E C O N O M I C S   B U L L E T I N

Signal Qualities, Order of Decisions, and Informational Cascades: Experimental Evidence

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Abstract

This experimental study investigates the effect of signal strength on the formation of informational cascades by introducing heterogeneous signal qualities associated with the fixed order of decisions on the two different decision−making systems, anti−seniority and seniority. Major findings include that complete cascades occur more frequently in seniority than in anti−seniority, that seniority is more efficient than anti−seniority, but increases the risk of creating negative cascades, and that private signals can be extracted more effectively in anti−seniority than in seniority. For both treatments, rational complete cascades occur less frequently than those suggested by the Bayesian model. For the heuristic subjects employed, the anchoring effect of private signals is partially identified.

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1 Introduction

Informational cascades are said to occur if players ignore private signals by following an established pattern of actions that their predecessors have chosen as a result of Bayesian updating in a sequential decision-making problem. Anderson, L. R. and C. A. Holt (1997) confirmed that informational cascades certainly occur in the laboratory as Bikhchandani, S., D. Hirshleifer, and I. Welch (1992) suggests. However, other experimental studies including Çelen, B. and S. Kariv (2004), Nöth, M. and M. Weber (2003), Kraemer, C., M. Nöth, and M. Weber (2000), and Huck, S. and J. Oechssler (2000) generally argue that subjects put more weight on their private signals than the Bayesian model assumes.

This experimental study investigates the effect of signal strength on the formation of informational cascades by introducing heterogeneous signal qualities associated with the fixed order of decisions on the two different decision-making systems, *anti-seniority* and *seniority*. Major findings include that complete cascades occur more frequently in seniority than in anti-seniority, that seniority is more efficient than anti-seniority, but increases the risk of creating negative cascades, and that private signals can be extracted more effectively in anti-seniority than in seniority. For both treatments, rational complete cascades occur less frequently than those suggested by the Bayesian model. For the heuristic subjects use, the anchoring effect of private signals is identified in deviations by overconfidence, but is not identified clearly in deviations by underconfidence.

The remainder of the paper is organized as follows. Section 2 introduces the analytical framework and presents some theoretical predictions. Section 3 describes experimental procedure, and section 4 reports and discusses the results.

2 Analytical Framework

There are two states of the world $\omega \in \{A, B\}$. Each state is realized equally likely, $\Pr(A) = \Pr(B) = 1/2$. In the experiment, each of six subjects $i \in \{1, 2, ..., 6\}$ does not observe the realized state, but receives a *private signal* σ^i_ω for the underlying state ω. The quality of private signal $\Pr(A|\sigma^i_A)$ or $\Pr(B|\sigma^i_B)$ is drawn from the six levels of precision $\{.55, .6, .65, .7, .75, .8\}$ and is exogenously determined by the position to which a subject is assigned. In addition to private signals, subjects later assigned to position 2 can observe their predecessors' predictions. After observing the private signal and the predecessors' predictions, each subject makes a prediction π^i_ω of which states would be realized one-by-one in sequence.

In the experiment, two treatments *anti-seniority*[1] and *seniority* are conducted. The difference in each treatment lies in the combination of signal qualities and order in which predictions are made, as summarized in Table 1. In anti-seniority, six subjects make predictions in ascending order of the signal qualities. That is, the subject who has the least precise signal makes the prediction in position 1 ($\Pr(A|\sigma_A^1) = \Pr(B|\sigma_B^1) =.55$), the subject who has the second least precise signal makes the prediction in position 2 ($\Pr(A|\sigma_A^2) = \Pr(B|\sigma_B^2) =.6$), and in like manner, the subject who has the most precise signal makes the prediction in position 6 ($\Pr(A|\sigma_A^6) = \Pr(B|\sigma_B^6) =.8$). In seniority, six subjects make predictions in descending order of the signal qualities. That is, the subject who has the most precise signal makes the prediction in position 1 ($\Pr(A|\sigma_A^1) = \Pr(B|\sigma_B^1) =.8$), the subject who has the second most precise signal makes the prediction in position 2 ($\Pr(A|\sigma_A^2) = \Pr(B|\sigma_B^2) =.75$), and in like manner, the subject who has the least precise signal makes the prediction in position 6 ($\Pr(A|\sigma_A^6) = \Pr(B|\sigma_B^6) =.55$).

In the experiment, the combination of signal qualities and order of decisions are common knowledge among all subjects. Thus, if subjects act as rational Bayesians, these two different treatments would create different behavioral patterns in the aggregate as follows.

In anti-seniority, complete informational cascades[2] occur if subjects in the first three consecutive positions make the same predictions. For example, the posterior probability that state A would be realized given that the subjects in the first three consecutive positions have predicted A and the subject in position 4 observes σ_B^4 is $\Pr(A|\pi_A^1, \pi_A^2, \pi_A^3, \sigma_B^4) = \frac{\frac{1}{2}\times.55\times.6\times.65\times.3}{\frac{1}{2}\times[(.55\times.6\times.65\times.3)+(.45\times.4\times.35\times.7)]} = .593$. In this case, the subject in position 4 should ignore his or her private signal by following the established pattern of predictions. Once he or she enters a cascade, the subjects in positions 5 and 6 should ignore their own private signals of σ_B as well. In seniority, the subject in position 2 should make the same predictions as the first subject, even when the private signal of the second subject does not correspond to the prediction of the first subject since $\Pr(A|\pi_A^1, \sigma_B^2) = \Pr(B|\pi_B^1, \sigma_A^2) = \frac{\frac{1}{2}\times.8\times.25}{\frac{1}{2}\times[(.8\times.25)+(.2\times.75)]} = .571$. This leads to the result that subjects in a round should always make unanimous predictions regardless of whether they enter informational cascades or they truthfully reveal their own private signals.

[1] The term anti-seniority is used in Ottaviani, M. and P. N. Sørensen (2001).

[2] For the definition of complete informational cascades, see section 4.1.

3 Experimental Procedure

Subjects were recruited from undergraduate students at Keio University. Before the experiment began they were instructed about the entire structure of the experiment[3]. At the beginning of each round, the experimenter announced which treatment was to be conducted in order to make the combination of signal quality and the order of decision common knowledge. The experimenter drew one of the two cards from a box. On the card a letter, either "A" or "B" was printed and the letter on the card drawn represented the state of the world for that round. After confirming the letter, the experimenter then hid it from the subjects until the round was completed. Each subject then drew one of the six cards for determining the combination of the signal quality and the order of the decision.

Private signals were implemented by having the subjects draw one of 20 white or red marbles from a box. The white marbles represented state A and the red marbles represented state B. Different signal qualities were created by varying the proportion of white and red marbles in a box given the realized state, treatment, and the assigned signal quality for each subject. For example, if state A had been realized, a subject who was assigned to position 1 in the anti-seniority treatment drew a marble from the box containing 11 white and nine red marbles[4].

The experimenter approached each subject in turn and presented the box containing the exact proportion of white and red marbles for each subject from the set of six[5]. The subject drew a marble from the box and wrote down the state indicated by the color on the subject's record sheet. Then, the subject made a prediction by writing down one of the two states he or she thought which was more likely to be on the subject's record sheet. The experimenter wrote down the subject's signal and prediction on the experimenter's record sheet. The experimenter then approached the subject in the next position and showed the sequence of his or her predecessors' predictions. After all six subjects submitted predictions, the card the experimenter had drawn at the beginning of the round was revealed. This process was repeated 16 times in one session with combinations of each treatment[6].

[3] Subject instructions are available upon request to the author.

[4] The various combinations of the marbles in each position and the state for each treatment are summarized in Tables 2 and 3.

[5] A set of six identical boxes, upon which codes were marked, was stored in a larger box separately from the states and kept in another room. After confirming the state, the experimenter brought the appropriate set from that room so that subjects could not identify which set was actually used. By checking the codes on the box, the experimenter could choose the appropriate box for each subject.

[6] The actual order of treatment in each session is shown in Table 4.

Sixty-six subjects participated in the experiment. After the session, subjects were privately paid their payoffs in cash. For each correct prediction, 200 Japanese yen (equivalent to $1.84) was paid. The average, minimum, and maximum payment was 2309 yen, 800 yen and 3200 yen, respectively.

4 Results

4.1 Aggregated Behavior

In order to compare the aggregated behavior of each treatment, the analysis is based on the following three criteria: *complete positive (negative) cascades*, *partial cascades*, and *full revelations*.

A *complete positive (negative) cascade* denotes a pattern of behavior such that at least one subject ignores his or her private signal by following the established pattern of predictions, and all of the six subjects in a round make unanimous correct (incorrect) predictions. Among complete positive (negative) cascades, a pattern of behavior such that all predictions are consistent with Bayesian posterior probability is called a *rational complete positive (negative) cascade*. A *partial cascade* denotes a pattern of behavior such that at least one subject ignores his or her private signal by following the established pattern of predictions, but at least one subject collapses it. As a result, predictions are not unanimous in a round. A *full revelation* denotes a pattern of behaviors such that all of the subjects make predictions consistent with their private signals. An aggregated behavior is counted as a full revelation regardless of whether predictions are consistent with Bayesian posteriors, or whether they are unanimous. Note that these three criteria do not overlap each other.

Result 1: Learning within each session was not observed.

Tables 5 and 6 report the Mann–Whitney U-tests on an equal proportion of predictions which is consistent with the Bayesian posterior between the first and the last two rounds within each session for each treatment. In both treatments, the null hypothesis of no difference cannot be rejected for all sessions[7]. Therefore, any systematic pattern of learning within each session was not observed, so that we can pool the data for each treatment and compare their properties.

[7] In seniority, almost all predictions in the first and the last two rounds within each session are identically consistent with Bayesian posterior, such that the Mann–Whitney U-test cannot be performed for those sessions. In sessions 6 and 11 where different proportions of Bayesian consistent predictions were observed, they are not significantly different between the first and last two rounds.

Result 2: Subjects made more correct predictions in seniority than in anti-seniority.

The proportion of correct predictions in anti-seniority is 69.49%, whereas that in seniority is 81.94% (Table 7, row 1). The Mann–Whitney U-test shows that this difference is statistically significant (Table 8, row 1). We can then say that seniority increases subjects' welfare in the sense that it leads to more correct predictions.

Result 3: Complete (positive and negative) cascades and rational complete (positive and negative) cascades occurred more frequently in seniority than in anti-seniority, whereas partial cascades occurred more frequently in anti-seniority than in seniority.

The observed proportions of complete (positive and negative) cascades and rational complete (positive and negative) cascades are higher in seniority than in anti-seniority (Table 7, row 2- row 5). The Mann-Whitney U-test shows that all of these differences are statistically significant (Table 8, row 2-row 5). However, the observed proportion of partial cascades is higher in anti-seniority than in seniority (Table 7, row 6), which is significantly different (Table 8, row 6). Therefore, seniority enhances the occurrence of positive cascades, but also increases the risk of negative cascades. Meanwhile, the established cascades are more likely to be collapsed in anti-seniority than in seniority.

Result 4: Full revelations occurred more frequently in anti-seniority than in seniority.

The proportion of full revelations in anti-seniority is 58.04% whereas that in seniority is 20.00% (Table 7, row 7), which is significantly different (Table 8, row 7). Thus, anti-seniority extracts private signals more effectively than in seniority.

Result 5: For both treatments, rational complete (positive and negative) cascades occurred less frequently than the Bayesian model would suggest.

The probability that rational complete cascades occur is given by the probability that unanimous predictions by full revelations occur, subtracted from the probability that complete cascades occur since unanimous predictions by full revelations are not counted in rational complete cascades. In anti-seniority, rational complete positive cascades for state A occur with $[\Pr(A|\sigma_A^1) \times \Pr(A|\sigma_A^2) \times \Pr(A|\sigma_A^3)] - [\Pr(A|\sigma_A^1) \times \Pr(A|\sigma_A^2) \times \Pr(A|\sigma_A^3) \times \Pr(A|\sigma_A^4) \times \Pr(A|\sigma_A^5) \times \Pr(A|\sigma_A^6)] = .125$. Rational complete negative cascades for state A occur with $[\Pr(A|\sigma_B^1) \times \Pr(A|\sigma_B^2) \times \Pr(A|\sigma_B^3)] - [\Pr(A|\sigma_B^1) \times \Pr(A|\sigma_B^2) \times \Pr(A|\sigma_B^3) \times \Pr(A|\sigma_B^4) \times \Pr(A|\sigma_B^5) \times \Pr(A|\sigma_B^6)] = .062$. In seniority, rational complete positive cascades for state A occur with $\Pr(A|\sigma_A^1) -$

$[\Pr(A|\sigma_A^1)\times \Pr(A|\sigma_A^2)\times \Pr(A|\sigma_A^3)\times \Pr(A|\sigma_A^4)\times \Pr(A|\sigma_A^5)\times \Pr(A|\sigma_A^6)] = .710$. Rational complete negative cascades for state A occur with $\Pr(A|\sigma_B^1) - [\Pr(A|\sigma_B^1)\times \Pr(A|\sigma_B^2)\times \Pr(A|\sigma_B^3)\times \Pr(A|\sigma_B^4)\times \Pr(A|\sigma_B^5)\times \Pr(A|\sigma_B^6)] = .199$.

However, observed proportions of rational complete cascades are consistently lower than the probabilities calculated above (Table 7, rows 4 and 5). The one-tailed tests of population proportion show that for both treatments, the observed proportions of rational complete (positive and negative) cascades are significantly lower than those suggested by the Bayesian model (Tables 9 and 10).

4.2 Analysis of Deviation

Given these observations, we investigate why some subjects do not act as the Bayesian theory predicts. To do so, we focus on two types of deviation, *overconfidence* and *underconfidence*. In the current experiment, overconfidence can be defined as a prediction that is not consistent with Bayesian posterior, but is consistent with the subject's private signal. Underconfidence can be defined as a prediction that is consistent with neither Bayesian posterior, nor the subject's private signal, but is consistent with a prediction that is made by at least one of his or her predecessors[8].

As Tables 11–12 show, overconfidence and underconfidence certainly exist[9]. Given the existence of them, one may think that each subjects' predictions are "anchored" by their own signal qualities. That is, subjects with more precise signals tend to be overconfident and subjects with less precise signals tend to be underconfident.

In anti-seniority, the anchoring hypothesis postulates that deviations by underconfidence would occur more in earlier positions and less in later positions. On the other hand, deviations by overconfidence would occur more in later positions and less in earlier positions. Observed deviations by underconfidence (Table 11, third column) certainly decrease from 9.82% in position 3 to 1.78% in position 5. However, there are two increases from 4.47% in position 2 to 9.82% in position 3 and from 1.78% position 5 to 2.68% position 6. This latter observation is not consistent with the systematic pattern of

[8]The other pattern of deviation can be called irrational because it is consistent with neither Bayesian posterior, the subject's private signal, nor any predecessor's predictions. 19 irrational predictions were observed only in anti-seniority (among 672 decisions). Note that these three patterns of deviation do not overlap each other.

[9]In anti-seniority, overconfidence cannot occur in positions 2 and 3 because obeying private signals is always consistent with the Bayesian posteriors. In seniority, underconfidence cannot occur in position 2 because obeying the prediction of the subject in position 1 is always consistent with the Bayesian posterior.

deviations discussed, so that we conclude that the observed deviations by underconfidence do not perfectly support the anchoring hypothesis. Observed deviations by overconfidence (Table 11, second column) increase consistently from 5.36% in position 4 to 12.50% in position 6. This systematic pattern of deviations supports the anchoring hypothesis.

In seniority, the anchoring hypothesis postulates that deviations by underconfidence would occur more in later positions and less in earlier positions. On the other hand, deviations by overconfidence would occur more in earlier positions and less in later positions. Observed deviations by overconfidence decrease from 15.0% in position 2 to about 0% in position 2 later (Table 12, second column). This moderately supports the anchoring hypothesis for overconfidence. However, the few observations of deviations for underconfidence (Table 12, third column) do not support it for underconfidence. To summarize, we have the following.

Result 6: The anchoring effect is identified in deviations by overconfidence, but is not identified clearly in deviations by underconfidence.

The unidentification problem of the anchoring effect in deviations by underconfidence in seniority could be attributed to the intrinsic structure of posteriors. Subjects in later positions frequently face extreme high or low posteriors, such that they can make relatively easy predictions consistent with Bayesian posteriors by following the established pattern of predictions, even when their private signals do not correspond to it. The unclear identification problem of the anchoring effect in deviations by underconfidence in anti-seniority could be related to the number of available private signals. The results of experiments by Çelen and Kariv (2004) indicate that subjects in earlier positions are more likely to be overconfident on private signals than subjects in later positions. If this tendency exists in the current experiment, underconfidence in earlier positions could be offset by this overconfidence and therefore result in the unclear identification of the anchoring effect in anti-seniority. In order to distinguish between overconfidence in earlier positions and the anchoring effect, we need to investigate how these two effects interact under various conditions.

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Appendix

Table 1: Combination of signal qualities and order of decisions in each treatment

		Position					
		1	2	3	4	5	6
Treatment	Anti-seniority	.55	.6	.65	.7	.75	.8
	Seniority	.8	.75	.7	.65	.6	.55

Table 2: Contents of boxes in each state and each position: Anti-seniority

Anti-seniority							
		Position (signal quality)					
Realized state	Marbles	1 (.55)	2 (.6)	3 (.65)	4 (.7)	5 (.75)	6 (.8)
A	White	11	12	13	14	15	16
	Red	9	8	7	6	5	4
B	White	9	8	7	6	5	4
	Red	11	12	13	14	15	16

Table 3: Contents of boxes in each state and each position: Seniority

Seniority							
		Position (signal quality)					
Realized state	Marbles	1 (.8)	2 (.75)	3 (7)	4 (.65)	5 (.6)	6 (.55)
A	White	16	15	14	13	12	11
	Red	4	5	6	7	8	9
B	White	4	5	6	7	8	9
	Red	16	15	14	13	12	11

Table 4: Treatments conducted in each sessions
(A: Anti-seniority, S:Seniority)

Sessions	1	2	3	4	5	6	7	8	9	10	11
Rounds 1-12	A	A	A	A	A	S	A	S	A	S	A
Rounds 12-16	-	A	S	S	S	A	S	A	S	A	S

Table 5: Mann-Whitney U tests of equal proportion of predictions which is consistent with Bayesian posterior probability between the first and the last two rounds for each session: Anti-seniority

Anti-seniority						
Session	1	2	3	4	5	6
z	$-.440$	$-.604$	.000	1.319	$-.604$	1.813
$P > \|z\|$	.660	.546	1.000	.187	.546	.070
Session	7	8	9	10	11	
z	$-.604$	1.000	-1.000	.000	.604	
$P > \|z\|$	.546	.3173	.3173	1.000	.546	

Table 6: Mann-Whitney U tests of equal proportion of predictions which is consistent with Bayesian posterior probability between the first and the last two rounds for each session: Seniority

Seniority		
Session	6	11
z	1.000	1.000
$P > \|z\|$	.3173	.3173

Table 7: Aggregated behavior

	Anti-seniority 112 rounds, 672 decisions	Seniority 60 rounds, 360 decisions
Correct predictions	467 (69.49%)	295 (81.94%)
Complete positive cascades	16 (14.29%)	36 (60.00%)
Complete negative cascades	2 (1.79%)	6 (10.00%)
Rational complete positive cascades	7 (6.25%)	36 (60.00%)
Rational complete negative cascades	1 (.89%)	6 (10.00%)
Partial cascades	29 (25.89%)	6 (10.00%)
Full revelations	65 (58.04%)	12 (20.00%)

Table 8: Mann-Whitney U tests of equal proportion for each treatment

	z	$P > \|z\|$
Correct predictions	-4.335	.0000
Complete positive cascades	-6.204	.0000
Complete negative cascades	-2.431	.0151
Rational complete positive cascades	-7.736	.0000
Rational complete negative cascades	-2.873	.0041
Partial cascades	2.460	.0139
Full revelations	4.767	.0000

Table 9: Tests of population proportion on the equality between theoretical prediction and actual occurrence: Rational complete positive cascades

Anti-seniority	Seniority
z=-2.000, $P < z$=.0228	z=-1.878, $P < z$=.0302

Table 10: Tests of population proportion on the equality between theoretical prediction and actual occurrence: Rational complete negative cascades

Anti-seniority	Seniority
z=-2.329, $P < z$=.0099	z=-1.921, $P < z$=.0274

Table 11: Percentage of deviations from Bayesian posterior by position: Anti-seniority

Position	Overconfidence	Underconfidence
1	-	-
2	-	4.47%
3	-	9.82%
4	5.36%	3.57%
5	9.82%	1.78%
6	12.50%	2.68%

Table 12: Percentage of deviations from Bayesian posterior by position: Seniority

Position	Overconfidence	Underconfidence
1	-	-
2	15.00%	-
3	.00%	.00%
4	.00%	1.67%
5	1.67%	.00%
6	.00%	.00%