Are longer cascades more stable?*

by

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Abstract

Yes, they are. We consider data from experimental cascade games that were run in different laboratories, and find uniformly that subjects are more willing to follow the crowd, the bigger the crowd is – although the decision makers who are added to the crowd should in theory simply follow suit and hence reveal no information. This correlation of length and strength of cascades appears consistently across games with different parameters and different choice sets for the subjects. It is also observed in games where it runs counter to the theoretical prediction, so behavior moves away from equilibrium play over the stages of the games.

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1 Introduction

This paper reports a behavioral regularity that shows up in many social learning experiments: Decision makers are more willing to agree with the choices of others, the more others there are who all agree. This correlation is noteworthy because in the games we consider, Bayes Nash theory would predict that a larger set of agreeing players conveys the same amount of information to later players as does a smaller set. After a few initial decision makers who all predicted that some state of the world A is more likely than B, a "cascade" starts where everyone else should simply follow suit and hence no additional information should be revealed (see e.g. Banerjee, 1992, and Bikhchandani, Hirshleifer and Welch, 1992). In controlled experiments, the subjects' stated beliefs about the true state of the world should therefore be constant over the length of an observed cascade, as should be the frequency of subjects who confirm the cascade by also predicting state A. However, both outcome measures are correlated with the length of the cascade. Behaviorally, longer cascades are more stable.

We will shortly discuss potential information-based reasons for this correlation (Section 2), and then focus on the phenomenon on an aggregate level, rather than reporting much evidence on biases in individual updating. To obtain such an aggregate picture, we summarize previous experimental studies on cascade games, and find a clear pattern – in virtually all data sets is there a correlation between the length and strength of cascades.[1] In a new experiment described in Section 3.4, we measure the correlation of cascade length and strength in a game where the equilibrium prediction runs in the opposite direction. This experiment, together with a previous experiment by Ziegelmeyer et al (2002), demonstrates the potential economic significance of the discussed correlation, in that it may lead behavior away from the equilibrium prediction. In Ziegelmeyer et al's data, this effect dominates towards the end of the games, as the majority of subjects conforms to their predecessors' choices. In our experiment, we observe a similar dynamic at a more moderate level. Finally, Section 4 concludes with a short discussion of possible non-informational reasons for the

[1] We restrict attention to experiments of the kind first run in the lab by Anderson and Holt (1997) and later reproduced and modified by many researchers. However, not all such papers report evidence on the correlation of length and stabilibity of behavioral cascades, see for example the recent papers by Cipriani and Guarino (2003), Drehmann et al (2003) and Goeree et al (2004). However, in a slide presentation at the 2004 EEA Annual Congress, Goeree et al indicated that the correlation between length and stability of cascades shows up in all of their four treatments as well, and the correlation even persists in longer cascades. For other experiments with the possibility of social learning see e.g. the herding games by Celen and Kariv (2004), the advice games by Celen et al (2003), the parimutual betting games by Ziegelmeyer et al (2004), the information avalanche games by Guarino et al (2004), and the social network games by Choi et al (2004). All of these could be studied with regard to questions of the stability of social learning phenomena, but would require different kinds of data analyses. Other related papers about cascade-like decision tasks are Huck and Oechssler (1999) and Kraemer and Weber (2004).

observed correlations.

2 Potential reasons for a correlation of cascade length and stability

The subjects of Anderson and Holt (1997) played the following game, which served as the benchmark for several other studies: There are two equally likely states of the world, represented by two urns labeled A and B. Of the balls in urn A, a fraction q is labeled a and $1-q$ is labeled b. Urn B , analogously, has fractions of q labeled b and $1-q$ of the balls labeled a. (Anderson and Holt set the parameter q at 2/3.) Each player receives a private signal, which is a ball drawn from the true but unknown urn. The players are then asked to predict the state of the world, i.e. to predict from which urn $\omega \in \{A, B\}$ the ball was drawn. If a player correctly identifies the urn, he or she gets a fixed amount U. Social learning is possible because the players make their predictions one after another, and each player t observes the predictions made by all previous players $1, ..., t-1$.

In this setup information cascades can develop. E.g., if the first two players make an identical prediction, say, A, then the third player should, in theory, ignore his own signal and also choose A, even if he or she has a contradicting signal b. The fourth player should then follow the prediction of the initial three players, etc.[2] The

[2] The reasoning is slightly complicated by the possibility of extreme tie-breaking rules that players may apply in the case of indifference, and that are not ruled out by restricting attention to Bayes Nash outcomes, i.e., there is a multiplicity of equilibria. But for almost all tie-breaking rules, and

question of this paper is whether experimental subjects who act as fourth or even later players, and who observe a cascade, follow their predecessors more often than those acting as third players, who observe only a shorter string of predecessors who all agree.

To organize the many possible arguments why such a correlation may show up in the data, we look at the prediction made by a well-known model of boundedly-rational decision making, the Quantal Response Equilibrium (QRE). In the logit specification of QRE, each player responds to his or her updated belief about the true state of the world with some imperfect level of precision λ, which is common knowledge among the players. Goeree et al (2004) derive a set of QRE predictions for cascade games, and the reader is referred to their paper for a full discussion. To illustrate what QRE predicts for the correlation of length and strength of cascades, consider the frequently reached decision node where player 4 observes a sequence of identical decisions, say, AAA. The question of interest is whether the third A is informative for player 4, or whether he or she ignores it. In Bayes Nash theory, the third A does not change his or her posterior belief about the true state of the world, because the equilibrium prediction for player 3 after observing AA is to predict A unconditionally, i.e. even in the case of a contradicting private signal b. In QRE, however, the third A is

particularly the more reasonable ones, the likelihood that cascades occur is high. E.g., only in 'non-generic' equilibria where the third player thinks that the second player disregards his or her own signal *with certainty* can the third player optimally follow her own signal.

informative for the third player, for two reasons that have to do with the imperfect precision of the previous decisions: (i) Player 4 correctly thinks that player 3 is not convinced that players 1 and 2 have revealed their private signals, and (ii) player 4 knows that for any history before stage 3, player 3 is more likely to choose A after a confirming signal a than after a contradicting signal b.

The common-knowledge assumption about the response precision is used in different ways in (i) and (ii), as there are different levels of reasoning that are applied in the two arguments. In (ii), player 4 thinks only about player 3, whereas in (i), player 4 thinks about how player 3 thinks about players 1 and 2. In a previous paper (Kübler and Weizsäcker, 2004), we use cascade games to estimate a generalized version of QRE, where the common knowledge assumption is relaxed. There, we find that subjects appear to make only few steps of reasoning in cascade games. They consistently behave as if they responded to the belief that their predecessors do not consider their respective predecessors' actions. This affects the stability of longer cascades: If player 4 disregards the possibility that player 3 learns from his or her predecessors (as follows from our estimations), then argument (i) becomes inflated: In the eyes of player 4, player 3 ignores the previous A choices, and hence it is very likely that the third A indicates an underlying signal a. Players should therefore be more likely to follow the crowd after the history AAA than after AA.

3 Evidence of a length-strength correlation

3.1 Increasing frequency of disregarding the private signal

In Figure 1, experimental treatments from sixe studies are summarized with regard to the question whether longer cascades are broken less frequently. All of these experiments basically follow the Anderson and Holt design. In this and all subsequent figures, the labels on the horizontal axes give the history observed by the decision makers when they choose their action.[3] The frequencies reported on the vertical axes of the figures correspond to the actions predicted by Bayes Nash theory. Importantly, the decisions reported in all figures are those where a cascade has already started, i.e. where the decision maker should ignore his or her own signal. According to Bayes Nash theory, the players' posterior beliefs about the true state of the world should therefore not change along the reported stages of the games, nor should action frequencies change. For descriptions of the games and experimental designs, the reader is referred to the notes of the figures, and to the papers from which the data averages are taken.

The figure shows an overall increase in the frequency of following the predecessors after a contradicting signal. In all six of the reported studies does the frequency of following the predecessors increase from the second decision situation in the figure

[3] For notational convenience, we denote by "A" the urn that is chosen more often. Sequences of two or more A decisions are abbreviated as $2Ab$, $3Ab$, etc.

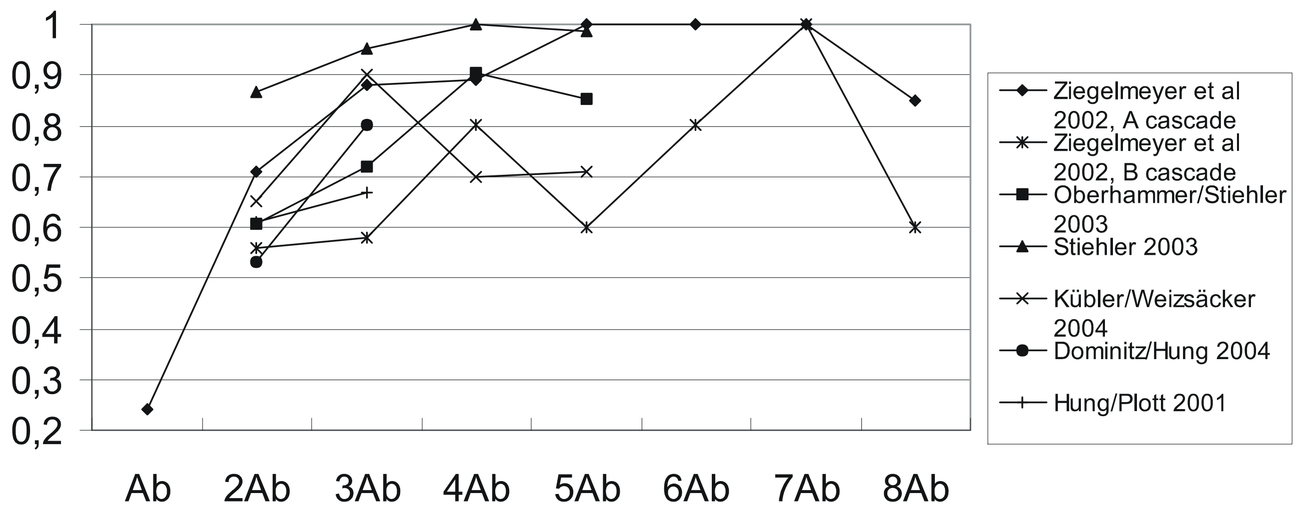

Figure 1: Disregarding contradicting signals. Note: Ziegelmeyer et al 2002: priors $P(A) = 0.55$ and $P(B) = 0.45, q = 2/3, T = 9$, 54 subjects. An A cascade starts after one A decision, a B cascade starts after two B decisions. Oberhammer/Stiehler 2003: $q = 0.6, T = 6$, 48 subjects. Stiehler 2003: $q = 0.6, T = 6$, 39 subjects, strategy method, computer opponents. Kübler/Weizsäcker 2004: Treatment NC, after signal acquisition, $q = 2/3, T = 6$, 36 subjects. Dominitz/Hung 2004: $q = 2/3, T = 10$, 90 subjects. Hung/Plott 2001: $q = 2/3, T = 10$, 20 subjects, reported in Dominitz/Hung.

(subjects who act as player 3 and observe AA) to the third decision situation (player 4 observing AAA). In five of the six studies it increases from the first half of the available observations to the second half.

3.2 Increasing subjective belief statements

Another measure of cascade stability are subjective belief statements. The decisions reported in Figure 2 are not choices in the game, but average probability statements for the event that A is the true state of the world, reported by a set of subjects who observe play by other subjects. (The subjects who state beliefs do not observe a private draw.) In all experiments, subjects were remunerated for the accuracy of their stated beliefs. As the figure shows, the belief statements are more in favor of A the longer the string of predecessors is who agree on A. Again, we restrict attention to decisions that are made after a cascade has started, so the theoretical posterior belief about the true state of the world does not change along the length of the cascade, not even in early stages.[4]

[4] In some games, the posterior belief in Bayes Nash equilibrium depends on the tie-breaking rule applied by the players and hence can differ depending on the selected equilibrium. But if all players apply the same tie-breaking rule to the decision of player 2 when they form their posterior belief, the belief is constant along the stages of the game. There exist equlibria in which later players use a different updating rule than earlier players when they interpret player 2's decision, but these equilibria are highly implausible, and the subjective beliefs could at most vary within a small range.

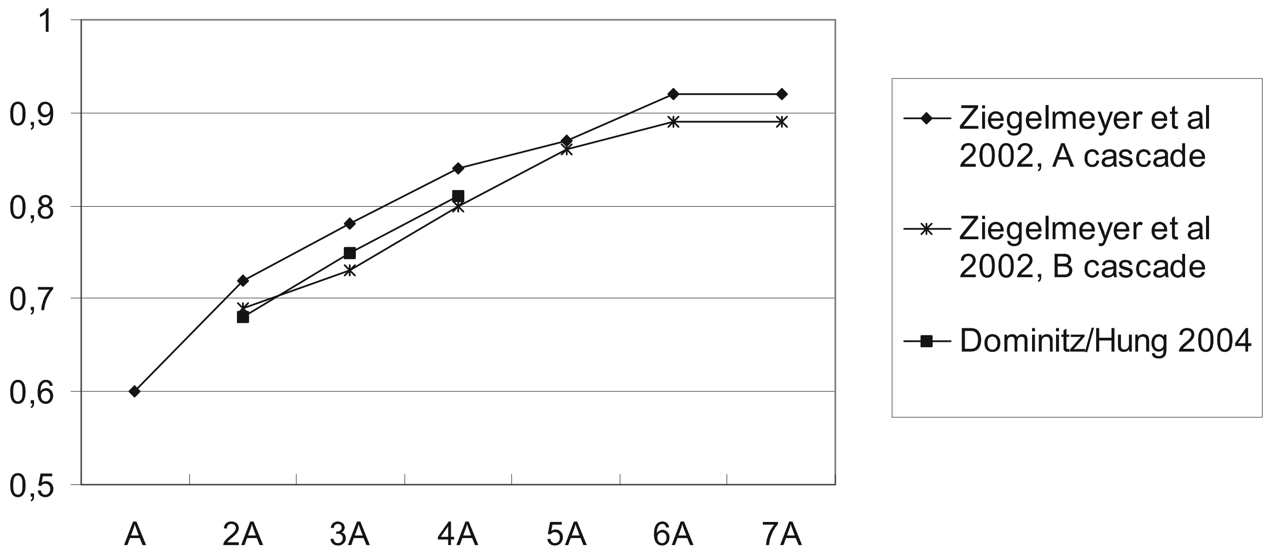

Figure 2: Subjective belief statements $\Pr(A)$. Note: Ziegelmeyer et al 2002: priors $P(A) = 0.55$ and $P(B) = 0.45, q = 2/3, T = 9$, 54 subjects. An A cascade starts after one A decision, a B cascade starts after two B decisions. Theoretical beliefs are $P(A|observation) = 0.71$ and $P(B|observation) = 0.78$. Dominitz/Hung 2004: $q = 2/3, T = 10$, 60 subjects. Theoretical belief is $P(A|observation) = [0.71, 0.80]$, depending on tie-rule, but constant across stages.

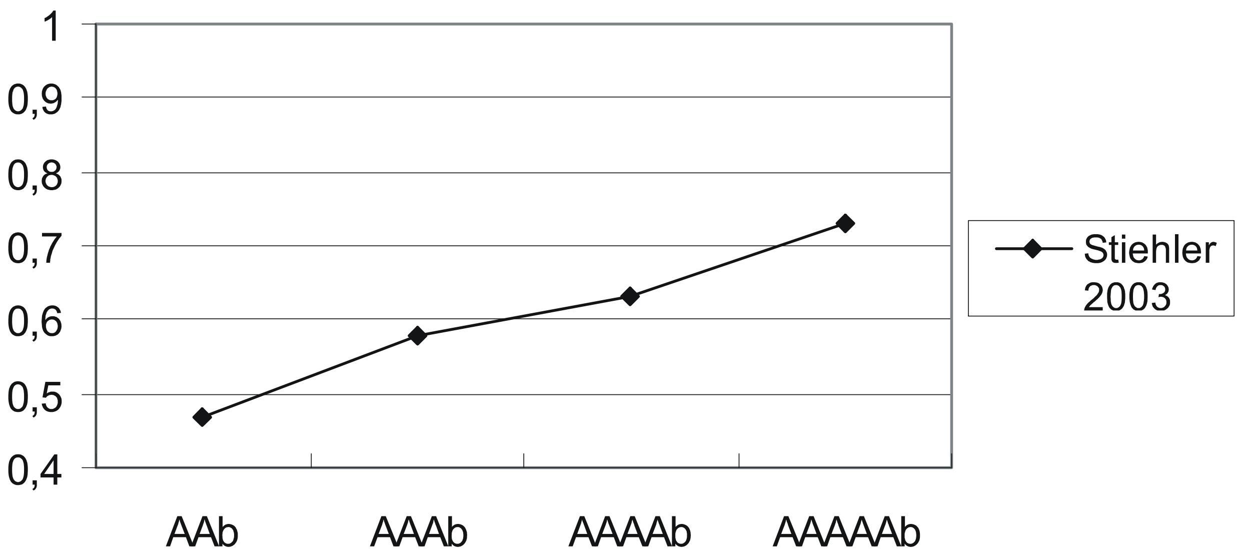

Figure 3: Subjective belief statements $\Pr(A)$. Note: Stiehler 2003: $q = 0.6$, $T = 6$, 39 subjects, strategy method, computerized opponents. Theoretical beliefs are $\Pr(A|observation) \in [0.5, 0.6]$, depending on tie rule, but constant accross stages.

A further study with similar results is provided by Stiehler (2003), who gave the subjects a private draw from the true urn before they stated their beliefs. (And the subjects participated in the game after they stated the belief.) Figure 3 shows the average belief statements for the case that subjects receive a private signal that contradicts the cascade. Stiehler's experiment is interesting for the additional reason that the subjects played against computer opponents that followed the Bayes Nash prediction. Thus, subjects knew that their predecessors would make no mistakes. The observation that longer cascades induce higher subjective probability statements for state A can hence be taken as further evidence that subjects do not understand that previous players learn themselves and should optimally follow their predecessors once a cascade has started.[5]

3.3 Decreasing rate of buying additional information

The third measure of cascade stability that we consider is information acquisition. In some experiments the subjects can decide whether or not they want to buy a private draw from the urn, at a cost. This changes the equilibrium – typically cascades start earlier, as it is often suboptimal to spend money on information that would either confirm the previous choices or, in the case of a contradicting signal, is not strong enough to swamp the information conveyed by the other players' choices. In theory,

[5] See also the related evidence by Kraemer and Weber (2001) cited in footnote 6.

once again, the rate of information acquisition should be constant along all stages of a cascade.

Figure 4 shows the evidence for three treatments from two different studies. In all three data sets does the frequency of following the equilibrium action – not buying a private signal – increase from early positions in the cascade to later ones.[6]

3.4 Moving away from equilibrium: New data and Ziegelmeyer et al (2002)

In the experiments discussed so far, the subjects' choice to follow the crowd coincided with the action prescribed by Bayes Nash theory. And we saw that the equilibrium action was chosen with higher frequency the longer the cascade lasted.[7] Now, to learn

[6] This is confirmed by a related experiment by Kraemer and Weber (2001), where subjects learn about their predecessors' subjective probability statements, and can decide whether or not they want to obtain additional information before reporting their own probability statement. Subjects face computer opponents, so the previously stated probabilites strictly follow Bayes' rule, and subjects should be aware that a posterior probability of 0.8 is equally informative for positions early in the game and positions late in the game. However, as the number of previous computerized 'decision makers' increases, subjects find the same probability statement more and more credible, and buy less and less information.

[7] The equilibrium action in the belief statement experiments is to report a belief in the equilibrium range. In these studies we observe a stronger belief in the event indicated by the cascade in later stages of the games.

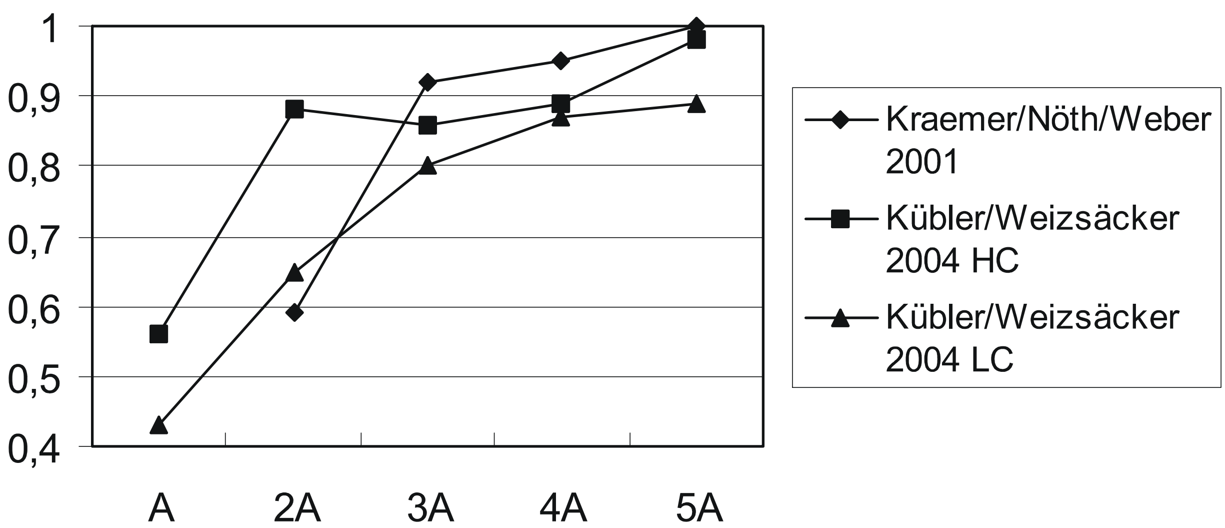

Figure 4: Non-acquisition of additional private information. Note: Kraemer/Nöth/Weber 2001: $q = 0.6$ or $q = 0.8$ (random, pooled data), $T = 6$, 39 subjects, cascade starts after two A decisions. Kübler/Weizsäcker 2004 HC: $q = 2/3, T = 6$, 36 subjects, signal cost at 3/4 of theoretical signal value for player 1. Kübler/Weizsäcker 2004 LC: $q = 2/3, T = 6$, 30 subjects, signal cost at 1/4 of theoretical signal value for player 1.

more about the robustness of the effect, we ask whether the correlation of length and strength of cascades also appears if the equilibrium prediction goes in the opposite direction, i.e. if it prescribes *not* to follow the crowd. This robustness may be natural to expect, because all the available evidence points at fundamental updating biases of the subjects. But it may also be true that these biases show up much more strongly in situations where also the equilibrium reasoning requires subjects to follow the crowd.

In a new experiment, we give some players information that not only runs counter to an existing cascade, but is also strong enough (relative to the theoretical value of the information conveyed by the cascade) that the players should break the cascade. The same basic idea was used in the earlier experiment by Ziegelmeyer et al (2002).[8] In their experiment, some subjects watched others play a cascade game of the standard format by Anderson and Holt. The subjects acting as observers were also given two signal draws from the true urn before they made a prediction about the true state of the world themselves. In cases where these two draws contradicted an existing cascade, Bayes Nash theory would predict that the subject breaks the cascade and follows his or her own private information.

In our experiment, we let subjects choose whether or not they want to obtain a private draw, at a small cost (the same cost level as in the LC treatment of Kübler

[8] This study, in turn, is in part based on an earlier similar experiment by Willinger and Ziegelmeyer (1998).

and Weizsäcker 2004), but gave one of the six players an 'extra draw' for free. (Thus, a player who obtains an extra draw knows that no other player in the game receives one.) In the absence of the extra draw, cascades should develop regardless of the chance moves, and all later players should follow the first player. In cases where the extra draw contradicts the cascade (e.g. AAb or $AAAb$) the player with the extra draw should decide to buy a signal: The cascade is based on one private draw only, so the two draws would cancel out, making the acquisition of more information worthwhile. We conducted three different treatments with one session per treatment, using 18, 12, and 18 subjects respectively, who played 2×15 rounds in fixed groups of 6 subjects.[9] The three treatment differed only slightly in the second halves of the sessions, i.e. after the first 15 rounds were played, in that we attempted to 'debias' the subjects by asking them to predict their opponents' acquisition behavior.[10]

[9] We used the strategy method with respect to the extra-draw outcome: Subjects indicated whether or not they wanted to pay for an additional draw conditional on three cases: No free extra draw, free extra draw a, free extra draw b. This increases the number of observations for the relevant decision situations. The experiment was conducted using the software Z-Tree (Fischbacher, 1999).

[10] The data set with the largest number of independent observations is hence the data labeled 'extra draw I' in Figure 6 (bold line), where the data from the first halves of all sessions are pooled. The other three lines in the figure show the data from the second halves of the three treatments. After half of the rounds were played in the two treatments 'extra draw + debiasing I/II', we asked subjects to estimate the acquisition behavior of others, to learn whether this could debias them. We hypothesized that subjects would be more willing to buy additional information in later stages if they understand that the cascade is worth the information of only one private draw. However, we

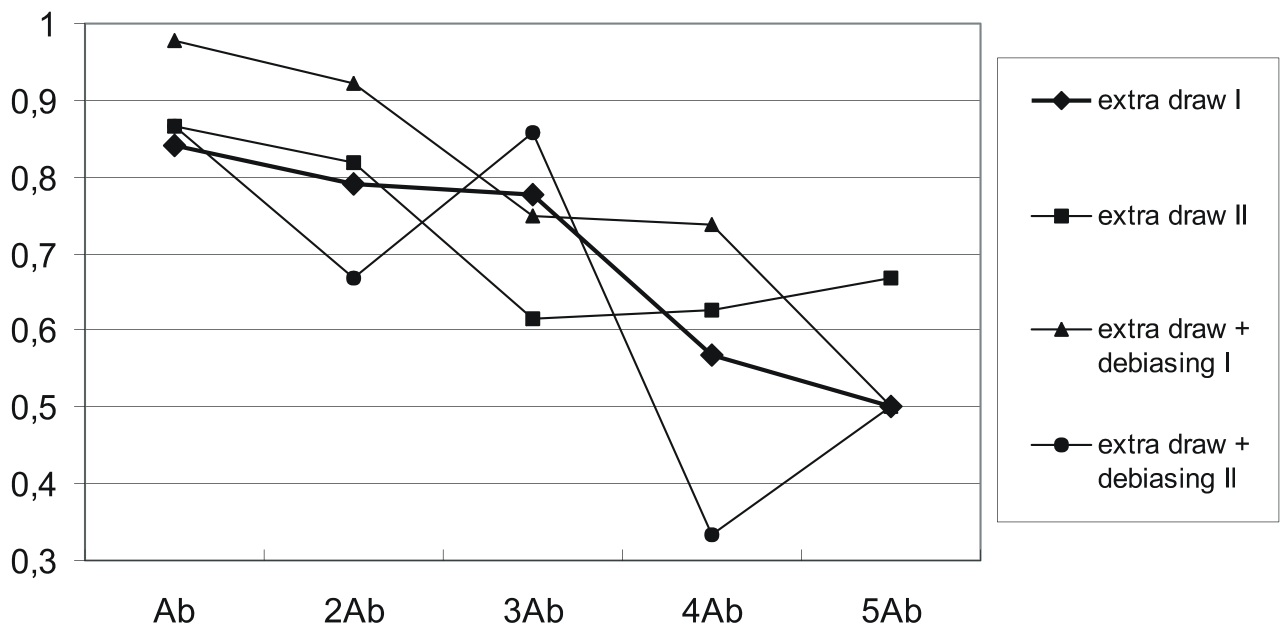

Figure 5: Acquisition of additional private information after contradicting extra draw. Note: New data: extra draw I&II: $q = 2/3$, cost at $1/4$ of theoretical signal value for player 1, $T = 6, 48\&18$ subjects. extra draw +debiasing I&II: $q = 2/3$, cost at $1/4$ of theoretical signal value for player 1, $T = 6, 18\&12$ subjects – subjects were asked to predict whether their immediate predecessors bought private draws (and to predict predecessor's prediction).

Figures 5 and 6 show the data of the two experiments, for the cases where the subjects should break the cascade and buy new information (in our experiment, Figure 5), or follow their own signal (Ziegelmeyer et al, 2002, in Figure 6). In both experiments the frequency of following the equilibrium decreases over the length of the cascade. While this decrease is stronger in Ziegelmeyer et al's case than in our experiment, behavior in both experiments moves away from the equilibrium prediction, and conformity with the predecessors's choices becomes more frequent.

4 Conclusions

The above survey shows that the correlation of length and strength of cascades is robust to changes in the underlying games. Under several choice sets and a range of different parameter specifications we observe the same pattern – the more people agree with one another, the more likely it is that the next person will also agree. We therefore argue that while some of the behavioral biases that were discussed in the cascade literature seem to contradict each other (see e.g. Huck and Oechssler, 1999, Kraemer and Weber, 2001, Goeree et al 2004, and Kübler and Weizsäcker, 2004), one should also take notice that all of the data sets are consistent with regard to a central feature of the aggregate cascade development, the correlation of length and strength.

An important question is whether the observed correlation may be a result of

found no such effect (or we had too few data), see Figure 5.

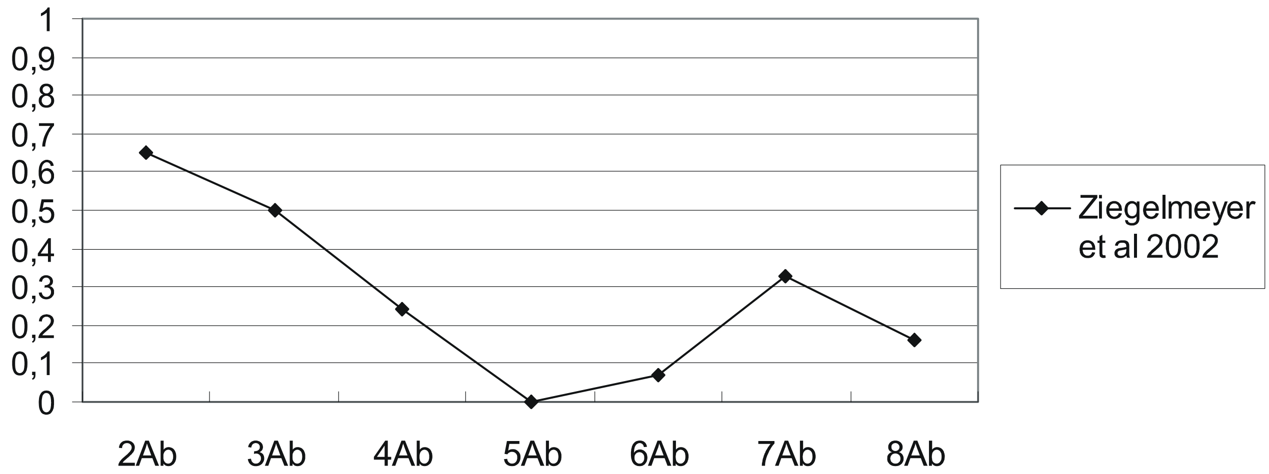

Figure 6: Following own strong contradicting signal. Note: Ziegelmeyer et al 2002, "Green line" treatment: $q = 2/3, T = 9$, 42 subjects. Prior $P(A) = 0.55$ (data pooled). Subjects observe a different group, receive a private draw of strength $q = 4/5$, and are paid as if they played the game as well. Bayes Nash equilibrium predicts that they follow their signal, regardless of others' decisions.

social pressure or other effects that have nothing to do with information extraction. One can easily think of reasons why human decision makers feel more inclined to do what everyone else does (deriving utility from conformity of actions, equality of payoffs, etc.). This may be partly what drives the observed correlation, but it is also important to point out that the experimental setup gives strong arguments in favor of information extraction explanations. First, the experiments are designed such that social spillovers other than information are minimal. Decisions are anonymous as a rule, and in several experiments the subjects face computer opponents, so no social pressure should apply here. Second, two of the three measures of cascade stability strongly suggest that longer cascades are considered as a more credible source of information to subjects: Stated beliefs are more in favor of the crowd if the crowd is bigger, and subjects demand less additional information if they observe a longer cascade. Both measures indicate that subjects feel they can rely on the information conveyed by a larger number of predecessors, even if the predecessors should also have followed the crowd.

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