Can You Believe Your Neighbors' Behaviors?

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Abstract

In the theoretical assumption of informational cascades, private signals and predecessors' actions are equivalently informative before informational cascades, but are not once informational cascades have started. This experimental study tests this assumption by measuring the informativeness of private signals and predecessors' actions for human subjects in and out of informational cascades. We observed that subjects in informational cascades do not extract much information from predecessors' actions, indicating that they recognize other subjects' cascading behaviors, that subjects rely more on their private signals than on predecessors' actions even when both of them are equivalently informative, and that subjects cannot estimate posterior beliefs precisely in a Bayesian way due to cognitive biases such as anchoring and adjustment or conservatism.

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1 Introduction

Suppose a situation where individuals observe informative but noisy private signals for an underlying state and choose an appropriate action for that state one by one in sequence. If individuals' actions are publicly observable, successors can infer their predecessors' private signals. These publicly inferred signals are aggregated as the decision-making process goes on. When an individual's private signal does not correspond to the aggregated publicly inferred signals, rational individuals may ignore it and follow the action the majority of predecessors have chosen. Informational cascades, formulated by Bikhchandani, Hirshleifer, and Welch (1992) (hereafter BHW), are said to occur if all the individuals in a society choose an identical action irrespective of their private signals as a consequence of rational Bayesian belief updating

In the BHW theory, individuals are supposed to update their posterior beliefs in a Bayesian way before informational cascades, but they are supposed not to update once informational cascades have started. This behavioral hypothesis is implicitly based on the assumption that private signals and predecessors' actions are equivalently informative before informational cascades, but are not once informational cascades have started. In informational cascades, private signals always reflect the underlying state, whereas predecessors' actions convey no information about the underlying state because they may not reflect predecessors' private signals.

The primary objective of this experimental study is to test the assumption above by measuring the informativeness of private signals and predecessors' actions for human subjects. To do that, we implement scoring rules on a one-person cascades treatment where subjects observe only private signals, and on a six-person cascades treatment where subjects observe only predecessors' actions. Then, we examine their belief updating behaviors in the two different treatments[1].

From the experimental results, we observed that subjects in informational cascades do not extract much information from predecessors' actions, indicating that they recognize other subjects' cascading behaviors, that subjects rely more on their private signals than on predecessors' actions even when both of them are equivalently informative, and that subjects cannot estimate posterior beliefs precisely in a Bayesian way due to cognitive biases such as anchoring and adjustment or conservatism.

The remainder of the paper is organized as follows. Section 2 introduces the experimental design and procedure, Section 3 proposes behavioral assumptions, Section 4 reports the results, and the final section discusses them.

2 Design and procedure

2.1 The prediction game

There are two states of the world $\omega = \{A, B\}$. Each state is realized with the commonly known priors $\Pr(A) = p = 1/2$, and $\Pr(B) = 1 - p = 1/2$. Subjects do not know which

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[1] There have been many experimental studies on informational cascades. Most of them have examined whether informational cascades actually occur in the laboratory as the BHW theory predicts (e.g. Anderson and Holt (1997)). A few studies have investigated subjects' belief updating behaviors by using scoring rules (Dominitz and Hung (2004)) or by using the BDM mechanism (Stiehler (2003)). However, to our knowledge, there has been no study which directly analyzes each informativeness of private signals and predecessors' actions.

state would be realized. However, they can infer the realized state by making use of two types of information, *private signals* σ_ω and *predecessors' predictions* π_ω in each of six stages in one round.

Private signals can be observed by drawing one ball from an urn with replacement. There are two urns, A and B. Each urn contains white or red balls, which represent state A and state B, respectively. If state A has been realized, subjects draw one ball from urn A which contains two white balls and one red ball, and if state B has been realized, subjects draw one ball from urn B, which contains two red balls and one white ball. Thus, the posterior probability that the ball drawn indicates the correct state is $\Pr(A|\sigma_A) = 0.67$ and $\Pr(B|\sigma_B) = 0.67$.

In addition to private signals, subjects may observe all predictions made by their predecessors; subjects in stage t can observe $t-1$ predictions made by their predecessors.

The main role of the subjects in this experiment is to submit predictions and beliefs about which state would be realized with what probability in the following two different treatments.

2.2 Treatments

2.2.1 One-person cascades treatment

In the one-person cascades treatment (1-CAS), the prediction game is played by only one player. Since subjects in 1-CAS do not interact with other subjects, they cannot observe predecessors' predictions. Instead, they can observe one independent private signal in each of six stages per round. After observing one private signal, they are requested to submit both predictions and beliefs.

2.2.2 Six-person cascades treatment

In the six-person cascades treatment (6-CAS), the prediction game is played by a group of six subjects in an exogenously determined order. When subjects in stage t are requested to submit both predictions and beliefs, they can observe $t-1$ predecessors' predictions and one private signal. We name the stages where subjects submit both predictions and beliefs as *decision stages*. A decision stage is assigned to each subject once per round and the prediction submitted in a decision stage is announced publicly to the other five subjects of the same group. Subjects who do not submit predictions in stage t cannot observe private signals but observe $t-1$ predecessors' predictions. They are requested to submit beliefs after observing $t-1$ predecessors' predictions. We name such stages where subjects submit only beliefs as *nondecision stages*. Nondecision stages are assigned to each subject five times per round and the beliefs reported in nondecision stages are not announced to the other subjects[2].

2.3 Payoffs

Payoffs to the subjects consist of prediction points and belief points.

In 1-CAS, subjects receive the prediction point ¥50 if they have submitted the correct prediction in the stage which is randomly chosen by the computer among six stages per

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[2] Whereas a sequence of decision stages corresponds to the ordinary structure of informational cascades experiments (e.g., Anderson and Holt (1997)), our experimental design requires subjects who are not in the decision stage to report their beliefs.

round. In 6-CAS, subjects receive the prediction point ¥50 if they have submitted the correct prediction in the decision stage.

For belief points, we use the incentive compatible 'scoring rule' as in Nyarko and Schotter (2002) and Dominitz and Hung (2004). Specifically, subject i is requested to report the probability that he/she thinks state A would be realized $\mu_i(A)$ and the probability that he/she thinks state B would be realized $\mu_i(B)$[3]. If state A is realized in that round, the belief point to subject i is

$$¥15(2-[(1-\mu_i(A))^2+(\mu_i(B))^2]), \tag{1}$$

and if state B is realized in that round, the belief point to subject i is

$$¥15(2-[(\mu_i(A))^2+(1-\mu_i(B))^2]). \tag{2}$$

3 Behavioral assumptions

We compare subjects' belief updating behaviors in the situation where subjects observe only private signals and in the situation where subjects observe only predecessors' predictions. To do that, we restrict our analysis to their posterior beliefs reported in stages 1–5 of 1-CAS and those reported in nondecision stages 2–6 of 6-CAS. Note that subjects in stage t of 1-CAS observe t private signals and those in the nondecision stage $t+1$ of 6-CAS observe the same number of t predecessors' predictions.

In 1-CAS, subjects observe only private signals. Since private signals always reflect the realized state, subjects can update their posterior beliefs in a Bayesian way. Thus, informational cascades cannot occur.

In the nondecision stage of 6-CAS, subjects observe only predecessors' predictions. If they observe at least three agreeing predecessors' predictions consecutively, they would think that their predecessors in decision stage may have ignored private signals since $\Pr(A|\pi_A^1,\pi_A^2,\sigma_B^3)=0.67$, for example. In such a situation where informational cascades may have occurred, subjects in nondecision stage of 6-CAS cannot update posterior beliefs in a Bayesian way because newly added predecessors' predictions convey no information about the realized state. Once informational cascades have occurred, posterior beliefs of subjects in nondecision stage $t+1$ would be $\Pr(A|\pi_A^1,\pi_A^2,...,\pi_A^t)\in[0.67,0.89]$ if the most recently observed predecessor's prediction is same as the formerly agreeing ones[4]. Posterior beliefs of subjects in nondecision stage $t+1$ would be $\Pr(A|\pi_A^1,\pi_A^2,...,\pi_B^t)=0.67$ if the most recently observed predecessor's prediction is different from the formerly agreeing ones[5].

We name stages where informational cascades would not occur in 6-CAS as *no-cascades stages* and those where informational cascades would occur in 6-CAS as *cascades stages.*

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[3] Subjects are instructed that the sum of $\mu_i(A)$ and $\mu_i(B)$ should be 1. The computer program does not accept a belief pair that does not sum to 1.

[4] This is because the subjects in decision stage t observe either σ_A^t or σ_B^t.

[5] Obviously, in informational cascades, reporting the different predictions from the formerly agreeing ones in decision stage is not a Bayesian Nash equilibrium. However, we do not exclude such cases and examine subjects' posterior beliefs after observing predecessors' off-the-equilibrium path predictions. We assume that subjects in decision stage would report off-the-equilibrium path predictions if and only if they observe different private signals from the formerly agreeing predictions.

In no-cascades stages, since private signals and predecessors' predictions are equivalently informative, subjects in 1-CAS and in 6-CAS can update posterior belief in a Bayesian way. Thus, they would report exactly the same posterior beliefs if the sequences of the observed private signals/predecessors' predictions are the same. In cascades stages, since private signals are informative, but predecessors' predictions are not informative, subjects in 1-CAS can update posterior beliefs in a Bayesian way, whereas those who in 6-CAS cannot. Thus, posterior beliefs reported in 1-CAS would be higher than those reported in 6-CAS even if the sequences of the observed private signals/predecessors' predictions are the same.

To summarize the discussion above, we provide the following hypotheses:

- Hypothesis 1: In 1-CAS, subjects update their posterior beliefs in no-cascades stages and cascades stages in a Bayesian way.
- Hypothesis 2: In 6-CAS, subjects update their posterior beliefs in no-cascades stages in a Bayesian way, but do not update their beliefs in cascades stages.
- Hypothesis 3: In cascades stages, subjects' posterior beliefs reported in 1-CAS are higher than those reported in 6-CAS. However, in no-cascades stages, subjects' posterior beliefs reported in 1-CAS and those reported in 6-CAS are the same if the sequence of the observed private signals or predecessors' predictions is the same.

4 Results

Thirty undergraduate students from Future University-Hakodate and thirty undergraduate and graduate students from Osaka University participated in the experiment. They played the prediction game for six rounds in each of the 6-CAS and 1-CAS treatments. Each experimental session took less than 100 minutes including instructions and payment. Average payment was ¥3220 including a show-up fee. The whole experimental procedure was programmed and implemented by z-Tree (Fischbacher (1999)).

For presenting results, we categorize all stages into no-cascades stages 1-3 and cascades stages 1-3 by the hypothetical posterior probabilities we assumed in the preceding section[6]. Table 1 provides subjects' average posterior beliefs reported in no-cascades stages along with the hypothetical posterior probabilities given the sequences of observed private signals/predecessors' predictions. Table 2 provides those reported in cascades stages when the most recently observed private signals/predecessor's prediction is same as the formerly agreeing ones, whereas Table 3 provides those reported in cascades stages when the most recently observed private signals/predecessor's prediction is different from the formerly agreeing ones.

They are also displayed graphically in Figures 1-4. Note that the vertical axes represent the posterior belief that one of the states would be realized and the horizontal axes represent each stage. Note also that bold lines represent subjects' average posterior beliefs and dotted lines represent the hypothetical posterior probabilities.

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[6] Because of the symmetric signal configuration, we can regard the posterior beliefs for state A reported in each stage given a sequence of private signals/predecessors' predictions as equal to those for state B given its complementary sequence.

4.1 Belief updating behaviors

Table 4 reports the Spearman's rank correlation tests. In 1-CAS, we can reject the null hypothesis of no correlation between subjects' posterior beliefs and the sequences of observed private signals/predecessors' predictions in no-cascades stages and cascades stages. In 6-CAS, we can reject the null hypothesis in no-cascades stages, whereas we cannot reject it in cascades stages. We argue that subjects' posterior beliefs increase as the agreeing private signals increase in no-cascades stages and cascades stages of 1-CAS. They also increase as the agreeing predecessors' predictions increase in no-cascades stages of 6-CAS, but they do not increase as the agreeing predecessors' predictions increase in cascades stages of 6-CAS. Since increases of posterior belief would reflect subjects' belief updating, we derive the following results.

- Result 1: In 1-CAS, subjects update their posterior beliefs in both no-cascades stages and cascades stages.
- Result 2: In 6-CAS, subjects update their posterior beliefs in no-cascades stages, but do not update their beliefs in cascades stages.

4.2 Informativeness of private signals and predecessors' predictions

Tables 5 and 6 report the Mann-Whitney test of difference in the posterior beliefs reported in each stage of 1-CAS and 6-CAS. For the beliefs when the most recently observed private signal/predecessor's prediction is same as the formerly agreeing ones, we can reject the null hypothesis of no difference for all stages. For the beliefs when the most recently observed private signal/predecessor's prediction is different from the formerly agreeing ones, we can reject the null hypothesis of no difference for all stages[7]. Thus, we derive the following result.

- Result 3: Subjects' posterior beliefs reported in 1-CAS are significantly higher than those reported in 6-CAS not only in almost all the cascades stages but also in all the no-cascades stages.

5 Discussion

Results 1 and 2 are consistent with our hypotheses 1 and 2. For Result 2, subjects in cascades stages of 6-CAS do not extract much information from predecessors' predictions, indicating that they recognize other subjects' cascading behaviors. However, this observation is not consistent with previous results of similar experiments by Dominitz and Hung (2004) and Stiehler (2003). The difference might be due to the fact that our subjects, unlike subjects in those experiments, participated in both 1-CAS and 6-CAS. By participating in both treatments, our subjects may be aware the different informativeness of private signals and predecessors' predictions in cascades stages.

Result 3 is consistent with the first half and inconsistent with the last half of hypothesis 3. This observation indicates that private signals are more informative than

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[7] In cascades stage 1, the average posterior belief reported in 6-CAS is higher than that in reported in 1-CAS.

predecessors' predictions not only in cascades stages but also in no-cascades stages. This is clear evidence that subjects distrust other subjects. They might think that information obtained by my own is more reliable than that obtained via other people's behaviors even though both of them have exactly the same informativeness. This would be consistent with overconfidence on private signals which has been pointed out in previous experiments (e.g. Anderson and Holt (1997), Çelen and Kariv (2004), Hung and Plott (2001), Kübler and Weizsäcker (2004), and Nöth and Weber (2003)).

In addition, we observe that subjects' posterior beliefs are higher than the hypothetical posterior probabilities in no-cascades stage 1, but they are lower than the hypothetical posteriors in all the other stages. This observation indicates that human subjects cannot estimate posterior beliefs precisely in a Bayesian way even in 1-CAS where Bayesian updating seems to be done relatively easily. The observation that subjects in no-cascades stage 1 overestimate posterior beliefs is consistent with the anchoring and adjustment (e.g., Tversky and Kahneman (1974)). We argue that when the actual Bayesian posterior is 0.5, subjects' estimation would be anchored by the most recently observed private signals/predecessors' predictions and be adjusted by the formerly observed ones. However, since adjustments tend to be insufficient as Tversky and Kahneman (1974) pointed out, they would overestimate posterior beliefs. The observation that subjects in all the other stages underestimate posterior beliefs is consistent with the conservatism (e.g., Edwards (1968)). We argue that when the actual Bayesian posteriors are more than 0.5, subjects would not extract enough information from the observed private signals/predecessors' predictions and would underestimate posterior beliefs[8].

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[8] In cascades stages of 6-CAS when the most recently observed private signals/predecessors' predictions are same as the formerly agreeing ones, posterior beliefs lie about the lower bound of the hypothetical posterior probabilities. This would happen if subjects in nondecision stage $t+1$ think that subjects in decision stage t observe the different private signals from the formerly agreeing predecessors' predictions. However, this would be less realistic since $\Pr(\sigma_A, \sigma_A, \sigma_A|A) = 0.30 > \Pr(\sigma_A, \sigma_A, \sigma_B|A) = 0.15$, for example. Thus, we argue that subjects in these stages tend to underestimate Bayesian posterior probabilities, although their posteriors are justified by Bayesian Nash equilibrium.

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Tables and Figures

Table 1: Hypothetical posterior probabilities and subjects' average posterior beliefs reported in no-cascades stages

No-casc. stages	Sequence of signals/predictions	Hypothetical prob.		Subjects' beliefs	
		1-CAS	6-CAS	1-CAS	6-CAS
1	AB, BA, ABAB, ABBA, BAAB, BABA	0.5	0.5	0.56	0.51
2	A, B, ABB, ABA, BAB, BAA, ABABB, ABABA, ABBAB, ABBAA, BAABB, BAABA, BABAB, BABAA	0.67	0.67	0.62	0.59
3	AA, BB, ABAA, ABBB, BAAA, BABB	0.8	0.8	0.69	0.64

Table 2: Hypothetical posterior probabilities and subjects' average posterior beliefs reported in cascades stages: When the most recently observed signal/prediction is same as the formerly agreeing ones

Casc. stages	Sequence of signals/predictions	Hypothetical prob.		Subjects' beliefs	
		1-CAS	6-CAS	1-CAS	6-CAS
1	AAA, BBB, ABAAA, ABBBB, BAAAA, BABBB	0.89	[0.67,0.89]	0.79	0.66
2	AAAA, BBBB	0.94	[0.67,0.89]	0.81	0.72
3	AAAAA, BBBBB	0.97	[0.67,0.89]	0.87	0.70

Table 3: Hypothetical posterior probabilities and subjects' average posterior beliefs reported in cascades stages: When the most recently observed signal/prediction is different from the formerly agreeing ones

Casc. Stages	Sequence of signals/predictions	Hypothetical prob.		Subjects' beliefs	
		1-CAS	6-CAS	1-CAS	6-CAS
1	AAB, BBA, ABAAB, ABBBA, BAAAB, BABBA	0.67	0.67	0.51	0.56
2	AAAB, BBBA	0.8	0.67	0.67	0.58
3	AAAAB, BBBBA	0.89	0.67	0.68	0.59

Table 4: Results of the Spearman's rank correlation test

Treatment	Stages	Obs.	Spearman's rho	Prob>|t|
1-CAS	No-cascades	1036	0.4146	0.00
	Cascades (same signals/predictions)	281	0.1198	0.0448
	Cascades (different signals/predictions)	249	0.2921	0.00
6-CAS	No-cascade	876	0.2424	0.00
	Cascades (same signal/predictions)	389	0.0822	0.1055
	Cascades (different signal/predictions)	140	0.0366	0.6932

Table 5: Results of the Mann–Whitney test of difference in beliefs reported in 1-CAS and 6-CAS: When the most recently observed signal/prediction is same as the formerly agreeing ones

	No-cascades stage			Cascades stage		
	1	2	3	1	2	3
Z	2.87	3.75	3.87	5.43	3.24	2.63
Prob>|Z|	0.0041	0.0002	0.0001	0.0000	0.0012	0.0085

Table 6: Results of the Mann–Whitney test of difference in beliefs reported in 1-CAS and 6-CAS: When the most recently observed signal/prediction is different from the formerly agreeing ones

	Cascades stage		
	1	2	3
Z	-2.36	1.92	1.61
Prob>|Z|	0.018	0.0554	0.0967

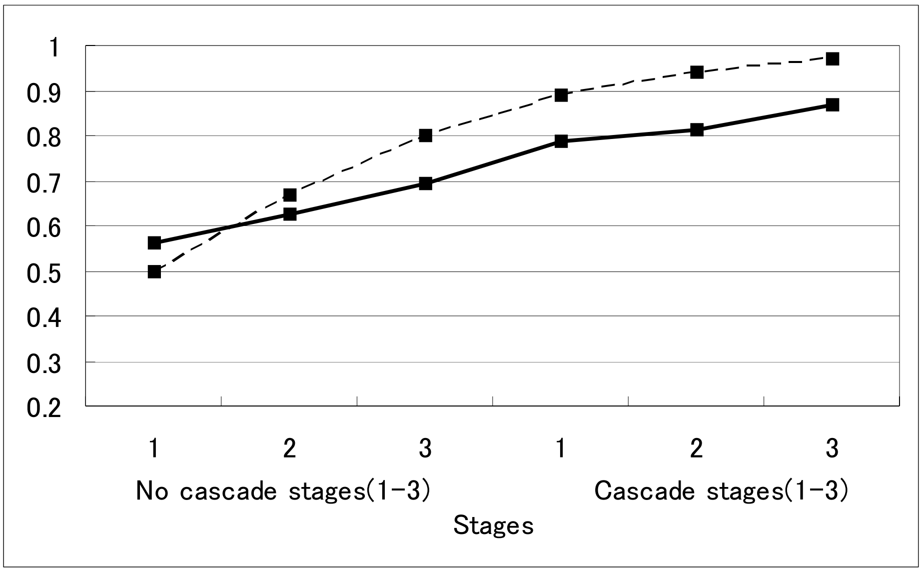

Figure 1: Subjects' average posterior beliefs in 1-CAS: When the most recently observed signal/prediction is same as the formerly agreeing ones

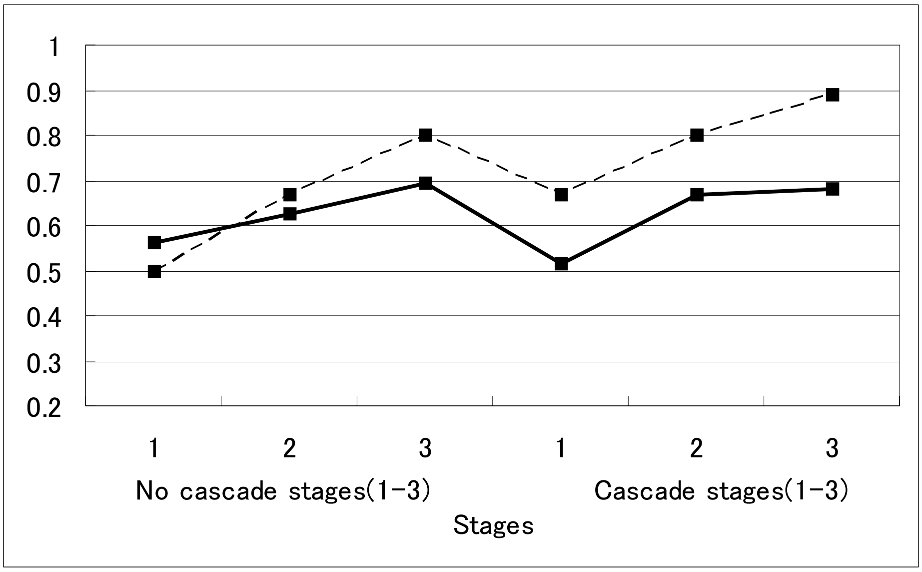

Figure 2: Subjects' average posterior beliefs in 1-CAS: When the most recently observed signal/prediction is different from the formerly agreeing ones

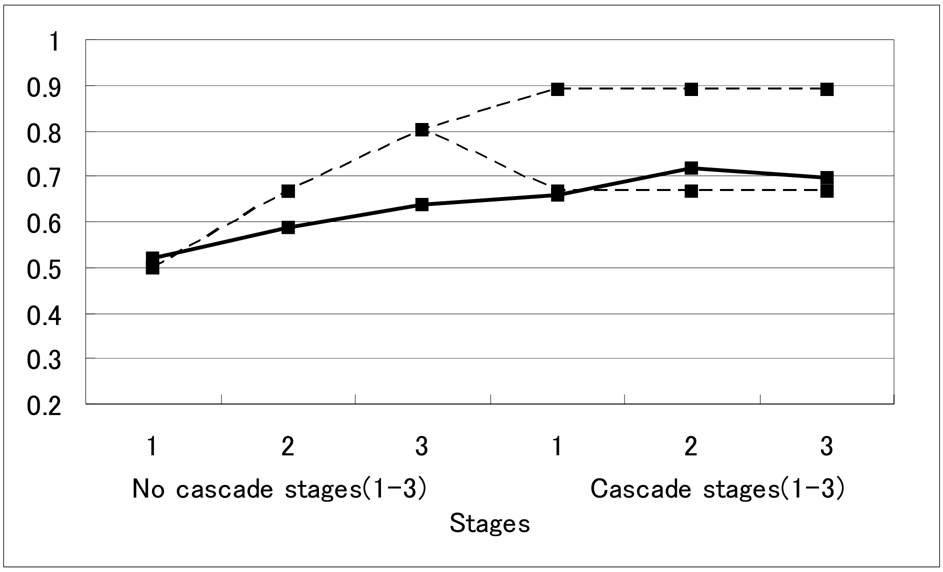

Figure 3: Subjects' average posterior beliefs in 6-CAS: When the most recently observed signal/prediction is same as the formerly agreeing ones

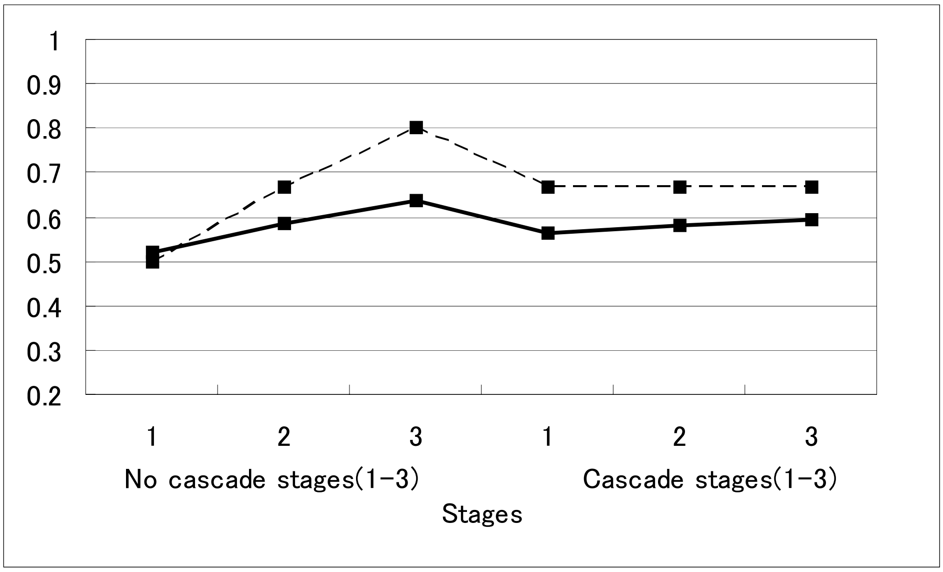

Figure 4: Subjects' average posterior beliefs in 6-CAS: When the most recently observed signal/prediction is different from the formerly agreeing ones