Prospect Theory: from Individuals to Teams

Department of Computer Science
University of California
Santa Barbara, CA 93106

October 27, 2020

Motivation

- Prospect Theory is an established model for explaining risk-taking at the individual level
- Understand how risky behavior changes in the team setting from the individual level and explain this change

Outline

- Experimental setup
- Models
- Findings

Experimental Setup

- Issue example:
  - Option A: A gamble in which you may win \$828 with probability $P = 0.57$ or lose \$1466 with probability $(1 - P) = 0.43$
  - Option B: A gamble in which you may win \$1594 with probability $P = 0.67$ or lose \$3718 with probability $(1 - P) = 0.33$
  - Which option would you choose?
- Two phases:
  - Sequence of individual issues
  - Sequence of group issues:
    - Pre-discussion choice
    - Post-discussion choice
    - Gathering of influence matrix

Datasets

- Winter 2019 (UCSB):
  - 107 individuals
  - 30 groups (of 3 or 4 people)
  - 30 individual issues, 12 group issues
- Spring 2019 (Fort Bragg):
  - 29 individuals
  - 8 groups (of 3 or 4 people)
  - 28 individual issues, 12 group issues

Prospect Theory Details

- Prospect theory parameters:
  α, β (sensitivity to gain/loss),
  λ (perceived impact of loss relative to gain),
  γ^+, γ^- (degree to which gain (loss) probabilities are over- or under-weighted).
  $\alpha = \beta \in [0, 1]$, $\gamma^{+/-} \in [0, 1]$, and $\lambda \in [0, 10]$.

Proposed Models

- PT
- Neural Net: Choice based on the learned weights of neural net that takes gamble parameters as input.
- Utility: Rational choice based on utility
- Max Gain: Choice based on maximum gain
- Min Loss: Choice based on minimum loss

Neural Net Architecture

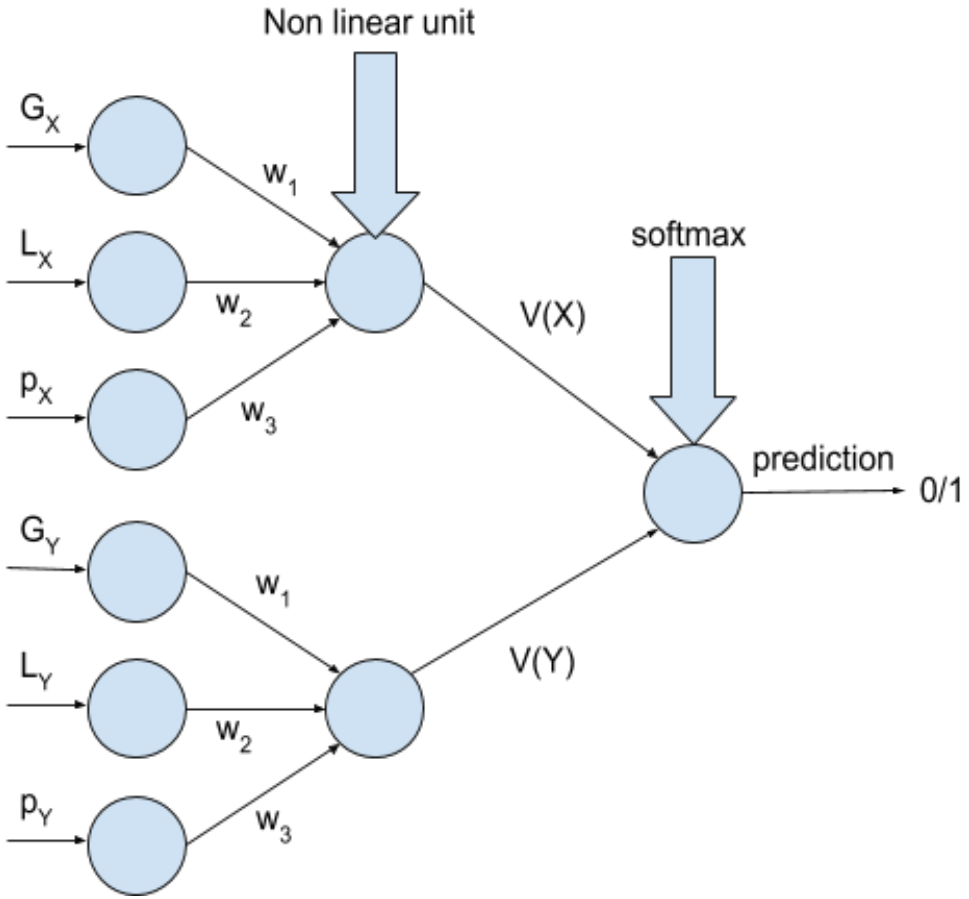


Figure: G, L, p are Gain, Loss and probability of Gain values respectively. X and Y are two different choices and V is a valuation function. Neural Net is learning w_1, w_2, w_3, where each w_i is shared for different choices.

Models: IND, PRE, POST

Three measurements for each individual

- Prior to entering group setting (IND)
- Within a group setting and prior to group discussion on an issue (PRE)
- Within a group setting and after group discussion on an issue (POST)

Prospect Theory Model Performs Better Empirically

Model	*Spring IND*	*Spring PRE*	*Spring POST*	*Winter IND*	*Winter PRE*	*Winter POST*
PT	0.747	0.73	0.782	0.723	0.692	0.699
Neural Net	0.739	0.704	0.704^{*}	0.706^{*}	0.682	0.688
Utility	0.56^{**}	0.606^{**}	0.606^{**}	0.56^{**}	0.639^{**}	0.645^{**}
Max Gain	0.396^{**}	0.399^{**}	0.417^{**}	0.393^{**}	0.431^{**}	0.469^{**}
Min Loss	0.4^{**}	0.397^{**}	0.379^{**}	0.374^{**}	0.385^{**}	0.418^{**}

$^{**}\ p < 0.01$ $^{*}\ p < 0.05$

Table: N-fold cross validation accuracy results for different models. PT model performs best. p-values are calculated with paired t-test between PT and baselines. Neural Net model is closest to PT in terms of accuracy.

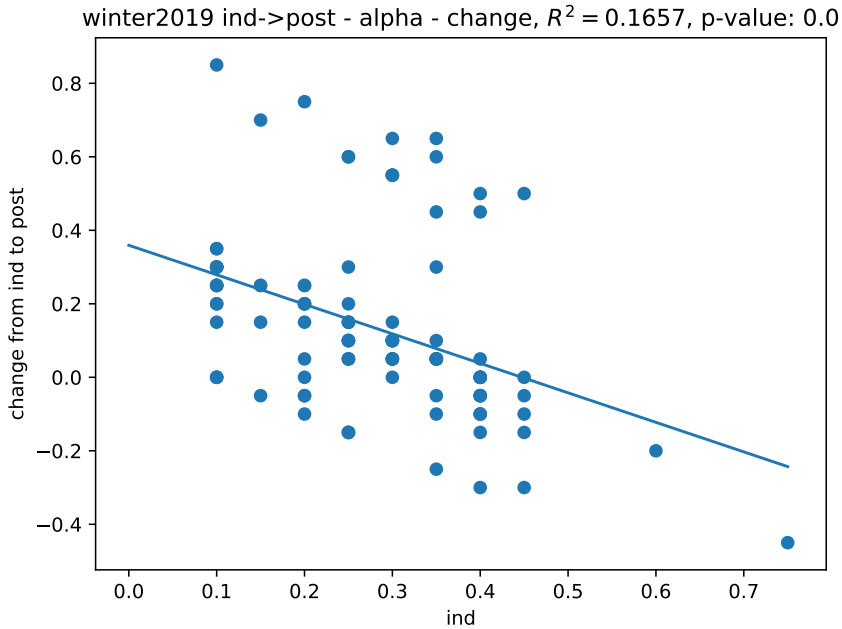
PT Parameter Statistics

	$\alpha = \beta$			λ			$\gamma^+ = \gamma^-$		
Model	*IND*	*PRE*	*POST*	*IND*	*PRE*	*POST*	*IND*	*PRE*	*POST*
Winter 2019	0.28	0.41	0.41	1.47	1.22	0.78	0.58	0.63	0.58
Spring 2019	0.36	0.56	0.54	1.42	1.16	1.43	0.50	0.60	0.56

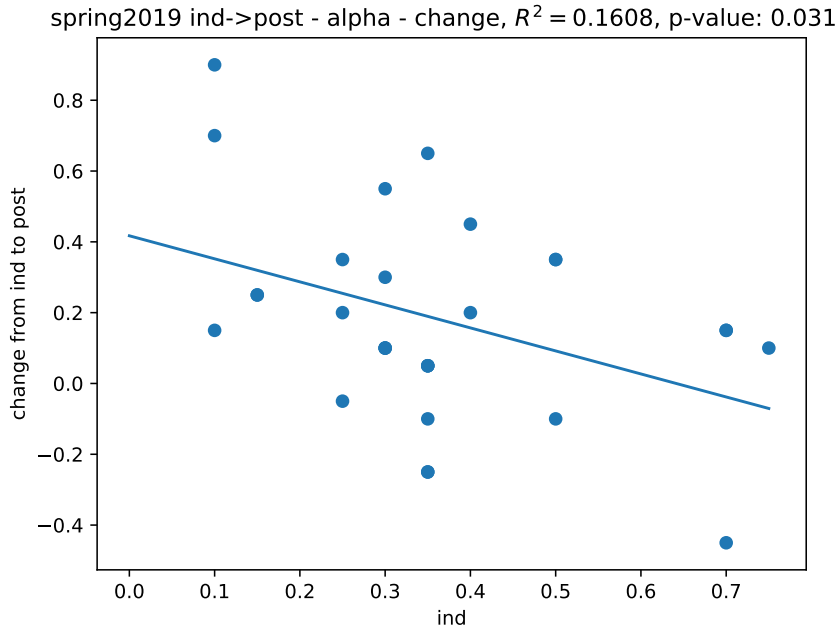
Table: The average statistics of PT parameters for IND/PRE/POST across all individuals.

- In Winter 2019 dataset, $\alpha(\beta)$ increases from IND to PRE to POST (i.e. sensitivity to gain/loss increases) and λ decreases (i.e. teams become less risk-averse).
- In Spring 2019 dataset, there is an increase in $\alpha(\beta)$ from IND to PRE but POST reverts back to IND values, whereas in case of λ, the change happens from IND to PRE without any perceptible change from PRE to POST.
- Parameter γ is relatively stable across all measurements.

Shifts in $\alpha(\beta)$ correlate with their magnitude.



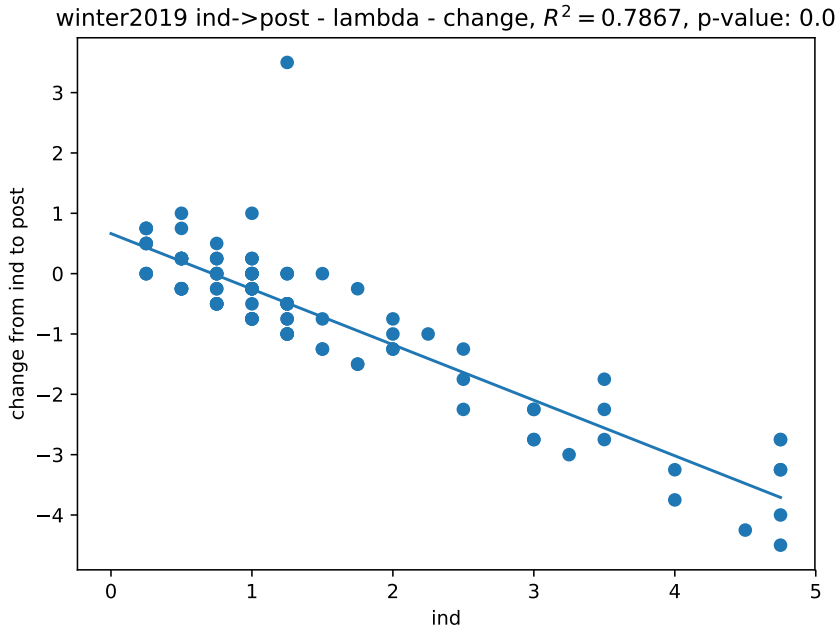
(a) Winter 2019



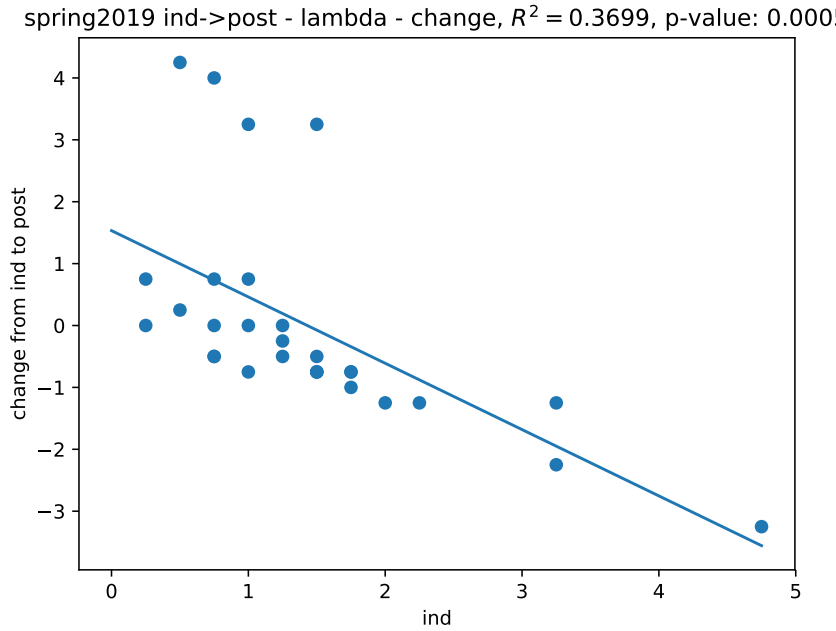
(b) Spring 2019

Figure: When an individual has a higher α value in IND, the change from IND to POST is higher. Significance of this effect < 0.01 for the Winter 2019 dataset and < 0.05 for the Spring 2019 dataset.

Shifts in λ correlate with their magnitude.



(a) Winter 2019



(b) Spring 2019

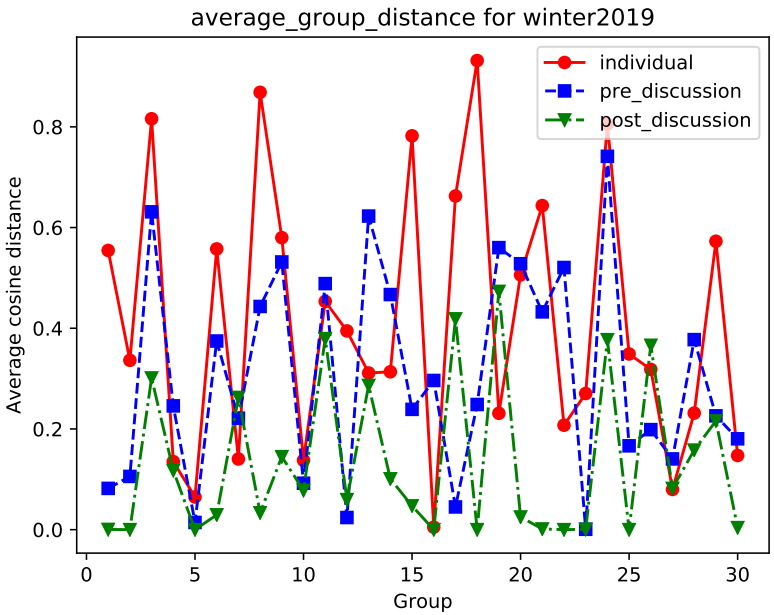
Figure: When an individual has a higher λ value in IND, the change from IND to POST is higher. The significance of this effect < 0.01 for both datasets. However, the correlation is higher for the Winter 2019 dataset.

Measuring Distance between Individuals

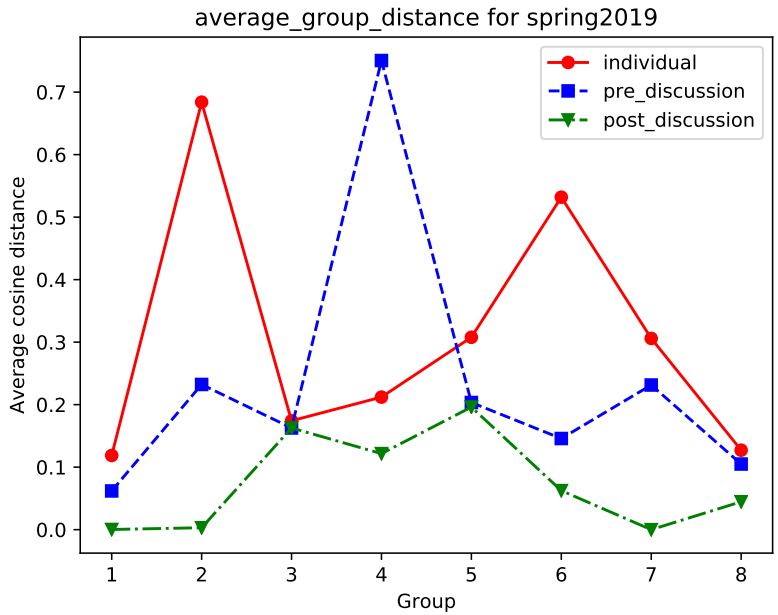
Define a novel measure of "behavioral" distance between individuals based on their PT parameters:

- Sample at random to obtain a random sequence of gambles
- Profile an individual over the gamble sequence to obtain the individual's valuation sequence.
- Compute pairwise distance between two individuals: Compute the cosine distance between the valuation sequences of two individuals. The choice of cosine distance is to capture the orientation and not the absolute magnitude.

Group Behavior Shifts towards Consensus



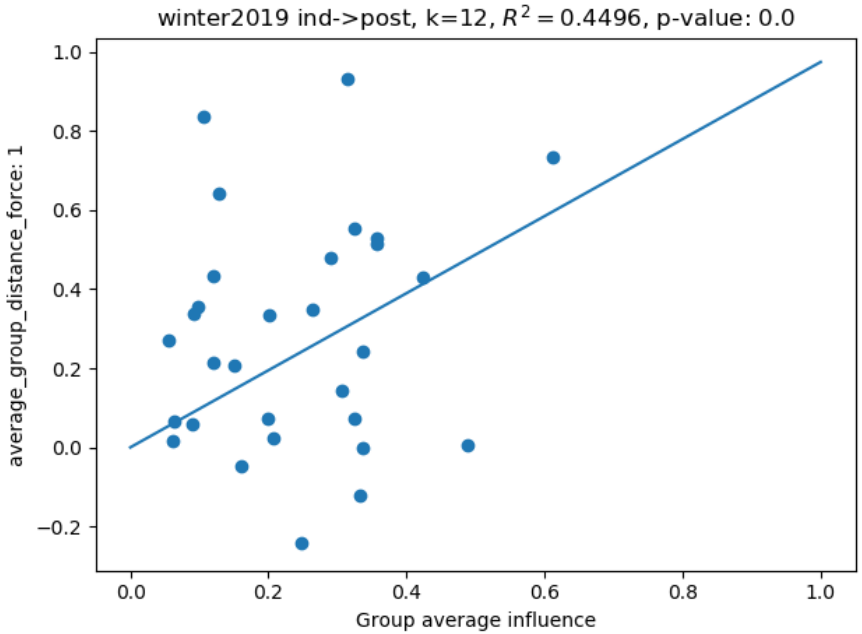
(a) Winter 2019



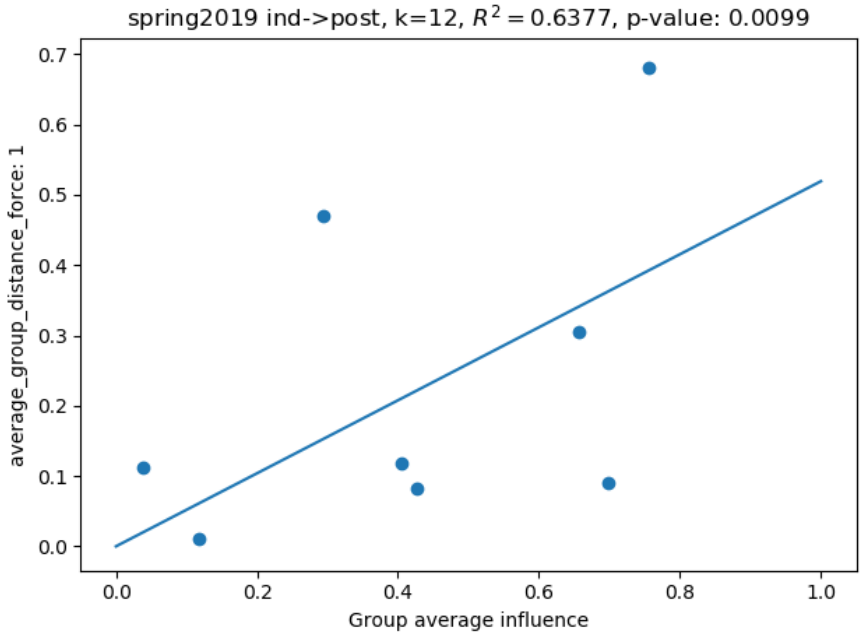
(b) Spring 2019

Figure: Average pairwise distance between individuals in each group for IND, PRE and POST parameters. For most groups, pairwise IND distances $>$ pairwise PRE distances $>$ pairwise POST distance. This shows that the behavior of individuals shifts towards consensus in a group setting. Results hold for both the datasets.

Influence Explains Shift



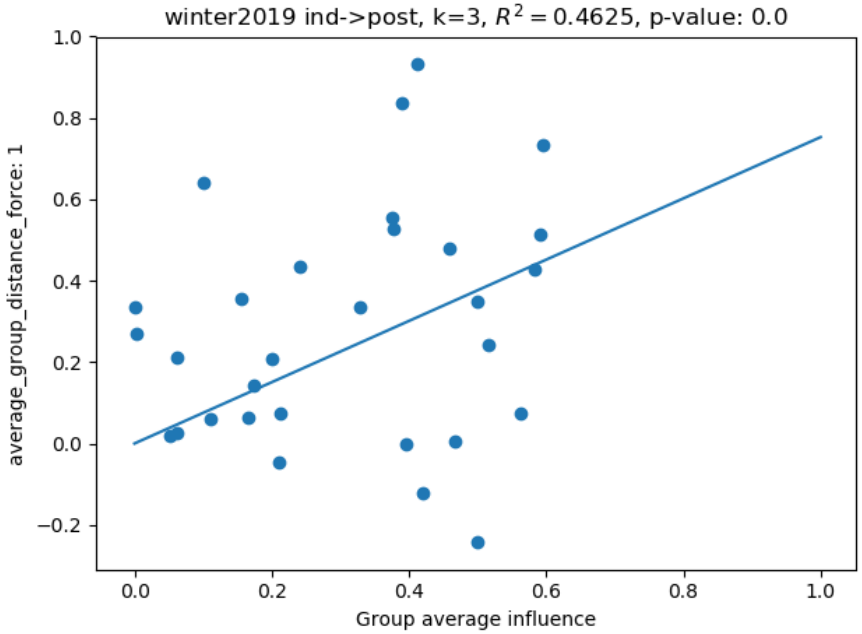
(a) Winter 2019



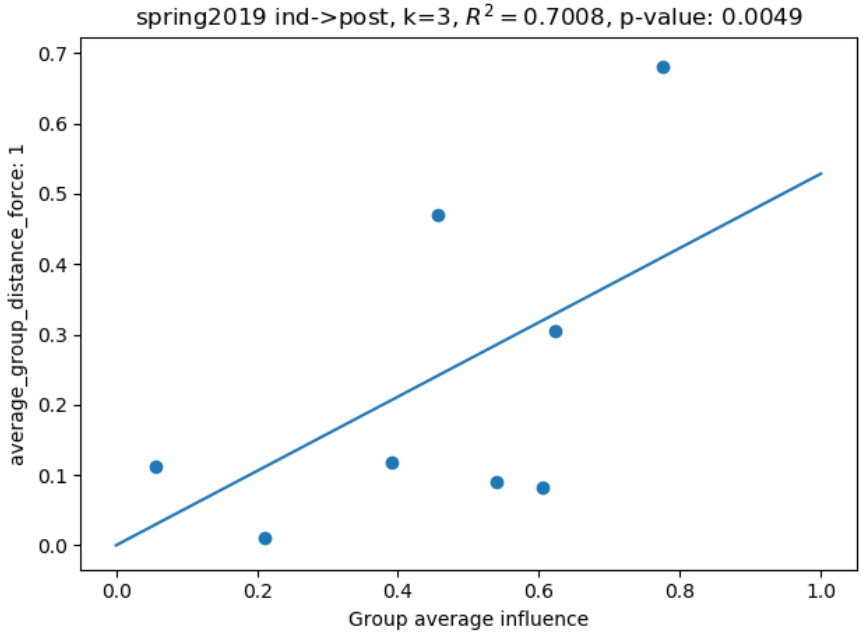
(b) Spring 2019

Figure: The distance of an individual's behavior between IND and POST correlates with the average influence on the individual. The effect is observed on both datasets.

Influence Happens Early



(a) Winter 2019



(b) Spring 2019

Figure: The degree of correlation is marginally higher if we consider the average influence over the first three influence matrices instead of all of them.

POST prediction via PRE and Influence

- $\text{Choice}_{\text{PRE}}$: Pre choices for each questions. It uses influence matrices to calculate the prediction for Post choices for each each group: $I \times \mathit{Choice}_{\text{PRE}} \sim \mathit{Choice}_{\text{POST}}$
- PT_{PRE}: PT Pre parameters learned for Pre questions for each individual. It uses the likelihood of each question for prediction of Post choices.

	Winter2019			**Spring2019**		
$\text{Choice}_{\text{PRE}} \backslash \text{PT}_{\text{PRE}}$	*None*	*Individual*	*Group*	*None*	*Individual*	*Group*
None	0.5	0.731	0.706	0.5	0.847	0.799
Individual	0.956	0.943	0.929	0.922	0.916	0.899
Group	<u>0.977</u>	**0.979**	0.976	**0.98**	<u>0.977</u>	0.974

Table: The n-fold cross-validated *Logistic Regression* accuracy results based on the usage of $\text{Choice}_{\text{PRE}}$ and PT_{PRE}. The experiments show that post prediction for each individual is better with the usage of group member's choices and individual PT parameters.