# Centralized vs. Decentralized Management: An Experimental Study

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**Abstract**: We study the tradeoffs between centralized and decentralized management using a new experimental game, the decentralization game. This game models an organization with two divisions and one central manager. Each division must choose or be assigned a product type. Both divisions benefit from coordinating their product types, but each prefers to coordinate on products that are close to its local tastes. The central manager aims to maximize the sum of division payoffs. Which product type achieves this goal varies with taste shocks that are known to the divisions but not the central manager. Under centralization, the central manager assigns products to divisions after receiving the divisions' messages about the state of the world (i.e., the taste shock); under decentralization, the divisions choose their own products. Contrary to the theory, overall performance is higher under centralization than under decentralization. Communication between divisions and suggestions from central managers modestly improves performance under decentralization. Nonetheless, centralization remains the best-performing organizational form.

**Keywords:** Coordination, Experiments, Organizations, Asymmetric Information

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**1. Introduction:** Should organizations be centrally managed or should units within the organization operate independently? This is an old question in economics that appears in various guises across a wide selection of fields such as political economy, industrial organization, and the economics of organizations. Should an economy be centrally managed as in a socialist economy or decentralized as under capitalism? Should a firm let its divisions make decisions (e.g., what products to offer) independently or impose decisions in a top-down fashion? Should managers delegate decision-making authority (e.g., what projects to pursue, how to execute projects) to their subordinates or make decisions for them? There is a long history of theory papers looking at the tradeoffs between centralization and decentralization, and the past decade has seen a new burst of research, both theoretical and empirical, on this issue.[1] Much of the recent literature sees this tradeoff in terms of a comparison between the benefits of coordination and the costs of distorted information that accompany centralization.

To better understand the tradeoffs between centralization and decentralization, consider an organization with a manager and two subordinates. Each subordinate is assigned (under centralization) or chooses (under decentralization) an option from a menu of possible choices. As an example of the sort of situation we have in mind, imagine a large firm where either a central manager assigns or division managers choose the product types to be sold in different locations. Or, as another example, think of a small company where either the owner decides or lets workers choose what type of computers the workers will use (e.g., Windows or Apple). There are often obvious advantages to subordinates coordinating, in the sense of making the same choice. Economies of scale imply that costs are lower for a large firm if its local branches sell similar product types, and it is easier for workers to share computers if they use the same type of machine. The problem is that subordinates may have differing opinions about what option best fits their needs. Local branches will want to choose product types that conform to local tastes. Workers will want to use a type of computer with which they are already familiar. If each subordinate is free to choose an option, they are unlikely to spontaneously coordinate on a single choice. Having the manager impose a choice on her subordinates solves this coordination problem. However, suppose the manager knows less than her subordinates about the relative benefits of the various options. She could ask her subordinates for input, but they have incentives to exaggerate the benefits of their preferred option as a way of influencing the manager's choice. Is it better to let subordinates make their own decisions, taking advantage of their private information, or to impose choices, solving the coordination problem, but potentially failing to take

[1] See Lange and Taylor (1938) and Hayek (1945) for classic papers on centralization in an economy. See Mookherjee (2006) for a good survey of the older theoretical literature on centralization versus decentralization within a firm. Prominent examples of the more recent theory literature include Hart and Moore (2005), Alonso, Dessein, and Matuouschek (2008a, 2008b and 2015), Rantakari (2008), Hart and Holmstrom (2010), Dessein, Garicano, and Gertner (2010). For recent empirical studies using observational data see Thomas (2011) and McElheran (2014).

advantage of the subordinates' information? Are there organizational tools the manager can use to help her subordinates coordinate their choices while maintaining the informational benefits of decentralization?

We study these questions via laboratory experiments utilizing a new game, the decentralization game. Following much of the related theory literature, we frame the experiment as a game between central management and two divisions of a firm. Either the central manager assigns product types to each division (under centralization) or division managers choose their own product types (under decentralization). Each division has a profit function that depends on local tastes, a randomly determined state of the world, and the chosen or assigned product types for the two divisions. The central manager is benevolent, earning the sum of the divisions' profits. Several features combine to create strategic tension in the game. (1) Local tastes for the product types differ between the divisions. Under decentralization, there exist multiple equilibria where the divisions coordinate on a common product type. The game is constructed so the divisions have diametrically opposed tastes over possible equilibrium outcomes. (2) Tastes change over time depending on a randomly determined state of the world. The efficient equilibrium, which maximizes total profits across the two branches, coordinates on different product types over time, coming closer to the local tastes of one division or the other depending on the state of the world. *Ex ante*, the efficient equilibrium yields equal expected payoffs for the two divisions, but, for most states of the world, the efficient equilibrium yields a higher profit to one division than the other. (3) Unlike the Battle of the Sexes (BOS) game, in the decentralization game there exists an equilibrium that is safe (both divisions play their maximin strategy), does not require divisions to make different decisions as the state of the world changes, and yields both divisions identical payoffs in all states of the world. This safe equilibrium provides the divisions with a relatively easy way to coordinate but does not maximize total profits because it does not take advantage of the divisions' information about the state of the world. (4) The divisions know the state of world, while central management only knows the distribution of possible states. Under centralization the divisions report information about demand to the central manager. Due to differing local tastes, the divisions have incentives to distort their reports which, in theory, renders the reports uninformative. The central manager could implement the efficient equilibrium *if she knew the state of the world,* but the game is constructed so the only equilibria under centralization are babbling equilibria in which the division reports reveal no useful information to the central manager.

Because there exists an equilibrium that takes advantage of the divisions' information under decentralization, but not under centralization, standard theory predicts that the *maximum* possible equilibrium payoff is higher under decentralization. We nevertheless find that centralization increases total profits relative to decentralization. The poor performance of decentralization is primarily due to the inability of divisions to coordinate on a single product type. Even when divisions coordinate their choices they often choose the safe equilibrium, failing to take advantage of their private information. Although centralization outperforms decentralization, payoffs are no better than in the babbling equilibrium. This is *not* because the babbling equilibrium is being played, as the divisions often share useful information. Centralization fails to beat the babbling equilibrium because of systematic errors by central managers in interpreting the information they receive. These mistakes are not subtle and cannot be explained by repeated interactions or social preferences. Experience has little impact on the frequency of mistakes. If central managers could use the information they receive more effectively by eliminating the most obvious mistakes, centralization would significantly outperform the babbling equilibrium.

The poor performance of decentralization came as a surprise to us, but perhaps it should not have. The game under decentralization is a complex coordination game. Lacking the ability to communicate and in the absence of an obvious coordination device, achieving coordination is a challenging task. We therefore added two treatments studying organizational tools designed to ease the coordination problem between divisions while taking advantage of the divisions' information: (1) horizontal communication between divisions and (2) suggestions from central management about product type choices subject to the state of the world. The theoretical predictions are unchanged by the addition of horizontal communication or manager suggestions, but related experimental results made us optimistic that both mechanisms would lead to improved performance compared to decentralization. We also hoped to outperform centralization by combining the primary benefit of centralization (coordination) with the primary benefit of decentralization (use of divisions' information). In practice, neither change in the communication structure led to a significant increase in performance over decentralization. In both cases performance was significantly worse than under centralization. With horizontal communication between divisions, the problem of coordinating actions directly is replaced by the problem of reaching an agreement on what actions to take. Divisions often don't reach an agreement and, when they do, it is mostly on the safe equilibrium rather than the efficient equilibrium. When central managers make suggestions to the division, suggesting play of the efficient equilibrium is quite effective. The problem is that central managers only suggest this about a third of the time.

To summarize, centralization does surprisingly well in our experiments. It is far from perfect, failing to take advantage of the divisions' private information, but it has the critical virtue of solving the coordination problem between the divisions. Even with institutions designed to ease the coordination problem facing divisions, decentralization leads to frequent and persistent coordination failures. Matters are worsened by the tendency of divisions to coordinate on the safe equilibrium under decentralization, failing to take advantage of their private information.

The most closely related experimental papers to ours are Evdokimov and Garfagnini (2015) and Hamman and Martínez-Carrasco (2015). These are described in more detail in Section 2. Both papers test specific predictions of existing theories comparing centralization and decentralization. They generally find support for the comparative statics predicted by the models. Our paper does not focus on testing any specific prediction of an existing theory but rather focuses on the behavioral assumptions underlying many existing models of centralization and decentralization.

Along a different dimension, the failure of central managers to correctly process information under centralization resembles results reported by Vespa and Wilson (2015), but is more extreme. Vespa and Wilson receivers fail to fully extract information from senders' signals for cases where it is relatively difficult to infer the correct course of action. In our data, central managers get it wrong even in cases where the best response is rather obvious, and they fail to learn with experience.

Centralization works far better than decentralization in our experimental environment, but it would be obviously excessive to claim this is a universal result. The game we study is intentionally simple and confronts subjects with stark trade-offs. In the future we plan to extend our study by adding complexities that mirror real-world organizations. Some possible extensions are probably not worth the effort. For instance, it could be argued that we should be using "real" people (i.e., experienced managers) rather than students. Existing evidence (see Frechette, 2009, for a summary) gives little reason to think that use of a different subject population would affect our results.[2] We think several other issues are of greater interest.

First, all of the decisions in our experiment are made by individuals. This matches some of the organizational settings we have in mind, like our example about workers choosing a type of computer, where an individual manager confronts individual employees. In other settings, such as central management of a large multinational firm interacting with national divisions, the relevant decisions would be made by groups. There is an extensive literature suggesting that groups and individuals do not make identical decisions either for games generally or coordination games specifically (see Feri et al., 2010). It would be interesting to see how performance under centralization and decentralization was affected by the use of groups as decision makers. For instance, are groups playing the role of central management less prone to making mistakes in processing messages from the divisions, leading to total surplus exceeding the babbling equilibrium?

Second, we have explored two natural ways of adding communication to the game under decentralization but there are an infinite number of ways communication can be implemented. Would a different version of communication work better? For example, existing experimental papers suggest that rich communication is more effective at fostering efficient equilibria (see Charness and Dufwenberg, 2010; Cooper and Kühn, 2014). Perhaps allowing central managers to send a text message along with their suggestions would be more effective.

[2] In the field, information transmission is done by professionals, who typically are strongly influenced by notions of professional integrity and may, therefore, be reluctant to lie (Gintis, 2014). This suggests that the truth-telling we observe in our experiments may carry over to actual organizations.

Finally, our experiment makes coordination relatively easy by only having two divisions. A natural question is how performance would change with the greater complexity of having more divisions.

**2. Related Empirical Literature:** The study with observational data that most closely relates to our work is Thomas (2011).[3] She presents a detailed empirical analysis of two large multinational companies in the laundry detergents industry in Western Europe. The central variable of the analysis is the product-range. In both companies, product-range decisions were made in a decentralized way at the brand-country level by local managers. The results show that the organizational form leads to product-range variation exceeding the optimal firm-level response to local conditions. The paper finds that too many products are being produced in this industry, as a result of mis-coordination between local managers, but cannot investigate how companies would fare under centralization.

There is a rich literature in experimental economics dealing with coordination, issues of truth-telling, and information processing in isolation. For a general discussion of experiments related to coordination problems see Camerer (2003), and for surveys of experimental work on organizational issues see Camerer and Weber (2012) and Kriss and Weber (forthcoming). The paper from the experimental literature on coordination most closely related to our current work is Cooper et al. (1989).[4] They study the effect of communication in BOS games. Without communication, coordination is difficult in these games due to the lack of a focal equilibrium. Subjects do a bit better than the symmetric mixed-strategy equilibrium, but are still far from efficiency. With one-way communication, coordination rates are high as the sender can call for her preferred equilibrium and the receiver generally follows. Two-way communication is less effective, although coordination rates improve somewhat with multiple rounds of pre-play communication.[5] If a pair sends messages that agree on an equilibrium, this equilibrium is generally played, but there are numerous cases where each calls for their preferred equilibrium, and play akin to the mixed-strategy equilibrium results.

Our Horizontal Communication treatment is similar to the Cooper et al. treatment with multiple rounds of two-way pre-play communication, but there are two important differences. The safe equilibrium equalizes payoffs between the two divisions in all states of the world. Unlike in the BOS game, this safe equilibrium gives subjects in the decentralization game an easy way of coordinating that does not benefit one division over the other. Additionally, the Horizontal Communication treatment is played using partners

[3] See also McElharan (2014).

[4] For another related paper on coordination in games similar to BOS, see Kuzmics, Palfrey, and Rogers (2014).

[5] With no communication, the coordination rate is 48%. This improves to 95% with one way communication as opposed to 55% with two way communication. Allowing three rounds of two way communication increases the coordination rate to 63%.

matching while Cooper et al. use strangers matching. The number of opportunities to communicate per period is the same in both experiments, but in our experiment there are many more opportunities overall for a pair of divisions to communicate. These two differences made us expect a larger impact from two-way communication in our experiments than the modest improvement observed by Cooper et al.[6]

There is also a large literature on truth-telling. For a recent discussion of lie aversion, see Erat and Gneezy (2012) and the references therein. The most striking finding from this literature is the unwillingness of many subjects to tell a lie even when doing so is Pareto improving (Erat and Gneezy, 2012). Studies of cheap talk games find a similar bias towards telling the truth (Cai and Wang, 2006; Sanchez-Pages and Vorsatz, 2007), although in this case truthfulness could stem from either an aversion to lying or a failure to grasp the strategic benefits of distorting one's message.

Finally, information processing of various types has also been studied with lab experiments in various environments. Notable examples where subjects fail to correctly process information are experiments looking at individual decision making where subjects fail to correctly apply Bayes' Rule (e.g., Grether, 1980; Charness and Levin, 2005). In strategic settings, the paper most closely related to ours is the work by Vespa and Wilson described above. They examine variations of the cheap-talk model proposed by Battaglini (2002). Their experimental environment differs from ours in one critical aspect since, in keeping with Battaglini, they study games where messages should fully reveal the state of the world in equilibrium. We wanted to make the informational problems under centralization as severe as possible, so we designed a game where messages were not fully revealing (or even informative) in equilibrium due to a lack of common interest between the divisions. Nonetheless, their results have an obvious relationship to our experiments. They study three different games. In the two where it is relatively difficult (but possible) to infer the state of the world from sender's messages, receivers perform poorly at extracting information. The failure to extract information is even more severe in our experiments, as central managers make systematic errors in cases where the information extraction problem is rather simple.

The two experimental papers most closely related to ours are Evdokimov and Garfagnini (2015) and Hamman and Martínez-Carrasco (2015). The first of these papers provides a direct experimental test of the theoretical models of Alonso et al. (2008) and Rantakari (2008) in an experimental environment with two divisions and one central manager. The focus is on comparing the quality of horizontal communication

[6] We did not implement one-way communication, primarily because having only one division communicate is not particularly natural in the context of a decentralized organization. It is not obvious that one-way communication would increase coordination relative to two-way communication as much as in Cooper et al. In Cooper et al., the combination of strangers matching and role switching means that no individual always gets their most or least preferred equilibrium. Our experiment uses partners matching and roles are fixed. Even if there were a natural way to give one player the right to send messages, the resulting high degree of asymmetry would presumably make it less likely that subjects could easily achieve coordination.

between divisions with that of vertical communication between the divisions and central management, varying the importance of coordination. The results are largely in line with theoretical predictions: the quality of horizontal communication is significantly higher than that of vertical communication and divisions' actions are more coordinated when the importance of coordination is high. They do find some departures from the theoretical predictions, as centralized (decentralized) organizations are less (more) coordinated than expected. They show these deviations can be attributed to risk and ambiguity aversion. The basic setup of their experiment, an implementation of the Alonso et al. model, is related to the decentralization game as discussed in Section 3.1., but the focus is different. Evdokimov and Garfagnini largely focus on testing predictions of Alonso et al. and Rantakari, while we are more concerned with behavioral issues that affect the relative performance of centralization and decentralization.

Hamman and Martínez-Carrasco (2015) examine decentralization in the context of a more complex environment involving task selection. Central management first chooses what type of workers to hire, homogenous or heterogeneous, and then chooses either to keep decision-making rights over task assignment (centralization) or to delegate task assignment to workers (decentralization). They find that, consistent with their theory, decentralization is more common as task uncertainty grows. In other words, decentralization increases as the informational advantage of the workers grows. There is a bias toward choosing centralization which they attribute to a desire for control by central managers. They also find a persistent tendency to choose centralization too frequently, driven by a tendency to overreact to bad decisions by the workers. While the environment studied by Hamman and Martínez-Carrasco is rather different from ours, the endogenous choice of structures is an important contribution. We would be curious whether similar biases occur in our environment.

**3. Experimental Design and Procedures:** We made a number of design choices intended to yield a game with features that accentuate the tradeoffs between centralization and decentralization. A simpler example than the actual decentralization game gives a flavor of how the game works. Imagine a restaurant chain with two locations, a restaurant in Hamburger City and a restaurant in Pizza City. People in Hamburger City prefer hamburgers to pizza and people in Pizza City prefer pizza to hamburgers. There are several factors that determine the restaurants' earnings. First, it is cheaper to buy ingredients in bulk, so costs are lower if both locations sell the same thing, either hamburgers or pizza. This leads to losses from coordination failure – each restaurant has higher costs if it sells something different from the other. Second, people in Hamburger City always want hamburgers, so the restaurant in Hamburger City always wants to sell hamburgers. Analogously, the restaurant in Pizza City always wants to sell pizza. This causes adaptation losses. Each restaurant loses if it doesn't sell products that match the local tastes they face. Finally, tastes are subject to shocks. These don't affect what people want, but instead affect the intensity of tastes. When hamburgers are fashionable, customers in Hamburger City strongly favor hamburgers. Customers in Pizza City still prefer pizza over hamburgers, but now they don't care so much. This makes adaptation losses state dependent. A shock in favor of hamburgers causes the restaurant in Hamburger City to lose a lot if it sells pizza, while the restaurant in Pizza City doesn't lose much if it sells hamburgers. So total payoffs across the two locations are maximized if both restaurants sell hamburgers. Similar logic applies when there is a shock in favor of pizza.

The two restaurants (divisions) are assumed to know local demand and, by extension, the current state of the world (taste shock). The owner of the restaurant chain (central management) only knows the distribution of taste shocks. Under decentralization, the divisions have all the information needed to coordinate on a menu that maximizes total payoffs, but the restaurant in Hamburger City *always* wants them to coordinate on selling hamburgers and the restaurant in Pizza City *always* wants them to coordinate on selling pizza. This yields a difficult coordination problem. With centralization the central manager can force the two restaurants to coordinate but doesn't know whether hamburgers or pizza is the best choice to maximize total payoffs. She can ask the divisions, but they have an incentive to lie. This illustrates the main tension in the decentralization game: maximizing total surplus involves solving the coordination problem and, at the same time, taking advantage of the divisions' private information. Centralization is well-suited to achieving coordination while decentralization eases the informational problems. Which does better overall (and why)? By changing how the organization functions, particularly by adding different sorts of communication, can we improve performance?

**(Table 1 about here)**

*3.1. Stage Game Payoff Functions:* There are three players in the game, a central manager (CM) and two division managers (D1 and D2). G denotes the state of the world: $G \in \{1,2,3,4,5\}$. The state of the world is randomly determined before players take any actions. Draws of G are i.i.d. with each state equally likely. Both divisions are assumed to know the state of the world, but CM only knows the *ex ante* distribution over states. This represents a situation where both divisions know the general business conditions in the field, while central management does not. As standard nomenclature, we refer to states of the world by the game they induce (e.g., Game 1 for G = 1). The divisions choose (under decentralization) or are assigned (under centralization) a product type from the space $T_i \in \{1,2,3,4,5\}$. Equations 1a, 1b, and 1c give the payoff functions for D1, D2, and CM respectively. For all treatments, $k_1 = 54$, $k_2 = 7$, and $k_4 = 15$. The value of $k_3$ is varied as a treatment variable.

$$\pi_{D1} = k_1 - k_2|T_1 - 5| - k_3|T_1 - G| - k_4|T_1 - T_2| \quad \textbf{(Eq. 1a)}$$

$$\pi_{D2} = k_1 - k_2|T_2 - 1| - k_3|T_2 - G| - k_4|T_1 - T_2| \quad \textbf{(Eq. 1b)}$$

$$\pi_{CM} = \pi_{D1} + \pi_{D2} \quad \textbf{(Eq. 1c)}$$

The division payoffs are better understood through Equation 2. Division payoffs equal a constant minus three types of losses. "Adaptation losses," given by the first term in the payoff function, are losses due to deviations from local tastes that do ***not*** depend on the state of the world. Divisions face diametrically opposed local tastes, with $T_1 = 5$ most preferred by D1's customers and $T_2 = 1$ most preferred by D2's customers. The second term in the division payoff functions represents "state losses", the component of adaptation losses which are state dependent. When tastes change they shift the degree to which the two branches care about staying close to the product type that is most preferred at their location. If changing product types shifts a division away from its most preferred choice but towards the state of the world (current tastes), the adaptation loss is relatively low. If the division shifts away from both its most preferred choice and the state of the world, adaptation losses are high. This implies that there is a kink in adaption losses at the state of the world. The final term represents "coordination losses," losses from not choosing the same product type as the other division. We assume $k_4 > k_2 > k_3$. These assumptions make the games induced by the five states of the world into coordination games where the two divisions have diametrically opposed interests.[7]

$$\pi_D = k_1 - k_2 * adaptation\ loss - k_3 * state\ loss - k_4 * coordination\ loss \qquad \textbf{(Eq. 2)}$$

CM's payoff is the sum of the divisions' payoffs. In other words, central management seeks to maximize total firm profits. This need not be interpreted as benevolence on the part of central management, but instead can represent a setting where the rewards of division managers largely depend on how their division does while central management is concerned with profits across the entire firm.

The payoff functions in Equations 1a, 1b, and 1c are related to those used in Alonso et al.'s (2008a) model, but differ in several important ways. First, tastes in the Alonso et al. model are determined by two independent shocks (one for each division). Tastes in our model are subject to a single common shock. We chose to have a single shock to simplify the experimental environment, as the central manager's uncertainty is over a single dimension rather than two and there is no asymmetric information between D1 and D2. Second, the functional form of adaption and coordination losses in Equations 1a and 1b are absolute values of differences rather than squared differences as used by Alonso et al. This sharpens the divisions' incentives to coordinate. Rather than shading their choices away from local tastes and towards

[7] If adaption losses are higher than the sum of coordination and state losses ($k_2 > k_3 + k_4$, it becomes a dominant strategy for each division to perfectly conform to local tastes. For less extreme cases ($k_3 + k_4 > k_2 > k_4$), there are multiple equilibria but some choices become dominated implying that the subgames no longer have five equilibria and in some cases have a unique equilibrium. If state losses are larger than adaption losses ($k_3 > k_2$), the divisions' preferences over equilibria will be aligned.

the other division's choice, in equilibrium divisions do exactly the same thing as the other division. Finally, we assume each division manager is solely concerned with their own division's profits rather than a weighted average over both divisions' profits. This again simplifies the game and sharpens the incentives faced by division managers. Our payoff functions were chosen to simplify the game and confront subjects with sharp tradeoffs.

Having five possible product types and five states of the world (rather than three of each) makes the game more complex, but nevertheless has distinct advantages for our experimental design. An important issue in our analysis is distinguishing whether subjects' play is consistent with an efficient (i.e., total payoff maximizing) or safe equilibrium. With only three states and product types, for a uniform distribution over states, the efficient and safe equilibrium would coincide for a third of the data. Using five states and product types reduces the probability of being unable to distinguish the efficient and safe equilibria to one-fifth. Under centralization, having five product types also makes it possible to observe partial responses to messages (e.g., CMs can split the difference between staying at the safe equilibrium and moving to one division's preferred equilibrium.)

Table 1 shows examples of the payoff tables subjects actually saw in our experiments. The five states of the world yield these five payoff tables when $k_3 = 4$. The three numbers in each cell correspond to the payoffs, denominated in ECUs, of D1 ($\pi_{D1}$), D2 ($\pi_{D2}$), and CM ($\pi_{CM}$). The row and column are the product types chosen by D1 and D2 respectively (or chosen for them by CM). The row (R) and column (C) numbers correspond to the product types chosen by the divisions (e.g. R3 ≡ $T_1 = 3$; C4 ≡ $T_2 = 4$).

As an example of how the payoffs work, suppose D1 chooses R1 ($T_1 = 1$) and D2 chooses C1 ($T_2 = 1$) for Game 1. This is the efficient (i.e., total surplus maximizing) equilibrium for Game 1, but is also the least preferred equilibrium for D1 yielding a payoff of 26 ECUs. If D1 deviates to choosing R2 ($T_1 = 2$) instead of R1 ($T_1 = 1$), D1 loses 14 ECUs for ceasing to be coordinated with the other division and loses another 4 ECUs for moving away from the state of the world but gains 7 ECUs from moving closer to his preferred choice R5 ($T_1 = 5$). The total loss is 11 ECUs, the difference between 26 and 15 ECUs.

*3.2: Equilibrium, Decentralization:* Under decentralization, each division chooses a product type and CM is a passive bystander. Ignoring the payoff for CM, all five games are coordination games with five pure-strategy Nash equilibria where the two divisions choose the same product type: ($T_1 = T_2 = 1$), ($T_1 = T_2 = 2$), ($T_1 = T_2 = 3$), ($T_1 = T_2 = 4$), and ($T_1 = T_2 = 5$). For convenience, we refer to these as Equilibrium 1, Equilibrium 2, etc.

In all five games, there is a tension similar to the battle-of-the-sexes (BOS) game since D1 most prefers Equilibrium 5 and least prefers Equilibrium 1, while for D2 the reverse is true. Moreover, CM prefers the equilibrium that maximizes total surplus. This implies that the CM always wants a different equilibrium than at least one of the divisions and wants a different equilibrium than either division in Games 2 – 4. Alternative principles for selecting an equilibrium, such as safety and efficiency, suggest different ways of resolving the tensions stemming from divisions' differing interests.

Unlike a BOS game, the decentralization game has a relatively easy way to coordinate and achieve equal payoffs since in all five games Equilibrium 3 yields the same payoff to both divisions. Equilibrium 3 is also safe, in the sense that $T_i = 3$ is the maximin strategy for both divisions in all five games. The problem with always playing the safe equilibrium is that, except in Game 3, Equilibrium 3 does not maximize total surplus.

All five games have an equilibrium that maximizes total surplus. This is always equivalent to the game number (i.e., Equilibrium 1 in Game 1, Equilibrium 2 in Game 2, etc.). The efficient equilibrium, where the divisions play the surplus-maximizing equilibrium in all states of the world, is procedurally fair (i.e., equalizes expected payoffs under the veil of ignorance about the state of the world; see Brandts et al., 2005) but yields asymmetric payoffs for all games except Game 3 once the state of the world is known.

Achieving high total surplus relies more on the ability of divisions to coordinate on an equilibrium than on coordinating at any particular equilibrium. Looking at Table 1, notice that if one division selects the product type corresponding to the efficient equilibrium and the other division misses it by *only one level*, then average surplus drops from 80 in the efficient equilibrium to either 41 or 55. This is similar to always coordinating on the worst possible pure-strategy equilibrium which yields an expected payoff of 54.4. The payoff table is set up to favor successful coordination given the large losses caused by coordination failure.

*3.3: Equilibrium, Centralization:* Under *centralization* the two divisions do not choose rows and columns directly. After being informed about the state of the world (i.e., Game 1, Game 2, etc.) each division independently sends a message to the CM indicating which state of the world has been selected ($M_i \in \{1,2,3,4,5\}$). There is no requirement that these messages be truthful, a point emphasized in the instructions.[8] After receipt of the two messages, the CM chooses both a row and a column. The CM has no knowledge about which game has been selected beyond the initial distribution over states of the world and whatever information she gleans from the divisions' messages. With centralization, the main obstacle to efficiency is not coordination failure. The CM can directly enforce coordination and has clear incentives to choose identical product types for the two divisions.[9] Asymmetric information is the central barrier to

[8] The instructions state " … [D1 and D2] will separately send messages to [CM] saying which game has been selected. This message can be truthful or not."

[9] It is trivial to prove that the CM's best response for any beliefs over states of the world must involve setting the row and column equal to each other (i.e., coordinating). See Appendix A.

achieving efficiency under centralization. Conditional on enforcing coordination, Equations 1a and 1b are constructed so the sum of adaptive losses across D1 and D2 is a constant. This implies that CM does not care about local tastes, but the divisions do. Given their opposing interests, the divisions have no incentive to be truthful with the CM. If both divisions always report the game where the efficient outcome is best for them (Game 5 for D1, Game 1 for D2), the best the CM can do is to choose the safe outcome ($T_1 = T_2 = 3$).[10] Any benefits from the private information of the divisions are lost and the CM generally will not choose the surplus-maximizing outcome given the state of the world.

More formally, we can prove the following theorem. Given that the CM must choose the same row and column ($T_1 = T_2$) in any Perfect Bayesian equilibrium (PBE), we refer to the CM as choosing a single product type in response to the divisions' messages.

**Theorem:** There does not exist a pure-strategy PBE where the CM chooses different product types for two different states of the world. This implies that the only pure-strategy PBE are babbling equilibria where the safe outcome ($T_1 = T_2 = 3$) is always chosen.

The preceding theorem is not a generic property of this class of games (Battaglini, 1992). The decentralization game is constructed to make information transmission under centralization difficult due to the diametrically opposed interests of the two divisions.

The theory assumes messages are cheap talk, with the divisions incurring no cost, pecuniary or psychological, for sending false messages. If we add a psychological cost for sending false messages, it is trivial to construct cases where truthful revelation is consistent with an equilibrium. For example, let $c_L = |M_i - G|$ be a division's psychological cost of lying (where $M_i$ is the message sent by individual i). If $c_L > k_2 - k_3$, there exists an equilibrium in which both divisions truthfully reveal their information. This is supported by CM choosing the safe outcome ($T_1 = T_2 = 3$) in any case where the two divisions do not agree.

*3.4 Experimental Design:* We have a total of eight treatments. In all treatments, participants were assigned the role of CM, D1, or D2 at the beginning of the session and these roles remained constant throughout the session. In treatments with decentralized decision-making, the participants in the CM role were pure observers. We did this to keep the possible influence of other-regarding preferences constant across treatments. Subjects played a total of 18 rounds in all treatments.

[10] Given that payoffs are linear, this isn't transparent. The advantage of choosing the safe outcome is that it limits the size of the error the CM can make. Define a CM's error as the difference between the product type she chooses (assumes she sets $T_1 = T_2$) and the efficient choice. If she chooses the safe outcome, her average error is 1.2. If she chooses product type 2 or 4, the average error rises to 1.4. Choosing 1 or 5, the average error goes up to 2.0.

The first six treatments compare centralization with decentralization in three different settings. The last two treatments combine decentralization with different types of communication.

*Baseline:* We set $k_3 = 4$, yielding the payoff tables shown in Table 1. A fixed (or partners) matching was used with participants matched with same two other subjects throughout the entire experiment. At the beginning of the session, they were only told that the matching would be fixed for the first nine-round block (they were given no information about the second block). After the first block was over, subjects were informed that there would be an additional nine rounds of the same game using the same groups as in the first nine rounds.

*Strangers:* Here we used the same parameters as in baseline but with strangers matching; that is, groups changed from round to round. Participants were told that they would play an initial block of nine rounds in which they would be re-matched with two new players in each round. This was done in such a way that none of the participants met another person twice in the nine-round block (a point which the instructions stressed). At no time were participants informed about the identity of the other two people in their group. After the first nine-round block was over, subjects were informed that there would be an additional nine-round block of the same game in which matchings would made as in the first nine-round block (i.e., they would not meet any other subject more than once in the nine-round block).

Comparing the two types of matching gives us two different views of the problem. With the strangers matching we are as close to the one-shot game as possible. This largely eliminates any repeated-game effects, but makes it relatively difficult to learn how to coordinate and, arguably, is less realistic. Partners matching should make coordination easier. The set of (subgame perfect) equilibrium outcomes is not expanded with partner matching,[11] but it does become possible to engage in strategic teaching in the decentralized game.[12]

*High State Losses:* We use strangers matching as in the Baseline treatment but set $k_3 = 6$, increasing state losses from the baseline ($k_3 = 4$). This change does not affect the theoretical predictions for the game under either decentralization or centralization, but makes the gain for moving from the efficient equilibrium

[11] To be more precise, the set of equilibrium outcomes does not expand under centralization. Given that the stage game has a single payoff-vector consistent with equilibrium, backward induction implies that the stage-game equilibrium is played in every period. Put differently, there is no way to support an efficient equilibrium via punishment. With decentralization, any sequence of stage-game equilibria is a subgame perfect equilibrium with either partners or strangers matching. With partners matching, it is also possible to construct equilibria in which outcomes that are not stage-game equilibria are played in early rounds (if one division deviates, they are punished via play of the other division's ideal equilibrium). Such equilibria are implausible, as they are both Pareto dominated and virtually impossible to coordinate upon in the absence of communication.

[12] Strategic teaching refers to attempts to alter others' future choices by manipulating their learning processes. For experimental evidence of strategic teaching see Terracol and Vaksmann (2009), Hyndman et al. (2009), Fehr et al. (2012) and Hyndman et al. (2012).

to a division's most preferred equilibrium tiny. For example, moving from Equilibrium 1 to Equilibrium 5 in Game 1 gains D1 12 ECUs in the Baseline treatment, but only 4 ECUs in the High State Losses treatment.

The purpose of this treatment was to make the efficient equilibrium relatively more attractive, making it easier to achieve efficiency. Under decentralization, increasing the state losses both increases the gap in payoffs between the efficient and safe equilibria (excepting Game 3 where the efficient and safe equilibrium coincide) and decreases the potential gain from deviating from the efficient equilibrium. Under centralization, potential gains from sending untruthful messages are reduced.

Within each of these three settings (Baseline, Strangers, and High State Losses), we conducted sessions with decentralization (i.e., divisions choose their product types) and centralization (i.e., divisions send messages to the central manager who then chooses their product types), giving a total of six treatments. All subjects received feedback about the realized state of the world after each round. In the centralization treatments, this made it possible for CMs know if a division had lied about the game being played.

The goal is to achieve a high degree of coordination with decentralization while taking full advantage of the divisions' information. Foreshadowing our results, centralization yields significantly higher total surplus than decentralization in all three settings but generally does not maximize total surplus. Centralization solves the coordination problem but does a poor job of using the divisions' information. We therefore introduced two new treatments that augment decentralization with additional communication channels, hoping to achieve coordination *and* effective use of the divisions' information.

*Horizontal Communication:* This treatment was identical to the Baseline treatment with decentralization, except pre-play communication between divisions was added. Prior to each round of play, each division sent three rounds of messages. Within each round of messages, the divisions simultaneously chose a pair of messages proposing product types for themselves and the other division. Divisions observed each other's messages at the end of each round of messages. The purpose of having three rounds of messaging was to make it easier for divisions to agree upon a course of action.[13]

*Manager Suggestions:* This treatment was identical to the Baseline treatment with decentralization, except the CM sent a message to the divisions prior to each round of play. This message suggested product types for both divisions in each of the five possible games. The full message (a 5 x 2 matrix) was shown to both divisions prior to making choices.

We used a between subjects design, so each subject participated in a single session with just one of the eight possible treatments. We conducted three sessions for each of the six treatments with fixed matching and five sessions for each of the two treatments with strangers matching. There were 27 participants in each session.

[13] See Cooper, DeJong, Forsythe, and Ross (1989).

Each session began with instructions (see Appendix B). Participants had printed copies of the payoff tables for all five games. The sessions were run at the LINEEX lab at the University of Valencia, with undergraduate students from the university as participants. The payoffs were denominated in Experimental Currency Units, with 1 ECU = 0.2€. Participants were paid for all rounds. Including a 5€ show-up fee, average pay was 19.90€. Sessions lasted around an hour.

*3.5: Hypotheses:* There is an efficient equilibrium under decentralization where maximum total surplus is achieved. No such equilibrium exists with centralization. If subjects play the efficient equilibrium under decentralization, decentralization will yield the highest possible surplus and outperform centralization. This leads to H1. Of course, achieving coordination under decentralization, let alone the surplus maximizing equilibrium, may be difficult.

**H1:** *Total surplus will be greater under decentralization than with centralization in the Baseline, Strangers, High State Losses treatments.*

The theory implies that messages under centralization will contain no useful information. The best-case scenario is that play converges to the babbling equilibrium. H2 follows from this logic. Once again, there are good reasons to be skeptical. Our design differs from many of the existing experiments, especially since there is more than one sender, but the general finding that individuals are reluctant to tell lies that benefit themselves and harm others is likely to apply. As noted previously, it is possible to support an efficient equilibrium under centralization as long as the cost of telling lies is sufficiently large.

**H2:** *Under centralization, messages from the divisions will contain no useful information about the state of the world. Total surplus will not exceed the expected payoff from a babbling equilibrium.*

Increasing state losses does not affect the theoretical predictions, but changes the marginal costs of deviating from the efficient equilibrium as well as the cost of telling lies. These changes should favor efficiency under both decentralization and centralization, yielding H3.

**H3:** *Under either decentralization or centralization, total surplus will be higher in the High State Loss treatment than in the Baseline treatment.*

The theoretical predictions are not changed by the introduction of communication,[14] since babbling equilibria always exist, but previous results indicate that communication can serve as a powerful coordination device. The related results of Cooper et al. (1989) would only lead us to expect modest improvements from Horizontal Communication, but differences in the structure of our game and the BOS game gave us reason to be more optimistic that efficient coordination would be more common with communication between the divisions (see Section 2 for a more detailed discussion). It has been shown in other coordination games that suggestions from the experimenter or external leaders can act as a coordination device (e.g., Van Huyck, Gillette, and Battalio, 1992; Brandts and Cooper, 2007; Brandts, Cooper, and Weber, 2014). We hoped that the Manager Suggestion treatment would likewise increase the likelihood of efficient coordination. Together these two expectations yield H4. This hypothesis is stated relative to surplus under decentralization, but we hoped that the two communication treatments would also yield higher total surplus than under centralization in the Baseline treatment. We did not have any *ex ante* prediction comparing the two communication treatments.

**H4:** *Compared to the Baseline treatment, we expect higher total surplus in the Horizontal Communication and Manager Suggestions treatments than under decentralization in the Baseline treatment.*

**4. Results:** Section 4.1 gives an overview of the main treatment effects. Section 4.2 studies the three centralization treatments in detail. We look at the details of what messages divisions send and how central managers interpret these messages, with the goal of explaining why centralization fails to improve surplus beyond the babbling equilibrium. Section 4.3 studies the messages sent in the two treatments combining decentralization with communication. We focus on why the addition of communication has a relatively small effect on total surplus.

*4.1. Treatment Effects:* Table 2 summarizes outcomes by treatment, with the two sub-tables dividing the data between the first (Rounds 1 – 9) and second (Rounds 10 – 18) halves of the experiment. The first two columns show average total surplus and coordination rates (i.e., choice/assignment of identical product types: $T_1 = T_2$) across all games. As a point of comparison, recall that the maximum possible total surplus always equals 80. The final three columns look at the frequency of specific outcomes in Games 1, 2, 4, and 5. As defined previously, the safe equilibrium refers to mutual choice of 3 ($T_1 = T_2 = 3$) and the efficient equilibrium indicates choices matching the state of the world ($T_1 = T_2 = G$). "Other" equilibrium refers to

[14] Using the terms of Aumann (1990), a message in the Horizontal Communication treatment calling for play of the efficient equilibrium is self-committing but not self-signaling. Even this ignores the additional problem that the divisions need to reach an agreement to coordinate on one particular equilibrium.

any other outcome where the divisions' product choices are identical. These three columns do not use data from Game 3 because the efficient and safe equilibrium coincide in this case.

**Table 2: Summary of Outcomes**

**Rounds 1 - 9**

| Treatment | All Data | | Games 1, 2, 4, and 5 | | |
|---|---|---|---|---|---|
| | Total Surplus | % Coordinate | % Safe Equilibrium | % Efficient Equilibrium | % Other Equilibrium |
| Baseline, Decentralized | 53.5 | 46.1% | 27.0% | 9.0% | 5.8% |
| Baseline, Centralized | 70.0 | 97.5% | 28.6% | 38.1% | 31.7% |
| Stranger, Decentralized | 50.0 | 38.3% | 19.0% | 12.7% | 3.5% |
| Stranger, Centralized | 69.3 | 97.8% | 28.9% | 31.7% | 37.5% |
| High State Loss, Decentralized | 49.2 | 43.6% | 16.9% | 18.0% | 3.2% |
| High State Loss, Centralized | 66.5 | 95.9% | 24.3% | 40.7% | 30.7% |
| Horizontal Communication | 62.7 | 72.8% | 44.4% | 20.1% | 5.3% |
| Manager Suggestions | 57.9 | 55.1% | 23.3% | 23.8% | 3.7% |

**Rounds 10 - 18**

| Treatment | All Data | | Games 1, 2, 4, and 5 | | |
|---|---|---|---|---|---|
| | Total Surplus | % Coordinate | % Safe Equilibrium | % Efficient Equilibrium | % Other Equilibrium |
| Baseline, Decentralized | 61.4 | 69.5% | 48.1% | 12.6% | 4.9% |
| Baseline, Centralized | 71.7 | 99.6% | 31.1% | 36.1% | 32.2% |
| Stranger, Decentralized | 55.0 | 46.7% | 31.5% | 7.2% | 3.0% |
| Stranger, Centralized | 70.3 | 99.5% | 37.7% | 28.9% | 33.4% |
| High State Loss, Decentralized | 60.0 | 59.3% | 11.5% | 40.4% | 1.1% |
| High State Loss, Centralized | 68.2 | 97.5% | 24.6% | 48.1% | 24.0% |
| Horizontal Communication | 65.7 | 77.8% | 36.1% | 30.6% | 8.2% |
| Manager Suggestions | 64.4 | 69.5% | 32.8% | 30.1% | 4.4% |

We begin by comparing total surplus under centralization and decentralization in the Baseline, Stranger, and High State Losses treatments.[15] Total surplus is always higher under centralization than decentralization. Using a Wilcoxon rank-sum test on average total surplus across Rounds 1 – 18, the difference between centralization and decentralization is significant at the 1% level in all three cases: Baseline ($n = 54$; $z = 5.56$; $p < .01$), Strangers ($n = 10$; $z = 2.61$; $p < .01$), and High State Loss ($n = 54$; $z = 4.65$; $p < .01$).[16] The difference between centralization and decentralization narrows over time, but remains significant for Rounds 10 – 18 in all three cases: Baseline ($n = 54$; $z = 3.89$; $p < .01$), Strangers ($n = 10$; $z = 2.61$; $p < .01$), and High State Loss ($n = 54$; $z = 4.65$; $p < .01$).

The low total surplus under decentralization relative to centralization stems from frequent failures to coordinate on identical product types. For all three centralization treatments, coordination is close to 100% throughout; subjects playing as CMs have no difficulty in understanding that choosing the same product types for both divisions is always preferable. In stark contrast, coordination in the decentralization treatments is below 50% in the first half of the experiment. This increases with experience but never gets

[15] We define total surplus as the sum of the payoffs for D1 and D2. This is equivalent to CM's payoffs.

[16] For the two treatments with a partner matching (Baseline and High State Loss), the unit of observation is a single three-subject group. In the Strangers treatment, the unit of observation is all participants in a session.

close to the near-perfect coordination observed under centralization. The difference in coordination rates between decentralization and centralization is significant (based on Wilcoxon rank-sum tests) across Rounds 10 – 18 in all three settings: Baseline (n = 54; z = 4.82; p < .01), Strangers (n = 10; z = 2.66; p < .01), and High State Loss (n = 54; z = 5.91; p < .01).

There is a direct link between the low coordination rates and low surplus under decentralization. This can be seen through a counterfactual exercise where simulated data are created in the following way. When the product types of D1 and D2 differ, adjust the choice of one division to obtain coordination on a single product type. Since there are always two ways to adjust the outcome, choose the one that corresponds to lower total surplus. Table 3 summarizes the results of this exercise. For each treatment, the first column shows average total surplus in Rounds 10 – 18 in the experimental data. The second column gives the average total surplus for the same time period from the simulated data. Even taking the conservative approach of assuming coordination always takes place at the worse of the possible outcomes (between the two that were chosen by one of the divisions), artificially resolving the frequent coordination failures under decentralization largely eliminates the gap in total surplus between centralization and decentralization. To further illustrate this point, calculate the difference in total surplus between centralization and decentralization (averaging across the Baseline, Stranger, and High State Loss treatments) for both the real and simulated data. The difference from the real data reflect losses due to coordination failure and losses due coordinating on less efficient (i.e., lower total surplus) outcomes, while the difference from the simulated data only reflect losses due to coordination on less efficient outcomes. Taking the ratio of these differences, 99.6% of the differing total surpluses under decentralization and centralization can be attributed to coordination failure.[17]

**Table 3: True vs. Simulated Total Surplus, Rounds 10 - 18**

| Treatment | True Total Surplus | Simulated Total Surplus |
|---|---|---|
| Baseline, Decentralized | 61.4 | 70.5 |
| Baseline, Centralized | 71.7 | 72.0 |
| Stranger, Decentralized | 55.0 | 70.3 |
| Stranger, Centralized | 70.3 | 70.5 |
| High State Loss, Decentralized | 60.0 | 70.6 |
| High State Loss, Centralized | 68.2 | 69.0 |

[17] For the three treatments with centralization, average true total surplus is 70.11 across Rounds 10 – 18 and average simulated total surplus is 70.47. The equivalent figures under decentralization are 58.10 and 70.42. The ratio (70.47 – 70.42)/(70.11 – 58.10) = .004. This gives the fraction of lost surplus under decentralization that remains after coordination failure is artificially eliminated. The fraction of lost surplus under decentralization due to coordination failure is 1 - .004 = .996, yielding the 99.6% figure in the text.

**Result 1:** *Total surplus is higher under centralization than decentralization for all three settings (Baseline, Stranger, and High State Loss). The data are not consistent with H1. Increased coordination failure largely explains the lower total surplus with decentralization.*

While better coordination would improve total surplus under decentralization, the simulated total surpluses shown in the right column of Table 3 remain well below the theoretical maximum total surplus of 80. This points to an additional problem under decentralization. If the divisions take advantage of their information, they should coordinate at the efficient equilibrium, maximizing total surplus *subject to the state of the world*. Contrary to this expectation, coordination is overwhelmingly at the safe equilibrium in the Baseline and Strangers treatments with decentralization, representing 75% of the cases where the divisions coordinate (Rounds 10 – 18, $G \neq 3$). The High State Loss treatment was designed to make coordination at the efficient equilibrium more attractive, and indeed the efficient equilibrium is played in 76% of the cases where the divisions coordinate (Rounds 10 – 18, $G \neq 3$). This is only a limited success, as the divisions either fail to coordinate or coordinate at inefficient outcomes in the majority of cases (50% across all five games).

**Result 2:** *When divisions coordinate under decentralization, play is generally consistent with the safe equilibrium in the Baseline and Stranger treatments, implying a failure to use the divisions' information. Play consistent with the efficient equilibrium is more frequent in the High State Loss treatment under decentralization.*

The difference between total surplus under centralization and the babbling equilibrium is small in all three settings – recall that the expected total surplus from the babbling equilibrium is either 70.4 (Baseline and Stranger) or 65.6 (High State Loss). Wilcoxon matched-pairs signed-rank tests (using average total surplus across all 18 rounds) generally do not find significant differences from the babbling equilibrium: Baseline ($n = 27$; $z = 0.43$; $p > .10$), Strangers ($n = 5$; $z = 2.02$; $p < .05$), and High State Loss ($n = 27$; $z = 1.43$; $p > .10$).[18] The results are about the same if we only use data from the second half of the experiment (Rounds 10 – 18): Baseline ($n = 27$; $z = 0.41$; $p > .10$), Strangers ($n = 5$; $z = 1.75$; $p < .10$), and High State Loss ($n = 27$; $z = 0.27$; $p > .10$). The two significant differences are due to average total surpluses being slightly lower in the Strangers treatment than the babbling equilibrium.

**Result 3:** *Total surplus under centralization is about the same as in the babbling equilibrium. The data are consistent with H2 along this dimension.*

[18] The unit of observation is defined as before. For the two treatments with a partner matching (Baseline and High State Loss), the unit of observation is a single three-subject group. In the Strangers treatment, the unit of observation is all participants in a session. The surpluses from the babbling equilibrium are based on what the total surplus would have been if the CM had always set $T_1 = T_2 = 3$ as predicted by the babbling equilibrium.

Given the high degree of coordination under centralization and average total surpluses close to the expected value from the babbling equilibrium, it is tempting to guess that play under centralization converged to the babbling equilibrium as predicted by the theory (implying that CMs makes no use of the divisions' information). This is not the case. In the babbling equilibrium, the safe equilibrium (Equilibrium 3) should always be chosen. Returning to Table 2, the frequency of the safe equilibrium for cases where the safe and efficient equilibria can be distinguished ($G \neq 3$) rises slightly over time but remains below a third (32.3%) averaging across the three centralization treatments for Rounds 10 – 18.

The efficient (i.e., surplus-maximizing) equilibrium also does not emerge under centralization. Even in the High State Loss treatment, which is designed to encourage play off the efficient equilibrium, the frequency of the efficient equilibrium falls below 50% in the second half of the experiment (excluding $G = 3$).

The preceding analysis is on a population basis, and the failure to see a high percentage of any one equilibrium could reflect groups converging to different equilibria. The data indicates that this is *not* the case. For treatments with partners matching (Baseline and High State Loss), define a group as having converged to an equilibrium if it is played at least eight times in nine opportunities over Rounds 10 - 18. For the Strangers treatment, define a group as having converged to an equilibrium if it is played at least 80% of the time over Rounds 10 - 18. For the two treatments with centralization and partners matching, only 6 of 54 groups converge to the efficient equilibrium and only 6 of 54 converge to the safe equilibrium. In the Strangers treatment, none of the five sessions converge to an equilibrium.[19]

**Result 4:** *Play under centralization is generally consistent with neither the babbling equilibrium nor the efficient equilibrium. The data are therefore not consistent with H2.*

Under either centralization or decentralization, total surplus is lower in the High State Loss treatment than the Baseline treatment. The difference narrows over time and is not significant in Rounds 10 – 18 for either Decentralization ($n = 54$; $z = 0.59$; $p > .10$) or Centralization ($n = 54$; $z = 1.41$; $p > .10$). The data do not support our prediction of higher total surplus in the High State Loss treatment.

Coordination rates under decentralization are also lower in the High State Loss treatment than the Baseline treatment, but the difference is modest and not significant across Rounds 10 – 18 ($n = 54$, $z = 1.53$; $p > .10$). We predicted the High State Loss treatment would encourage play of the efficient equilibrium and, as noted above, it does so. So why is H3 not supported by the data? The modest increase in coordination failure in High State Loss more than offsets the movement toward the efficient equilibrium. The main problem under decentralization is coordination failure, and this doesn't change with higher state losses.

[19] The closest is one session where 51% of the play across Rounds 10 – 18 is consistent with the safe equilibrium.

**Result 5:** *Total surplus is lower, albeit not significantly, in High State Loss than in Baseline. The data are not consistent with H3.*

Comparing the Baseline and Strangers treatments, the type of matching has little effect on total surplus with centralization. Total surplus is higher with partners matching under decentralization, but this difference does not achieve significance using an admittedly conservative Wilcoxon rank-sum test either over the entire session ($n = 32$; $z = 1.43$; $p > .10$) or the final nine rounds ($n = 32$; $z = 1.48$; $p > .10$). Coordination under decentralization is less frequent with strangers matching than with partners matching (Strangers vs. Baseline). The difference is large but, based on a Wilcoxon rank-sum test, not significant ($n = 32$; $z = 1.55$; $p > .10$). This is a conservative statistical test, and we think it likely that coordination is genuinely higher with the partners matching consistent with findings in earlier papers (e.g., Clark and Sefton, 2001).[20] Overall, the partners-strangers distinction is not crucial in our data.

Centralization generates far higher total surplus than decentralization but fails to reach the theoretical maximum total surplus of 80. CMs realize the advantage of imposing coordination on a single product type but as noted above generally do not pick the efficient outcome. This implies that CMs in the centralization treatment cannot take advantage of the divisions' information. This leads us to the question addressed by the final two treatments: can we achieve the best case scenario (i.e., coordination and taking advantage of the divisions' information) by adding communication to the decentralization treatment? This challenge involves more than achieving coordination. Even when the divisions coordinate under decentralization, they generally do not coordinate at the efficient equilibrium unless the incentives are heavily slanted in favor of this outcome (and state losses are a parameter of the environment, not an organizational feature that we think a manager could easily control).

Returning to Table 2, we compare total surplus in the Horizontal Communication and Manager Suggestions treatments with the Baseline treatment both under decentralization and under centralization. The Baseline treatment is the correct point of comparison since it uses the same payoffs ($k_3 = 4$) and the same matching scheme (partners) as the two new treatments. Horizontal Communication and Manager Suggestions both yield higher total surplus than the Baseline treatment under *decentralization*, but the difference narrows in later rounds. Using Wilcoxon rank-sum tests, neither difference is significant across Rounds 10 – 18 (Baseline, Decentralized vs Horizontal Communication: $n = 54$; $z = 1.43$; $p > 0.10$. Baseline, Decentralized vs Manager Suggestions: $n = 54$; $z = 0.81$; $p > 0.10$). Neither treatment does as well as the Baseline treatment under *centralization*. Again the difference narrows with experience, but in this case the

[20] If we run either a median test (continuity-corrected) or a Fisher-Pitman permutation test, the difference is significant at the 10% level.

differences are significant across Rounds 10 – 18 (Baseline, Centralized vs Horizontal Communication: n = 54; z = 1.92; $p < 0.10$. Baseline, Centralized vs Manager Suggestions: n = 54; z = 2.61; $p < 0.01$).

To understand why the Horizontal Communication and Manager Suggestions treatments have an underwhelming effect on total surplus, we turn again to Table 2. Recall that decentralization performs poorly largely because of coordination failure. Neither Horizontal Communication nor Manager Suggestions do much better along this dimension in Rounds 10 – 18. In neither case is the coordination rate significantly higher across Rounds 10 – 18 than in the Baseline treatment with decentralization (Baseline, Decentralized vs Horizontal Communication: n = 54; z = 0.96; $p > 0.10$. Baseline, Decentralized vs Manager Suggestions: n = 54; z = 0.07; $p > 0.10$). Where these treatments generate improvement is by moving play away from the safe equilibrium and toward the efficient equilibrium. Excluding data from Game 3 where the efficient and safe equilibrium cannot be distinguished, this improvement is significant for Horizontal Communication (n = 54; z = 1.75; $p < .10$) but not Manager Suggestions (n = 54; z = 1.31; $p > .10$).[21]

**Result 6:** *The Horizontal Communication and Manager Suggestions treatments yield slightly higher total surplus than is achieved in the Baseline treatment under decentralization, but do significantly worse than the Baseline treatment under centralization. Neither achieves the goal of efficient coordination.*

*4.2. Information Transmission with Centralization:* This subsection studies the details of what messages divisions send and how central managers interpret these messages, with the goal of understanding why centralization fails to produce higher surplus than the babbling equilibrium.

In the three centralization treatments, the divisions have private information that could help the central manager make a decision. For this information to help the CM, two things have to happen. D1 and D2 have to send messages that are, collectively, informative about the state of the world, and CM has to correctly interpret the information contained in the messages. The theory presented in Section 2 focuses on the first issue and concludes that information transmission will fail since D1 and D2 have no incentive to send informative messages. Built into the theory is an assumption that the messages would be interpreted correctly if informative. This section shows that neither assertion is warranted. The messages sent by D1 and D2 contain useful information. CMs respond to this information, but make systematic errors in how they use the messages. This explains why CMs are performing about the same as in the babbling equilibrium even though a babbling equilibrium is not being played – any advantages from better than expected information transmission are wiped out by errors in using this information.

[21] These weak results may say more about the low power of the rank-sum test than the differences between treatments, as both differences are significant at the 5% level if we use a Fisher-Pitman permutation test (p = .02 and p = .04 respectively).

Table 4 shows the frequency of the different messages sent by a division as a function of the realized game for the three cases with centralization. The data from D2s are remapped to be shown as if all division managers were D1s. With this remapping, Game 1 is always the least preferred and game 5 the most preferred game. Throughout our remaining discussion of messages sent by division managers (i.e., through the end of discussion of Table 5), when we refer to games and messages we are using these remapped data.[22] A message is defined as truth-telling if it equals the game being played and as a lie if it does not.

**Table 4: Message Sent as a Function of the Game (Remapped)**

| | Baseline Treatment | | | | | Stranger Treatment | | | | | High State Loss Treatment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Message | | | | | Message | | | | | Message | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Game 1 | 24.9% | 1.1% | 10.7% | 18.1% | 45.2% | 15.3% | 5.1% | 7.1% | 20.0% | 52.5% | 39.6% | 5.1% | 10.2% | 18.1% | 27.1% |
| Game 2 | 0.5% | 36.4% | 13.9% | 13.9% | 35.4% | 2.5% | 21.2% | 12.3% | 16.6% | 47.4% | 1.5% | 53.3% | 7.2% | 14.4% | 23.6% |
| Game 3 | 1.3% | 1.3% | 68.0% | 9.2% | 20.2% | 1.6% | 1.6% | 50.8% | 9.0% | 37.1% | 0.9% | 0.9% | 70.2% | 8.8% | 19.3% |
| Game 4 | 2.1% | 1.0% | 2.6% | 73.3% | 21.0% | 1.2% | 1.2% | 2.5% | 55.4% | 39.7% | 0.5% | 1.0% | 4.1% | 74.9% | 19.5% |
| Game 5 | 2.3% | 1.1% | 4.5% | 4.5% | 87.6% | 0.3% | 0.3% | 1.7% | 4.4% | 93.2% | 0.6% | 1.1% | 5.1% | 4.0% | 89.3% |

**Note: Cell entries are percentage of messages sent by game. Let G ∈{1,2,3,4,5} be the game being played and let $M_2$ ∈{1,2,3,4,5} be the message sent by D2. The remapped game is given by RG = 6 – G. The remapped message for D2 is given by $RM_2$ = 6 - M2.**

Divisions' messages should be uninformative in a babbling equilibrium. Instead, there is strong correlation between the message sent and the game being played (ρ = .37). Underlying this, divisions tell the truth more than expected. With five possible states of the world, play of a babbling equilibrium implies that divisions will only tell the truth in 20% of the observations (i.e., no more than by chance). In reality, the likelihood of truth-telling is 55%. Even in the case where it is least beneficial to do so (Game 1), 24% of messages tell the truth. Truth-telling decreases only slightly with experience, falling from 56% in Rounds 1 – 9 to 54% in Rounds 10 – 18. This implies that truth-telling is probably not due to a failure to grasp the strategic value of lying. When division managers do lie, it is often an incomplete lie which is shaded towards the truth. Purely self-interested division managers can reasonably be expected to always send a message of 5.[23] This is indeed the most common type of lie in all three treatments for all states of the world other than G = 5. But 38% of lies involve sending a message other than 5.[24]

The regressions reported in Table 5 put the preceding discussion on firmer statistical footing. The dataset includes all observations from the centralized treatment. An observation is the message sent by a single division manager in a single round. The dependent variable for Models 1 and 2 is the message,

[22] Let G ∈ {1,2,3,4,5} be the game being played and let $M_2$ ∈ {1,2,3,4,5} be the message sent by $D_2$. The remapped game (RG) is given by RG = 6 – G. The remapped message (RM) for D2 is given by $RM_2 = 6 - M_2$. This effectively remaps the games and messages to make them identical for D1 and D2.

[23] Recall that Equilibrium 5 corresponds to the division manager's preferred equilibrium for all games. If they expect the CM's choices to respond to their messages, they should always send a message of 5.

[24] This is similar to the partial lying observed by Fischbacher and Föllmi-Heusi (2013).

remapped as described above for D2. Since messages have a natural order and are categorical, we use an ordered probit model. In Models 3 and 4 the dependent variable is whether the division manager told the truth. This is a binary variable so we use a probit model, reporting marginal effects. In all regressions, the independent variables include the game (remapped), dummies for the Stranger and High State Loss treatments, and a dummy for Rounds 10 – 18. Models 2 and 4 add interactions between the game and the other three variables (dummies for Stranger, High State Loss, and Rounds 10 – 18). Observations are not independent, so the standard errors are corrected for clustering at the session level (strangers matching) or the group level (partners matching). This yields a total of 59 clusters.

**Table 5: Regression Analysis of Messages**

| Dependent Variable | Message (Remapped) | | Truth-telling | |
|---|---|---|---|---|
| Model Type | Ordered Probit | | Probit (Marginal Effects) | |
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Game (Remapped) | 0.334***<br>(0.029) | 0.309***<br>(0.045) | 0.188***<br>(0.011) | 0.163***<br>(0.016) |
| Stranger | 0.304***<br>(0.065) | 0.345*<br>(0.189) | -0.134***<br>(0.044) | -0.246***<br>(0.071) |
| High State Loss | -0.178***<br>(0.080) | -0.711***<br>(0.250) | 0.086<br>-0.054 | 0.206***<br>(0.079) |
| Rounds 10 - 18 | 0.145***<br>(0.044) | 0.260**<br>(0.112) | -0.017<br>-0.02 | -0.151***<br>(0.043) |
| Game * Stranger | | -0.015<br>0.049 | | 0.037*<br>(0.020) |
| Game * High State Loss | | 0.184***<br>(0.065) | | -0.045**<br>(0.023) |
| Game * Rounds 10 - 18 | | -0.040<br>(0.033) | | 0.046***<br>(0.013) |
| Log-likelihood | -4600.62 | -4581.62 | -2010.17 | -1993.43 |
| # Observations | 3,564 | 3,564 | 3,564 | 3,564 |

Note: Standard errors, reported in parentheses, are corrected for clustering at the session level (strangers matching) or the group level (partners matching). Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% levels respectively.

Model 1 indicates that the relationship between the game being played and the message sent is strongly significant. This is the most important takeaway from the regressions, indicating that the messages convey information about the state of the world. Looking at Model 2, the relationship between games and messages is stable over time as indicated by the small and insignificant estimate for the interaction term between the game and Rounds 10 – 18. It is also worth noting that the relationship between the game being played and the message sent is significantly stronger in the High State Loss treatment.

Model 3 shows that truth-telling is significantly more likely for games closer to a division's preferred equilibrium. This makes sense as the divisions have less to gain by lying in these cases. The small difference in the frequency of truth-telling between the Baseline and Stranger treatments is significant, but the difference between the Baseline and High State Loss treatments is not. Looking at Model 4, the relationship between the likelihood of telling the truth and the game being played becomes more sensitive with experience. Subjects become more likely to lie when it is to their benefit and less likely to lie when gains from lying are small. The probability of telling the truth is significantly more sensitive to the game being played in the Stranger treatment than the Baseline treatment and significantly less sensitive in the High State Loss treatment than the Baseline Treatment. The latter result presumably follows from the change in payoffs which makes it less valuable to deceive the CM.

**Result 7:** *The messages sent by division managers are informative. The data are not consistent with H2.*

**Table 6: Central Manager Choices**

| | | Message D2 | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Message D1 | 1 | 1.35<br>(0.72) | --- | --- | --- | --- |
| | 2 | 2.00<br>(1.10) | 2.23<br>(0.62) | --- | --- | --- |
| | 3 | 2.46<br>(1.01) | 2.69<br>(0.60) | 2.98<br>(0.50) | --- | --- |
| | 4 | 2.79<br>(1.28) | 3.14<br>(0.86) | 3.55<br>(0.57) | 3.75<br>(0.74) | --- |
| | 5 | 3.11<br>(1.44) | 3.24<br>(1.28) | 3.73<br>(0.95) | 4.12<br>(0.79) | 4.74<br>(0.65) |

On aggregate, the CMs seem to realize that the division managers' messages contain valuable information. Table 6 shows the CM's average choices as a function of the messages sent by the two division managers, with standard deviations shown in parentheses. The relationship between messages and CMs' choices are similar across the three centralization treatments, so we have pooled the data across treatments. Note that the messages from D2 are ***not*** being remapped. Cells where D2's message is greater than D1's message have been left blank due to the small number of observations. One can easily see that when the two messages coincide the CM follows those messages rather closely. When the two messages differ, the CM's choices are increasing in a division's message (holding the other division's message fixed). Hence, the CMs consistently respond to the divisions' messages. The standard deviation grows as the difference between the divisions' messages increases. This presumably reflects the increased difficulty of interpreting the messages when they do not agree.

**Table 7: Regression Analysis of Information Usage**

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Dependent Variable | Row/Column | Row/Column | Row/Column | Row/Column |
| Game | 0.207*** (0.030) | | | |
| D1 Message | | 0.406*** (0.027) | 0.371*** (0.055) | 0.323*** (0.034) |
| D2 Message | | 0.368*** (0.039) | 0.400*** (0.052) | 0.340*** (0.044) |
| Stranger | | | 0.193 (0.338) | 0.062 (0.107) |
| Stranger * D1 Message | | | 0.022 (0.063) | |
| Stranger * D2 Message | | | -0.071 (0.081) | |
| High State Loss | | | -0.178 (0.430) | 0.099 (0.096) |
| High State Loss * D1 Message | | | 0.068 (0.087) | |
| High State Loss * D2 Message | | | -0.002 (0.092) | |
| Strangers * Lagged Truth (D1) | | | | -0.379 (0.326) |
| Strangers * Lagged Truth (D2) | | | | -0.364 (0.256) |
| Partners * Lagged Truth (D1) | | | | 0.094 (0.143) |
| Partners * Lagged Truth (D2) | | | | -0.541*** (0.186) |
| Strangers * D1 Message * Lagged Truth (D1) | | | | 0.096 (0.061) |
| Strangers * D2 Message * Lagged Truth (D2) | | | | 0.138** (0.066) |
| Partners * D1 Message * Lagged Truth (D1) | | | | -0.032 (0.056) |
| Partners * D2 Message * Lagged Truth (D2) | | | | 0.127** (0.065) |
| Log-likelihood | -2600.34 | -2371.11 | -2366.71 | -2220.13 |
| # Observations | 1,748 | 1,748 | 1,748 | 1,658 |

Note: Standard errors, reported in parentheses, are corrected for clustering at the session level (strangers matching) or the group level (partners matching). Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% levels respectively. Only observations where divisions' product types are coordinated ($T_1 = T_2$) are included in the regression.

Table 7 looks more formally at the relationship between DMs' messages and the CM's choices through regression analysis. The dataset only includes observations where the CM choose the same product type for both divisions, imposing coordination ($T_1 = T_2$). This eliminates 34 out of 1782 observations, but allows us to summarize a CM's choice as a single number. The dependent variable is the row/column (1, 2, 3, 4, or 5) chosen by the CM. The CM's choices are categorical and ordered in nature, so we use an ordered probit model. Standard errors are corrected for clustering at the session level (strangers matching) or the group level (partners matching).

If information is being transmitted from the divisions to the CM, the CMs' choices should be correlated with the game being played. In Model 1, the sole dependent variable (other than period dummies) is the game being played. The estimate is positive and significant, indicating that successful information transmission occurs. Model 2 looks directly at the effect of the divisions' messages, with the messages of D1 and D2 added as separate variables. Both estimates are positive and significant, consistent with our observation from Table 5 that CMs are responding to the divisions' messages. The two estimates are virtually identical (and not significantly different). There is no particular reason for CMs to be more systematically more responsive to one division than the other, and indeed they aren't. Model 3 adds a dummy for the Stranger and High State Loss treatments as well as interactions between these dummies and the messages from the two divisions. None of these added variables are significant. There is no significant difference in responses to messages across the three treatments.

Model 4 looks at a different aspect of how CMs respond to divisions' messages. Recall that the feedback allows CMs to know, *ex post*, whether D1 or D2 lied. Model 4 modifies Model 2 by adding information about whether D1 or D2 told the truth in the previous period. In the Stranger treatment the CM knows that a lagged observation of truth-telling came from a *different* subject than the current division manager, but in either treatment with a partners matching (Baseline and High State Loss) the CM knows that it came from the *same* division manager who sent the current message. We therefore expect the response to previous truth-telling to differ across the two types of matching. For each type of matching and each division manager (D1 and D2), we add a dummy for whether the CM observed truth telling by that division manager in the previous round plus an interaction between that dummy and the division manager's current message (data from Round 1 are dropped since there is no previous round). This adds eight variables to the regression, two for each cell of matching type and division manager. We also add dummies for the Stranger and High State Loss treatment to avoid biasing the estimates for the terms relating to past truthfulness. For the Stranger treatment, none of the four variables related to past truthfulness are significant, but for the partners matching treatments, three of the four variables are statistically significant. For both division managers, the term for lagged truthfulness is negative and the interaction with the division managers' current message is positive. With partner matching CMs are more sensitive to a message from a division manager who they know told the truth in the previous period.

**Result 8:** *CMs respond to the division managers' messages. With partners matching a history of truth-telling makes CMs more sensitive to division managers' messages.*

Just because CMs respond to the information contained in divisions' messages doesn't mean that their use of this information is optimal. We frequently observe mistakes in CMs' use of the information contained in the divisions' messages. Many of these mistakes are hard to explain since the best response seems obvious.[25] For example, in the frequent cases (29% of all observations) where the two divisions' messages match ($M_1 = M_2$), they are almost certainly telling the truth (97%). Not surprisingly, it is strongly a best response to assign both divisions the product type that corresponds to their messages ($T_1 = T_2 = M_1 = M_2$). Aggregating over the five possible cases, the CM does *not* play the best response in 19% of the observations. These CMs earn an average payoff of 62.7 ECUs, compared with 79.3 ECUs for those who play the best response.

Failures to best respond when the divisions send identical messages largely occur because CMs are drawn to the safe outcome. For cases where the divisions' messages match and the safe and efficient outcomes can be distinguished ($M_1 = M_2 \neq 3$), CMs fail to play the best response in 23% of the observations even though there is still a 97% chance the divisions are telling the truth. In 70% of these failures to best respond, the CM chooses the safe outcome ($T_1 = T_2 = 3$).

Given that this is both a serious and obvious error, we might expect it to disappear with experience. This is only true to a limited extent. Failure to play the best response when the divisions' messages agree drops from 23% in the first half of the experiment to 15% in the second half of the experiment. However, this is almost entirely due an increasing frequency of CMs choosing $T_1 = T_2 = 3$ when both divisions send a message of 3 (79% in the first nine rounds vs. 98% in the final nine rounds). When the divisions agree and do *not* send a message of 3, the frequency of failures to best respond is 24% in the first half of the experiment versus 22% in the second half.

The preceding makes it appear that CMs' mistakes are due solely to being overly cautious, but the opposite occurs as well. Suppose D1 sends a message of 5 and D2 sends a message of 1 (22% of all observations). Obviously at least one of the divisions is lying. Given that each division is sending the message that is most to their advantage, there is no obvious reason to believe one over the other. Indeed, the safe outcome ($T_1 = T_2 = 3$) is clearly the best choice because it both maximizes the expected payoff of CMs and, as the name implies, minimizes the variance of CM's payoffs. 63% of CMs don't play the safe

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[25] This refers empirical best responses, not theoretical constructions. For each combination of messages observed in the data, we calculate the average payoff the CM would have achieved by always choosing $T_1 = T_2 = 1$, $T_1 = T_2 = 2$, etc. The best response is the product type that maximizes the CM's average payoff.

outcome. This figure only decreases slightly with experience, going from 65% in Rounds 1 – 9 to 61% in Rounds 10 – 18. When CMs don't play the safe outcome, they almost always follow the message from one division and ignore the other: if $M_1 = 5$ and $M_2 = 1$, 48% of all assignments (77% of non-best responses) by CMs are either $T_1 = T_2 = 1$ or $T_1 = T_2 = 5$. This error reduces the CMs' average payoffs (67.1 vs 61.2 ECUs), but the CMs don't learn to stop making it (48% in Rounds 1 – 9 vs. 49% in Rounds 10 – 18).[26]

Errors in using the information contained in divisions' messages explain why CMs in the Centralized treatment do no better than a babbling equilibrium. Averaging across all observations from treatments with centralization, the average total surplus is 69.4. CMs would have generated an average total surplus of 69.7 by always choosing the safe outcome ($T_1 = T_2 = 3$). Using a Wilcoxon matched-pairs signed-rank test, this difference is not significant ($n = 59$; $z = 0.99$; $p > .10$). However, suppose they had adopted the following simple strategy. If the divisions' messages agree, choose the product type that matches their messages. If $M_1 = 2$ and $M_2 = 1$, set $T_1 = T_2 = 2$. If $M_1 = 5$ and $M_2 = 4$, set $T_1 = T_2 = 4$. The preceding two cases cover situations where the divisions "almost" agree. For all other pairs of outcomes choose the safe outcome ($T_1 = T_2 = 3$). This simple strategy amounts to avoiding the most obvious errors: not following the divisions when their messages agree and following one division over the other when their messages clearly disagree. This simple strategy would have yielded an average total surplus of 72.6, which is significantly more than what CMs actually achieved ($n = 59$; $z = 5.42$; $p < .01$). This may not seem like much of a gain, but recall that the maximum possible total surplus is 80. Compared to always playing the safe outcome, our CMs actually did worse. If they had avoided obvious errors by playing the safe strategy, they would have gained 28% of the maximum possible gains from using the divisions' information.

**Result 9:** *CMs systematically make errors using the information contained in divisions' messages. These mistakes are responsible for their failure to beat the babbling equilibrium.*

*4.3: Alternative Forms of Communication:*

Contrary to our hypotheses, neither treatment combining decentralization with communication (Horizontal Communication and Manager Suggestions) has much impact on total surplus. In neither case does surplus rise to the levels seen under centralization, let alone the theoretical maximum total surplus of 80. This subsection considers the messages sent in these two treatments in greater depth to gain insight into the relatively poor performance.

The Horizontal Communication treatment only has a limited impact because it creates a different but still challenging coordination problem for divisions. Rather than having to coordinate on product types,

[26] We conjectured that departures from choosing $T_1 = T_2 = 3$ are due to one division having been more truthful than the other in the past. This is not obvious in the data. When the two divisions were equally truthful in the previous period, there is a 40% chance of choosing $T_1 = T_2 = 3$ versus 36% if one division was truthful and the other wasn't.

the game with horizontal communication tests the ability of divisions to coordinate on messages. If divisions agree following the third round of communication, they almost always coordinate (96%). The problem is that the divisions only reach an agreement in 63% of the observations. The divisions still manage to coordinate sometimes when they don't reach an agreement, but the rate is low (40%).

Agreeing to coordinate does not make the divisions much more likely to coordinate at the efficient outcome subject to coordinating (53% with an agreement, 49% without). This follows from the nature of agreements. For games where the efficient and safe equilibrium do not coincide ($G \neq 3$), 63% of agreements call for play of the safe equilibrium. When the divisions agree on the efficient equilibrium (33% of agreements when $G \neq 3$), they always play the agreed upon equilibrium. The problem is that agreeing on an efficient equilibrium doesn't happen very often.

It is tempting to think that groups will become better at reaching agreements with experience or that some groups always agree while others never do. Neither of these statements is true. The agreement rate only rises slightly with experience, increasing from 59% in Rounds 1 – 9 to 66% in Rounds 10 – 18. There are groups that almost always reach agreements (16 – 18 agreements; 8/27 groups) and groups that rarely reach agreements (0 – 2 agreements, 2/27 groups), but most groups fall between these extremes (3 – 15 agreements, 17/27 groups). Not surprisingly, this inconsistency relates to the game being played. Reaching an agreement is relatively easy in Game 3, where the two divisions are in a symmetric position (75%), but agreeing is harder in the other four games (59%). Even with the assistance of multiple rounds of horizontal messages, coordination remains a formidable problem.

Turning to the Manager Suggestions treatment, in which CMs provide suggestions for division managers' choices in each possible game, guidance from the CM is fairly effective. To set terminology, we say the CM "suggested the safe equilibrium" if *for the realized game* the CM's message called for play of the safe equilibrium ($T_1 = T_2 = 3$). Suggesting the efficient equilibrium or an "other equilibrium" are defined in an analogous fashion. When suggestions of the safe and efficient equilibrium coincide in $G = 3$, we classify the CM as having suggested the safe equilibrium. The probability that the divisions coordinate is high when the CM suggests either the safe or the efficient equilibrium (71% and 68% respectively, averaging across all games and all rounds). This compares well with 40% for all other suggestions as well as the 58% coordination rate in the Baseline treatment under decentralization. If the divisions coordinate, they generally follow the CMs' suggestions. When the safe equilibrium is suggested *and the divisions coordinate*, they almost always coordinate on the safe equilibrium (99%). Likewise, the divisions usually coordinate on the efficient equilibrium (92%) if it is suggested *and the divisions coordinate*.

The strong correlation between suggestions and outcomes does not prove causality. Given the major role of precedence in coordination games, both the suggestions and the outcomes may reflect lagged outcomes. For example, a CM may suggest the safe equilibrium because she knows the divisions have previously coordinated on the safe equilibrium. The regressions in Table 8 address this issue of causality. The data are all observations from the Manager Suggestions treatment and the Baseline treatment with decentralization. The dependent variables are a dummy for coordinating ($T_1 = T_2$) in Model 1, a dummy for the safe equilibrium ($T_1 = T_2 = 3$) in Model 2, and a dummy for the efficient equilibrium ($T_1 = T_2 = G$) in Model 3. Since these are binary outcomes, all of the regressions use probit models. We report marginal effects with standard errors corrected for clustering at the group level.

**Table 8: Regression Analysis, Effects of Manager Suggestions**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Dependent Variable | Coordinate | Safe Equilibrium | Efficient Equilibrium |
| Suggest Safe Equilibrium | 0.064<br>(0.075) | 0.194**<br>(0.082) | -0.059<br>(0.043) |
| Suggest Efficient Equilibrium (Game ≠ 3) | 0.175***<br>(0.067) | -0.356***<br>(0.063) | 0.562***<br>(0.102) |
| Suggest Other Equilibrium | -0.223**<br>(0.106) | -0.270***<br>(0.076) | -0.119<br>(0.083) |
| Don't Suggest Equilibrium | -0.096<br>(0.109) | -0.198**<br>(0.079) | 0.014<br>(0.068) |
| Lagged Safe Equilibrium | 0.260***<br>(0.052) | 0.445***<br>(0.059) | -0.029<br>(0.035) |
| Lagged Efficient Equilibrium | 0.110**<br>(0.048) | -0.080*<br>(0.042) | 0.139**<br>(0.058) |
| Lagged Other Equilibrium | 0.319***<br>(0.055) | -0.199*<br>(0.106) | 0.028<br>(0.131) |
| Log-likelihood | -513.71 | -406.96 | -362.42 |
| # Observations | 918 | 918 | 918 |

Note: Data from Period 1 are dropped to allow use of lagged variables. Standard errors, reported in parentheses, are corrected for clustering at the group level. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% levels respectively.

As independent variables, all three regressions include the CM's suggestion in the current round. These four variables (Suggest Safe, Suggest Efficient, Suggest Other, and Don't Suggest Equilibrium) capture all possible suggestions. The associated parameter estimates measure differences from the Baseline treatment under decentralization. For example, the parameter estimate for Suggest Safe in Model 1 captures how much higher the probability of coordinating is following a suggestion of the safe equilibrium in the Manager Suggestions treatment as compared to the Baseline treatment under decentralization where no suggestions are possible. Dummies for the lagged outcome are included in all three regressions. Data from the first period are dropped due to the use of a lagged variable. All three models include game and period dummies. These are not reported to save space.

The results differ somewhat from our observations from the raw data. Once we control for the lagged outcome, the results of Model 1 indicate that suggesting the safe equilibrium only has a small (and not significant) effect on the likelihood of coordinating relative to the Baseline treatment. Suggesting the efficient equilibrium, which looks less effective in the raw data, has a large and strongly significant effect. Suggestion of another equilibrium has a strong *negative* effect relative to the baseline.

Model 2 finds that suggesting the safe equilibrium significantly increases the probability of playing the safe equilibrium relative to the Baseline treatment, while suggesting the efficient equilibrium significantly reduces the likelihood of the safe equilibrium. These effects are consistent with the raw data, but, somewhat to our surprise, the second effect is significantly stronger than the first ($\chi^2 = 4.30$, $p < .05$). Model 3 shows that suggesting the efficient equilibrium increases the likelihood of the efficient equilibrium relative to the Baseline treatment, but suggesting the safe equilibrium has little effect. Overall, the message from the regressions is clear. The CMs' suggestions impact outcomes. The most powerful sort of suggestion (from a positive point of view) is a call for the efficient equilibrium.

The preceding implies that CMs in the Manager Suggestions treatment could be quite helpful if they gave good advice by calling for play of the efficient equilibrium. The problem is that CMs generally don't give good advice. It is striking that 15% of messages (based on *all* five messages sent in each period for each of the possible games, regardless of whether the game was realized or not) do not even call for the divisions to coordinate their product types. Given that CMs in the centralization treatments almost always choose the same product type for the two divisions, it is hard to fathom why CMs would give advice to *not* coordinate. More to the point, suggesting the efficient equilibrium is less common than its efficacy would suggest. Excluding Game 3, where the safe and efficient equilibrium coincide, only 36% of all messages suggest the efficient equilibrium. This percentage increases with experience, but only slightly, rising from 34% in Rounds 1 – 9 to 38% in Rounds 10 – 18.

**Result 10:** *Performance in the Horizontal Communication treatment is limited by frequent failures to reach an agreement between the divisions. In the Manager Suggestions treatment, poor outcomes can be attributed to the failure of CMs to suggest play of the efficient equilibrium.*

**5. Concluding Remarks:** The question of whether to centralize or decentralize decision making comes up in numerous economic settings. Our experiments use a new game, the decentralization game, to study how organizations perform under centralization and decentralization. Ideally, the divisions would coordinate on a single product type *and* make use of the divisions' private information. Standard theory suggests that the maximum total surplus can be achieved under decentralization, but this relies on divisions not only coordinating, but also coordinating on the efficient equilibrium. Under centralization the predicted outcome is a babbling equilibrium that fails to use the divisions' information.

We observe significantly higher total surplus under centralization than decentralization. This reflects frequent coordination failure under decentralization. Performance under decentralization is also limited by a strong tendency to coordinate on playing the safe equilibrium regardless of the state of the world. If the primary advantage of decentralization is direct access to the divisions' information, use of an equilibrium that does not respond to the state of the world eliminates this advantage.

Centralization does no better than the babbling equilibrium, but the babbling equilibrium is not being played. There is better information transmission from divisions to central managers than expected with centralization, reflecting a bias towards truth-telling, but the benefits of successful information transmission are almost completely offset by failures to respond correctly to this information.

Our hope was that either messages between divisions (Horizontal Communication) or advice from the central manager (Manager Suggestions) would act as a coordination device under decentralization, making it possible to combine the informational benefits of decentralization with the coordination offered by centralization. The reality falls far short of this, as total surplus is higher under centralization than in either of the two treatments adding communication to decentralization. Centralization is far from perfect, but the almost 100% coordination that occurs with centralization makes it by far the best-performing form of organization in our experiments.

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**Table 1: Stage Game Payoffs**

Note: Each cell contains the payoffs for D1 ($\pi_{D1}$), D2 ($\pi_{D2}$), and CM ($\pi_{CM}$).

**Game 1**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| R1 | 26, 54, 80 | 12, 29, 41 | -2, 4, 2 | -16, -21,-37 | -30,-46,-76 |
| R2 | 15, 40, 55 | 29, 43, 72 | 15, 18, 33 | 1, -7, -6 | -13, -32,-45 |
| R3 | 4, 26, 30 | 18, 29, 47 | 32,32, 64 | 18, 7, 25 | 4, -18, -14 |
| R4 | -7, 12, 5 | 7, 15, 22 | 21, 18, 39 | 35, 21, 56 | 21, -4, 17 |
| R5 | -18, -2, -20 | -4, 1,-3 | 10, 4, 14 | 24, 7, 31 | 38, 10, 48 |

**Game 2**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| R1 | 22, 50, 72 | 8, 33, 41 | -6, 8, 2 | -20, -17, -37 | -34,-42,-76 |
| R2 | 19, 36, 55 | 33, 47, 80 | 19, 22, 41 | 5, -3, 2 | -9, -28,-37 |
| R3 | 8, 22, 30 | 22,33, 55 | 36, 36, 72 | 22, 11, 33 | 8, -14, -6 |
| R4 | -3,8, 5 | 11,19,30 | 25, 22, 47 | 39, 25, 64 | 25, 0, 25 |
| R5 | -14,-6,-20 | 0,5,5 | 14, 8, 22 | 28, 11, 39 | 42, 14, 56 |

**Game 3**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| R1 | 18, 46, 64 | 4, 29, 33 | -10,12, 2 | -24, -13, -37 | -38, -38, -76 |
| R2 | 15, 32, 47 | 29, 43, 72 | 15, 26, 41 | 1, 1, 2 | -13, -24,-37 |
| R3 | 12, 18, 30 | 26, 29, 55 | 40, 40, 80 | 26, 15, 41 | 12, -10,2 |
| R4 | 1,4, 5 | 15, 15, 30 | 29,26, 55 | 43,29, 72 | 29, 4, 33 |
| R5 | -10,-10,-20 | 4,1, 5 | 18,12, 30 | 32, 15, 47 | 46, 18, 64 |

**Game 4**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| R1 | 14, 42, 56 | 0, 25, 25 | -14, 8,-6 | -28, -9, -37 | -42, -34, -76 |
| R2 | 11, 28, 39 | 25, 39, 64 | 11, 22, 33 | -3, 5, 2 | -17,-20,-37 |
| R3 | 8, 14, 22 | 22, 25, 47 | 36, 36, 72 | 22, 19, 41 | 8, -6, 2 |
| R4 | 5, 0, 5 | 19, 11, 30 | 33, 22, 55 | 47, 33, 80 | 33, 8, 41 |
| R5 | -6,-14,-20 | 8, -7, 5 | 22, 8, 30 | 36, 19, 55 | 50, 22, 72 |

**Game 5**

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| R1 | 10, 38, 48 | -4, 21, 17 | -18, 4,-14 | -32,-13,-45 | -46,-30, -76 |
| R2 | 7, 24, 31 | 21, 35, 56 | 7, 18, 25 | -7, 1,-6 | -21,-16,-37 |
| R3 | 4, 10, 14 | 18, 21, 39 | 32, 32, 64 | 18, 15, 33 | 4, -2, 2 |
| R4 | 1,-4,-3 | 15, 7, 22 | 29, 18, 47 | 43, 29, 72 | 29, 12, 41 |
| R5 | -2,-18,-20 | 12,-7, 5 | 26,4, 30 | 40, 15, 55 | 54, 26, 80 |

## Appendix A: Proof of Theorem

**Lemma:** For any beliefs, the central manager (CM) will choose the same actions for the two divisions (D1 and D2).

**Proof:** Suppose not. This implies the CM is choosing an outcome that is not a Nash equilibrium if the two divisions are allowed to choose their own actions. Either of the divisions could improve its payoff by switching to the action chosen by the other division. Moreover, the other division's payoff is also increased by this change. Since the CM's payoff equals the sum of the two divisions' payoffs, the CM's payoff also increases. This implies that the CM's initial choice could not have been optimal.

Given the preceding lemma, we can refer to the CM as choosing a single action in response to the divisions' messages.

**Theorem:** There does not exist a pure-strategy PBE where the CM chooses different actions for two different states of the world.

**Proof:** Suppose that such an equilibrium existed. Let S1 and S2 be two states where different actions are chosen. Let A1 and A2 be the actions chosen by the CM in equilibrium in S1 and S2 respectively, where A1 ≠ A2. Without loss of generality, assume that D1 prefers the outcome in S1 and D2 prefers the outcome in S2. Let $M_i^j$ be the message sent by Di in Sj.

It cannot be the case that $M_1^1 = M_1^2$. Proof is by contradiction. Suppose $M_1^1 = M_1^2$. This implies that the CM's choice is determined solely by D2's message. Since D2 prefers A2, it should always send $M_2^2$ whether the true state of the world is S1 or S2. But then the CM would choose A2 in both S1 and S2. A contradiction follows. By the same logic, $M_2^1 \neq M_2^2$.

Suppose that D1 deviates by sending $M_1^1$ in S2. The resulting pair of messages ($M_1^1$, $M_2^2$) cannot make D1 better off than A2 or a profitable deviation from equilibrium exists. It follows that ($M_1^1$, $M_2^2$) leads to an outcome that makes D1 worse off (weakly) than A2. However, because the two divisions' preferences over possible outcomes are diametrically opposed, this implies that D2 can gain by sending $M_2^2$ in S1, giving D2 a profitable deviation from equilibrium. A contradiction follows. **Q.E.D.**

**Appendix B: INSTRUCTIONS**

**DECENTRALIZATION TREATMENT**

Thanks for coming to the experiment. You will receive 5 euros for participation in the experiment. Also, you will earn additional money during the experiment.

Participants have been randomly assigned to one of three roles: F, C and A. This role will be the same throughout the experiment.

There will be 18 separate periods. We will now present the instructions for the first block of nine periods. Later you will receive further instructions. In each period, you will be in a group of three participants, one in each role. The persons that you are matched with will change from period to period. During the nineperiods you will never meet another person twice. Also, at no time will you know the identity of who you are matched with.

Each period is independent from the others and develops in the following way. At the beginning of the period, the computer will randomly determine which of the following five games will be played.

In each of the cells the first number shown in yellow is the payoff that the person in the F role will receive, the second number shown in green is the payoff that the person in the C role will receive and the third number shown in red is the payoff for the person in the A role. As you can see all five games have five rows: f1, f2, f3, f4 and f5 [Note: The Spanish word for row is “fila”.  We have kept the original abbreviations in the payoff tables.], and five columns; c1, c2, c3, c4 and c5. [Note: The Spanish word for row is “fila”.  We have kept the original abbreviations in the payoff tables shown below.] Observe also that the numbers in the different cells differ between the games.

Game 1

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 26, 54, 80 | 12, 29, 41 | -2, 4, 2 | -16, -21,-37 | -30,-46,-76 |
| f2 | 15, 40, 55 | 29, 43, 72 | 15, 18, 33 | 1, -7, -6 | -13, -32,-45 |
| f3 | 4, 26, 30 | 18, 29, 47 | 32,32, 64 | 18, 7, 25 | 4, -18, -14 |
| f4 | -7, 12, 5 | 7, 15, 22 | 21, 18, 39 | 35, 21, 56 | 21, -4, 17 |
| f5 | -18, -2, -20 | -4, 1,-3 | 10, 4, 14 | 24, 7, 31 | 38, 10, 48 |

Game 2

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 22, 50, 72 | 8, 33, 41 | -6, 8, 2 | -20, -17, -37 | -34,-42,-76 |
| f2 | 19, 36, 55 | 33, 47, 80 | 19, 22, 41 | 5, -3, 2 | -9, -28,-37 |
| f3 | 8, 22, 30 | 22,33, 55 | 36, 36, 72 | 22, 11, 33 | 8, -14, -6 |
| f4 | -3,8, 5 | 11,19,30 | 25, 22, 47 | 39, 25, 64 | 25, 0, 25 |
| f5 | -14,-6,-20 | 0,5,5 | 14, 8, 22 | 28, 11, 39 | 42, 14, 56 |

Game 3

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 18, 46, 64 | 4, 29, 33 | -10,12, 2 | -24, -13, -37 | -38, -38, -76 |
| f2 | 15, 32, 47 | 29, 43, 72 | 15, 26, 41 | 1, 1, 2 | -13, -24,-37 |
| f3 | 12, 18, 30 | 26, 29, 55 | 40, 40, 80 | 26, 15, 41 | 12, -10,2 |
| f4 | 1,4, 5 | 15, 15, 30 | 29,26, 55 | 43,29, 72 | 29, 4, 33 |
| f5 | -10,-10,-20 | 4,1, 5 | 18,12, 30 | 32, 15, 47 | 46, 18, 64 |

Game 4

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 14, 42, 56 | 0, 25, 25 | -14, 8,-6 | -28, -9, -37 | -42, -34, -76 |
| f2 | 11, 28, 39 | 25, 39, 64 | 11, 22, 33 | -3, 5, 2 | -17,-20,-37 |
| f3 | 8, 14, 22 | 22, 25, 47 | 36, 36, 72 | 22, 19, 41 | 8, -6, 2 |
| f4 | 5, 0, 5 | 19, 11, 30 | 33, 22, 55 | 47, 33, 80 | 33, 8, 41 |
| f5 | -6,-14,-20 | 8, -7, 5 | 22, 8, 30 | 36, 19, 55 | 50, 22, 72 |

Game 5

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 10, 38, 48 | -4, 21, 17 | -18, 4,-14 | -32,-13,-45 | -46,-30, -76 |
| f2 | 7, 24, 31 | 21, 35, 56 | 7, 18, 25 | -7, 1,-6 | -21,-16,-37 |
| f3 | 4, 10, 14 | 18, 21, 39 | 32, 32, 64 | 18, 15, 33 | 4, -2, 2 |
| f4 | 1,-4,-3 | 15, 7, 22 | 29, 18, 47 | 43, 29, 72 | 29, 12, 41 |
| f5 | -2,-18,-20 | 12,-7, 5 | 26,4, 30 | 40, 15, 55 | 54, 26, 80 |

Each of the five games has the same chance of being chosen in each period separately. That is in each period, each of the games will be chosen with 20%probability. Player F and player C will be informed of which game has been chosen, but player A will not be informed of which game has been chosen.

After having seen which game has been selected by the random draw, players F and player C will separately make decisions. Player F will choose between f1, f2, f3, f4 and f5 and player C will choose between columns c1, c2, c3, c4 and c5. Player A will not make any decisions.

The payoffs of players F, C and A will be the ones in the cell determined by the row chosen by F and the column chosen by C for the game selected by the random draw. Remember that players F and C will make their decisions independently from each other.

After each period everybody will be informed about what row was chosen by F and what column was chosen by C sent and about which game was randomly selected.

After this, a new period will start which will develop in the same way until reaching period 9. Remember that the persons you play with will change from period to period.

Each ECU is worth 0,02 euros. At the end of the session you will receive 5 euros plus what you will have earned in all 18 rounds of the experiment.

You can ask questions at any time. If you have a question, please raise your hand and one of us will come to your place to answer it.

## INSTRUCTIONS
## CENTRALIZATION TREATMENT

Thanks for coming to the experiment. You will receive 5 euros for participation in the experiment. Also, you will earn additional money during the experiment.

Participants have been randomly assigned to one of three roles: F, C and A. This role will be the same throughout the experiment.

There will be 18 separate periods. We will now present the instructions for the first block of nine periods. Later you will receive further instructions. In each period, you will be in a group of three participants, one in each role. The persons that you are matched with will change from period to period. During the nine periods you will never meet another person twice. Also, at no time will you know the identity of who you are matched with.

Each period is independent from the others and develops in the following way. At the beginning of the period, the computer will randomly determine which of the following five games will be played.

In each of the cells the first number shown in yellow is the payoff that the person in the F role will receive, the second number shown in green is the payoff that the person in the C role will receive and the third number shown in red is the payoff for the person in the A role. As you can see all five games have five rows: f1, f2, f3, f4 and f5, and five columns; c1, c2, c3, c4 and c5. Observe also that the numbers in the different cells differ between the games.

Game 1

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 26, 54, 80 | 12, 29, 41 | -2, 4, 2 | -16, -21,-37 | -30,-46,-76 |
| f2 | 15, 40, 55 | 29, 43, 72 | 15, 18, 33 | 1, -7, -6 | -13, -32,-45 |
| f3 | 4, 26, 30 | 18, 29, 47 | 32,32, 64 | 18, 7, 25 | 4, -18, -14 |
| f4 | -7, 12, 5 | 7, 15, 22 | 21, 18, 39 | 35, 21, 56 | 21, -4, 17 |
| f5 | -18, -2, -20 | -4, 1,-3 | 10, 4, 14 | 24, 7, 31 | 38, 10, 48 |

Game 2

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 22, 50, 72 | 8, 33, 41 | -6, 8, 2 | -20, -17, -37 | -34,-42,-76 |
| f2 | 19, 36, 55 | 33, 47,80 | 19, 22, 41 | 5, -3, 2 | -9, -28,-37 |
| f3 | 8, 22, 30 | 22,33, 55 | 36, 36, 72 | 22, 11, 33 | 8, -14, -6 |
| f4 | -3,8, 5 | 11,19,30 | 25, 22, 47 | 39, 25, 64 | 25, 0, 25 |
| f5 | -14,-6,-20 | 0,5,5 | 14, 8, 22 | 28, 11, 39 | 42, 14, 56 |

Game 3

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 18, 46, 64 | 4, 29, 33 | -10,12, 2 | -24, -13, -37 | -38, -38, -76 |
| f2 | 15, 32, 47 | 29, 43, 72 | 15, 26, 41 | 1, 1, 2 | -13, -24,-37 |
| f3 | 12, 18, 30 | 26, 29, 55 | 40, 40, 80 | 26, 15, 41 | 12, -10,2 |
| f4 | 1,4, 5 | 15, 15, 30 | 29,26, 55 | 43,29, 72 | 29, 4, 33 |
| f5 | -10,-10,-20 | 4,1, 5 | 18,12, 30 | 32, 15, 47 | 46, 18, 64 |

Game 4

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 14, 42, 56 | 0, 25, 25 | -14, 8,-6 | -28, -9, -37 | -42, -34, -76 |
| f2 | 11, 28, 39 | 25, 39, 64 | 11, 22, 33 | -3, 5, 2 | -17,-20,-37 |
| f3 | 8, 14, 22 | 22, 25, 47 | 36, 36, 72 | 22, 19, 41 | 8, -6, 2 |
| f4 | 5, 0, 5 | 19, 11, 30 | 33, 22, 55 | 47, 33, 80 | 33, 8, 41 |
| f5 | -6,-14,-20 | 8, -7, 5 | 22, 8, 30 | 36, 19, 55 | 50, 22, 72 |

Game 5

| | c1 | c2 | c3 | c4 | c5 |
|---|---|---|---|---|---|
| f1 | 10, 38, 48 | -4, 21, 17 | -18, 4,-14 | -32,-13,-45 | -46,-30, -76 |
| f2 | 7, 24, 31 | 21, 35, 56 | 7, 18, 25 | -7, 1,-6 | -21,-16,-37 |
| f3 | 4, 10, 14 | 18, 21, 39 | 32, 32, 64 | 18, 15, 33 | 4, -2, 2 |
| f4 | 1,-4,-3 | 15, 7, 22 | 29, 18, 47 | 43, 29, 72 | 29, 12, 41 |
| f5 | -2,-18,-20 | 12,-7, 5 | 26,4, 30 | 40, 15, 55 | 54, 26, 80 |

Each of the five games has the same chance of being chosen in each period separately. That is in each period, each of the games will be chosen with 20%probability. Player F and player C will be informed of which game has been chosen, but player A will not be informed of which game has been chosen.

After having seen which game has been selected by the random draw, players F and player C will separately send messages to player A saying which game has been selected . This message can be truthful or not. Once player A has received the messages he will choose a row and column without knowing which game was selected.

The payoffs of players F, C and A will be the ones in the cell determined by the row and the column chosen by A for the game selected by the random draw. Remember that players F and C willsend their messages independently from each other.

After each period everybody will be informed about what row and what column was chosen by A and about which game was randomly selected.

After this, a new period will start which will develop in the same way until reaching period 9. Remember that the persons you play with will change from period to period.

Each ECU is worth 0,02 euros. At the end of the session you will receive 5 euros plus what you will have earned in all 18 rounds of the experiment.

You can ask questions at any time. If you have a question, please raise your hand and one of us will come to your place to answer it.