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Misery loves company: Social regret and social interaction effects in choices under risk and uncertainty

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ABSTRACT

Extensive field evidence shows individuals' decisions in settings involving uncertainty depend on their peers' decisions. One hypothesized cause of peer group effects is social interaction effects: an individual's utility from an action is enhanced by others taking the same action. We employ a series of controlled laboratory experiments to study the causes of peer effects in choice under uncertainty. We find strong peer group effects in the laboratory. Our design allows us to rule out social learning, social norms, group affiliation, and complementarities as possible causes for the observed peer group effects, leaving social interaction effects as the likely cause. We use a combination of theory and empirical analysis to show that preferences including "social regret" are more consistent with the data than preferences including a taste for conformity. We observe spillover effects, as observing another's choice of one risky gamble makes *all* risky gambles more likely to be chosen.

1. Introduction

There is often a strong relationship between the decisions of an individual and the choices they observe their peers making. Peer group effects have been identified for many important decisions including saving and investment decisions, criminal activity, drug use, divorce, out-of-wedlock fertility, educational attainment, and welfare use.[1] Choice under risk and uncertainty is an important element of many of these decisions, such as criminal activity and out-of-wedlock fertility, and is central in the case of savings and investment choices (Duflo and Saez, 2002, 2003; Madrian and Shea, 2000; Kelly and Ó Gráda, 2000; Hong et al., 2004).

Many possible causes have been identified for peer group effects. A particularly intriguing possibility is that an individual's utility from an action is enhanced by others taking the same action. To fix terms, we refer to the empirical phenomenon that an individual's choices are correlated with the choices of his peers as a "peer group effect." As a potential explanation for peer group effects, the possibility that others' actions appear directly in an individual's utility function is referred to as a "social interaction effect." The primary goals of this paper are to use laboratory experiments to cleanly identify the existence of social interaction effects in choices under risk and uncertainty and, most importantly, to understand the nature of social interaction effects in such settings. We focus on *social regret* as a plausible source of social interaction effects in choices

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[1] Notable examples include Crane (1991), Sacerdote (2001), Hoxby (2000), Lalive and Cattaneo (2005), Case and Katz (1991), Glaeser et al. (1996), Katz et al. (2001), Ludwig et al. (2001), Kling et al. (2005), Bertrand et al. (2000), Aizer and Currie (2004).

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under risk and uncertainty. "Regret" refers to disutility experienced when an action not taken would have led to higher payoffs ex post (Loomes and Sugden, 1982; Bell, 1982, 1983). "Social regret" means that regret is less intense if others have chosen the same. In other words, misery loves company.

Identifying social interaction effects in observational data is notoriously difficult due to suspicions of omitted variable bias (Manski, 1993, 1995). Peers whom we might expect to influence one another are likely similar in ways not fully captured by observable characteristics. If peers are similar in their unobserved taste for risk taking behavior (possibly due to self-selection into peer groups) or are subject to unobserved common shocks that affect their decisions, we would expect to observe positive behavioral correlations even in the absence of social interaction effects. Adding to these difficulties, social learning (e.g. Banerjee, 1992; Bikhchandani et al., 1992) and knowledge spillovers also provide good explanations for many examples of peer group effects.[2] Little work has been done on separating these informational stories from social interaction effects. The controlled environment in laboratory experiments allows us to cleanly identify the existence of social interaction effects in choices under risk and uncertainty. Using a combination of theory and empirical analysis, we show that these social interaction effects are better explained by preferences including social regret than preferences including a taste for conformity.

We focus on choice under risk and uncertainty for two reasons. First, as noted previously, this is a common element linking many situations in which peer group effects have been observed. Second, we are interested in documenting a specific cause of social interaction effects, social regret, which has not been identified in previous studies of peer group effects. Choice under risk and uncertainty is a setting in which social regret is natural. In other settings in which peer group effects have been observed, social regret is a less likely mechanism.[3]

Going into the details, participants make a series of choices between pairs of gambles that vary in expected value, risk, and ambiguity. The series of choices between gamble is repeated three times, with the order randomly scrambled and no feedback about realized outcomes. Critically, subjects are randomly divided into groups of six. In the "private feedback" treatment, subjects receive information about the choice they made the last time they faced the same pair of gambles in a previous round. In the "social feedback" treatment, subjects receive this information as well as information about the other group members' choices the last time they chose between the same two gambles. We refer to this information about others' decisions as "social feedback."

To help us understand the possible effects of social feedback, we develop a model of decision making for our experimental environment. The predictions generated by this model allow us to separate between possible causes of peer group effects. Assume preferences include social regret. Averaging across groups, subjects are predicted to be more likely to switch away from risky gambles in the social feedback treatment. If we assume preferences for conformity rather than social regret, social feedback is not predicted to change the likelihood of switches away from risky gambles. Instead, averaging across groups, individuals with social feedback are predicted to be more likely to switch to the more popular gamble *across groups*. The same prediction holds if peer group effects are due to pure imitation driven by bounded rationality.[4]

Data from the social feedback treatment exhibits strong peer group effects. Controlling for reversion to the mean, the likelihood of switching gambles increases by fifteen percentage points if the majority of the social feedback disagrees with the subject's lagged decision. This is a large effect since the overall frequency of switching is only twenty percentage points. Compared with the private feedback treatment, social feedback causes subjects, averaging across groups, to be more likely to switch away from choosing riskier gambles. No tendency is observed for popular gambles, averaging across groups, to become more popular over time. Given our theoretical results, these observations indicate that social regret is a better explanation for the observed peer effects than preferences for conformity or pure imitation. This establishes social regret as a new source of social interaction effects, one which should be particularly relevant in situations that involve choice under uncertainty and risk.

Ambiguous gambles were included in the design as an additional tool for identifying the roles of social learning and imitation in generating the observed peer group effects. Models incorporating social learning and imitation predict that the response to social feedback will vary depending on the presence and type of ambiguity, but these predicted effects are absent in the data. Although not conclusive by themselves, these results provide additional evidence that the peer group effects in our data reflect social regret rather than social learning or pure imitation due to bounded rationality.

As noted previously, elements of risk and uncertainty are present in many settings where peer group effects have been observed. This raises an interesting question: if peer group effects share a common link across many settings, how context specific are these effects. Specifically, if I observe my peers taking a risky action in one situation does this make me more likely to take risky actions in other situations as well? Our theory of social regret implies this and our data supports this

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[2] Social learning and knowledge spillovers both involve gaining information from peers, but differ in whether information is acquired indirectly or directly. See Section 3 for detailed descriptions of social learning and knowledge spillovers.

[3] There are a number of existing experimental papers on peer group effects: see Falk and Ichino (2006) on work effort, Falk and Fischbacher (2002) on reciprocity and crime, Falk et al. (2002) and Großer and Sausgruber (2007) on public goods provision, Fortin et al. (2007) on tax evasion, and Thöni and Gächter (2008) on gift exchange. These are settings where we would not expect social regret to play a central role.

[4] Predicting that individuals with social feedback are more likely to switch to the more popular gamble *within their group* need not imply a shift of the average *across groups*. As an illustration, consider a pair of gambles where individuals are indifferent *ex ante* and hence equally likely to choose either gamble. With social feedback, suppose subjects are more likely to switch to a gamble previously favored by the majority of others in their group, with the size of the effect independent of which particular gamble was more popular. Across groups the feedback effect is equally likely to favor either gamble, so average play *across groups* does not shift with social feedback.

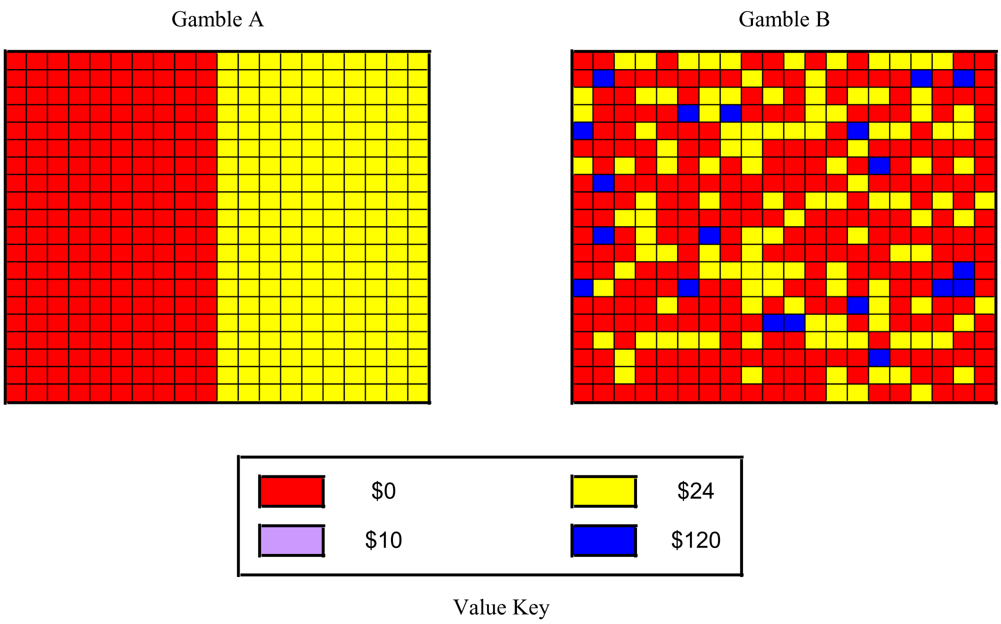

Fig. 1. Sample pair of gambles, scrambled format for ambiguity.

prediction with evidence of spillovers between gambles – if subjects receive social feedback that others are choosing the risky gamble in one pair of gambles, it makes them more likely to choose the risky gamble in all pairs of gambles. This result suggests the existence of broad cultures of risk taking or avoidance.

The organization of the paper is as follows. Section 2 lays out the experimental design. Section 3 describes a number of possible causes of peer group effects, presents a model of decision making in our experimental environment, and lays out initial hypotheses for the data. Section 4 summarizes the experimental results, and Section 5 discusses the implications of these results.

2. Experimental design

Subjects in all treatments had to choose one of two gambles in a series of rounds. After subjects had played all rounds, we randomly selected one round for each subject for payment. Each round was equally likely to be selected and selected rounds were independent across subjects. For the selected round, we played out the subject's chosen gamble and paid the subject based on this outcome.

The remainder of this section describes the gambles, explains how the presentation of gambles varied, and introduces the main treatment variable – feedback about prior choices of others facing the same pair of gambles. We conclude by summarizing the procedures we used.

2.1. The gambles

In each round subjects saw a pair of gambles projected on a screen in the front of the room. The gambles were presented in 20×20 colored grids as illustrated in Fig. 1. If a gamble was played out, one of the 400 cells was randomly selected with all cells equally likely. The payoff for the gamble depended on the color of the selected cell. The key below the pair of gambles gives the relationship between colors and payoffs. There are four possible payoffs that were used at some point in the experiment, but only three were present in any pair of gambles. The value key with all four colors was used in all rounds to limit subjects' confusion due to changing the key from round to round.

To separate social interaction effects from social learning, we varied the potential for social learning from feedback by introducing ambiguity. On a more general level, we are interested in risk and uncertainty as common links between many settings where peer group effects have been observed. Including ambiguity as well as risk in our experiments allows us to answer basic questions such as whether peer group effects will be stronger when uncertainty is involved or whether spillovers will be more pronounced with uncertainty.

Gambles were either presented in a "simple" or an "ambiguous" format. The gamble shown on the left in Fig. 1 is an example of the "simple" format. Cells of the same color are grouped together in continuous blocks, making it easy for subjects to determine the likelihood that a particular color will be drawn. The goal was for subjects to feel that the gamble's probabilities and payoffs are unambiguous.

Ambiguity was introduced in two different ways, either by presenting gambles in a "scrambled" format or a "blackout" format. An example of the "scrambled" format is shown on the right of Fig. 1. The cells for the gamble have been randomly scrambled, making it difficult to rapidly ascertain how many cells of any particular color are present. Subjects had eight

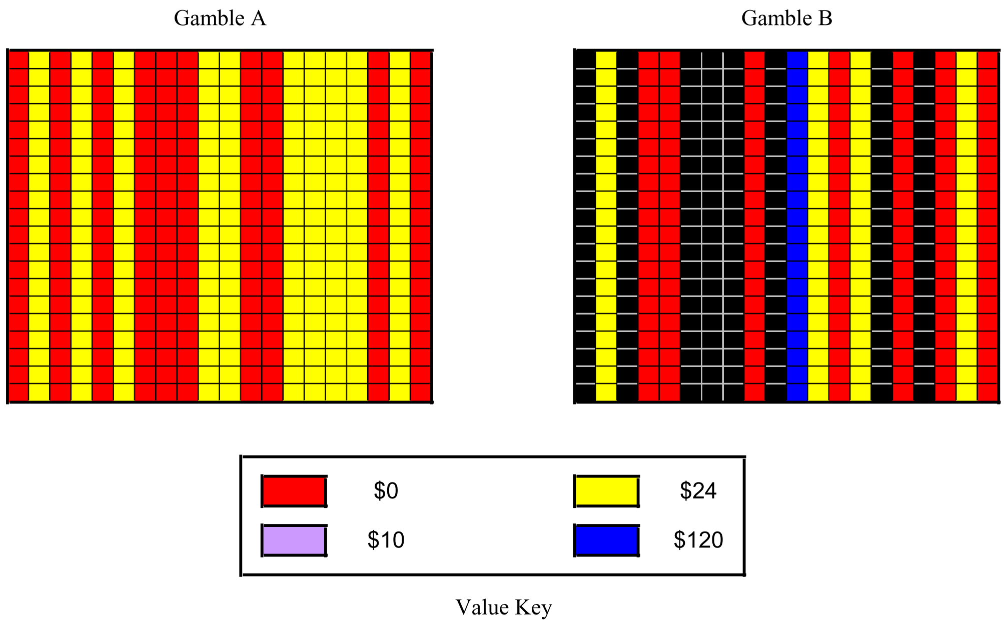

Fig. 2. Sample pair of gambles, blackout format for ambiguity.

seconds to view each pair of gambles when the scrambled format was used to generate ambiguity. Based on pre-testing with undergraduates, a subject could count less than 25% of the cells in a scrambled gamble in this time period (and they had to view two gambles, not one). We therefore expect that most subjects only had an impression of the likelihood of the various outcomes for a gamble presented in scrambled format (e.g. there aren't many blue squares) rather than knowing precise probabilities for each outcome (e.g. 20 of the 400 squares are blue).[5]

It can be reasonably argued that the scrambled format does not create true ambiguity since the term commonly refers to cases where subjects cannot possibly know the distribution of outcomes (Knight, 1921). With the scrambled format, subjects had all the necessary information to know the distribution of outcomes, but were given the information in a way that was (exceedingly) difficult to process. Sampling (e.g. counting colors for 25% of the squares) allowed subjects to at least approximate the proportion of each color, although it is our impression that few subjects did so. Even without any direct attempt at approximation, a subject's subjective probabilities can be viewed as reflecting the true probabilities with errors. Unlike true Knightian uncertainty, this form of ambiguity allows for the possibility that rational social learning can account for any observed feedback effects.

We therefore used a "blackout" format as a second alternative for creating ambiguity. Fig. 2 shows the same gambles as Fig. 1, but uses the blackout format rather than the scrambled format to generate ambiguity. Note that the columns of both the simple and ambiguous gamble are randomly scrambled to eliminate any spatial correlation in the colors of the columns. We generated ambiguity by randomly blacking out 40% of the columns as illustrated on the right of Fig. 2. The instructions explained that, "[T]he color (red, purple, yellow, or blue) for a blacked out square is hidden from you. Blacked out squares are just as likely to be chosen as any other square. If a blacked out square is chosen, your payoff will be based on the color that is hidden beneath." Subjects had no way of knowing what color was hidden in the blacked out squares, creating true ambiguity (within fairly broad bounds).

To maintain comparability to the simple format when columns were not scrambled, subjects were given twenty seconds to view each pair of gambles when ambiguity was created by blackout. This was more than enough time to count the number of columns of each color. Ex post, we ran regressions confirming that the use of scrambled columns in gambles with no ambiguity has no significant effect on behavior. In the following we refer to gambles presented with no ambiguity as "simple," regardless of whether the columns were scrambled or not.

Table 1 summarizes the pairs of gambles used in the experiment. Ten or twelve pairs were used for each session. Subjects first saw the pairs in a random order, saw the pairs a second time in a different random order, and then saw them a third time in yet another random order. We refer to these sets of ten or twelve pairs of gambles as "blocks." Subjects saw each pair of gambles with the same presentation format (e.g. simple vs. scrambled) in all three blocks. In sessions using the blackout format to generate ambiguity, the scrambling of columns was identical and the same columns were blacked out in all three viewings. Thus, repeated viewings did not provide subjects with any additional information about what cells had been blacked out.

[5] To make counting harder for the subjects, we did not allow them to have anything to write with (pen, pencil, etc.) during the experiment and monitored to make certain they weren't taking notes while the gambles were displayed.

Table 1
Description of gambles.

Pair number	Class	Gamble *A*			Gamble *B*		
		EV	StDev	Ambiguous	EV	StDev	Ambiguous
1	1	10.0	0.0		12.0	12.0	
2	2	10.0	0.0		12.0	36.0	
3	3	12.0	12.0		13.2 (18.0)	26.8 (32.7)	X
4	4	8.4	11.4		7.2 (12.0)	26.4 (33.2)	X
5	3	12.0 (12.0)	12.0 (12.0)	X	13.2 (18.0)	26.8 (32.7)	X
6	4	8.4 (6.0)	11.4 (10.4)	X	7.2 (12.0)	26.4 (33.2)	X
7	5	12.0	31.5		13.2 (12.0)	11.9 (12.0)	X
8	6	8.4	26.6		7.2 (8.0)	11 (11.3)	X
9	5	12.0 (16.0)	31.5 (39.6)	X	13.2 (12.0)	11.9 (12.0)	X
10	6	8.4 (2.0)	26.6 (6.6)	X	7.2 (8.0)	11 (11.3)	X
11	5	12.0	31.5		13.2	11.9	
12	6	8.4	26.6		7.2	11.0	
13	3	12.0	12.0		13.2	26.8	
14	4	8.4	11.4		7.2	26.4	

Notes: Numbers in parentheses give expected values and standard deviations observed by subjects for ambiguous gambles in the blackout treatment. Pairs 11–14 were displayed with Gamble *B* on the left and Gamble *A* on the right, but are displayed here in the same order as other pairs in the same class to ease the exposition.

For each gamble Table 1 reports the expected value, standard deviation of payoffs (our primary measure of risk), and whether the presentation was simple or ambiguous. In the blackout treatment, the underlying expected value and standard deviation of payoffs of an ambiguous gamble might differ substantially from what subjects could observe from columns that were not blacked out. Since subjects' decisions necessarily cannot rely on information they don't observe, we report in parentheses the *observed* expected value and standard deviation for ambiguous gambles in the blackout treatment. The pairs of gambles in our experiment are constructed such that one gamble has a lower probability of earning the worst possible payoff, zero, and a lower standard deviation of payoffs. By any reasonable standard, this is the less risky gamble.

A number of the gambles were repeated with different presentations. The second column of Table 1 gives the "class" of the gamble pair–two pairs in the same class contain identical gambles with different presentations. Classes 1 and 2 compare a certain outcome with a risky gamble presented in the simple format. The remaining four classes each include three pairs differentiated by how the gambles were presented: simple versus simple, simple versus ambiguous, and ambiguous versus ambiguous. Classes 3–6 are designed to systematically distinguish interactions between social feedback and expected value, risk, and ambiguity. Specifically, the riskier gamble is equally likely to have a higher or lower expected value or to be presented in an ambiguous (scrambled or blackout) format.[6] We also systematically vary whether the riskier gamble appears on the left or right.

2.2. Treatments

Treatments vary by the use of social feedback and presentation format for ambiguous gambles. Subjects saw each pair of gambles three times. They did not learn the realized outcome of any gamble until all decisions were completed. In all treatments, subjects in Blocks 2 and 3 (the second and third time they saw each pair of gambles) were shown their previous choice for the same pair of gambles. In the private feedback treatment, subjects received no further information about previous choices. This treatment serves as a control for the social feedback treatment.

For the social feedback treatment, subjects were divided into groups of six which remained fixed for all three blocks. In Blocks 2 and 3, each subject was informed about the other five group members' choices in the previous block between the same pair of gambles. In other words, in Block 2 subjects received social feedback about Block 1 choices and in Block 3 they received social feedback about Block 2 choices. The instructions made clear to subjects that their payoffs depend solely on their own choices, not on the choices of other subjects. Subjects were still informed about their own previous decision to eliminate any possibility of the feedback biasing subjects' memories of their own previous actions. This also gives subjects a stimulus to respond to beyond the social feedback. Instructions for all treatments told subjects that they might be receiving feedback and subjects never knew what feedback they might be seeing in future blocks. Thus, behavior in the first block cannot depend on the type of feedback being used. Subjects knew that the social feedback was coming from the same five subjects in all periods.

6 Due to the random choice of which columns were blacked out, the observed differences between gambles is weakened for several pairs in the blackout format and reversed in two cases (expected value for Pairs 9 and 10). Thus, all cells of the design are not filled for ambiguity versus ambiguity pairs with the blackout format.

Table 2
Summary of treatments.

Sessions	Feedback		Form of ambiguity		# subjects	Gambles
	Private	Social	Scrambled	Blackout		
1		X	X		24	1–10
2		X	X		18	1–10
3		X	X		24	3–14
4	X		X		20	1–10
5	X		X		22	1–10
6	X		X		25	3–14
7		X		X	24	3–14
8		X		X	18	3–14
9		X		X	18	3–14
10	X			X	16	3–14
11	X			X	21	3–14
12	X			X	8	3–14
13	X			X	16	3–14

2.3. Procedures

Table 2 summarizes the sessions. Sessions vary by what feedback was used (no vs. full feedback) and what format was used to present ambiguous gambles (scrambled vs. blackout). Given that subjects never interact with subjects outside of their group, there are at least ten independent observations per treatment.

Sessions 1 and 2 used Pairs 1 and 2 but did not include Pairs 11–14. After some reflection, we decided it was more important to get the simple versus simple comparisons these pairs provide than to include Pairs 1 and 2. To maintain parallelism, Pairs 1–10 were used in the first two sessions of the private feedback treatment using the scrambled format, but all other sessions used Pairs 3–14. Time constraints made it impossible to use all fourteen pairs in a single session.

The random ordering of pairs of gambles was determined prior to the beginning of each session. Different orderings were used for each session within a treatment. To ensure that effects of social feedback were not confounded by experience effects, the same ordering was used for parallel sessions with no feedback and full feedback.

Sessions were run in the fall and spring of 2006 at Case Western Reserve University. Subjects were recruited from the CWRU undergraduate population via emails. Subjects with blue–yellow color blindness were excluded. The average session took about an hour and average earnings were slightly more than fifteen dollars, including a five dollar show-up fee.

All sessions were run in a computerized laboratory using *z*-Tree (Fischbacher, 2007). Instructions are available as Appendix C under supplemental materials on GEB's website. Following the instructions, subjects were asked to complete a short quiz testing their understanding of the experimental instructions.

After the two gambles were displayed, the overhead display switched to a "waiting" slide. This was posted sufficiently long that subjects had about a minute to make a choice.[7] The computer randomly chose a gamble for the subject if no decision was made within the allotted time. This was observed on rare occasions in the first few rounds, presumably due to subject confusion.

Subjects only received information about the outcome of their chosen gambles when all rounds were completed. *This implies that any switches between gambles across blocks cannot be attributed to information about the realized outcome for any specific gamble.* Subjects were paid for the randomly selected round (as well as a $5 show-up fee) privately in cash at the conclusion of the experiment.

Due to a software error, data from the last round of session 3 was not saved. Due to a programming error, the gamble that was displayed on the overhead did not match the gamble that the computer used in calculating payoffs and generating feedback for one round in session 4 and one round in session 11. All affected data has been removed from the dataset.

3. Causes of peer group effects

The first portion of this section (3.1–3.3) summarizes possible causes of peer group effects that have been identified in the field literature and discusses how our experimental design either attempts to rule out these causes or allows us to distinguish between them. The final subsection (3.4) presents a theoretical model of decision making in our experimental environment. We develop predictions for this model if preferences include either social regret or a taste for conformity as possible causes of social interaction effects.

[7] To be precise, they had 56 seconds in sessions using the scrambled format and 65 seconds in sessions using the blackout format.

3.1. Possible confounding factors

3.1.1. Omitted variable bias

For omitted variable bias to cause identification problems in our experiment there would have to be some *unobserved* common factor for subjects in the social feedback treatment that was not present in the private feedback treatment and caused subjects to change their behavior in the direction of the majority choice. Given that subjects are randomly assigned to treatments, it is difficult to imagine any such factor.

3.1.2. Reflection

The reflection problem (Manski, 1993) is a well known problem in estimating non-biased peer group effects. Suppose an individual's choice responds to the choices of his peers. If he interacts repeatedly with the same peers, as is normally the case in field settings, his peers' choices will reflect the individual's own previous choices. The reflection problem is ruled out by design in the second (but not third) block of our experiment. Individuals in the second block are responding to information about peers' previous choices but those peers hadn't seen any of the individual's choices before making these previous decisions.

3.2. Learning and imitation

3.2.1. Rational social learning

In standard models of social learning (Banerjee, 1992; Bikhchandani et al., 1992), decision makers receive noisy signals about the values of their options by observing the choices of others. We refer to this as "rational" social learning.

The scrambled format for ambiguous gambles is designed so subjects don't have adequate time to assess the probability of each outcome. This is "as if" each subject receives noisy information about the probability distribution over outcomes. Rational social learning can therefore occur since subjects can gain better information about the distribution over outcomes by observing the choices of others.

Rational social learning should be absent when the blackout format is used for ambiguous gambles since all subjects have identical information. Comparing the response to social feedback with the differing formats for ambiguous gambles therefore gives us a way of checking for rational social learning.

3.2.2. Imitation

Subjects in our experiment are faced with complex problems, especially when ambiguity is involved, in an environment they have not experienced previously. Rather than reflecting a carefully considered attempt to learn from others' choices or a fully rational response to non-standard preferences, peer group effects could be driven by the adoption of a simple minded heuristic in the face of a demanding environment: pure imitation. In the words of a prominent recent paper on the topic, "Imitation is prevalent in much of everyday decision making, in particular when the environment is complex or largely unknown" (Apesteguia et al., 2007, p. 217). Within the framework of our experiment, imitation can be motivated as a form of "boundedly rational" social learning. As seems likely, suppose that some subjects are uncertain about the quality of their decision making. Imagine that such an individual observes that he chose a different gamble from most other subjects the previous time the same pair of gambles was available. Knowing that other subjects had the same information as him, he might conclude he has probably made a mistake. Consequently he may switch gambles and imitate the previous choice of others. This is not because he learned anything new about the gambles from observing others' choices, but because he inferred something about the quality of his decision. Likewise, if he observes others choosing the same gamble that he picked, he might conclude that his decision was likely correct and therefore imitate by not switching gambles.

From a theoretical point of view, predicted effects of pure imitation due to bounded rationality are derived within the framework of the formal model of choice over gambles presented in Section 3.3. We therefore defer discussion of these predictions until the end of that section. Taking a more behavioral approach, imitation is a simple heuristic for choosing a gamble. There exists ample evidence in the psychology literature that increasing cognitive load by increasing the difficulty or complexity of problems leads to a greater probability that simple heuristics will be used (e.g. Bodenhausen and Lichtenstein, 1987; Betsch et al., 2004; De Neys, 2006; Harbaugh et al., forthcoming). In our context, pairs of gambles that involve ambiguity confront subjects with a more complex decision. As such, we would expect the probability of imitation, to be higher when ambiguity is present. It follows that if pure imitation is partially responsible for peer group effects, these effects should be weakest in simple versus simple comparisons.[8]

3.2.3. Knowledge spillovers

Like social learning, knowledge spillovers are an explanation of peer group effects that rely on information transmission. The difference is that knowledge spillovers involve direct sharing of information rather than indirect inference of others'

[8] A referee has suggested that imitation is less likely to be prevalent in gambles with ambiguity, as subjects should anticipate that others are also confused and therefore be less willing to imitate them. Fortunately, the test for pure imitation proposed in Section 3.3 does not rely on any assumption about whether subjects are more likely to employ pure imitation when decisions are simple or complex.

information based on their choices. In our experiments there are no direct interactions between individuals, eliminating knowledge spillovers as a possible cause for the observed peer group effects.

3.3. Social interaction effects

A social interaction effect occurs when an individual's utility from an action is enhanced by others taking the same action. Social interaction effects differ from social learning because utility *ex post* is affected by others' actions. To illustrate this point using a well known example, consider a choice between two restaurants, A and B, of unknown quality. Compare rational social learning with preferences for conformity (i.e. the individual gains utility from taking the same action as others). Both models lead to peer group effects, but only the effect from tastes for conformity would be classified as a social interaction effect. Suppose Restaurant B happens to be a bad restaurant. Under a model of rational social learning, individuals are just as unhappy with a bad meal at this restaurant if many people go to Restaurant B as when no people go there. Information about their peers' choices affects their ex ante expectations about the likely quality of the two restaurants, but does not affect their utility from the realization of this gamble. With tastes for conformity, an individual's utility from the realization of the gamble does depend on others' choices. When he gets a bad meal at Restaurant B, he enjoys it more if other people are also eating at Restaurant B.

3.3.1. Social interaction effects ruled out by design

Section 3.4 presents a model showing how social regret and tastes for conformity can cause social interaction effects in our experiments. Two other channels through which social interaction effects may occur for choices under risk and uncertainty, social norms and payoff complementarities, are eliminated by design.

Social norms. To distinguish social norms from a general taste for conformity, we specifically define a social norm as a rule of behavior that is enforced by social sanctions, which can take the form of social approval or disapproval (Coleman, 1990).[9] There is ample evidence that people's choices are affected by social norms (Ostrom, 2000). Social interaction effects arise if social norms are conditional in nature, that is, when the sanctions for not adhering to a norm are stronger when more of one's peers adhere to the norm. In our experiment subjects play anonymously and there is no way to express approval or disapproval. Social norms, in the specific sense defined above, therefore cannot play a role in our experiment.

Payoff complementarities. Payoff complementarities occur for investment decisions if others' investments make a high return more likely. For example, an investment into a start-up firm is more likely to be profitable with more initial investors (or to be precise, more start-up capital; Fairlie and Robb, 2007). This type of social interaction effect is ruled out in our experimental design since the monetary payoffs of the gambles do not depend on how many other individuals choose them. Another variant of payoff complementarities occurs when participating in an activity provides opportunities for socializing, making the activity inherently more desirable. This is also eliminated by design since there is no face-to-face interaction in our experiment.

3.4. A theory of social regret and tastes for conformity

This subsection develops a simple theory of how individuals choose between pairs of gambles like those used in our experiments. Incorporating social regret and tastes for conformity into the theory, we generate hypotheses that allow us to separate between several possible explanations for the observed peer group effects.

3.4.1. Basic setup

Consider an individual choosing between two gambles, A and B. The support for both gambles consists of three possible payoffs: X, Y, and Z, paralleling the pairs of gambles used in the experiment which also had three possible outcomes. Assume $X > Y > Z \geqslant 0$. Let p_X, p_Y, and p_Z be the probability of the three outcomes for A, and let q_X, q_Y, and q_Z be the probability of the three outcomes for B. Without loss of generality assume that A is the less risky of the two gambles. For all pairs of gambles used in our experiments, $Z = 0$ and $p_X = 0$.

Individual i's utility for choosing A in Block t is given by Eq. (1). The first term is an "inherent utility" from the gamble. Given our focus on switching and feedback, the source of the inherent utility is not particularly important. The second term is a "social regret" function, described in more detail below. The utility for choosing B, shown in Eq. (2), is defined in an analogous manner.

$$u_A^{it} = U_A - \rho_{it}(A, B) \tag{1}$$

$$u_B^{it} = U_B - \rho_{it}(B, A) \tag{2}$$

[9] Social norms can be more broadly defined as a desire to make choices that are socially acceptable. In the absence of enforcement by social sanctions, social norms can be viewed as a possible cause of tastes for conformity.

An individual experiences non-negative disutility k from regret if he gets the worst outcome (Z) and would have done better (X or Y) if he had chosen the other gamble. As a simplifying assumption, the disutility of regret does not depend on how much better he would have done by choosing differently. To give regret a social aspect, disutility k is weighted by the probability that another individual would have chosen differently. Anticipated social regret is the likelihood of experiencing regret multiplied by the disutility due to social regret. Eq. (3) gives the anticipated social regret for an individual choosing A and Eq. (4) gives the anticipated social regret if B is chosen. The first two terms of Eq. (3), $p_Z(1-q_Z)$, give the probability that individual i receives the worst outcome and would have done better by choosing B. The next term, π^B_{it}, gives individual i's probability estimate that another individual will choose B in Block t – this is a belief not an exogenous probability. The final term, k, is the (unweighted) disutility from regret. Eq. (4) is constructed in an analogous manner.

Intuitively, a decision maker feels regret if, *ex post*, he made the wrong decision. This isn't to say the decision maker made a mistake, as long as the decision was correct *ex ante*, but there is a natural tendency to think about how things would have been better if only a different choice had been made. How badly an individual feels about a negative outcome may depend on how defensible his decision is, not to others (nobody but the experimenter can see a subject's choices) but to himself. One way to defend a decision is by appealing to the judgment of others. An individual might tell himself that his decision couldn't have been too wrong if virtually everyone did the same thing. This is the essence of social regret – regret is less intense when others made the same choice. As an old cliché puts it, misery loves company.

$$\rho_{it}(A,B) = p_Z(1-q_Z)\pi^B_{it}k \tag{3}$$

$$\rho_{it}(B,A) = q_Z(1-p_Z)\pi^A_{it}k \tag{4}$$

To close the model we specify beliefs. Let π^A_{i0} and π^B_{i0} be individual i's initial beliefs. For now we make no assumption about these priors. Absent social feedback, individual i's beliefs remain fixed. Suppose individuals receive social feedback about the share of people playing A in the previous block. Let $\alpha_{i,t-1}$ denote the proportion of others individual i observes choosing A in the previous block. We assume individuals respond naively to information about α in Block $t-1$, believing that α will be the same in Block t. Thus, $\pi^A_{it} = \alpha_{i,t-1}$ and $\pi^B_{it} = 1-\alpha_{i,t-1}$. This is a simplifying assumption, as the main results go through with any reasonable updating process.

Individual i chooses between A and B in Block t by comparing the utility for the two gambles and choosing the gamble with the higher utility. Adding an element of stochastic choice, the model includes the possibility of random mistakes (choices of the gamble with lower utility). These occur with decreasing probability as the difference between the gambles' utilities increases. Specifically, Gamble A is chosen if $\Delta U_{it} \geqslant 0$ as defined in Eq. (5), where τ_i is an individual error term uniformly distributed over the interval $[-T,T]$ and ε_{it} is an idiosyncratic error term uniformly distributed over the interval $[-E,E]$. Use of uniformly distributed error terms greatly simplifies the analysis, but otherwise isn't important for our results.

$$\Delta U_{it} = u^{it}_A - u^{it}_B + \tau_i + \varepsilon_{it} = (U_A - U_B) - \big(\rho_{it}(A,B) - \rho_{it}(B,A)\big) + \tau_i + \varepsilon_{it} \tag{5}$$

We assume T and E fulfill the condition shown in Eq. (6). This guarantees that both gambles are chosen with positive probability for all individuals.

$$T + E > \max\big[\text{abs}\big((U_A - U_B) + kq_Z(1-p_Z)\big), \text{abs}\big((U_A - U_B) - kp_Z(1-q_Z)\big)\big] \tag{6}$$

3.4.2. Reversion to the majority

A notable feature of our data is reversion to the majority in the private feedback treatment. Even though subjects in this treatment receive no social feedback, the software still assigns them to a fixed group of six subjects. Looking at the raw data, subjects in the private feedback treatment are more likely to switch gambles if their choice did not agree with the choice of the majority of others in their group. Given that choices can vary solely due to changes in the idiosyncratic error term, ε_{it}, our simple model predicts this effect. The intuition behind Theorem 1 is that a person is more likely to switch gambles if he made a mistake. Moreover, a person is more likely to have made a mistake if he played differently than the majority. The proofs of all theorems are included in Appendix A, posted on GEB's website as supplementary material.

Theorem 1. *Subjects in the private feedback treatment are more likely to switch gambles between Block $t-1$ and Block t if their choice from Block $t-1$ disagrees with the majority of choices in Block $t-1$ by others in their group.*

3.4.3. Response to feedback

Theorem 2 predicts that with preferences including social regret, social feedback about other group members' choices leads to positive correlation between the choices of group members, controlling for the likelihood of choosing each gamble across all groups. Intuitively, the social regret associated with a gamble is an increasing function of the probability that others choose a different gamble. Observing *more* individuals who agree with his choice in Block $t-1$ makes an individual believe it is *less* likely that others will choose differently than him in Block t. This decreases the anticipated social regret for the gamble he chose in Block $t-1$ and increases the anticipated social regret for the gamble he did not choose. Hence, an individual's likelihood of switching gambles decreases when more feedback agrees with his choice in Block $t-1$.

Theorem 2. *Assume $k > 0$. The difference between the likelihood of an individual switching gambles between Block $t-1$ and Block t if their choice from Block $t-1$* disagrees *with the majority of choices in Block $t-1$ by others in their group and the likelihood of an individual switching gambles between Block $t-1$ and Block t if their choice from Block $t-1$* agrees *with the majority of choices in Block $t-1$ by others in their group is greater with social feedback than with private feedback.*

To discuss the effect of social feedback on the probability of switching to or from risky gambles we must specify initial beliefs. This requires introducing some new notation. Let $\Pi(\pi_A^{it}, k)$ be the probability that Gamble A, the less risky gamble, is chosen as a function of beliefs and k, the disutility due to social regret. Implicitly the other parameters of the model are held fixed. Let $\pi^*(k)$ be the probability that solves the following equation: $\Pi(\pi^*(k), k) = \pi^*(k)$. In words, $\pi^*(k)$ gives a fixed point in the mapping from beliefs to probabilities of choosing Gamble A. Using Eq. (5) we can solve for the value of $\pi^*(k)$, as shown in Eq. (7).

$$\pi^*(k) = \frac{(U_A - U_B) + kq_Z(1-p_Z) + E}{k[p_Z(1-q_Z) + q_Z(1-p_Z)] + 2E} \tag{7}$$

If $\pi_{i0}^A = \pi^*(k)$, then group members are playing a Bayesian Nash equilibrium in Block 1 (treating the error terms as shocks to utility). Beliefs are correct and therefore don't change (on average) between Blocks 1 and 2. By extension, average behavior cannot change. What is more interesting is what happens when individuals don't have "rational" expectations. To be specific, suppose $\pi_{i0}^A = \pi^*(0)$. In other words, individuals have correct expectations except they fail to account for social regret. Given this assumption, Theorem 3 shows that, under weak conditions, switches to the risky gamble in Block 2 are relatively less likely for the social feedback treatment than in the private feedback treatment.

Intuitively, social regret biases choices against the risky gamble. Choosing the risky gamble makes the worst outcome more likely *and* makes it more likely that choosing the other gamble would have resulted in a better outcome. On both accounts, the risky gamble leads to greater anticipated social regret. If initial beliefs do not account for the effects of social regret, feedback shifts beliefs, on average, in favor of the less risky gamble. This makes it less likely subjects will switch to the risky gamble in Block 2 and more likely they will switch from it.

Theorem 3. *Assume $k > 0$ and $\pi_{i0}^A = \pi^*(0)$. The probability of switching from (to) the riskier gamble in Block 2 is larger (smaller) with social feedback if the condition in Eq. (8) holds.*

$$\frac{\pi^*(0)}{1-\pi^*(0)} > \frac{p_Z(1-q_Z)}{q_Z(1-p_Z)} \tag{8}$$

The condition in Eq. (8) is unlikely to be violated. It must hold if $\pi^*(0) > \frac{1}{2}$, and, for the specific probabilities we used in our gambles, the worst case is Class 3 which requires $\pi^*(0) > 0.35$. For all the other classes it is sufficient that $\pi^*(0) > 0.18$. Looking at the data for Block 1 from the social feedback treatment, the less risky gamble is chosen for 60% of the observations. Even in the worst case, Class 3, the safer gamble is chosen for 44% of the observations.[10]

Theorem 3 is stated in terms of specific initial beliefs, $\pi_{i0}^A = \pi^*(0)$, to ease exposition. More generally, Theorem 3 holds if initial beliefs underweight the effect of social regret ($\pi_{i0}^A = \pi^*(k')$ where $0 < k' < k$).

3.4.4. Conformity

Social psychology provides evidence that people feel better by conforming to the behavior of valued groups (Cialdini and Goldstein, 2004). Subjects in our experiments play anonymously in randomly matched groups, limiting the importance of group affiliation. Nevertheless, it is possible that social interaction effects arise because people like to behave as others. Our basic model can be modified to replace social regret with tastes for conformity by giving an individual additional utility, k/N, for each other group member who chooses the same as him where N is the number of other group members. Removing the social regret function and incorporating the appropriate beliefs, the following utility functions replace Eqs. (1) and (2) from above. The second term is the expected utility from conformity. The stochastic choice rule is constructed in the same way as above.

$$u_A^{it} = U_A + k\pi_{it}^A \tag{9}$$

$$u_B^{it} = U_B + k\pi_{it}^B \tag{10}$$

It is trivial to prove that Theorems 1 and 2 continue to hold if social regret is replaced with tastes for conformity. This implies that tastes for conformity are an alternative cause for any observed social interaction effects. As above, define $\pi^*(k)$ as the fixed point in the mapping from beliefs into probabilities of choosing A. Theorem 3 can be modified into Theorem 4.

[10] To intuitively understand what happens if the condition in Eq. (8) is violated, consider the worst case scenario where $\pi^*(0) = 0$. Only the less risky gamble has any anticipated social regret in this case since all individuals are expected to choose the risky gamble. Social regret therefore biases choices toward the risky gamble.

Theorem 4. *Assume $k > 0$ and $\pi_{i0}^A = \pi^*(0)$. Allowing feedback increases the probability of switching to Gamble A in Block 2 if and only if $\pi^*(0) > 1/2$.*

Unlike Theorem 3, Theorem 4 does not imply that individuals are either more or less likely to switch to risky gambles with tastes for conformity. Instead, Theorem 4 implies a bias in favor of switching to the majority choice *across all groups*. This is not the same result as Theorem 2 which implies a bias in favor of the majority choice *within a group* rather than a bias in favor of switching to the majority choice *across all groups*. Intuitively, tastes for conformity bias individuals in favor of the gamble that is expected to be more popular *ex ante*. If this bias is not anticipated, more of the popular choice is observed (on average) than expected. This leads to even greater movement toward the popular choice.

3.4.5. Spillovers

With either social regret or tastes for conformity, we predict positive spillovers between pairs of gambles. Assume subjects correctly believe that the use of risky gambles is correlated across pairs of gambles. Observing feedback in favor of the risky gamble, B, in one pair will then affect beliefs for other pairs of gambles, increasing the probability assigned to the risky gamble. The same argument used in proving Theorem 2 then applies and the probability of choosing the risky gamble increases. Analogous arguments apply to pairs of gambles where one gamble is presented in the simple format while the other uses an ambiguous format. Observing feedback in favor of the ambiguous gamble in one pair affects beliefs for other pairs of gambles where there is a simple and an ambiguous gamble, leading to an increased probability of choosing the ambiguous gamble.

3.4.6. Pure imitation

In Section 3.2 we raised the possibility that peer group effects are due to pure imitation. The idea is that social feedback allows subjects who are confused and uncertain about their ability to make good choices to identify possible mistakes, a type of "boundedly rational" social learning. As a practical matter this amounts to assuming that some proportion of decisions will be driven by a simple heuristic of imitating the most popular choice. Having developed a formal model of choice between gambles, it is easy to extend this to a model of imitation and generate some predictions. Start with the model developed in Eqs. (1)–(6). For simplicity, assume there is no social regret and no taste for conformity ($k = 0$). Use this model to generate probabilities of choosing A or B in Block 1. Imitation cannot play a role in Block 1 since subjects have no information about others' choices. In Blocks 2 and 3, assume that subjects with social feedback imitate the majority choice of other subjects in their group with probability I. With probability $1 - I$, the same choice rule is used as in Block 1.

This model predicts that imitation will generate peer group effects. Individuals who imitate will switch to the majority choice in their group but never switch away from the majority choice. As with tastes for conformity (although for different reasons), imitation also implies a bias in favor of switching to the majority choice *across all groups*. To see this, notice that if the probability of A being chosen by an individual in Block 1 is greater than $1/2$ the probability that the majority choice of other subjects in the group is A is greater than the probability that an individual chooses A. The result follows directly, giving us a second way of checking if peer group effects can be attributed to pure imitation due to bounded rationality.

3.5. Summary of hypotheses

We conclude this section by summarizing our hypotheses about the experimental data as well as the sources of these hypotheses.

- H1 Controlling for regression to the majority, subjects are more likely to switch gambles if the majority of the feedback disagrees with their previous choice. Models of social learning, social regret, and tastes for conformity all give rise to this hypothesis.
- H2 The effect will be larger when the scrambled format is used for ambiguous gambles than with the blackout format. This hypothesis should hold if rational social learning plays a role in generating the observed peer group effects.
- H3 Switches between Blocks 1 and 2 of the social feedback treatment will be biased against the risky gamble as compared to the private feedback treatment. This effect is predicted if social regret plays a role in generating the observed peer group effects.
- H4 Switches between Blocks 1 and 2 of the social feedback treatment will be biased in favor of the more popular gamble *across all groups* as compared to the private feedback treatment. This effect is predicted if tastes for conformity or pure imitation play a role in generating the observed peer group effects.
- H5 Observing feedback in favor of the risky (ambiguous) gamble in one pair will make choice of the risky (ambiguous) gamble more likely in other pairs.
- H6 The peer group effect will be smallest for simple vs. simple comparisons. If pure imitation plays a role in generating the observed peer group effects, this prediction should hold.

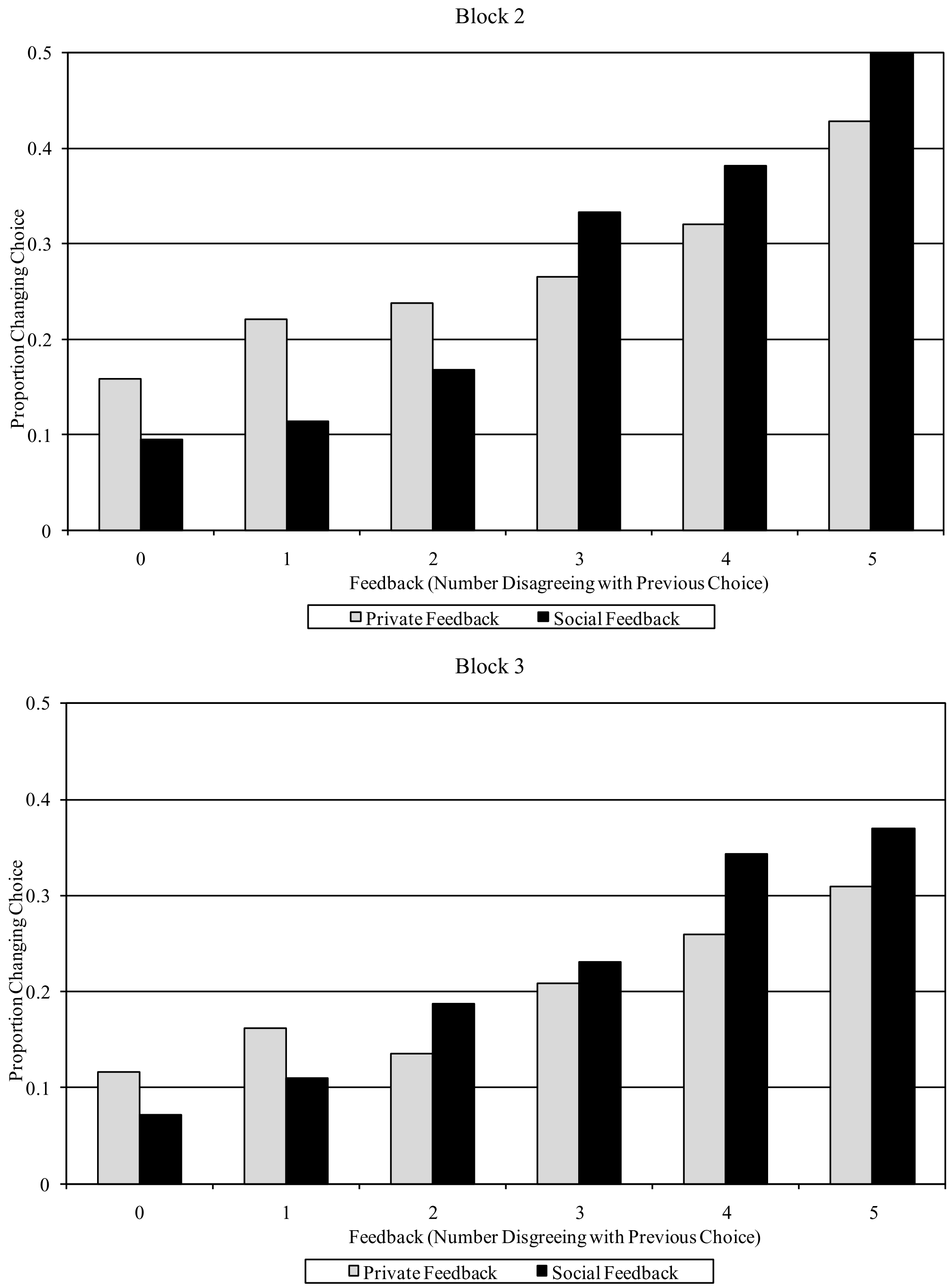

Fig. 3. Effect of feedback on switching.

4. Results

See Appendix B, online at GEB's website as supplementary material, for a summary of choices for each pair of gambles, broken down by block and treatment. The full dataset is available from the authors upon request.

4.1. Effect of feedback

Before we can ask why peer group effects occur for choices with risk and uncertainty, we need to establish that such peer group effects exist and cannot be attributed to regression to the majority. Fig. 3 does so. The top panel shows data from Block 2 and the bottom panels shows data from Block 3. Data in each panel is broken down by what feedback subjects received. We aggregate over sessions using the scrambled and blackout formats for ambiguous gambles. The x-axis sorts the data by how many other individuals in the group made the opposite choice from the decision maker in the previous block for the same pair of gambles. For the social feedback treatment, this indicates how much the feedback from the group disagrees with the decision maker's previous choice. In the private feedback treatment, the program puts the subjects

Table 3
Linear probability models: switching responds to feedback.

	Model 1	Model 2	Model 3	Model 4	Model 5
Treatment	Social feedback	Social feedback	Private feedback	Social feedback	Social feedback
Block	2	3	2	2	2
Subjects/obs	126/1392	126/1386	108/1224	126/1392	126/1392
Others disagreed	0.058*** (0.015)	0.025** (0.012)	0.007 (0.015)	–	–
1 disagreed	–	–	–	−0.002 (0.028)	–
2 disagreed	–	–	–	0.049 (0.038)	–
3 disagreed	–	–	–	0.154*** (0.038)	–
4 disagreed	–	–	–	0.160** (0.065)	–
5 disagreed	–	–	–	0.330*** (0.096)	–
Majority disagreed	–	–	–	–	0.153*** (0.033)
R-squared	0.153	0.127	0.135	0.159	0.151

into groups of six even though these are never used. Thus, for the private feedback treatment the x-axis shows what the feedback would have been *if the decision maker had received feedback*.[11] The y-axis shows the proportion of decision makers who switched their decision from the same pair of gambles in the previous block (either from Gamble A to Gamble B or vice versa).

For both the private feedback and social feedback treatments in Blocks 2 and 3, there is a positive relationship between the number of others disagreeing with the previous choice and the probability of switching. For the private feedback treatment this cannot be due to an effect of social feedback, but is consistent with reversion to the majority as predicted by Theorem 1. Critically, the association between the number of others disagreeing with the previous choice and the probability of switching is stronger in the social feedback treatment for both Blocks 2 and 3. This is consistent with social feedback causing subjects to switch their choices as predicted by Theorem 2. The effect of social feedback on switching is stronger in Block 2 than in Block 3.

The regressions shown in Table 3 put the preceding points on firmer ground. These are linear probability models.[12] Each observation is a single choice in a pair of gambles. The dependent variable is a dummy for whether the subject switched their choice from the same pair of gambles in the previous block. The first two lines of the table tell which feedback treatment (private or social feedback) and block of periods the data is being drawn from. Data is combined from sessions with the scrambled and blackout formats for ambiguous gambles.

The independent variable of interest, “Others disagreed,” gives how many other individuals in the group made the opposite choice from the decision maker in the previous block for the same pair of gambles. We expect the parameter estimate to be positive for this variable–increasing the amount of feedback that disagrees with my previous choice makes me more likely to switch.

As Fig. 3 shows, reversion to the majority induces correlation between switching and feedback even when no actual feedback is present. To control for this problem, all models in Table 3 include fixed effects for the pair of gambles interacted with dummies for sessions where the blackout format was used and which gamble was chosen for the same pair of gambles in the previous block. This gives us a total of 52 fixed effects.[13] Parameter estimates for the fixed effects are not displayed in Table 3 or subsequent tables, since they are of no direct interest. The fixed effects always achieve joint statistical significance at the 1% level.

To understand why the addition of these 52 fixed effects controls for reversion to the mean, consider a much simpler setting with a single pair of gambles and social feedback. Assume all individuals have identical preferences that Gamble A is inherently a better choice. Some individuals nonetheless choose Gamble B by mistake. Critically, assume that choices do *not* respond to social feedback. Now consider a decision maker whose previous choice disagrees with the majority of his social feedback. It is likely that his previous choice was Gamble B. In other words, he probably made a mistake. Since mistakes are transitory, this decision maker is relatively likely to switch gambles in the next round. This implies that if we regress a dummy for switches on the amount of social feedback that disagrees with the decision maker's lagged choice, but don't

[11] For the no feedback treatment, we did not force participation in multiples of six. This leaves a few subjects who are not assigned to a group by the software. For the purposes of Figs. 3, 4, and 6 as well as Model 3 in Table 3, their data is discarded.

[12] The marginal effects and statistical significance are qualitatively the same if a logit or probit model is used.

[13] The regressions do not include constants. There are 14 pairs of gambles used in the ambiguous treatment and 12 pairs of gambles used in the blackout treatment. Since there are two possible lagged choices in all cases, this gives us 28 fixed effects in the ambiguous treatment and 24 in the blackout treatment for a total of 52 fixed effects.

include a dummy for the lagged choice, we will find a positive relationship between the disagreeing social feedback and the likelihood of a switch. An omitted variable bias arises. The social feedback is correlated with the lagged choice, and the lagged choice is correlated with the likelihood of a switch. If the lagged choice is omitted, its effect on the likelihood of a switch shows up in the parameter estimate for disagreeing social feedback even though there is no causal relationship between social feedback and switches. With inclusion of a dummy for the lagged choice, this omitted variable bias is eliminated.

Our dataset includes multiple observations from the same individuals. These are not independent observations. In the social feedback treatment we also cannot treat choices from the same group as being independent. We therefore correct the standard errors for clustering at the individual level in the no feedback treatment and at the group level in the full feedback treatment. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% levels respectively.

Model 1 tests for the effect of social feedback in Block 2. The parameter estimate for social feedback is positive, as expected, and statistically significant at the 1% level. This estimate cannot be biased by reflection, since subjects in Block 2 are receiving information about others' choices in Block 1, choices made before the other group members saw any social feedback. Model 2 replicates Model 1 using data from Block 3. The magnitude of the estimated feedback effect is roughly halved, with the difference between the feedback effects for Blocks 2 and 3 being statistically significant at the 10% level. It isn't surprising that the responsiveness to feedback is lower in Block 3. Feedback for Blocks 2 and 3 is highly correlated, so Block 3 feedback generally is not news to the subjects. Their response will already be built into their choice from Block 2.[14]

Model 3 tests whether the inclusion of fixed effects controls for reversion to the majority. It replicates Model 1 using data from the private feedback treatment. Since subjects in this treatment cannot observe the lagged choices of other subjects in their group, the social feedback should not affect their likelihood of a switch. The parameter estimate for "Others disagreeing" is small and does not approach statistical significance at any standard level, indicating that the fixed effects effectively control for reversion to the majority. Reinforcing this point, the parameter estimate for "Others disagreeing" jumps from 0.007 to 0.050 (and is statistically significant at the 1% level) if the fixed effects are dropped from Model 3.

Model 4 uses the same dataset as Model 1, but replaces "Others disagreed" with dummies for the specific values of this variable (zero is the omitted category). This allows us to test whether the response to feedback is linear. The results indicate that it is not. There are large jumps in the probability of switching when a majority disagreed (Others disagreed $\geqslant 3$) and when disagreement is unanimous (Others disagreed $= 5$).

Model 4 gives us a clean measure of the magnitude of feedback effects. Not only are these effects statistically significant, they are also large in magnitude. For Block 2, moving from unanimous agreement to unanimous disagreement increases the chance of a switch by 33 percentage points. Changing the majority of the social feedback by moving from two others disagreeing to three others disagreeing increases the chance of a switch by 11 percentage points. To fully appreciate the economic significance of these effects, note that the overall probability of a switch in Block 2 with full feedback is only 21%.

Model 4 establishes that the effect of feedback is non-linear, with an obvious (and statistically significant) breakpoint at majority disagreement. Consequently, from this point forward we investigate the effect of feedback through regressions where the primary independent variable is a dummy for whether the majority disagreed with the choice of the decision maker in the previous block for the same pair of gambles. The basic version of this regression is shown in Model 5 – majority disagreement increases the likelihood of a switch by 15 percentage points compared to majority agreement. Use of this specification greatly simplifies the exposition without qualitatively affecting our results.

Conclusion 1. Subjects respond to feedback, confirming H1. This feedback effect is stronger in Block 2 than in Block 3 and cannot be attributed to reversion to the majority. Majority disagreement and unanimous disagreement are significant breakpoints in the likelihood of a switch. The magnitude of feedback effects is large relative to the likelihood of a switch.

4.2. Social learning and imitation

As described in Section 3, the effects of social feedback could reflect social learning or pure imitation rather than social interaction effects. The regressions in Table 4 distinguish between these causes. The dataset and basic specification for these regressions are identical to those used for Model 5 in Table 3. The dataset contains 1392 observations from 126 subjects in Block 2 of the social feedback treatment. The dependent variable is a dummy for whether the subject switched their choice from the same pair of gambles in the previous block. All regressions include fixed effects for the pairs of gambles interacted with dummies for the blackout format and the lagged choice for the same pair of gambles (52 fixed effects total). Standard errors are corrected for clustering at the group level. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% respectively.

Model 1 repeats Model 5 from Table 3 as a point of comparison. Model 2 compares the effect of feedback in pairs of gambles with no ambiguity to pairs of gambles with ambiguity. We do this by constructing a "No ambiguity" dummy for pairs of gambles where both gambles are in the simple format and an "Ambiguity" dummy for pairs of gambles where at

[14] Unlike Block 2, reflection can play a role in Block 3 decisions. A subject's choices in Block 1 affect others' choices in Block 2, which in turn affects the social feedback he receives in Block 3.

Table 4
Linear probability models: social learning.

	Model 1	Model 2	Model 3
Majority disagreed	0.153*** (0.033)	–	–
Majority disagreed *No ambiguity	–	0.198*** (0.061)	0.198*** (0.061)
Majority disagreed *Ambiguity	–	0.141*** (0.035)	–
Majority disagreed *Ambiguity *Scrambled	–	–	0.130** (0.056)
Majority disagreed *Ambiguity *Blackout	–	–	0.148*** (0.044)
R-squared	0.151	0.151	0.151

least one of the gambles was in an ambiguous format. The resulting two dummies are interacted with "Majority disagree." Model 2 shows that the effect of majority disagreement is slightly larger in pairs of gambles with no ambiguity, but this difference is not statistically significant. If pure imitation plays a role in generating the effect of social feedback on switching, the effect is predicted to be smaller in pairs of gambles with no ambiguity. This prediction (and H6) is rejected.

Model 3 breaks down the feedback effect further, distinguishing between pairs of gambles using the blackout format and pairs of gambles using the scrambled format for the presentation of ambiguous gambles. We do this by constructing a "scrambled" and a "blackout" dummy and interacting these with the "Ambiguity" and the "Majority disagree" dummies. Model 3 finds that the estimated effect of majority disagreement is somewhat larger in pairs of gambles using the blackout format compared to pairs of gambles using the scrambled format, but the difference isn't statistically significant. If rational social learning plays a role in generating the effect of social feedback on switching, the effect is predicted to be larger in gambles using the scrambled format. This prediction (and H2) is rejected.

Conclusion 2. Feedback effects in our data are not consistent with either rational social learning or pure imitation. We reject H2 and H6.

4.3. Feedback and choice of risky and popular gambles

This section addresses whether allowing feedback causes subjects to switch away from riskier gambles and toward more popular gambles, averaging across groups in both cases. As shown in Theorems 3 and 4, the existence or absence of these effects helps us understand the roles of social regret, tastes for conformity, and pure imitation in generating the observed peer group effects.

Fig. 4 examines how allowing feedback affects the likelihood of switching to the riskier or more popular gamble. Data is taken from subjects who switched gambles between Blocks 1 and 2. The left-hand pair of bars shows the probability, broken down by feedback condition, that subjects who switch gambles choose the riskier gamble in Block 2. The middle bars show the proportion of these subjects choosing the more popular gamble in Block 2, defined as the gamble chosen

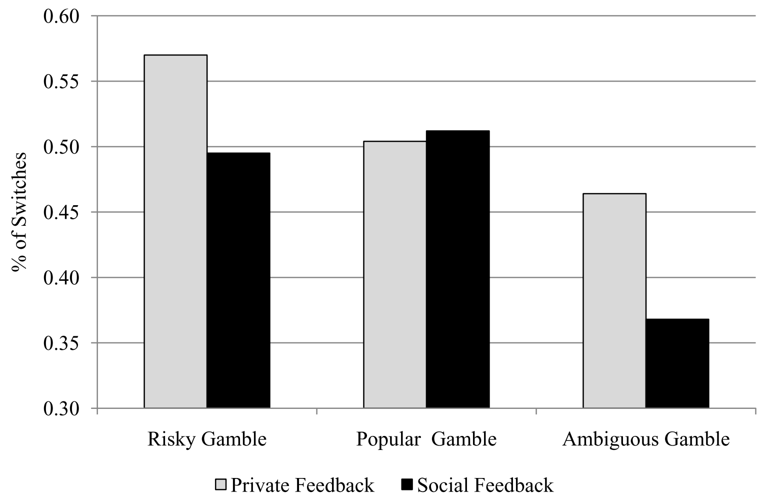

Fig. 4. Feedback and switches to risky, popular, and ambiguous gambles.

Table 5
Linear probability models: feedback and risk/ambiguity aversion.

	Model 1	Model 2	Model 3
Dependent variable	Choice of risky gamble	Choice of majority gamble	Switch
Social feedback	−0.047** (0.023)	0.002 (0.014)	–
Social feedback shift to risky	–	–	−0.046* (0.024)
Social feedback shift to majority	–	–	0.002 (0.015)
Social feedback shift to ambiguity	–	–	−0.059* (0.035)
R-squared	0.113	0.110	0.114

by the majority of subjects *across all groups*.[15] Although not directly relevant to the theory, for completeness the right-hand bars show the proportions of switchers choosing the ambiguous gamble in Block 2. This final pair of bars is based only on pairs of gambles where subjects chose between a simple and an ambiguous gamble.

The left-hand bars show that subjects with feedback are less likely to switch to the risky gamble with social feedback. This is consistent with H3, and hence supports the role of social regret in generating the observed peer group effects. The bars in the center show that subjects are equally likely to switch to the popular gamble (across all groups) with private and social feedback. The data gives little support for H4. This suggests that neither tastes for conformity nor pure imitation play important roles in generating the observed peer group effects. Looking at the bars on the right, social feedback also makes subjects less likely to switch to ambiguous gambles.

The regressions shown in Table 5 confirm our impressions from Fig. 4. Once again, these are linear probability models. The dataset is all data from Block 2 for the private and social feedback treatments (2844 observations from 254 subjects), pooling data from both formats for ambiguous gambles.

In Models 1 and 2 the dependent variable is a dummy for what type of gamble was chosen in Block 2, specifically choice of the risky gamble in Model 1 and choice of the popular gamble (across all gambles) in Model 2. All models include fixed effects for the pair of gambles interacted with dummies for sessions where the blackout format was used and which gamble was chosen for the same pair of gambles in the previous block (52 fixed effects total). The independent variable of interest in Models 1 and 2 is a dummy for the social feedback treatment. A positive estimate for this parameter indicates that subjects are more likely to switch to the risky/popular gamble in Block 2 of the full feedback treatment. The standard errors are corrected for clustering at group level in the full feedback treatment and at the individual level in the no feedback treatment. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% respectively.

In Model 1 the parameter estimate for "Social feedback" is negative and statistically significant, while in Model 2 the parameter estimate for "Social feedback" is positive but tiny and nowhere close to statistical significance. The standard error for "Full feedback" is smaller in Model 2 than in Model 1, so the failure to find a significant effect in Model 2 cannot be attributed to a lack of precision in the estimate. The results of Models 1 and 2 indicate that social feedback causes significantly more switches away from risky gambles but has no significant effect on switches to popular gambles.

If social feedback changes the probability of switching between simple and ambiguous gambles, in the results of Models 1 and 2 may be biased due to a lack of control for whether gambles are simple or ambiguous. Model 3 addresses this concern by measuring the effect of social feedback on switching play away from the risky gamble and toward the popular gamble while controlling for any shifts vis-à-vis ambiguous gambles. The dependent variable for Model 3 is a dummy for whether the subject switched their choice from the same pair of gambles in the previous block. The independent variables need to be transformed to reflect this change in the dependent variable from Models 1 and 2. The first independent variable is a dummy for social feedback multiplied by an indicator variable that takes on a value of 1 if the less risky gamble was chosen for the same pair of gambles in the previous block and a value of −1 if the riskier gamble was chosen. The parameter estimate for this new variable, labeled "Social feedback shift to risky," captures the effect of social feedback on switches toward the riskier gamble controlling for the choice in the previous gamble. If this is the only independent variable (other than fixed effects), the parameter estimate and standard error must be identical to those shown in Model 1 for "Social feedback." The second independent variable ("Social feedback shift to majority) is constructed in an analogous manner for popular gambles, measuring the effect of social feedback in switching play toward the more popular gamble. If it is the sole independent variable, we get identical results to Model 2. A final independent variable ("Social feedback shift to ambiguity") equals a dummy for social feedback multiplied by a dummy for pairs of gambles comparing simple and ambiguous gambles multiplied by an indicator variable that takes on a value of 1 (−1) if the simple (ambiguous) gamble was chosen for the same pair of gambles in the previous block. This estimates the effect of social feedback on switches toward the ambiguous gamble when both a simple and an ambiguous gamble are available.

[15] To be specific, the data was divided into cells by pair of gambles, format used for ambiguity (scrambled or blackout), and block. The popular gamble was then determined for each cell.

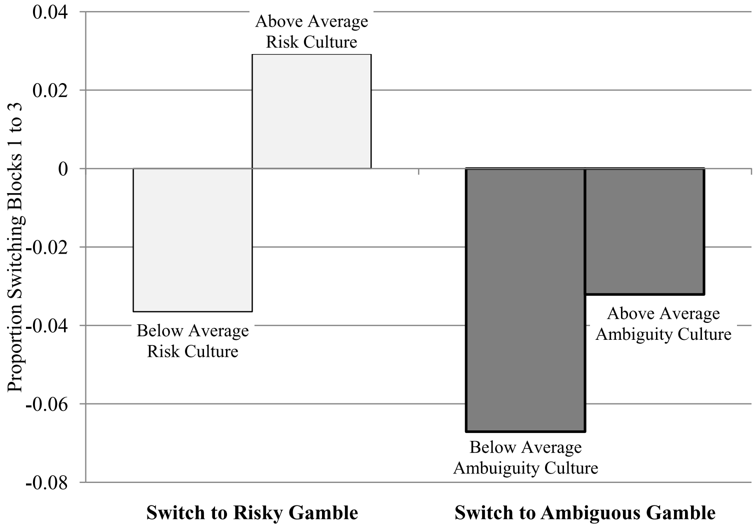

Fig. 5. Effect of risk and ambiguity culture switching.

The results of Model 3 indicate that our conclusions from Models 1 and 2 are robust. The parameter estimates for moves to riskier and popular gambles with social feedback are virtually unchanged with the addition of controls for ambiguity. The regression also shows significantly more switching away from ambiguous gambles with social feedback, consistent with Fig. 4. This final result does not help us sort out the causes of peer group effects, but is an interesting feature of the data that merits note.

For Theorem 3 to apply when ambiguous gambles are presented using the blackout format, we need to assume that subjects believe the blacked out blocks will not change which of the two gambles is riskier. To check whether this affects our results, we reran the regressions from Table 5 omitting observations where an ambiguous gamble using the blackout format is present. The results are basically unchanged. The estimated effect of social feedback on switching away from risky gambles is slightly larger (the relevant parameter estimate for Model 3 is increased to 0.056 with a standard error of 0.031) and remains statistically significant. The estimated effect of social feedback on switches to the popular gamble remains small and statistically insignificant.

Conclusion 3. Social feedback leads to relatively more switching away from the risky gamble. This result is consistent with H3, suggesting that social regret plays a role in generating the observed peer group effects. Social feedback does not cause more switches to popular gambles, contrary to H4. This is inconsistent with tastes for conformity or pure imitation playing an important role in generating the observed peer group effects.

4.4. Spillovers

Thus far we have documented direct feedback effects, where information about play for the *same* pair of gamble in previous blocks affects current decisions. Indirect effects may exist as well, where information about play for *other* pairs of gambles affects current decisions. We use measures of group risk and ambiguity "cultures" based on Block 1 choices to examine this possibility. For each individual and each pair of gambles in Block 1, the measure of risk culture calculates the average number of other individuals in the same group choosing the risky gamble for *other* pairs of gambles in Block 1.[16] Likewise, the measure of ambiguity culture calculates the average number of other individuals in the same group choosing the ambiguous gamble for *other* pairs of gambles in Block 1 that offer a simple and ambiguous gamble (i.e. Pairs 3, 4, 7, and 8).

We study the effects of risk and ambiguity culture on choices in Block 3 rather than Block 2 because subjects have received social feedback about all pairs of gambles in Block 3 while in Block 2 they have only received social feedback about some pairs. This lets us avoid controlling for exactly which pairs of gambles have been seen previously and lessens concerns about cultural effects being cumulative – it is difficult to imagine any cultural effects in the first few rounds on Block 2 when subjects have little experience with feedback from other gambles. Even though we are using Block 3 choices, reflection is not a concern here since our measures of risk and ambiguity culture are based on Block 1 choices which are exogenous.

Fig. 5 illustrates the relationship between risk and ambiguity culture in Block 1 and switches between Blocks 1 and 3. We split data from the social feedback treatment by whether the observation has below or above average risk/ambiguity culture.

[16] For ambiguous gambles displayed in the blackout format, the designation of the riskier gamble is based on the observed standard deviation of payoffs rather than the true (unobserved) value of this statistic.

Table 6
Linear probability models: cultural effects.

	Model 1	Model 2
Dataset	All data	Simple/ambiguous
Block 1	0.085**	–
Majority of group risky	(0.030)	
Block 1	0.077**	–
Risk culture	(0.031)	
Block 1	–	0.074*
Majority of group ambiguous		(0.037)
Block 1	–	0.032
Ambiguity culture		(0.026)
R-squared	0.403	0.404

The bars on the left show the (net) proportion of observations switching to the risky gamble between Blocks 1 and 3. There is a positive relationship between the risk culture in Block 1 and the probability of switching to the risky gamble between Blocks 1 and 3. In other words, subjects are more likely to switch to a risky gamble between Blocks 1 and 3 if more risky choices by other subjects have been observed for *other* pairs of gambles in Block 1. The bars on the right show the (net) proportion switching to the ambiguous gamble between Blocks 1 and 3 for pairs where subjects choose between gambles in the simple and ambiguous formats. Once again there is a positive, albeit weaker, relationship between culture in Block 1 and the likelihood of switching between Blocks 1 and 3. Subjects are more likely to switch to an ambiguous gamble between Blocks 1 and 3 if more ambiguous choices by other subjects have been observed for *other* pairs of gambles in Block 1 where simple and ambiguous gambles were available.

Two problems in measuring the impact of risk and ambiguity culture necessitate the use of regression analysis. First, pairs of gambles that are more likely than average to have the risky (ambiguous) gamble chosen must also have less than average measures of risk (ambiguity) culture.[17] Regression to the majority implies that if the risky (ambiguous) gamble is more likely to be chosen *ex ante*, individuals are also more likely to switch from the safer gamble than the risky gamble. Combining these observations, reversion to the majority works against the effects of risk (or ambiguity) culture. It follows that Fig. 5 systematically understates the effects of risk and ambiguity culture. Our trusty 52 fixed effects allow us to control for reversion to the majority. Second, if there are individual effects in the choice of risky or ambiguous gambles, the measures of risk and ambiguity culture are correlated with the social feedback on Block 1 choices for the *same* pair of gambles. Thus, the apparent effect of risk or ambiguity culture shown in Fig. 5 could be due to omitted variable bias rather than any true causal relationship.

The regressions shown in Table 6 address these issues. Once again these are linear probability models. The dataset for Model 1 is all choices in Block 3 from the social feedback treatment (1368 observations from 126 subjects), while Model 2 uses the subset of choices that compare a simple and ambiguous gamble (486 observations from 126 subjects). The dependent variable in Model 1 is a dummy for whether the risky gamble was chosen. In Model 2 it is a dummy for choice of the ambiguous gamble. Both regressions include fixed effects for the pair of gambles interacted with dummies for sessions where the blackout format was used and which gamble was chosen for the same pair of gambles in the previous block (52 fixed effects total). Both regressions control for the feedback about Block 1 choices for the same pair of gambles, eliminating omitted variable bias as a cause of the estimated spillover effects. To match the dependent variable, the independent variable is whether the majority of choices in the Block 1 feedback were for the risky (ambiguous) gamble, not whether the majority disagreed with the subject's previous choice for the same pair of gambles. Standard errors are corrected for clustering at the group level. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% respectively.

The parameter estimate in Model 1 for Block 1 risk culture (defined as the average number of *other* individuals in the group choosing the risky gamble for *other* pairs of gambles in Block 1) is positive and statistically significant at the 5% level. The size of the effect is large given that only 23% of subjects change choices between Blocks 1 and 3. In Model 2, the parameter estimate for Block 1 ambiguity culture is positive, but small and not statistically significant. This lack of statistical significance stems in part from having only a third as many observations for Model 2 as in Model 1. Nonetheless Model 2 deepens our impression from Fig. 5 that spillover effects in our experiment are weaker for choices between simple and ambiguous gambles than for choices between safe and risky gambles.[18]

Conclusion 4. A subject's choice of risky gambles responds to feedback about others' choices of risky gambles for other pairs of gambles in previous blocks. In other words, there are positive spillover effects, confirming H5 for risky gambles. There

[17] Risk culture is based on choices in the other pairs. If the current pair leads to above average usage of the risky gamble, the remaining pairs must have below average usage of the risky gamble.

[18] This relative weakness may be a function of how the experiment is constructed. Pairs where subjects choose between simple and ambiguous gambles are interspersed with pairs that force the subjects to choose a simple gamble and pairs that force choice of an ambiguous gamble. As such, it is relatively difficult for subjects to notice that one sort of gamble is generally being chosen when both are available.

are also positive spillover effects for ambiguous gambles, but weaker than for risky gambles and not statistically significant. The data does not confirm H5 for ambiguous gambles.

5. Discussion

This paper presents an experimental investigation of the causes of peer group effects in settings that involve choice under risk and (Knightian) uncertainty. We document large and significant peer group effects. Controlling for reversion to the mean, the likelihood of switching gambles increased by 15 percentage points if the majority of the social feedback disagreed with one's choice in the previous period. This is a large effect since the overall frequency of switching is only 20 percentage points.

A central goal of our paper is to use the tightly controlled environment available in the laboratory to cleanly identify the observed peer group effects as being due to social interaction effects. Alternative causes such as omitted variable bias and knowledge spillovers are eliminated through the experimental design.

Comparing theoretical predictions with the experimental data, the observed peer group effects are consistent with preferences that include social regret but not with rational social learning, tastes for conformity, or pure imitation due to bounded rationality. A central contribution of our work is identifying social regret as a potentially powerful source of social interaction effects in environments where risk and uncertainty play an important role.

An obvious doubt about our results is that the observed peer group effects could reflect a demand induced effect if subjects feel obligated to respond to the information that the experimenters have given them. Several factors argue against this. First, subjects observe their own past choices in addition to the social feedback. The argument for demand induced effects therefore requires subjects to feel an obligation to use *all* the information they are given, a much tougher standard. Second, if demand induced effects exist in our experiment and explain the observed peer group effects, they must make the subjects want to do what others have done. Even though this occurs because the subjects want to please the experimenter rather than having a taste for acting like others, the predicted effect is identical to the effect of having tastes for conformity. As has been established above, the data isn't consistent with this story. Finally, we observe strong spillover effects for the choice of risky gambles. This is a subtle effect that doesn't square well with demand induced effects as the driving force.

Our results should be interpreted with caution. Our purpose is to show that social interaction effects driven by social regret can cause peer group effects. It does not follow that other possible causes for peer group effects cannot exist. Some possible causes of peer group effects, such as social norms and knowledge spillovers, are eliminated by design in our experiments. Other possible causes, such as rational social learning and imitation, do not seem to play an important role in our experiments but could play an important role in other settings. Future work is needed to study the mapping between various settings and the relative importance of possible sources of peer group effects. It is also worth noting that our evidence for social regret is indirect: the theory predicts that social feedback will bias switches away from riskier games, and data consistent with this prediction is observed. We think it would be interesting in future work to gather direct evidence of social regret through the use of verbal protocols.

It is well known from the psychology literature that group decision making can lead to shifts in choices over gambles. Depending on how the gambles are constructed, both "risky" and "cautious" shifts have been observed (Davis, 1992). These choice shifts are a different phenomenon from the peer group effects we observe, since group decision making involves direct interactions in the decision making process rather than indirect interactions through observation. However, social regret as a general phenomenon could play a role in generating the shifts observed with group decision making.

The results of our paper on spillovers suggest an interesting avenue for investigation in field studies. The strong peer group effects in our data lead to increased group polarization – with feedback there is greater homogeneity within groups and greater heterogeneity between groups. Considered in conjunction with the spillovers observed between pairs of gambles, this implies that local cultures of risk taking or avoidance will emerge which encompass a broad range of activities beyond specific behaviors that have previously been studied. We hope that future field studies will identify the predicted broad cultures of risk behavior.

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Supplementary material

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