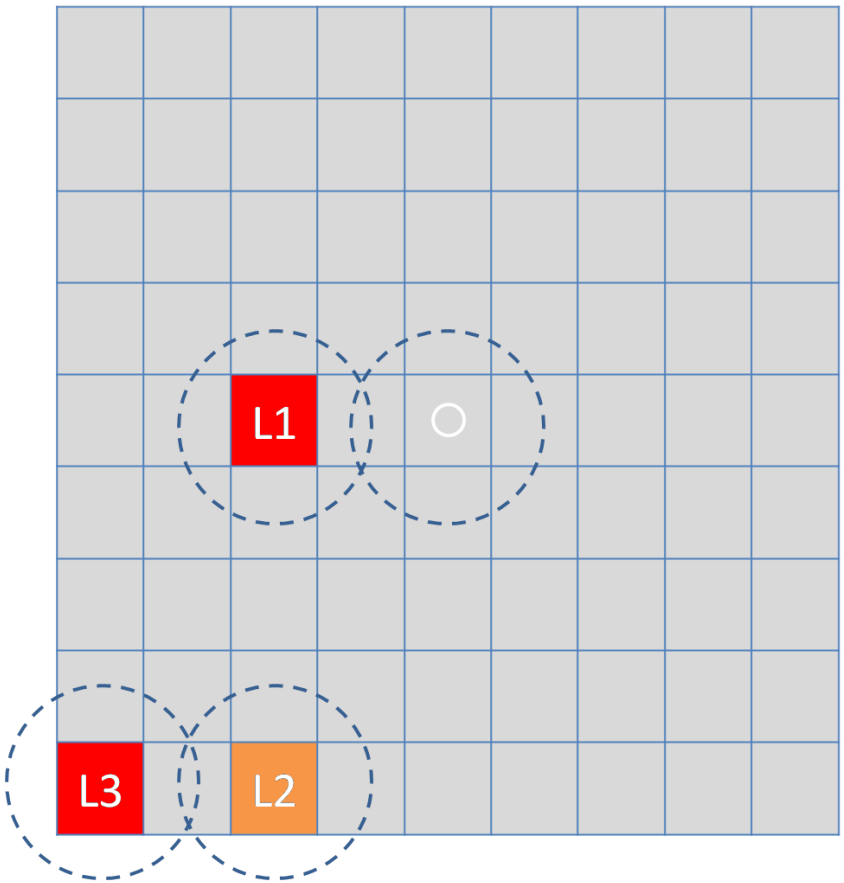
Member A
LEFT 2



Member B
BELOW 4

Level 3's Lookup behavior

Member A
LEFT 2



Member B
BELOW 4

Lookup behavior assumption

- Lookups will follow the sequence of best-responding implied by a Level-k model.
  1. But we don't assume lookups will follow this precise order in time.
  2. We assume each lookup corresponds to a state, so that the entire sequence of lookups constitutes a *state-switching* process.

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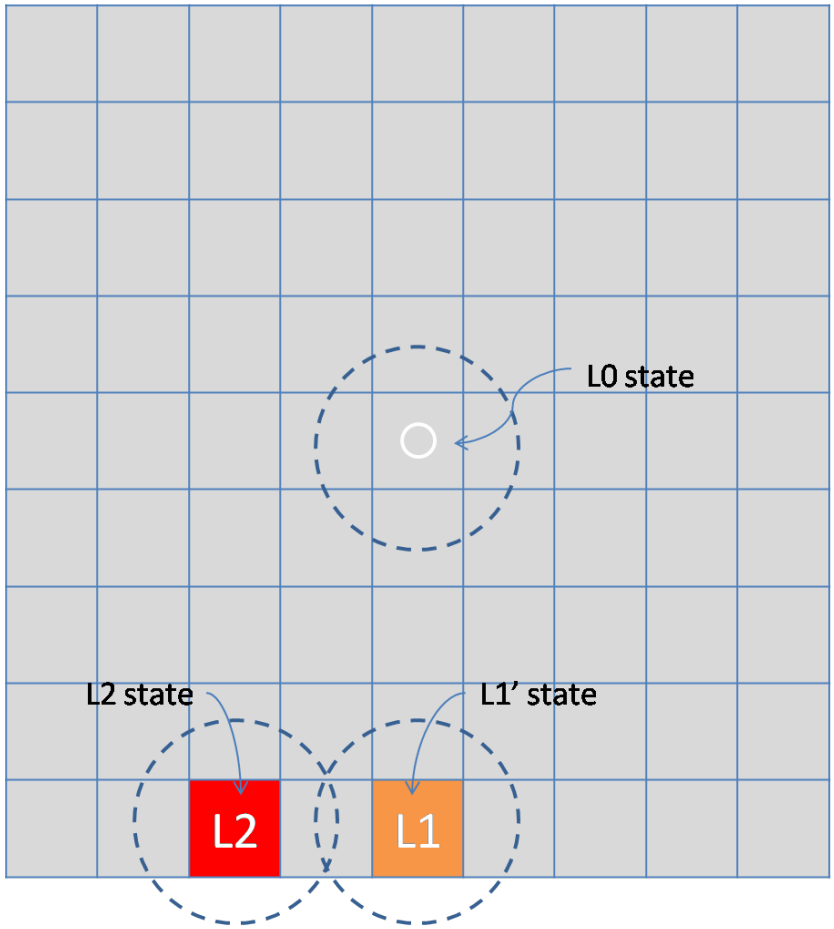
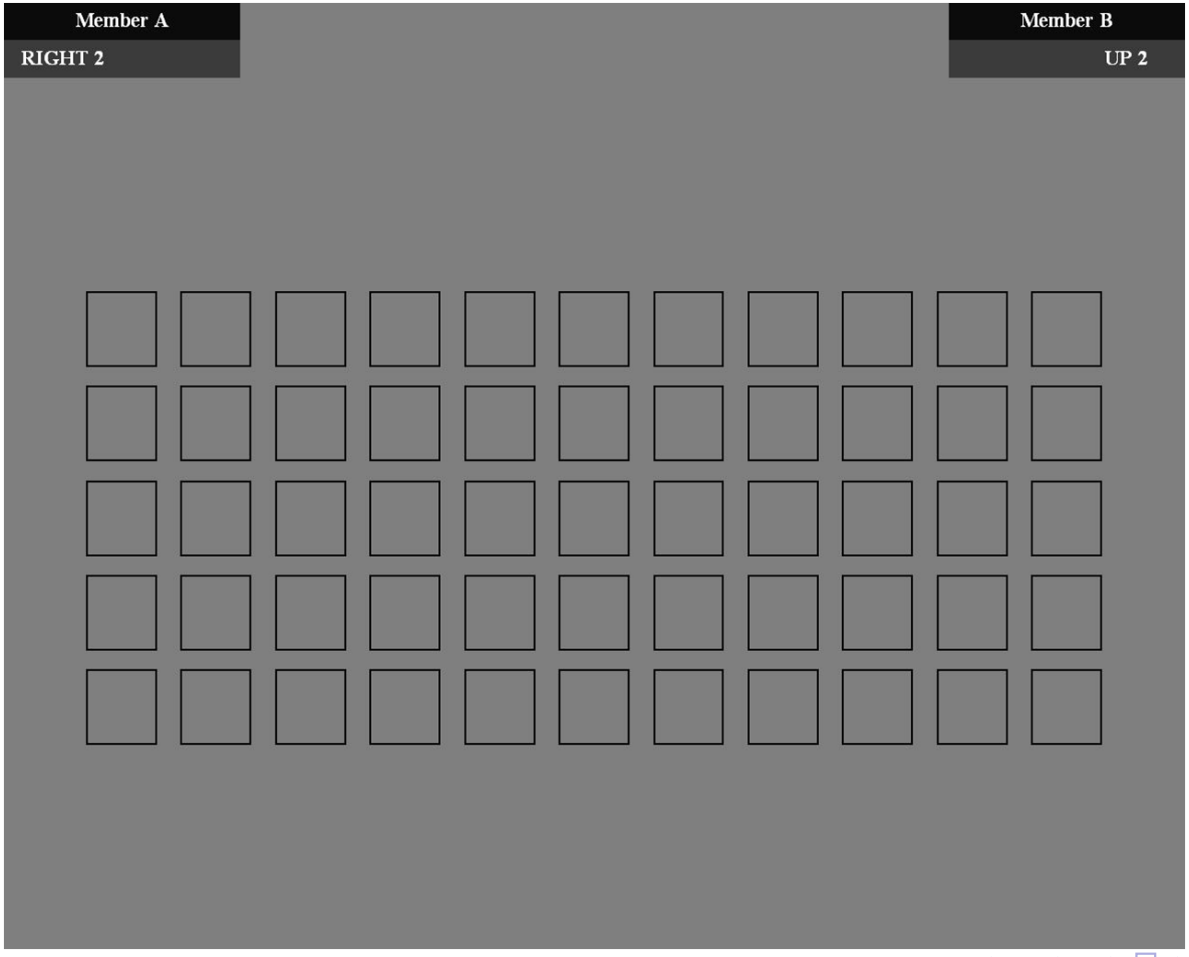
State switching

- State switching: L2 as an example



State switching

- An empirical sequence of lookups (Round 15 of Subject 9, who is classified as an L2).



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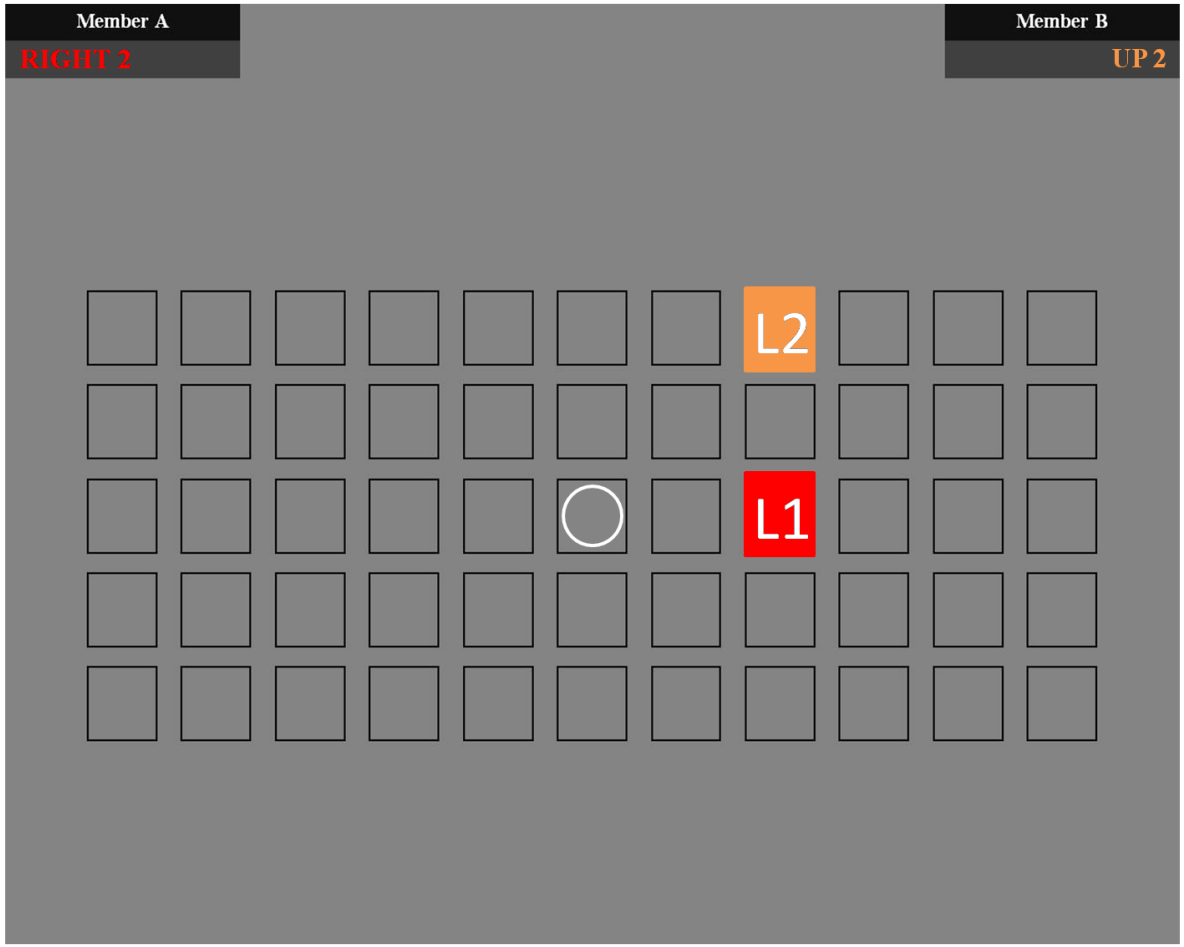

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Markov switching

- State Transition Matrix

Lower level ⟷ Higher level

	L0	*L1'*	*L2*
L0	0.92	0.04	0.04
L1'	0.05	0.92	0.02
L2	0.01	0.01	0.98

Note: Subject 9's estimated State Transition Matrix

Markov Transition Matrix property

We define the *UL ratio* to see whether states transit from lower levels to higher levels.

	L0	*L1'*	*L2*
L0	0.94	0.05	0.01
L1'	0.05	0.90	0.06
L2	0.03	0.02	0.95

U/L=0.12/0.10>1

Note: Subject 9's estimated UL ratio

Markov Transition Matrix property

- UL ratio

subject	*adjusted type*	*UL ratio*
12	L1	28183.0
8	L3	13.2
11	L3	3.5
15	L1	3.3
13	L3	3.0
6	L2	2.8
3	L3	2.6
14	L3	2.1
17	L3	2.0
1	L3	1.8
2	L2	1.4
5	L2	1.3
9	L2	1.1
4	L3	0.6
10	L3	0.3
16	L2	0.1
7	L0	-

Result

- The result suggests that states underlying lookups do transit from lower levels to higher levels.

The classification based on lookups+Hensen's LR Test

subject	*LK**	*Lk-** L0	L1	L2	L3	*adjusted type*
7	L2	0.067	0.035 *	-	-	L0
5	L2	0.006 *	0.005 *	-	-	L2
9	L2	0.002 *	0.017 *	-	-	L2
12	L3	0.000 *	0.130	0.000 *	-	L1
15	L3	0.000 *	0.058	0.000 *	-	L3
2	L3	0.000 *	0.001 *	0.327	-	L2
6	L3	0.000 *	0.000 *	0.413	-	L2
16	L3	0.000 *	0.001 *	0.227	-	L2
1	L3	0.000 *	0.000 *	0.000 *	-	L3
3	L3	0.010 *	0.016 *	0.014 *	-	L3
4	L3	0.000 *	0.036 *	0.003 *	-	L3
8	L3	0.000 *	0.001 *	0.001 *	-	L3
10	L3	0.000 *	0.000 *	0.000 *	-	L3
11	L3	0.000 *	0.000 *	0.017 *	-	L3
13	L3	0.000 *	0.000 *	0.000 *	-	L3
14	L3	0.000 *	0.013 *	0.000 *	-	L3
17	L3	0.030 *	0.039 *	0.001 *	-	L3

* indicates p-value less or equal than 0.05

Result

- 12/17 subjects can be strongly classified (p-value$\leq$0.05).
- 5/17 subjects are adjusted to lower level-k types with second highest maximum likelihood.

The classification based on choice+Hensen's LR Test

subject	Lk^*	$Lk-^*$			
		L0	L1	L2	L3
7	L0	-	0.105	0.143	**0.100**
9	L0	-	0.191	**0.418**	0.313
4	L1	0.172	-	**0.152**	0.129
10	L1	0.049*	-	0.047*	**0.051**
12	L1	0.050*	-	0.101	**0.074**
17	L1	0.083	-	0.088	**0.184**
2	L2	0.097	0.087	-	**0.142**
6	L2	0.055	0.085	-	**0.141**
11	L2	0.054	0.069	-	**0.387**
16	L2	0.045*	0.053	-	**0.081**
1	L3	0.061	0.070	**0.081**	-
3	L3	0.126	**0.403**	0.111	-
5	L3	0.066	0.070	**0.232**	-
8	L3	0.069	0.083	**0.095**	-
13	L3	0.053	0.111	**0.098**	-
14	L3	0.052	**0.221**	0.064	-
15	L3	0.084	0.111	**0.217**	-

Result

- No subjects can be strongly classified (p-value$\leq$0.05).

Hensen's LR Test for Classification: Choices vs. Lookup

subject	*Lk based on Lookups*	*Lk based on Choice only*	*H0: Choice is true H1:Lookups is true*	*H0: Lookups is true H1:Choice is true*
1	L3	L3	-	-
2	L2	L2	-	-
3	L3	L3	-	-
4	L3	L1	0.036**	0.129
5	L2	L3	0.000**	0.232
6	L2	L2	-	-
7	L0	L0	-	-
8	L3	L3	-	-
9	L2	L0	0.001**	0.418
10	L3	L1	0.000**	0.051*
11	L3	L2	0.017**	0.387
12	L1	L1	-	-
13	L3	L3	-	-
14	L3	L3	-	-
15	L3	L3	-	-
16	L2	L2	-	-
17	L3	L1	0.039**	0.184

** indicates p-value less or equal than 0.05; * indicates p-value less or equal than 0.1

Result

- 11/17 subjects' lookups agree with choices.
- 6/17 subjects' lookups do not agree with choices, but the classification according to lookups passes the LR test (p-value$\leq$0.05) that maximum likelihoods are significantly different from those estimated by choices.

Conclusion

1. We estimate a Markov Switching Transition Matrix from emipirical lookups.
2. 11/17 subject's lookups agree with choices.
3. when the two classifications disagree, choice data alone could not reject nearly all of the lookup-based type alternatives, while most of the choice-based type alternatives could be rejected using lookup data.

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