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Competing Against Experienced and Inexperienced Players

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Abstract

In certain markets success may depend on how well participants anticipate the behavior of other participants who have varying amounts of experience. Understanding if and how people's behavior depends on competitors' level of experience is important since in most markets participants have varying amounts of experience. Examining data from two new experimental studies similar to the beauty contest game first studied by Nagel (1995), the results indicate that (1) players with no experience behave the same against competitors with and without experience but (2) players quickly learn to condition their behavior on competitors' experience level, causing (3) behavior to stop moving toward the equilibrium whenever new players enter the game and (4) experienced players to earn more money than less experienced players. The paper discusses the implications of the results for understanding and modeling behavior in markets in which participants have different amounts of experience.

Keywords: game theory, learning, experimental methods

JEL Classification: C7, C9

Imagine playing poker and knowing how much experience your competitors have. To maximize your payoff, your strategy (e.g., how often to bluff) may depend on competitors' experience. Or consider negotiations (e.g., settling a lawsuit out, flea market haggling, employee compensation or buyer-supplier transactions) where each party knows how often the other party has been in similar negotiations. The success of a strategy (e.g., how aggressive to make an initial offer, how long to wait before accepting an offer, whether to make an exploding offer, etc.) may depend on the other party's level of experience. More generally, if people have different amounts of experience, experience is correlated with behavior and there is strategic interaction, then people can profit by conditioning behavior on the experience level of others. However, whether people condition their behavior on the amount of experience of others has heretofore not been examined.[1]

This paper hypothesizes that people form beliefs about competitors' behavior based on the amount of experience competitors have, and then best respond to these beliefs. A necessary condition for this hypothesis is that behavior changes in predictable ways as people gain experience. Extensive support for this condition exists; many learning models successfully predict how behavior changes with experience in individual tasks, games and markets.[2] For instance, behavior almost always converges toward the unique equilibrium in public goods (Andreoni, 1988) and dominance-solvable games (Nagel, 1999) and Ockenfels and Roth (2002) find that the timing of internet bids differs with the experience of bidders.

To test whether behavior depends on competitors experience level, this paper presents new experimental evidence from the dominance-solvable beauty contest (or guessing) game first studied by Nagel (1995). The paper addresses two questions: (1) do players *without experience* behave differently against competitors with and without experience and (2) do players *with experience* behave differently against competitors with and without experience. We find that the latter but not the former question is answered affirmatively, indicating people learn to condition behavior on competitors' level of experience.

These results have many implications (discussed in the conclusion), including implications for convergence and efficiency. For example, as the data will show, if new people constantly enter a market and experienced participants best respond to the inexperience of these entrants, then behavior converges more slowly toward the equilibrium. Thus, discussion of equilibrium that relies on learning (e.g., Osborne and Rubinstein, 1994) may be qualified to require that new participants do not enter markets too frequently.

Another implication of this paper's results is that learning models can be adjusted to allow players to learn to respond to their competitors' experience level. The idea that players learn to respond to other participants' experience level is closely related to the 'sophisticated' learning studied in Cooper and Kagel (2002), Camerer and Ho (1998), Camerer et al. (2002a), Stahl (2000) and others.[3] For example, Cooper and Kagel find that some players learn about opponent's reasoning in signaling games and Camerer et al. find that some players learn that other players are learning. The models presented in this literature are the natural starting point for addressing the empirical results presented in this paper since these models already endogenously allow players to recognize that other players are learning. However, these models examine players who learn about other players with identical levels of experience as themselves whereas this paper hypothesizes and finds that people also learn how competitors with different levels of experience behave.

1. The beauty contest game

In the beauty contest game (BCG) studied in this paper, three players simultaneously choose a real number from 0 to 100. The player whose number is closest to 2/3 of the median of the three numbers earns \$3 and the other players earn \$0. If there is a tie, the \$3 is divided evenly among the people who tied. After players have made their choices, the numbers, median and 2/3 of the median are publicly announced. The unique equilibrium for BCGs (when players choose real numbers) requires all players to choose 0.

In BCGs (e.g., using 2/3 or 1/2 of the mean or median and using 4, 7 or more subjects—see Nagel (1999) for a review and Camerer (1997) for robustness across subject populations) players choices fall with repeated play.[4] For example, when the winning number is closest to 2/3 of the mean, Nagel (1995) reports the mean choice falls from 36.7 to 23.9 to 15.9 to 12.3 over four periods. In these games, and virtually all experiments and theoretical treatments of learning, players always have the same amount of experience (e.g., when a player plays a game for the nth time, his opponents are playing for the nth time).[5]

The BCG is an important domain to begin examining how variation in the amount of opponent's experience affects behavior. First, being a constant-sum game, it eliminates externalities and several possible explanations for behavior including fairness, cooperation, coordination and reciprocity. Second, winners are clearly defined; if experienced players have an advantage, the advantage can easily be measured by how often they win. Third, the effect of experience is predictable; behavior in BCGs almost always converges toward the equilibrium. Fourth, the game offers substantial opportunities for introspection. Nagel's description of the mental process players may use suggests the introspection opportunities in BCGs:

> "In the simplest case, a player selects a strategy at random without forming beliefs ... (zero-order beliefs). A somewhat more sophisticated player forms first-order beliefs on the behavior of the other players. He thinks that others select a number at random, and he chooses his best response to this belief. Or he forms second-order beliefs on the first order beliefs of the others and maybe nth order beliefs about the $(n-1)$th order beliefs of the others, only up to a finite n, called the n-depth of reasoning," (Nagel, 1995, p. 1313).

Thus, players who believe there is a positive relationship between experience and reasoning, and thus behavior, will play the game differently against opponents with different levels of experience.

Finally, the BCG is an important game to study since it allows researchers to isolate and measure the limitations of (rational) thinking. Understanding the degree to which limited thinking occurs can improve our understanding of many (sometimes anomalous) market outcomes; e.g., Camerer et al. (2002b) argue that limited thinking may help explain "price bubbles, speculation and betting, competition neglect in business strategy, simplicity of incentive contracts, and persistence of nominal shocks in macroeconomics."

2. Hypotheses

The main hypothesis is that if experience predictably changes behavior, then players' behavior will depend on the amount of experience of other participants. In dominance solvable games (where behavior predictably moves toward the unique equilibrium as players gain experience), the hypothesis is that the more experience *other* players have, the more likely a player will make choices closer to the equilibrium.

We introduce notation to simplify and clarify predictions. The main hypothesis implies that player i believes opponent j's choice c_j is a decreasing function of j's experience: $\partial b_{ij}/\partial e_j < 0$, where b_{ij} is player i's belief of opponent j's choice and e_j is the number of times player j has played the game. We assume player i chooses $c_i(B_i)$ that is his best response to his beliefs B_i about his N opponents' choices, where $B_i = b_{i1}, b_{i2}, \ldots, b_{iN}$). Since beliefs are not observable, the testable hypothesis for the BCG is that players choose a lower number against new opponents the more experience the opponents have had $\partial c_i/\partial e_j < 0\ \forall j \neq i$.

This hypothesis is silent regarding a player's own level of experience e_i. A more specific hypothesis is that a player introspectively deduces how experience affects opponents' behavior. This hypothesis predicts that players' behavior depends on their opponents' experience level regardless of their own experience:

$$\text{H1:} \quad \frac{\partial c_i}{\partial e_j} < 0 \quad \forall j \neq i \quad \text{and} \quad e_i \geq 0.$$

Alternatively, players may not introspectively deduce how experience affects behavior, but may learn to. This hypothesis predicts that players' behavior depends on the level of their opponents' experience only after they have gained experience themselves:

$$\text{H2:} \quad \frac{\partial c_i}{\partial e_j} < 0 \forall j \neq i \quad \text{and} \quad e_i > 0 \quad \text{and} \quad \frac{\partial c_i}{\partial e_j} = 0 \forall j \neq i \quad \text{and} \quad e_i = 0.$$

Hypothesis 2 resembles Camerer et al.'s (2002a) sophisticated learner types who learn that other players may be learning and thus best respond to their opponent's level of experience. The null hypothesis is that players' behavior does not depend on opponent's experience level, regardless of their own experience:

$$\text{H0:} \quad \frac{\partial c_i}{\partial e_j} = 0 \quad \forall j \neq i \quad \text{and} \quad e_i \geq 0.$$

3. Experimental design

In every session, nine periods of the beauty contest game were played. The nine periods were divided equally into three supergames. Within each supergame the same three subjects played against each other for three games. In addition to the instructions, we wrote the following 'reminders' on the board: "Guesses must be from 0 to 100," "The winner is the person who guesses closest to 2/3 of the median" and "The winner receives \$3." At the beginning of each game we wrote the period (1 through 9) on the board. After subjects privately made their choices, we wrote them and the target number (2/3 of the median) on the board and announced the ID of the winner. Only subjects playing a game received this feedback.

In control sessions, players always had the same level of experience as each other. In treatment sessions, players had different levels of experience in the last two supergames. We refer to control sessions as SAME (same experience level always) and treatment sessions as MIX (mixed experience levels).

Nine subjects participated in each SAME session. In these sessions, after we read instructions, subjects were randomly divided into three rooms with three subjects each to play a supergame. After completing three games, subjects were re-matched to play a new supergame, and then re-matched again to play the final supergame. We designed the rematching so that subjects never play against another player in more than one supergame. Subjects received no feedback on games played in rooms they were not in. When we re-matched subjects, we reminded subjects that they had all played the same number of games.

Several studies examine a repeated supergame design (e.g., Andreoni, 1988; Croson, 1996) for public goods games and Selten and Stoecker, 1986; Andreoni and Miller, 1993, for prisoner's dilemma games). These studies document a "reset" effect; when players get re-paired, their behavior appears similar to the first time they played; e.g., see Andreoni and Miller (1993) and Selten and Stoecker (1986). Yet, no one has looked at a repeated supergame design for dominance-solvable constant-sum games, so SAME provides new information regarding whether a reset will occur in a new class of games. Observing a reset effect in a dominance-solvable constant-sum game would be interesting since one explanation for the reset is that players are trying to re-establish cooperation, a motivation that subjects cannot be supported in a constant-sum game.

Seven subjects participated in each MIX session; one subject, the *Insider*, plays in all nine periods and the other six subjects are divided equally among three *outsider* positions (in the instructions, we refer to these subjects as role 1 for Insiders and roles 2–4 as Outsider).[6] Outsiders only play games during one supergame. In supergame 1 (SG 1) all players had the same amount of experience and in SGs 2 and 3 the Insiders had 3 and 6 periods more experience than the Outsiders. After we read the instructions, we then randomly assigned roles. Thus, the time between when we read the instructions and when each game was played is identical for all subjects. We took Outsiders who were not playing games out of the room and did not allow them to communicate with anyone or receive any feedback on the games being played When Outsiders returned, we reminded everyone that the Insider had played 3 (or 6) games and the Outsiders had not played any games yet.

Comparing SAME and MIX, SG 1 is identical in that three players play each game, all subjects have the same level of experience and have been read identical instructions.[7] In SGs 2 and 3, SAME and MIX are identical in every respect except experience; in MIX, Insiders have either 3 or 6 more periods of experience than Outsiders and in SAME all players have the same level of experience.

Three SAME and ten MIX sessions were run (SAME: $N = 27$; MIX: $N = 70$). Each subject was given a \$5 show-up fee. In MIX, the Outsiders in the second and third positions were given an additional \$2 and \$4, respectively, to reduce expected payoff differences and as compensation for having to wait.

4. Results

Figure 1 shows mean choices across supergames and rounds.[8] Connected lines show consecutive games played by the same players. Arrows show choices made by subjects who play consecutive games against new opponents. The saw-tooth pattern of choices falling when subjects play the same opponents but rising when they play new opponents suggests that behavior depends on whether subjects previously played against their opponents. Figure 1 also suggests that the effect of new opponents on choices is larger when opponents have no experience (MIX: Insiders only) than when they have the same amount of experience (SAME: all players). We discuss inexperienced and experienced subject behavior in Sections 4.1 and 4.2, respectively, then the advantage experienced players had (Section 4.3), and finally the determinants of Insiders behavior (Section 4.4).

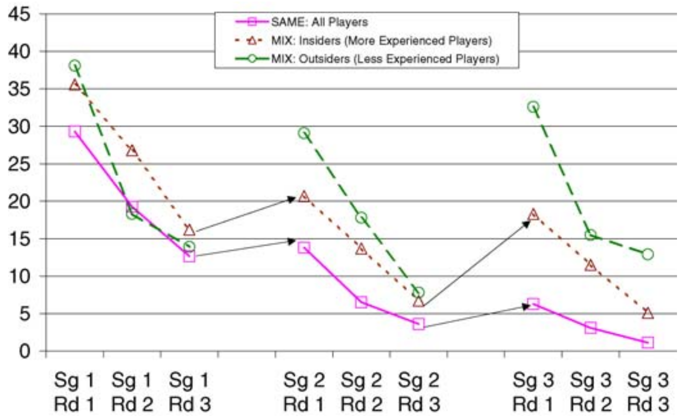

Figure 1. Average numbers chosen.

4.1. Players with no experience

Table 1 shows mean choices when players have no experience conditional on whether opponents have no experience (SAME and MIX: all choices in period 1) or have 3 or 6 periods of experience (MIX: Outsider's first choices in SGs 2 and 3). Though players with no experience make slightly lower choices against opponents with than without experience, the difference is not significant ($t = 0.89$, $p > 0.38$).[9,10] Thus, we cannot reject the null hypothesis when players are inexperienced, that is, we cannot reject that $\partial c_i/\partial e_j = 0$ if $e_i = 0$.

Result 1. Players with no experience behave similarly against opponents with and without experience. Thus, without experience players do not introspectively deduce the effect of opponents' experience on their behavior, which is consistent with H0 and H2, but not with H1.

Consistent with Result 1, Grosskopf and Nagel (2003) find that inexperienced players in two-person BCG games do not choose 0 despite this choice being a weakly dominant strategy in the two-person game. Thus, Result 1 and Grosskopf and Nagel (2003) suggest that players choose values greater than 0 not only because they believe their opponents may not understand the rationality of the iterated dominance of the game, but also because they themselves do not initially understand it.

Table 1. Choices of players with no experience.

Opponents' experience	Mean	S.E.	*N*
None	33.5	2.3	57
3 or 6 Periods	30.0	3.3	39

t-test: $t = 0.886$, $p = 0.378$.

4.2. Experienced players

Figures 2 and 3 show the choices made by players who play all nine periods in MIX (Insiders) and SAME (all subjects). The top six panels show changes in choices across consecutive periods *within supergames* against the same opponents and the bottom two panels show changes across consecutive periods *across supergames* against new opponents. Points below the 45-degree line indicate lower numbers were chosen across consecutive periods.

Figures 2 and 3 show that choices decrease when subjects play consecutive games against the same opponents; 80% and 93% of the choices decrease in SAME and MIX, respectively. For every pair of consecutive games against the same opponents, significantly more subjects decrease than increase their choices; e.g., from Round 1 to Round 2 in SG 1, 32 subjects decrease and only 4 increase their choices (binomial test, $p < 0.001$). In contrast, players are *relatively* more likely to increase (or, equivalently, relatively less likely to decrease) choices when playing against new opponents. Although only 13% of choices increase when players play against the same opponents in SAME, 59% of choices increase when playing against new opponents. This contrast is even greater in MIX; against the same opponents 7% of the choices increase while against new opponents 70% of the choices increase.

Since the absolute change in choices across consecutive periods tends to decrease over time, we will examine both absolute and relative changes in choices. So that the same absolute increase or decrease has the same relative change, we define the relative change using the midpoint of the two numbers chosen:

$$\textit{Relative Change in Number Chosen} = \frac{\textit{Number}(t) - \textit{Number}(t-1)}{0.5 * [\textit{Number}(t) + \textit{Number}(t-1)]} \tag{1}$$

Figure 4 shows the cumulative distribution of the Relative Changes in Number Chosen when subjects play against: (1) the same opponents, (2) experienced new opponents and (3) inexperienced new opponents. The relative changes are most negative when subjects play against the same opponents and most positive when subjects play against inexperienced new opponents.

Table 2 provides fixed effect linear regressions for the determinants of choice (Number) and changes in choice (Relative Change in Number).[11] Independent variables include dummies for First-Round-Against-New-Players (equals 1 if a player faces an opponent for the first time and 0 otherwise) and the interaction between First-Round-Against-New-Player and MIX. A positive coefficient for First-Round-Against-New-Players indicates players choose relatively higher numbers when playing against new rather than the same opponents. A positive coefficient for the interaction term indicates players choose relatively higher numbers against inexperienced than experienced new opponents. A positive interaction effect supports the sophisticated learning hypothesis H2 that players condition behavior on the experience level of competitors. Control variables include Period and Period Squared (to capture the non-linear trend that choices tend to decrease but at a decreasing rate—see figure 1). We also include Lag Average Others (= the average of each player's opponents choices from the previous period) since, as Nagel (1995) suggests, choices are likely to depend on the results of the previous game.[12]

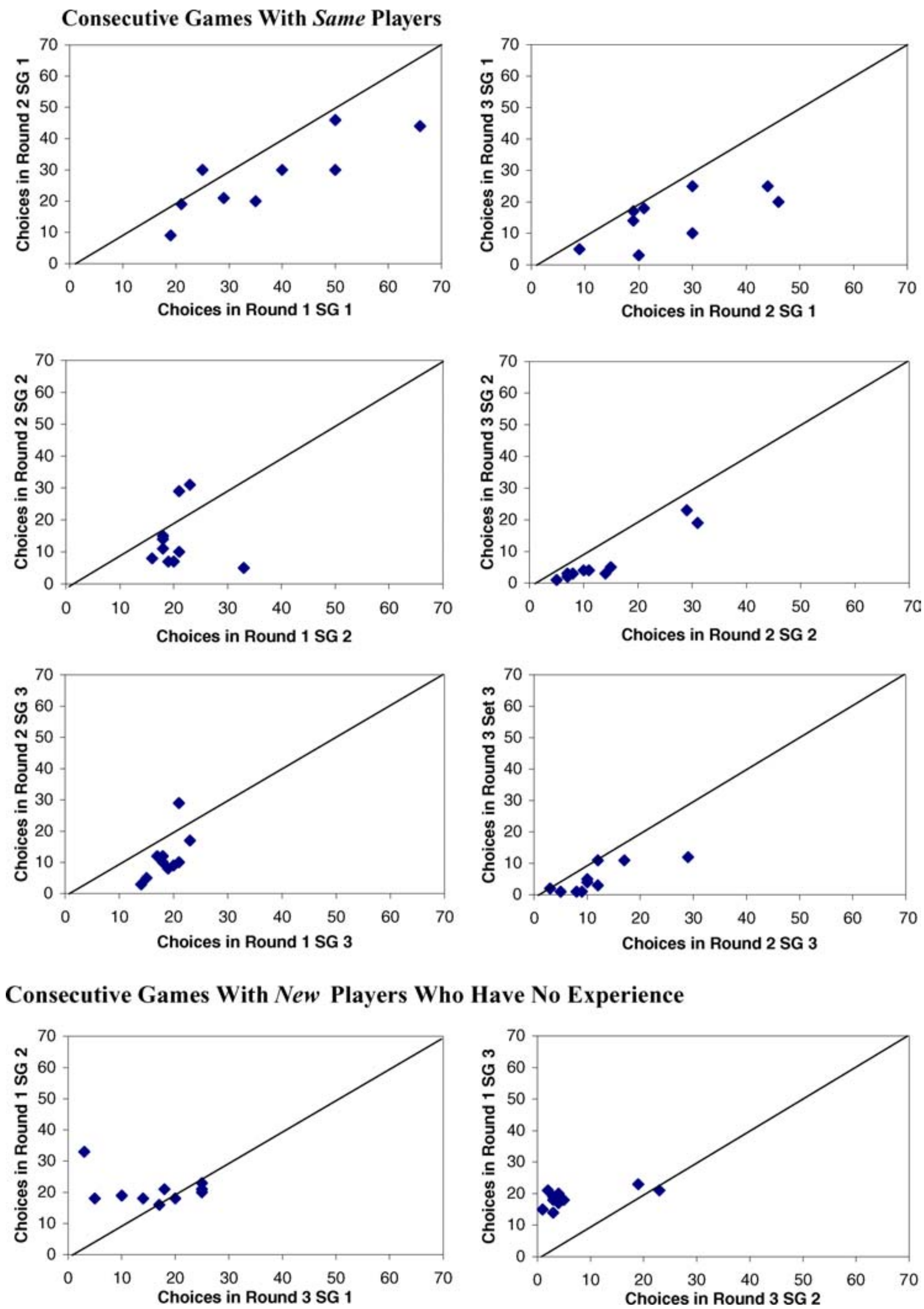

Figure 2. MIX treatment: Transition of numbers chosen for insiders.

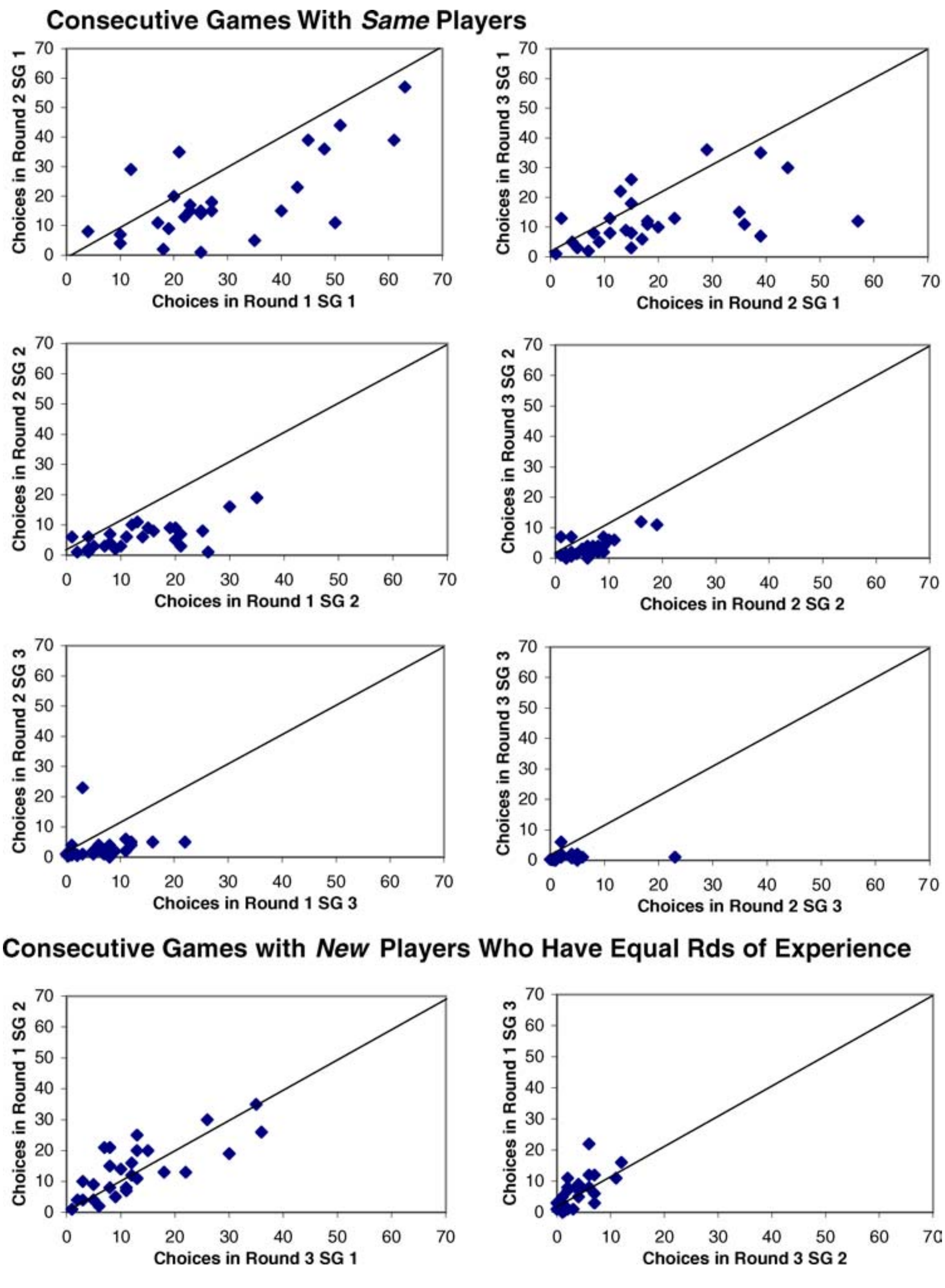

Figure 3. SAME treatment: Transition of numbers chosen.

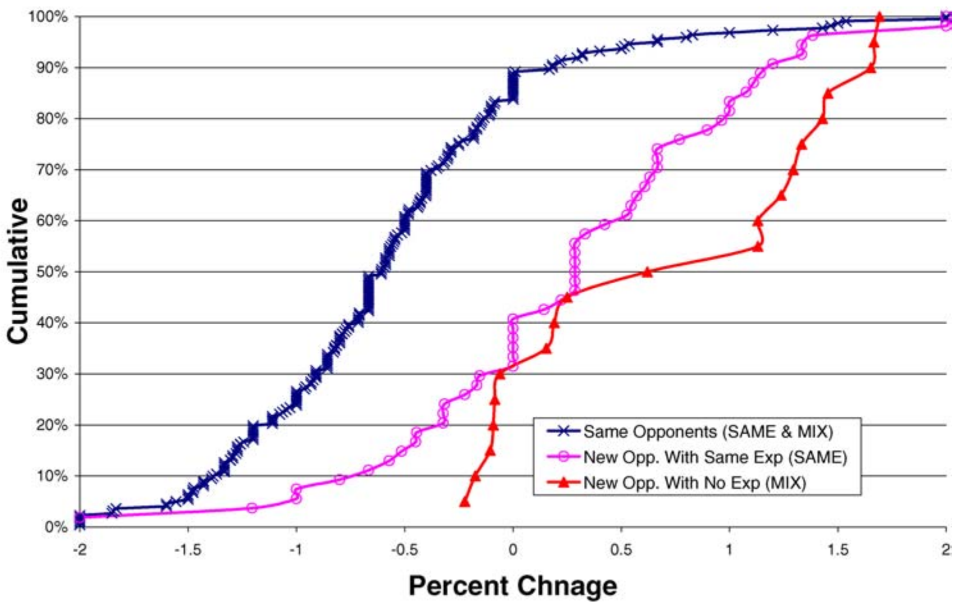

Figure 4. Cumulative distribution of changes in numbers.

Results (*Control variables*). Table 2 shows that choices decrease across periods, but at a decreasing rate. Lag Average Other is also significant; opponents' choices in the previous round influence subjects' choices.

Results (*Reset effect*). Table 2 also shows that when playing against new opponents, regardless of opponent's experience level, subjects make significantly higher choices than if

Table 2. Experienced players' choices (standard errors in parentheses[1].)

	Number	Relative change in number
Period	−6.67 (0.999)***	−0.104 (0.109)
Period^2	0.434 (0.087)***	0.008 (0.009)
Lag Average Others[2]	0.185 (0.047)***	
First-Game-Against-New-Players (1 if yes, otherwise)	4.66 (1.22)***	0.884 (0.115)***
First-Game-Against-New-Players * MIX[3]	6.21 (2.14)***	0.451 (0.185)**
N[4]	333	296
R^2	0.527	0.279

*, **, *** 10, 5 and 1% significance level.

[1]No constant is reported since the regressions are fixed effects. The mean (standard deviation) first period choice was 31.0 (15.6) and the mean (standard deviation) Relative Change across the first two periods was −0.43 (0.55).

[2]For Rel. Change in Number, Lag Average Other is dropped since Rel. Change already incorporates past play. For the first Number, we tried several values for the Lag, including 50, 33 and 22. Results are robust to these values.

[3]One-tail tests reported for Interaction of First Round New Players by MIX.

[4]Round 1 choices are excluded for Rel. Change in Number estimation since there is no previous choice.

they continued playing with the same opponents (4.66 higher, $p < .01$). Thus, a (partial) reset occurs since experienced players' choices move relatively toward their original (supergame 1, round 1) choices when they face new opponents.

Results (*Experience level of opponents affects experienced players' choices*). Table 2 also shows that when experienced players play against new opponents, they increase their choices significantly more if the new opponents are inexperienced rather than experienced (6.21, $p < .01$). Since experienced players behavior depends on new opponents experience level, we reject the null hypothesis H0 in favor of H2; experienced subjects make choices farther from the equilibrium when new opponents are inexperienced rather than experienced.

Results (*Relative Change in Number*). Table 2 shows that Relative Change provides identical conclusions for the main hypotheses. Experienced players increase their choices by 88% against new opponents relative to what they would choose against the same opponents ($p < .01$), and increase their choice by another 45% ($p < .05$) against the new opponents if the new opponents are inexperienced rather than experienced.

Result 2. Experienced players' behavior depends on whether they have played against their opponents. If they are playing against new opponents, a (partial) reset effect occurs.

Result 3. Experienced players make choices farther from equilibrium if new opponents have no experience than if they have experience. Thus, we reject H0 in favor of the main hypothesis H2.

Results 2 and 3 imply that if players constantly enter the game, behavior will either converge slower, or not at all, to the equilibrium. To see this, figure 1 shows difference in choices across treatments increasing in the last round of each supergame (SG). Whereas the mean choice in SAME falls from 13.7 to 3.6 to 1.1 in Round 3 across supergames, the mean choice in MIX (across Insiders and Outsiders) falls from 15.7 to 7.5 in SG 1 to SG 2, but then *increases* to 9.9 in SG 3. Thus, the mean choice from the last round of SG 2 (the first time inexperienced players enter in MIX) to the last round of SG 3 (the second time inexperienced players enter) actually moves away from the equilibrium. While behavior in SAME converges toward the equilibrium across supergames, choices in MIX flatten out.[13]

Result 4. Behavior is no closer to the equilibrium the second time inexperienced players participate than the first time inexperienced players participate.

4.3. The competitive advantage of experience

Does experience allow players to be more successful and, if so, does the advantage persist? Table 3 shows how often Insiders win when they have the same experience as Outsiders (row 1) and when they have more experience (rows 2–4). The first two columns show how often Insiders actually win. When Insiders (who make up 1/3 of the subjects) play opponents with the same experience as themselves, they win 23% (7/30) of the games. Yet, when Insiders are experienced and play opponents without experience (Round 1 of SGs

Table 3. Percent insiders win (actual and hypothetical) and chose lowest number.

	Actual		Against past supergame but same round		Insiders chose lowest number	
	Percent	Freq. (Obs)	Percent	Freq. (Obs)	Percent	Freq. (Obs)
Insiders and Outsiders have identical experience: (Rounds 1–3, set 1)	23%	7 (30)	n.a.	n.a.	23%	7 (30)
Insiders are more experienced and Outsiders have:						
No Experience: (Round 1, sets 2 and 3)	85%	17 (20)	90%	18 (20)	65%	13 (20)
One round of experience: (Round 2, sets 2 and 3)	50%	10 (20)	64%	12 (20)	45%	9 (20)
Two rounds of experience: (Round 3, sets 2 and 3)	39%	8 (20)	45%	9 (20)	55%	11 (20)

Table 4. Logit regression analysis of when insiders win (MIX only).

		Model 1	Model 2
	Constant	−1.190 (0.486)***	−1.190 (0.486)***
A	First Round New Players Play (= 1 if Round = 1 and SG = 2 or 3)	2.924 (0.760)***	
B	Second Round New Players Play (= 1 if Round = 2 and SG = 2 or 3)	1.190 (.643)**	
C	Third Round New Players Play (= 1 if Round = 3 and SG = 2 or 3)	1.390 (.597)**	
D	Dummy (SG > 1)		3.119 (0.990)***
E	Dummy (SG > 1) * Round		−0.672 (0.360)**
	N	90	90
	Log-likelihood	−52	−54

*, **, ***10, 5 and 1% significance level.
One-tailed tests for whether Insider wins more often in supergames (SG) 2 and 3.

2 and 3), they win 85% of the games. This experience advantage diminishes as Outsiders gain experience; Insiders win 50% and 39% of the games when Outsiders have one and two rounds of experience, respectively.

Table 4 presents two random effects logit regressions on the determinants of Insider winning. Both regressions show that Insiders win significantly more often if they have more experience than Outsiders (relative to when they have the same amount of experience), whether the Outsiders have zero, one or two rounds of experience (Model 1: rows A, B and C; $p < .05$ in every case) or whether we combine all levels of experience for the Outsiders (Model 2: row D, $p < .01$). Although Model 2 shows that the likelihood Insiders win decreases significantly the more experience the Outsiders have (row E, $p < .05$), note that the advantage Insiders have remains significant even after the Outsiders have two rounds of experience (Model 1, row C).

Result 5. Experienced players earn more money than less experienced opponents. This advantage is greatest when the less experienced players have no experience, and although it diminishes as less experienced players gain experience, it remains significant for all three rounds of play.[14]

4.4. Other determinants of Insider's behavior when playing new opponents

Table 3 provides additional information on Insiders' behavior. The last two columns show that Insiders learn more than to choose the lowest number to win. Across all rounds of SGs 2 and 3, Insiders win 33% (9/27) of the time if they did not choose the lowest number. In contrast, Outsiders win less than 5% of the time (4/88) if they did not choose the lowest number.

The middle two columns examine whether Insiders best respond to the choices previous supergame opponents make. These columns show how often Insiders during SGs 2 and 3 would win if the Outsiders in Round i (for $i = 1$, 2 and 3) of SG s make the same choice as the Insiders' opponents made in the same Round i of the previous SG s-1. For instance, in Round 3 of SG 2, one Insider chose 4 and his opponents chose 22 and 2, thus the Insider did not win. However, in Round 3 of SG 1 his opponents chose 17 and 5, so his choice of 4 is a best response to the choices his previous supergame opponents made. Table 3 shows that while Insiders win 58% of the games in SGs 2 and 3, 65% (39/60) of their choices are best responses to their opponents' previous supergame choices. Thus, Insiders may be (partially) best responding to the choices of the Outsiders who they played against in the previous supergame.

To test whether Insiders best respond to previous opponents' choices, we added variables to the regressions in Table 2 representing statistics on the choices of previous supergame opponents. For instance, we included $\text{Target}_{r,s-1}$ which equals 2/3 of the median of opponents previous supergame choices. Interestingly, none of the variables from past supergame are significant ($p > .20$). Thus, we cannot find statistical support for the hypothesis that Insiders best respond to choices that previous supergame opponent's make.

Another hypothesis for the Insiders' behavior is that they may learn the steps of reasoning that other players use. For instance, if opponents make choices consistent with one or two steps of reasoning, then Insiders may learn to make choices from two to three steps of reasoning, in which case they would choose between 25 (the high end of the range for 2 steps of reasoning—see Nagel, 1995 for this derivation) and 13 (the low end of the range for 3 steps of reasoning). Indeed, 95% (19/20) of Insider choices are in this range in Round 1 of SGs 2 and 3. In contrast, in Round 1 of SG 1, only 38% (22/57) of choices are in this range. Thus, the Insiders appear to learn to best respond to the steps of reasoning that inexperienced players may use.

If Insiders best respond to the steps of reasoning that inexperienced players use, then the variability of Insiders' choices should decrease across supergames as they gain experience with inexperienced opponents. Consistent with this hypothesis, we find that the variance of Insider choices decreases in Round 1 from SG 1 to SG 3 from 222 to 10.[15] To statistically test the change in variance, let c_{is} be Insider i's choice in round 1 of SG s, c_{s} be the mean choice during round 1 of SG s for all Insiders and let $v_{\text{is}} = (c_{\text{is}} - c_{\text{s}})^2$. Table 5 shows a

Table 5. Analysis of variance of insider choices.

	Variance v_{is}
Constant	614 (276)***
Supergame s	−487 (239)**
Supergame^2 s^2	95 (49)**
N	30
R^2	.304

*, **, *** 10, 5 and 1% significance level.

random effects regression of how supergame experience affects the variability v_{is} of the Insider' choices. It shows that supergame experience significantly decreases ($p < .05$) choice variability, at a decreasing rate ($p < .05$). This decreased variability is consistent with Insiders learning to best respond to the belief that their opponents are using one or two steps of reasoning to play the game.

5. Discussion

Players without experience do not behave differently against opponents with and without experience (result 1), but learn to (results 2 and 3). This learned behavior causes choices to stop moving toward the equilibrium when new players enter the game (result 4), but allows experienced players to earn more than less experienced players, especially when the less experienced players have no experience (result 5). These results have implications for modeling learning and to ultimately better understand markets.

Learning models do not currently address how opponents' level of experience affects a player's behavior. To address this issue, we may allow initial conditions in learning models to depend on opponents' level of experience. In this case, initial conditions would now be thought of as midstream conditions; each time players face new opponents, initial (midstream) conditions are reset for each player's own and his competitors' level of experience. Adjusting these conditions alone may not be sufficient to explain the entire effect of opponents' experience. For instance, the current result that Insiders maintain a winning advantage even after Outsiders obtain some experience suggests that Insiders stay ahead of Outsiders. Related research shows that experience accelerates the rate of learning and/or level of sophistication (e.g., Cooper and Kagel, 2002; Ho et al., 1998; Stahl, 2000). Thus, learning models may fit the data better if they endogenize the amount of sophistication that players believe other players have, where the endogenized level of sophistication is based on the amount of experience of the other players.

The current results show that when inexperienced players constantly enter, experienced players best respond such that behavior stops moving toward the equilibrium. Thus, discussion of equilibrium that relies on learning can be qualified to require that new participants do not enter the market too frequently. However, the impact of new participants entering a market is likely to depend on the market. For example, in first price auctions (where the market price is set by the highest bid), just one inexperienced bidder may significantly affect the equilibrium price; e.g., Kagel and Levin (1986) find that inexperienced bidders repeatedly suffer from the winners curse by bidding above the equilibrium price in common value auctions. On the other hand, Dufwenberg et al. (2003) find that new participants have little effect on prices in an experimental asset market. In this situation, perhaps only a few experienced traders could keep the market near the equilibrium.

Result 2 indicates that a reset occurs even when new opponents are experienced. One explanation may be that players are overconfident (Budescu et al., 1997; Harvey, 1997; Lichtenstein et al., 1982); if a player thinks his group is learning faster than other groups, then the player's best response to new opponents is to not lower his choice as much as he would if he continued playing against his group. Overconfidence in this case is related to an in-group out-group phenomenon in which players identify with, and attribute more ability to, players they have played with relative to new players (for a review of in-group out-group behavior, see Haslam et al., 1996). Finally, Camerer et al. (2002a) note that some learning models already reflect a form of overconfidence; e.g., Stahl and Wilson's (1995) model of "level-k type" players implicitly assumes that players believe they are one step ahead of their opponents.

Many markets reward experienced people with higher salaries. This study, as well as Dufwenberg et al. (2003), finds that experienced players earn more than less experienced players, but it is not always the case that more experienced players earn more. Other studies show that as players gain experience *at the same rate*, they can earn more (common value auctions, see Kagel et al., 1989), earn the same amount (any constant sum game) or earn less (finitely repeated public goods or prisoners dilemma games where players become less cooperative: Andreoni, 1988; Selten and Stoecker, 1986). Given the current results, knowing how robust the experience advantage is and under what conditions experience increases welfare are open questions.

In choosing to study a constant sum game, this paper excludes many behaviors that might be learned, such as cooperation, coordination, trust or reciprocity. If players learn any of these behaviors, then experienced players may be able to transfer these behaviors to inexperienced players, and thus provide positive or negative externalities. For example, if players learn to coordinate, then they may increase the speed of coordination and/or cause coordination at a Pareto improving level relative to what inexperienced players could achieve. On the other hand, if players learn to cooperate less often, then these player's presence may cause markets to unravel quicker than markets with only inexperienced players. Thus, having experienced and inexperienced players in the same market may have important implications for efficiency that are not observable in a constant sum game.

The current study does not allow inexperienced players to observe or communicate with experienced players before playing any games. In many situations, however, people may receive advice. For example, Schotter and Sopher (2003) examine how behavior evolves when one generation of players provides advice to the next generation, reflecting how inexperienced people may learn from experienced people (e.g., parents advising children, CEOs advising successors). Even without communication with more experienced people, in many markets people may observe behavior before participating. Several studies show that observational learning is possible, and observational learning may be as valuable, or more valuable, than actual experience.

In summary, this paper provides a first step towards understanding how individuals respond to competitors who have different levels of experience. It demonstrates that people learn to behave differently depending on the amount of experience of their competitors, and consequently obtain a competitive advantage that leads to greater earnings. How individuals respond to competitors with different levels of experience has implications for convergence, efficiency, income distribution and modeling behavior.

Appendix: Experimental instructions

We would like to thank everyone for coming today. We are going to play a game several times. Please pay careful attention as I read these instructions so that you understand how you can earn as much money as possible.

Getting paid. At the end of the experiment we will pay each of you, in cash, $5 for coming. In addition to this $5, we will also pay you, in cash, any money that you may earn while playing the games.

No talking. During the experiment, we require that you do not talk or communicate with anyone. We ask that you do not communicate with anyone because, as part of the scientific method of conducting research on decision-making, we do not want you to influence what other subjects are thinking about, nor do we want other subjects to influence what you are thinking about. If you have any questions at any time, please raise your hand and we will come over to answer them.

Identification number. In a few minutes, we will give each of you a unique identification number. This is how we will identify you during the game.

Median number. There is one important thing you need to know about numbers. We will use something called the Median Number of a group of numbers. The Median Number of a group of numbers is simply the middle number in the group when we list the numbers from smallest to largest (or from largest to smallest). For example, if the numbers are 1203, 311, 1100, 417 and 1090, then, arranging these numbers from smallest to largest, we have [WRITE ON BOARD] 311, 417, 1090, 1100 and 1203 and so the middle number, the median, is 1090. Do you have any questions about how to calculate the median number?

The game. We will play the same game several times. In each game, you will be asked to choose a number. You may choose any number from 0 to 100. [WRITE "Choose from 0 to 100"] We will provide you with paper to write your choice. Once everyone has written a number, we will ask you to place your paper face down so no one can see your number. We will collect the numbers, write all of them on the board, and then we will find the median. We will then multiply this median by 2/3 and write this new number on the board. The winner of the game will be the person who wrote a number that is closest to this new number [WRITE "Winning number is closest to 2/3 of Median"]. For each game, the winner will receive $3 and everyone else will receive nothing [WRITE "Winner gets $3"]. In the event of a tie, in which two or more numbers are equally close to 2/3 of the median, the $3 will be split equally among every person whose number was closest. For example, if 2/3 of the median is 800 and one person chose 795, another chose 805 and no other number was within five of 800, then the people choosing 795 and 805 would share the $3 equally; each of them would receive $1.50.

We will announce the identification number of the winner (or winners in case of a tie) and write it on our record sheet. We will use our record sheet to keep track of how many games each person wins so that we will know how much to pay you.

At the end of each game, we will erase the information off the board before we begin play of the next game.

Anonymity. *Do not let anyone know if you win or lose any game*. We want to keep this information private. If you let anyone know, we may ask you to leave and we may take away anything you have received during the games. We will not let anyone know how much money you have earned.

How we will identify you. When we play the games, we will give you several sheets of paper. We will also give you an index card that has your unique and private ID number. Each decision sheet will also have a space for you to write the game number and a space for you to write the number you want to use. We will use your ID # to identify and pay you at the end of the experiment.

Your choice. There are no right or wrong choices. However, you must choose a number from 0 to 100. If you choose a number less than 0 or greater than 100 for any game, we will not include your number in calculating the median for that game, nor will you be eligible to win that game.

Final comments. We will play this game several times. The winner of each game will be the person whose number is closest to 2/3 of the median of all the numbers. In each game the winner will receive $3 or, if there is a tie, the winners will share the $3 equally.

Before you leave, you will be paid in cash. In addition to how much you win during the games, everyone will also get $5 for showing up. So, if you don't win any games, you will get $5, if you win one game, you will receive a total of $8, if you win two games, you will receive a total of $11, and so on. The more games you win, the more you will get paid. Does anyone have any questions so far?

Instructions for MIX sessions continue as follows

Roles. We are going to always play the game with exactly three players. In order to do this, we are going to randomly select four of you to go outside for a few minutes. While you are outside, we are going to play the game three times with the remaining three participants. After we have played three games, two of these participants will be paid and may leave. We will then randomly select two of the people outside to return. Then we will play the game three more times. After the game has been played three more times, the two people who substituted in will be paid and may leave. The remaining two people will be asked to come in, and then we will play the game three more times.

So, there are four roles. If you are in role 1, then you will play all nine games. There will one person in role 1. If you are in role 2, you will play the first three times the game is played. If you are in role 3, you will be outside for the first three games and then come back to play the next three games. And if you are in role 4, you will be outside for the first six games, and then return to play the last three games. There will be exactly two of you in roles 2, 3 and 4. To compensate each of you who we select to be in roles 3 and 4, since you will have to go outside and wait a few minutes, we will give you a little extra money. If you are in role 3, and thus will be outside for the first three games, we will give you an extra two dollars. If you are in role four, and thus will be outside for the first six games, we will give you $4 each.

Selecting roles. To select which role you will be in, we are going to give each of you a number from 1 to 7. [Hand them index cards with the numbers on them]. We will then roll this ten-sided die. [SHOW DIE] Each number on the die is equally likely to come up when we roll it. We will now roll the die until a number between 1 and 7 comes up, and that person will be in role 1 and play all nine rounds. We will then keep rolling the die until two more of your numbers come up, and those two people will be in role 2 and so also will stay in the room to play the first three rounds. The rest of you will go outside initially. We use this procedure so that everyone has an equal chance at being in each role. [Roll the die until get everyone assigned]

Instructions for SAME sessions continue as follows

Roles. We are going to always play the game with exactly three players. In order to do this, we are going to randomly select three of you to stay in this room, three of you to go with XXX to another room and the remaining three to go with YYY to a third room. In each room, three games will be played. After the three games have been played, two people from each room will be asked to leave and go into two new rooms in such a way that there will be three players in each room again. The game will then be played three more times. After that, we will again have two people from each room move around such that there will be again three people in each room again. At this point, three more games will be played and that will complete the experiment.

In total, you will play the game nine times. You will play the game three times with one two other subjects, then three more times with two different subjects and finally three more times with again two different subjects. You will not play the game with the game with anyone more than three times. So, if you play the first three games with someone, then you will not play with that person again. Likewise, when you play the last three games with someone, you will not have played the game with them before.

Selecting who you play with. To select who you will play the games with, we are going to give each of you a number from 1 to 9. [Hand them index cards with the numbers on them]. Each number was randomly assigned prior to your coming here today to play the game in different rooms. We will tell you which room to go to depending on your identification number. The room assignments were:

Assignments

	Room A	Room B	Room C
Rounds 1–3	3, 6, 8	1, 4, 5	2, 7, 9
Rounds 4–6	3, 4, 9	5, 7, 8	1, 2, 6
Rounds 7–9	2, 3, 5	1, 8, 9	4, 6, 7

Roll the die until get everyone assigned.

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Notes

1. A working paper by Dufwenberg et al. (2003) is the only other paper that focuses on a mixture of inexperienced and experienced players. Johnson et al. (2002) include a treatment in which players have different levels of experience, but players not only have mixed experience levels, but also mixed training levels.
2. For example, see Camerer and Ho (1999) and Erev and Roth (1998).
3. See also Camerer et al. (2002a); Ho et al. (1998) and Stahl (1996).
4. The current paper examines the median game to minimize the noise that a single outlier choice might have on the target statistic and subsequent behavior. For instance, Ho et al. (1998) find that the mean choice is significantly higher in three than seven person games, whereas Duffy and Nagel (1997) find no significant difference in first round choices of mean and median games but that choices fall faster in subsequent rounds of median than mean games.
5. Dufwenberg et al. (2003) and Cooper et al. (2002) provide two exceptions. In Cooper et al., some subjects play twice as many games as other subjects, but since subjects do not know that other subjects play different numbers of games, they are unable to condition their behavior on their opponents (different) experience levels.
6. Insider and Outsider labels used here to describe asymmetries in experience should not be confused with the same labels used to describe asymmetric information of bidders in common value auctions, as in Kagel and Levin (1999).
7. The instructions vary across treatments only in describing matching procedures and the roles subjects would be in.
8. One Outsider chose 300 in round 1 of supergame 2. This observation is dropped from the presentation of the results and from the statistical analysis since it is more than 10 standard deviations from the next highest choice. Another Outsider indicated that he had played the beauty contest game previously. The results are identical whether this player, his supergame, or his session are included or excluded in the analysis. The analysis excludes his choices.
9. The mean Outsider choices against players with 3 and 6 periods of experience are 29.1 and 32.6, which is not significantly different ($t = 0.52$, $p = 0.61$). Interestingly, although just one of the 57 choices in Round 1 of

Supergame 1 is below 10, three of the 40 Outsider choices in Round 1 of Supergames 2 and 3 are below 5. Thus, when inexperienced players play against experienced players for the first time, a small number of them seem to be affected significantly.

10. This result adds some insight to results in Bosch-Domenech et al. (2002) and Weber (2003). Bosch-Domenech et al. find that choices are lower when subjects have one week to make a choice rather than five minutes. The current results suggest that having between 1 and 20 minutes makes little difference on choices. Weber finds that subjects who play the game without feedback also make lower choices with repetition. In combination with Weber's results, the current results suggest that requiring subjects to make choices, rather than the absolute time elapsing, caused the choices to fall.
11. The random effect specification addresses the statistical dependency of repeated observations per individual, but does not address statistical dependency of repeated interaction (per supergame) with the same individuals.
12. We also examined a model including Lag 2/3 Median of the previous period. This specification does not change the results. Since Lag Median includes a player's own past choice, the average of the other two players' choices is preferable since it avoids endogeneity.
13. Further regressions (not shown) show that we cannot reject the hypothesis that Insider's choices are the same from SG 2 to SG 3 in MIX, yet in SAME we find that subjects choices are significantly lower in SG 3 than SG 2 ($p < .05$).
14. Dufwenberg et al. (2003) similarly find that when there is a mixture of inexperienced and experienced traders, the more experienced traders earn significantly more money than the inexperienced traders.
15. Variability in choices also decreases in the SAME treatment, though not as much when players play against new opponents. It falls from 237 to 27 from Round 1 of SG 1 to Round 1 of SG 3.

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