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William N. Dilla
Marya L. Leatherwood
Richard J. Boland

College of Commerce and Business Administration
Bureau of Economic and Business Research
University of Illinois Urbana-Champaign

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William N. Dilla
Assistant Professor of Accountancy
University of Illinois at Urbana-Champaign

Marya L. Leatherwood
Assistant Professor of Business Administration
University of Illinois at Urbana-Champaign

Richard J. Boland
Professor of Management Information Systems
Case Western Reserve University

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ABSTRACT

Organizations are increasingly using information technologies as a means for coordinating the independent decision making activities of individual agents. Two important factors which facilitate such coordination are organizational communication pattern and the nature of incentives provided to individual agents.

In this paper, we investigate the effects on organizational performance of different communication structures, under both conflicting and nonconflicting incentive schemes. We report the results of a laboratory experiment designed to test hypotheses based on prescriptive design viewpoints espoused by Ackoff (1967) and Rappaport (1968) against hypotheses based on game-theoretic and decision-theoretic models. Student participants were paired into dyads and assigned the role of either a purchasing or merchandising manager. Participant teams were compensated based on one of two incentive schemes (conflicting and nonconflicting) and given one of three types of communication structures (no communication, unidirectional communication, and bidirectional communication).

The results show that teams with communication performed significantly better than those with no access, regardless of incentives structure. For conflicting incentives, this is consistent with the predictions of a game-theoretic model. For nonconflicting incentives, this is inconsistent with the assumption of perfect rationality, but consistent with alternative views on communication.

The analyses indicated no significant differences in performance between a simple, unidirectional communication structure, and a bidirectional structure, where a series of messages was sent between agents. Thus, for tasks such as the one examined in this study, a rudimentary communication system may achieve effective coordination of decision making. Also, learning effects are stronger and more consistent under nonconflicting incentives than under conflicting, indicating more effective coordination may be possible with nonconflicting than with conflicting incentives.

COMMUNICATION STRUCTURES, INCENTIVE SYSTEMS AND COORDINATED DECISION MAKING

In today's organizational environments, decision issues are increasingly modularized and distributed among individual managers who must interact with each other to coordinate their independent decision making. In many cases, these managers are located at widely dispersed sites. Therefore, organizations are turning to information technologies as a medium for coordinating their activities in a distributed decision making environment. The emergence of organizational environments with modularized tasks has stimulated research on new principles of organization design to facilitate the interaction of individual agents (Huber, 1984; Huber and McDaniel, 1986; Malone 1987; Malone and Smith, 1988).

In this research, a number of factors which expedite effective coordination have been identified. Among these, the organizational communication pattern is considered to be particularly important. The structure of linkages between agents (e.g., Malone 1987; Malone and Smith, 1988), as well as the manner in which messages are distributed (Huber, 1982) are both posited to have significant effects on organizational performance. A second factor, which has received somewhat less emphasis, is the nature of incentives provided to agents within the organization. Huber and McDaniel (1986) indicate that decision units should be rewarded for the quality of their decisions, but give only very general guidance as to the types of reward systems that should be implemented.

The prescriptive management information systems literature also has addressed communication and incentives issues relevant to the design of systems which are compatible with the structures and processes of user organizations. A classic article by Ackoff (1967) gives advice on whether or not to allow communications between decision makers, as well as on other design factors. In particular, Ackoff indicates that restrictions should be placed on communication between agents in order to enhance corporate performance outcomes when agents are assigned to maximize divergent goals. In a response to Ackoff, Rappaport (1967) cautions that the degree of information access afforded agents may not be the crux of the problem. Instead, Rappaport suggests that organizational incentives need to be considered when designing information systems, as well. He argues that full communication between agents may be in the interest of an organization, if corporate incentive schemes are "appropriate" and "nonconflicting".

In this study, we investigate the effects on organizational performance of allowing communication access between agents, under both conflicting and nonconflicting incentives schemes. For conflicting incentives, we develop and test a set of hypotheses which posit that communication may be a beneficial coordination mechanism, contrary to the viewpoint espoused by Ackoff (1967). The hypotheses are based on the assumption that individual agents act strategically. That is, agents consider the results of both their own actions and those of others in their environment when making decisions. This viewpoint is consistent with the assumptions of game-theoretic models, which have been applied to a variety of problems in business, economics, and public policy (e.g., Schotter and Schwödiauer, 1980; Ponssard, 1981; Shubik, 1982).

For nonconflicting incentives, we test Rappaport's viewpoint that communication will facilitate coordination of agents' activities when they have "appropriate" measures of performance. We also test a competing hypothesis which assumes that agents will approach the nonconflicting incentives scenario as a joint expected value maximization problem, where communication is not necessary to achieve an optimal solution.

In addition, we investigate the effects on performance of different types of communication structures, both under conflicting and nonconflicting incentives. This is done by comparing a simple communication structure, where a single message between agents is allowed, to a more complex one where multiple messages are allowed prior to agents' making a decision. We tested the propositions regarding communication in a simulated retailing environment similar to the one described by Ackoff (1967), in which participants assumed the role of merchandising or purchasing managers.

THEORETICAL DEVELOPMENT AND HYPOTHESES

Conflicting Incentives: The Ackoff Scenario

In his article, "Management Misinformation Systems", Ackoff (1967) described a retailing organization in which an information system provided full access to data and complete communication between two managers (merchandising and purchasing). The merchandising manager was evaluated based on gross sales; the purchasing manager was evaluated based on inventory turnover. Merchandising set the firm's selling prices, while purchasing determined order quantities. Merchandising made selling price decisions and order quantity requests based on optimistic estimates of sales demand. On the other hand, purchasing would consistently order less than merchandising had requested, not wanting to be penalized for poor inventory turnover. Upon learning of purchasing's actions, merchandising then would raise its selling price, after which purchasing would again lower its order quantity. According to Ackoff, this cycle of actions would continue if left unchecked, resulting in progressively deteriorating performance for the organization as a whole. His proposed solution is to stop all communication between the two managers and force them to "guess what the other was doing." His specific example is reproduced in Appendix A.

Conflicting Incentives: A Strategic Viewpoint

A fundamental problem with the Ackoff scenario is that the managers apparently ignore the effects their own actions would have on subsequent actions of the other manager. This is inconsistent with a strategic, or game-theoretic view of the world. We show here that the managers in Ackoff's scenario should be better off with communication than without, if they act in a strategic fashion.

First, consider the case where the managers must "guess what the other is doing", as Ackoff recommends. Figure 1 represents this case as a game in <u>extensive form</u>. The diagram is drawn as if merchandising first makes a price decision, purchasing makes a quantity decision, then a random market outcome occurs. However, the oval around the purchasing manager's nodes on the game tree indicates that purchasing's <u>information set</u> at the time he makes an order quantity decision does not include the selling price set by merchandising. Therefore, the game operates as if both managers were making their decisions simultaneously. The problem facing the managers is to determine a pair of actions such that neither individual, assuming the other is committed to their choice, can increase their payoff by unilaterally changing strategies. This pair of actions yields an <u>equilibrium point</u> (e.g., Shubik, 1982, p. 240).

A version of the Ackoff scenario with communication is shown in Figure 2. Here, the merchandising manager first chooses a price, which is communicated to purchasing. Then, purchasing chooses an order quantity, after which a random state of nature is realized. Merchandising knows that for a given selling price, purchasing will choose the order quantity that yields the highest expected value of inventory turnover. Therefore, merchandising must choose the selling price that yields the highest expected value of gross sales, in anticipation of purchasing's actions. This pair of actions is an equilibrium point for the scenario with communication. Even if one allows the managers to communicate price and quantity information back and forth several times before a state realization occurs, as occurs in Ackoff's example, it is still only the final price and quantity decisions that affect the payoffs to the two managers. Therefore, the complete Ackoff scenario can be modelled using a game tree such as that in Figure 2.

Insert Figures 1 and 2 about here.

Appendix B gives a numeric example for the Ackoff scenario which shows that the expected payoffs to both managers are greater when communication is allowed than when it is suppressed. Also, Appendix B uses a game theory result by Dubey and Shubik (1981) to show how in most cases, both managers will be better off with communication than without.

Another case to consider is what occurs when the Ackoff scenario is played out over a series of repeated trials. The game-theoretic analysis outlined here thus far presumes a single-period setting. However, players in a repeated noncooperative game may achieve outcomes which are Pareto improvements over single-period equilibrium outcomes through cooperation. They may play as if they were playing a cooperative, or bargaining game, since if one player "defects" from a cooperative solution, the other can "punish" him by changing strategies on the next round (Luce and Raiffa, 1957; Friedman, 1977). Therefore, it is possible that even pairs of managers with limited communication may achieve Pareto-optimal outcomes by coordinating their actions over time. However, it is still likely that pairs with communication will be better off than those without since the noncooperative "starting point" with communication yields higher expected payoffs for both managers than without.

Conflicting Incentives: Hypotheses

Based on the above discussion, there are two divergent hypotheses concerning performance under conflicting incentives when communication is and is not allowed.

H_{1A} (Ackoff): With conflicting incentives, performance outcomes will be less for dyads with communication than without.

H_{1B} (Strategic): With conflicting incentives, performance outcomes will be greater for dyads with communication than without.

Nonconflicting Incentives

As stated in the introduction, Rappaport (1968) suggests that communication between agents may be beneficial, if corporate incentive schemes are "appropriate" and "nonconflicting". However, he does not specify the "nonconflicting" incentives he had in mind. For purposes of this study, we operationalize a "nonconflicting" incentives scheme as an equal division of gross margin less inventory holding costs. The nonconflicting scheme is described more fully in Appendix C.

As shown in Appendix C, compensation for the two agents has a unique maximum. From a decision-theoretic viewpoint, communication should not be necessary for the agents to jointly select the price and quantity that will yield maximum compensation, if both are expected value maximizers (i.e., are risk-neutral). Even if one or both of the agents is not risk-neutral, outcome feedback from each trial conveys information about preferences. Therefore, they should be able to infer each others' risk preferences after a series of trials.

On the other hand, there may be limits to agents' abilities to infer each others' preferences. Not only is this a difficult problem to begin with, but it may be further complicated by individual preferences which are not stable across time. It seems reasonable to expect that allowing communication between agents under nonconflicting incentives may provide additional information that will assist them in overcoming their cognitive limitations. Indeed, March and Simon (1958, Ch. 6) indicate that communication between agents is one means by which organizations serve to mitigate the effects of individual agents' bounded rationality.

Rappaport (1968) does not explicitly mention this idea, but his assertions regarding communication as an aid to the decision maker are consistent with March and Simon's ideas.

Hypotheses concerning the effects of communication on performance under nonconflicting incentives are as follows.

> H_{2A} (Rappaport): With nonconflicting incentives, performance outcomes will be greater for dyads with communication than without.

> H_{2B} (Joint EV Maximization): With nonconflicting incentives, there will be no difference in performance outcomes for dyads with and without communication.

Degree of Communication

The prescriptive literature discussed above does not specify the form or amount of communication afforded agents within an information system. Ackoff describes a fairly rich communication structure, with multiple messages between agents. On the other hand, Rappaport's discussion of a nonconflicting incentives setting indicates communication may be beneficial, without indicating a precise communication structure.

The strategic analysis in this paper is quite specific about communication structure under conflicting incentives. It shows that a significant improvement in performance outcomes can be achieved by allowing a single message to be sent from the merchandising to the purchasing manager. Other messages could be sent prior to the final price and quantity decisions, but the predicted outcomes for such settings should be identical to the game diagrammed in Figure 2. This is because outcomes for the two managers depend only on the final price and quantity decisions. As far as final outcomes are concerned, messages sent before the final decisions are irrelevant.

There is a possibility, however, that allowing more than a single message between agents may affect performance outcomes. This argument follows from bounded rationality considerations similar to those discussed above. Specifically, the analysis in

Appendix B presumes risk-neutral agents. Like the nonconflicting incentives case, if one or both of the agents are not risk-neutral, they must infer each others' risk preferences over a series of trials. On the other hand, allowing agents to communicate their intended moves previous to taking final actions conveys additional information about their preferences beyond that contained in the outcome feedback from each trial of the game. In particular, this communication structure gives both agents information about each others' preferences during the course of each trial, while the communication structure diagrammed in Figure 2 only gives the purchasing manager information about the merchandising manager's preferences. In the rest of the paper, we will refer to a communication structure which allows multiple messages between agents as bidirectional, to distinguish it from the unidirectional structure diagrammed in Figure 2.

> H_3: With conflicting incentives, performance outcomes will be greater for dyads with bidirectional communication than with unidirectional communication.

Likewise, we can make a similar set of arguments about the effects of bi- versus unidirectional communication with nonconflicting incentives, as well.

> H_4: With nonconflicting incentives, performance outcomes will be greater for dyads with bidirectional communication than with unidirectional communication.

METHOD

Experimental Task and Design

To test the above hypotheses, we conducted an experiment in which student participants were randomly paired into dyads and assigned the role of either a merchandising or purchasing manager. Participants' incentive schemes were either conflicting, as in the Ackoff example, or nonconflicting, as suggested by Rappaport. Under the conflicting scheme, merchandising managers were compensated for the gross margin earned during each period of the experiment. Compensation for purchasing managers was based on inventory turnover. The conflicting compensation scheme was operationalized using the parameters described in Appendix B. The nonconflicting incentive scheme was an equal division of gross margin less inventory holding costs. The nonconflicting scheme is described more fully in Appendix C.

There were three types of communication structures within each incentives condition: no, unidirectional, and bidirectional communication. With no communication, the managers made their decisions simultaneously. (See Figure 3.) Participants did, however, learn the other manager's decision after the state outcome for each period was realized. With unidirectional communication, merchandising managers made a price decision and transmitted it to the purchasing manager. The purchasing manager then made a quantity decision. With bidirectional communication, merchandising managers made initial price (P1) and quantity (Q1) decisions and transmitted Q1 to the purchasing manager. The purchasing manager then made an initial quantity (Q2) decision, and transmitted this figure to the merchandising manager. The merchandising manager made a revised price (P2) decision, which was revealed to the purchasing manager, who then made a final quantity (Q3) decision. In both partial and full access, the merchandising manager received feedback on the final quantity decision, once the outcomes for the period were realized.

Insert Figure 3 about here.

Experimental Procedure

The participants were students at a large midwestern university. They were recruited from senior and graduate (MBA and Ph.D.) level business classes. Participants were assigned to experimental groups so that the proportion of each type of student was approximately equal in each group. There were ten dyads in each of the six experimental groups, for a total of 60 dyads or

120 participants. All participants completing a given session were in the same experimental group. "Points" earned during the experiment (the compensation measures described in Appendices B & C) were converted into cash at the end of the experiment at the rate of 10,000 points = 1 cash dollar. In addition, participants were also paid a flat fee of $3.00 for completing a post-experimental questionnaire. The incentives were designed so that the average compensation for a two hour experimental session would be approximately $15.00.

Participants completed the task on networked microcomputers, using specialized software developed for the experiment. They simulated 18 periods of operations, indicating pricing or purchasing decisions for each period. Market demand levels were generated at random by the computer. These were displayed to the participants at the end of each period along with the actions taken by their partners and themselves, as well as other pertinent data.

Experiment Software

The experiment software incorporates a display which allowed participants to view data relevant to their decisions. Participants used a mouse to access data. During each period of an experiment, participants viewed one of four types of screens: (1) analysis, (2) decision, (3) results, or (4) history.

The analysis screen allows access to data necessary to make decisions in each period. At the beginning of the period, all data on the screen is hidden from view. To access data, a participant must select a display mode, an order quantity, and a row or column from the display matrix by clicking the appropriate boxes with the mouse (Figure 4).

Participants use the decision screens to enter prices and order quantities (Figure 5). These screens are also entirely mouse-driven. The results screen appears at the end of every period (Figure 6). This is a "passive" screen in that all data are displayed; one need not use the mouse to view items on this screen. After the first period, participants may use the history screen to review the results of previous periods (Figure 7). As with the analysis screen, one must use the mouse to view data, which is displayed either by period or by data type.

Insert Figures 4, 5, 6, and 7 about here.

RESULTS

Dependent Variables

In order to assess the affects of communication structure on performance outcomes in the conflicting condition, we analyzed three dependent variables: gross margin, inventory turnover, and efficiency. Gross margin and inventory turnover are measures of each individual agent's welfare under the various types of communication access. They are calculated as discussed in Appendix B. Efficiency (EF_C) is a measure of the overall quality of decision outcomes for each conflicting condition dyad. It is defined as follows:

$$EF_C = \frac{E(PERF_C)}{E(OPT_C)}$$

where:

$E(PERF_C)$ = EV of (gross margin + (inventory turnover * 1000)) for actions actually taken during a period

$E(OPT_C)$ = Highest possible EV of (gross margin + (inventory turnover * 1000)).[1]

In the nonconflicting condition, we analyzed two dependent variables: net compensation (e.g., gross margin less holding costs, as defined in Appendix C) and efficiency. Both of these are measures of the overall quality of decision outcomes for each nonconflicting condition dyad. Efficiency in the nonconflicting condition (EF_{NC}) is defined as follows:

$$EF_{NC} = \frac{E(PERF_{NC})}{E(OPT_{NC})}$$

where:

$E(PERF_{NC})$ = EV of (gross margin - inventory holding costs) for actions actually taken during a period

$E(OPT_{NC})$ = Highest possible EV of (gross margin - inventory holding costs)

Tables 1 and 2 show the mean values of the dependent variables for the nonconflicting and conflicting conditions.

Insert Tables 1 and 2 about here.

Tests of Hypotheses

No communication versus communication allowed:

H_{1A} and H_{1B} were tested by comparing the dependent variable means for dyads with no communication to the average of the means for dyads with unidirectional and bidirectional communication, within the conflicting incentives condition. The multivariate test of this contrast is highly significant (Wilks $\lambda = 0.56$; $F(3,25) = 6.67$; $p = 0.002$). Univariate contrasts are statistically significant for all three dependent variables (See Table 3).[2] For all three variables, the means with communciation are greater than without, consistent with H_{1B}, i.e., with the predictions of the game-theoretic model.

Insert Table 3 about here.

The multivariate test of H_{2A} and H_{2B} (no communication vs. communication with nonconflicting incentives) is also highly significant (Wilks $\lambda = 0.44$; $F(2,26) = 16.56$; $p < 0.001$), as are the univariate tests of both nonconflicting condition dependent variables (See Table 4). Again, the partial and full communication access means are greater than the no access means for both dependent variables, consistent with H_{2A}.

Insert Table 4 about here.

Comparisons of communication levels:

H_3 and H_4 were tested by comparing unidirectional and bidirectional communication means within conflicting and nonconflicting incentives. Neither of these contrasts were statistically significant (conflicting: Wilks $\lambda = 0.93$; $F(3,25) = 0.63$; $p = 0.600$; nonconflicting: Wilks $\lambda = 0.94$; $F(2,26) = 0.77$; $p = 0.466$).

Within-Subjects Analyses

The means of the dependent variables were computed across blocks of trials to test for learning effects and the interaction these effects might have with tests of individual hypotheses. The overall main effect for trials is statistically significant in the conflicting incentives condition (Wilks $\lambda = 0.46$; $F(6,22) = 4.34$; $p = 0.005$).[3] While the individual variables in the conflicting condition tended to increase across time, tests of statistical significance show varying results. Gross margin showed neither a significant linear ($F(1,27) = 2.78$; $p = 0.107$) nor nonlinear ($F(1,27) = 2.92$; $p = 0.099$) trend across time. Inventory turnover showed a marginally significant increasing linear trend ($F(1,27) = 3.89$; $p = 0.059$) and a highly significant nonlinear trend ($F(1,27) = 7.04$; $p = 0.013$). Analysis of the nonlinear trend for inventory turnover shows a fairly large increase in mean inventory turnover per period from the first to the second block of trials, with a slight decrease from the second to the third block. Efficiency showed a highly significant increasing linear trend ($F(1,27) =$

22.83; $p = 0.000$), but the nonlinear trend was not significant ($F(1,27) = 3.11$; $p = 0.089$).

The overall main effect for trials is also statistically significant in the nonconflicting incentives condition (Wilks $\lambda = 0.43$; $F(4,24) = 8.07$; $p < 0.001$). Here, tests for increasing linear trends are highly significant for both net compensation ($F(1,27) = 30.78$; $p < 0.001$) and efficiency ($F(1,27) = 29.59$; $p < 0.001$). Tests for nonlinear trends are not significant for either of these variables (net compensation: $F(1,27) = 1.11$; $p = 0.302$; efficiency: $F(1,27) = 0.45$; $p = 0.509$).

The only within-subjects interaction test which approaches statistical significance is the test for the interaction between trials and the test of H_{2A} and H_{2B} (Wilks $\lambda = 0.73$; $F(4,24) = 2.27$; $p = 0.092$). The linear components of the interaction were not significant, but the nonlinear components were significant ($F(1,27) = 6.51$; $p = 0.017$ for gross margin, $F(1,27) = 6.24$; $p = 0.019$ for efficiency). Figure 8 is a diagram of this effect for efficiency. Inspection of the diagram shows that only a slight increase in performance occurred under full and partial access and that most of the increase occurred from the first to the second block of trials. On the other hand, the increase in performance under no access was somewhat larger, but it did not occur until after the third block of trials.

Insert Figure 8 about here.

Efficiency Data

The analysis of results thus far has shown that communication had a significant positive effect on performance, regardless of incentives. Given that these effects exist, another issue for investigation is how performance under the various communication conditions compares to normative efficiency benchmarks. The nonconflicting incentives problem has a unique maximum, so the benchmark in this condition is 1.0, regardless of communication structure. With conflicting incentives, we define the benchmarks as efficiency at the single-period equilibrium point. The efficiency benchmarks are 0.681 for no communication and 0.875 for unidirectional and bidirectional communication.[4]

Insert Table 5 about here.

95% confidence intervals were computed for the efficiency measures for each level of communication access within each communication condition. (See Table 5.) Within the nonconflicting incentives condition, efficiency measures which are significantly less than 1.0 indicate actions inconsistent with coordination of actions for expected payoff maximization. None of the confidence intervals for mean efficiency across all trials of the experiment in the nonconflicting incentives condition include the benchmark of 1.0. However, both the upper and lower confidence limits for the last 6 trials are close to 1.0 with unidirectional (0.963 - 0.994) and bidirectional (0.970 - 0.997) communication. The confidence limit for no communication (0.804 - 0.970), however, is somewhat further away from 1.0. Consistent with the within-subjects tests, learning appears to have occurred in all nonconflicting incentives conditions, but the dyads allowed communication achieve near optimal performance, while those with no communication do not.

In the conflicting incentives condition, efficiency measures which are significantly greater than those associated with single-period equilibria indicate that dyads may be achieving increased performance through cooperation across time. Efficiency measures which are significantly lower than those expected for single-period equilibria indicate that dyad members are not acting in a strategic fashion, as defined within the game-theoretic framework outlined in Appendix B.

The lower limit of the 95% confidence interval for mean efficiency across all trials of the experiment in the conflicting incentives / no communication condition is greater than the benchmark of 0.681 for all trials (0.692) and for the last six trials (0.695). On the other hand, the benchmark of 0.875 for the unidirectional communication condition is just barely inside the upper limit of the confidence interval (0.876) for all trials. However, the benchmark is well within the confidence interval for the last six trials (0.838 - 0.907). With bidirectional communication, the benchmark is well within the confidence limit for all trials (0.825 - 0.898) and the last six trials (0.812 - 0.909).

Indications of Cooperative Behavior

The efficiency data for the conflicting incentives condition indicate that cooperative behavior occurred in the no access condition, but not in the full and partial access conditions. However, efficiency measures which are greater than those expected at single-period equilibrium points do not by themselves indicate the presence of cooperation. This is because a 'cooperative' outcome is by definition a Pareto-improvement over a single-period equilibrium point. However, there are outcomes which represent efficiency improvements over single-period (noncooperative) equilibrium points, but do not represent Pareto-improvements over these points.[5] Therefore, analyses of gross margin and inventory turnover similar to the one for efficiency were performed in order to assess whether payoffs to both types of agents under conflicting incentives were consistent with those predicted by the single-period game-theoretic analysis. (See Table 6.)

Insert Table 6 about here.

The mean gross margin for no communication across all trials (13408) is greater than the expected single-period equilibrium outcome of 12596, but the lower bound of the 95% confidence interval (12581) is slightly less than the expected outcome. In the last six periods, the mean gross margin is 13506 and the lower bound of the 95% confidence interval is 12398. For mean inventory turnover, the lower bounds of the 95% confidence interval are greater than the noncooperative equilibrium expected outcome of 3.769 for all trials (4.002) and the last six trials (3.830). Therefore, while the efficiency data indicate cooperation took place in the no communication condition, only purchasing managers achieved significant gains from cooperation, on average.

In the unidirectional and bidirectional communication conditions, the mean gross margin for all trials (14267 and 14211, respectively) is slightly greater than the predicted single period equilibrium outcome of 14000, but the predicted outcome is above the lower bounds of the 95% confidence intervals (13706 and 13728). For the last six periods, the predicted equilbrium outcome is still greater than the lower bounds for both unidirectional (13739) and bidirectional (13308) access. The mean inventory turnover values for unidirectional communication are less than the single period equilibrium value of 7.000 for all trials (6.019) and for the last six trials (6.404). Only for the last six trials does the the 95% confidence interval (5.513 - 7.295) include the equilibrium value. With bidirectional communication, the mean inventory turnover values are also less than the noncooperative equilibrium value for all trials (6.403) and the last six trials (6.206). The predicted equilibrium value of inventory turnover is within the 95% confidence interval for all trials (5.706 - 7.100) and but is slightly outside the confidence interval for the last six trials (5.438 - 6.974).

To summarize, merchandising managers in the conditions with communication had performance outcomes on average that were as high as would be expected by dyads choosing the single-period (i.e., noncooperative) equilibrium point. On the other hand, the mean compensation to purchasing managers with communication was less than expected at the single-period equilibrium point. Therefore, the results for the communication conditions are not entirely consistent with the predictions of the game-theoretic model. Even so, the average payoffs to both types of managers with communication were significantly greater than without.

Selling Price and Order Quantity Data

Thus far, the presentation of results has focused on outcome data. The Ackoff scenario, however, also makes certain predictions about the prices and quantities chosen by the managers. If Ackoff's predictions are true, we should see higher selling prices and lower order quantities with communication than without, at least with conflicting incentives. Also, selling prices should increase and order quantities should decrease over time.

Table 7 shows mean selling price and order quantity data for blocks of trials and for the entire experiment. Multivariate tests on selling price and order quantity indicate significant differences between dyads with no and some communication, in both the conflicting (Wilks' $\lambda = 0.76$; $F(2,26) = 4.20$; $p = 0.026$) and nonconflicting (Wilks' $\lambda = 0.59$; $F(2,26) = 8.97$; $p = 0.001$) incentives conditions. Univariate tests showed that dyads with communication set significantly lower selling prices than those without, in both the conflicting and nonconflicting incentives conditions. (See Table 8.) Inventory order quantities were significantly larger with communication than without, again for both types of incentives. All these results are contrary to Ackoff's predictions. Multivariate tests showed no significant differences between unidirectional and bidirectional communication dyads, again in both the conflicting (Wilks' $\lambda = 0.92$; $F(2,26) = 1.14$; $p = 0.336$) and nonconflicting (Wilks' $\lambda = 0.99$; $F(2,26) = 0.07$; $p = 0.937$) incentives conditions.

Insert Tables 7 & 8 about here.

Within-subjects tests also show results contrary to Ackoff's predictions. The overall effect for trials only approaches significance in the conflicting incentives condition (Wilks' λ = 0.74; $F(4,24) = 2.15$; $p = 0.106$). Univariate tests do show a significant downward linear trend across trials for selling price ($F(1,27) = 7.61$; $p = 0.010$) and an upward linear trend for order quantity ($F(1,27) = 5.78$; $p = 0.023$). The overall effect for trials is highly significant in the nonconflicting incentives condition (Wilks' λ = 0.49; $F(4,24) = 6.15$; $p = 0.001$). Univariate tests in nonconflicting incentives also show a significant downward linear trend across trials for selling price ($F(1,27) = 15.96$; $p < 0.001$) and an upward linear trend for order quantity ($F(1,27) = 16.86$; $p < 0.001$).

SUMMARY AND CONCLUSIONS

This paper began by discussing contrasting views regarding the effects of communication on agents' performance in a distributed decision making environment. For environments where agents are assigned to maximize conflicting incentives, the contrasting viewpoints were: (1) Ackoff's (1967) view that communication between agents may be detrimental, and (2) a game-theoretic analysis, which showed that in many cases, communication is beneficial for pairs of managers with conflicting incentives. For environments with nonconflicting incentives, we discussed: (1) Rappaport's (1968) view that communication could be beneficial in such a setting, and (2) a decision-theoretic analysis, which indicated that communication access should not be necessary to find the optimal solution to the nonconflicting incentives problem. We also proposed hypotheses which indicate that not only the existence of communication, but the type of communication pattern may have an effect on performance outcomes.

The results of the experiment showed that dyads with communication performed significantly better than those with no communication, regardless of incentives. On the other hand, varying the type of communication structure had no significant effects on performance in either incentives condition. The results with conflicting incentives are contrary to Ackoff's views, but are consistent with the game-theoretic model. The results with nonconflicting incentives support Rappaport's viewpoint, that is, communication enhances performance with nonconflicting incentives. This is contrary to the assumption of perfectly rational agents who should be able to maximize their joint outcomes without communication.

Comparison of efficiency measures against normative benchmarks under conflicting incentives revealed that dyads with no communication performed significantly better than predicted by a noncooperative equilibrium model, but dyads with communication on average only performed at least as well as predicted by the model. Even so, both types of agents with communication still earned significantly higher payoffs than their counterparts without communication.

An analysis of performance across time showed that dyads with nonconflicting incentives and communication were able to achieve nearly optimal performance with experience. Even though nonconflicting incentives dyads with no communication exhibited stronger learning effects than those with partial or full access, their performance in the last block of trials was still significantly less than optimal. Also, most of the learning for no communication dyads did not take place until the last block of experimental trials. Learning effects also occurred with conflicting incentives, but were not as pronounced as those for nonconflicting incentives. Only inventory turnover and overall efficiency showed statistically significant increases across time.

From a prescriptive standpoint, it appears that in an environment where decision issues are modularized and distributed among managers, communication is beneficial under both conflicting and nonconflicting incentives systems. However, the results for conflicting incentives are conditional on whether or not game-theoretic equilibrium outcomes are predicted to be greater when communication is allowed than when it is not. We did not make a direct performance comparison between incentives conditions was not made, since performance under different schemes is contingent on the precise incentives chosen. However, the differential learning effects observed under the two schemes suggest nonconflicting incentives schemes are superior, as far as coordination issues are concerned. Apparently, improvements in performance under conflicting incentives are limited to the degree individual agents are willing to cooperate. On the other hand, no such limitation exists for nonconflicting incentives.

The lack of a significant difference between partial and full access results indicates that only a fairly rudimentary communication system is necessary in tasks such as the one presented here. This result is particularly important in situations where communication is costly, such as when operating divisions are located in different areas around the world. However, this finding is conditional on two factors. First, the task used in the experiment was a fairly simple one, although similar tasks are often found in practice. More complex tasks may require the transmission of more extensive verbal and numeric data, or even social cues such as vocal inflection or facial expression, to achieve optimal outcomes (Treviño, Lengel, and Daft, 1987; McGuire, Kiesler, and Siegel, 1987). Second, substantial opportunities for learning existed in the experiment, since the task was carried out over a number of repeated trials. In a case where such learning opportunities do not exist, then communication beyond a rudimentary level may be necessary.

FOOTNOTES

[1]Inventory turnover is multiplied by 1,000 in these analyses to make the gross margin and inventory turnover scales compatible. For example, at the outcome p = 85 and q = 350 with conflicting incentives, expected gross margin is 12250 and inventory turnover is 7.000, making $E(PERF_C) = 12250 + 7000 = 19250$. The highest possible outcome with conflicting incentives occurs at p = 75 and q = 550, where $E(PERF_C) = 13667 + 10333 = 24000$. So, efficiency for the outcome p = 85 and q = 350 is 19250/24000, or 0.802.

[2]Since the efficiency data are proportions, a variance-stabilizing arcsin transformation was applied to them before analysis (Neter and Wasserman, 1974, p. 507).

[3]A multivariate repeated measures approach was used, as described in Bock (1975, Ch. 7).

[4]Computations are as follows: no access--16364/24000; partial and full access--21000/24000.

[5]For example, the outcome (p = 100, q = 400) yields an efficiency measure of 0.72, which is greater than the no communication EP efficiency of 0.68. However, the expected payoff for the purchasing manager at this point is 2311, which is less than the EP expected payoff of 3769.

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TABLE 1
Dependent Variable Means per Period
Conflicting Condition

	Trials 1-6	Trials 7-12	Trials 13-18	Mean
Gross Margin				
No Communication	12858	13859	13507	13408
Unidirectional	13803	14410	14588	14267
Bidirectional	14312	14332	13988	14211
Mean	13658	14200	14028	13962
Efficiency				
No Communication	0.71	0.77	0.76	0.75
Unidirectional	0.81	0.85	0.87	0.84
Bidirectional	0.85	0.87	0.86	0.86
Mean	0.79	0.83	0.83	0.82
Inventory Turnover				
No Communication	4.292	5.239	4.788	4.773
Unidirectional	5.256	6.398	6.404	6.019
Bidirectional	6.463	6.539	6.206	6.403
Mean	5.337	6.059	5.799	5.732

TABLE 2
Dependent Variable Means per Period
Nonconflicting Condition

	Trials 1-6	Trials 7-12	Trials 13-18	Mean
Net Compensation				
No Communication	6212	6316	7021	6516
Unidirectional	7218	7910	7623	7583
Bidirectional	7051	7620	7822	7498
Mean	6828	7282	7489	7199
Efficiency				
No Communication	0.79	0.80	0.89	0.83
Unidirectional	0.92	0.97	0.98	0.96
Bidirectional	0.93	0.97	0.98	0.96
Mean	0.88	0.92	0.95	0.92

TABLE 3
Univariate Hypothesis Tests
Conflicting Incentives Condition

	Gross Margin		Inv. Turnover		Efficiency	
	F	p	F	p	F	p
No Communication vs. (Unidirectional + Bidirectional)/2	5.74	.024	16.78	.000	19.17	.000
Unidirectional vs. Bidirectional	0.01	.889	0.90	.352	0.65	.428

TABLE 4
Univariate Hypothesis Tests
Nonconflicting Incentives Condition

	Compensation		Efficiency	
	F	p	F	p
No Communication vs. (Unidirectional + Bidirectional)/2	17.16	.000	30.51	.000
Unidirectional vs. Bidirectional	0.89	.768	0.07	.794

TABLE 5
Confidence Intervals for Efficiency Measures

All 18 Periods	Mean	Std. Dev.	95% Conf. Interval
Conflicting Incentives			
No Communication	0.747	0.078	0.692 - 0.803
Unidirectional	0.841	0.048	0.807 - 0.876
Bidirectional	0.862	0.051	0.825 - 0.898
Nonconflicting Incentives			
No Communication	0.825	0.134	0.729 - 0.922
Unidirectional	0.958	0.022	0.942 - 0.974
Bidirectional	0.964	0.024	0.947 - 0.982
Periods 12-18			
Conflicting Incentives			
No Communication	0.765	0.097	0.695 - 0.834
Unidirectional	0.873	0.049	0.838 - 0.907
Bidirectional	0.860	0.068	0.812 - 0.909
Nonconflicting Incentives			
No Communication	0.887	0.116	0.804 - 0.970
Unidirectional	0.978	0.021	0.963 - 0.994
Bidirectional	0.984	0.019	0.970 - 0.997

TABLE 6
Confidence Intervals for Gross Margin and Inventory Turnover--Conflicting Condition

All 18 Periods	Mean	Std. Dev.	95% Conf. Interval
Gross Margin			
No Communication	13408	1156	12581 - 14234
Unidirectional	14267	785	13706 - 14828
Bidirectional	14211	675	13728 - 14693
Inventory Turnover			
No Communication	4.723	1.077	4.002 - 5.544
Unidirectional	6.019	0.595	5.594 - 6.445
Bidirectional	6.403	0.975	5.706 - 7.100
Periods 12-18			
Gross Margin			
No Communication	13507	1550	12398 - 14616
Unidirectional	14588	1186	13739 - 15436
Bidirectional	13988	951	13308 - 14669
Inventory Turnover			
No Communication	4.788	1.338	3.830 - 5.745
Unidirectional	6.404	1.245	5.513 - 7.295
Bidirectional	6.206	1.074	5.438 - 6.974

TABLE 7
Means for Sales Price and Order Quantity Across Blocks of Six Trials

Sales Price

	Trials 1-6	7-12	13-18	Mean
Conflicting Incentives				
No Communication	97.6	96.8	97.1	97.2
Unidirectional	96.1	93.0	91.6	93.6
Bidirectional	92.6	91.1	91.1	91.6
Mean	95.4	93.6	93.3	94.1
Nonconflicting Incentives				
No Communication	98.5	97.6	95.5	97.2
Unidirectional	93.4	91.3	89.7	91.5
Bidirectional	93.5	92.0	90.0	91.8
Mean	95.1	93.6	91.7	93.5

Order Quantity

	Trials 1-6	7-12	13-18	Mean
Conflicting Incentives				
No Communication	309.9	329.1	321.7	320.2
Unidirectional	336.7	360.8	372.6	356.7
Bidirectional	353.4	368.3	363.4	361.7
Mean	333.3	352.7	352.6	346.2
Nonconflicting Incentives				
No Communication	365.8	350.0	385.0	366.9
Unidirectional	403.3	435.8	448.2	429.1
Bidirectional	397.7	425.7	445.9	423.1
Mean	388.9	403.8	426.4	406.4

TABLE 8
Univariate Tests--Selling Price and Order Quantity

	Selling Price		Order Quantity	
	F	p	F	p
Conflicting Incentives				
No Communication vs. (Unidirectional + Bidirectional)/2	8.68	.007	6.51	.017
Unidirectional vs. Bidirectional	1.20	.283	0.08	.779
Nonconflicting Incentives				
No Communication vs. (Unidirectional + Bidirectional)/2	13.32	.001	17.32	.000
Unidirectional vs. Bidirectional	0.04	.836	0.13	.718

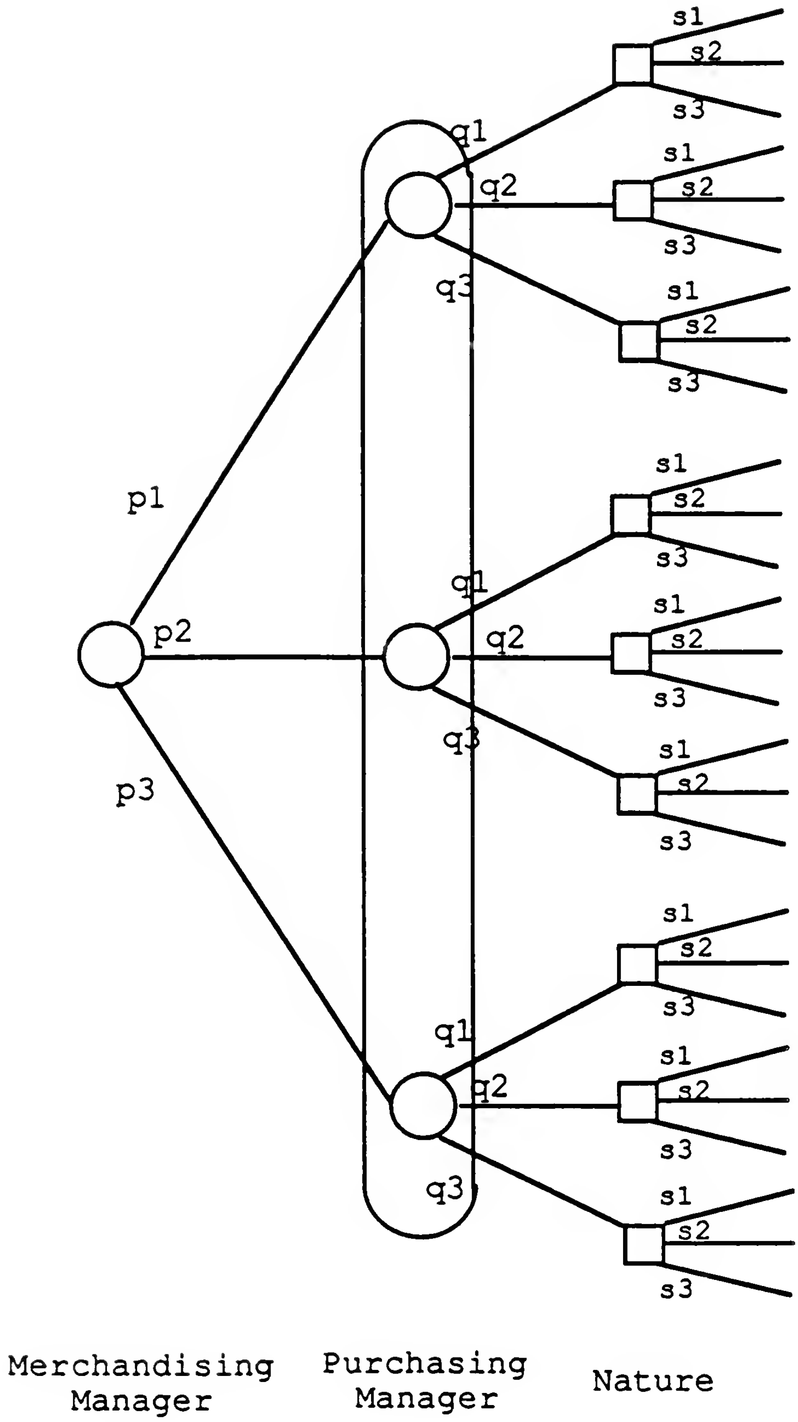

Figure 1
Extensive Form
Ackoff Scenario without Communication

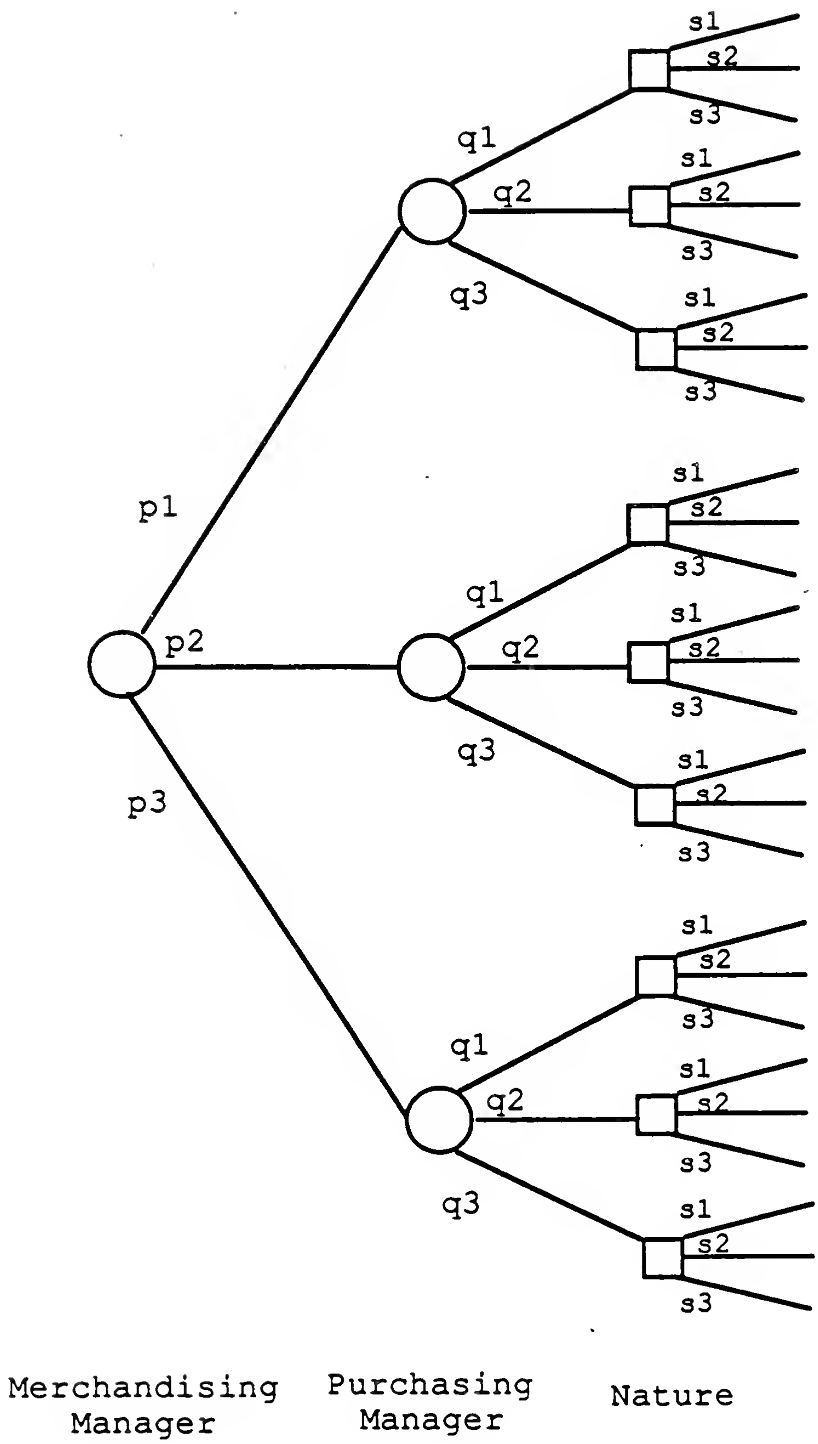

Figure 2
Extensive Form
Ackoff Scenario with Communication

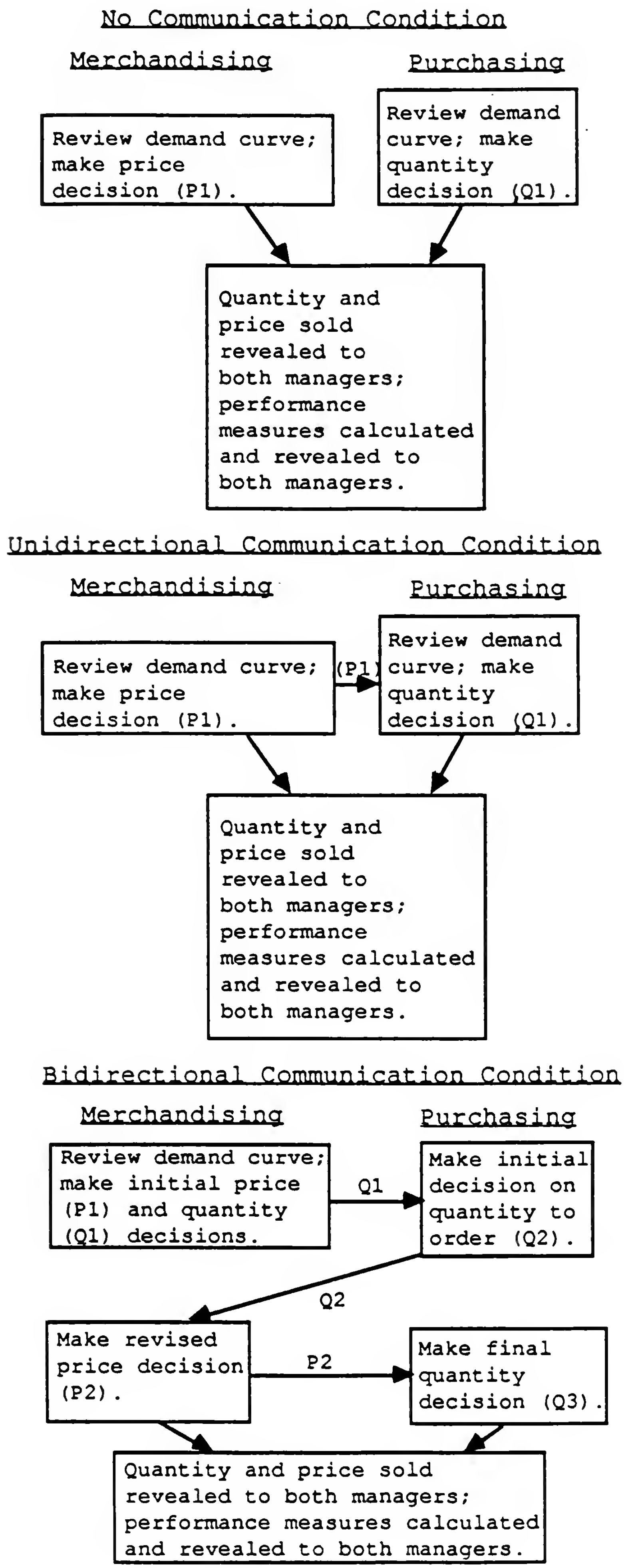
No Communication Condition
Merchandising
Purchasing
Review demand curve; make price decision (P1).
Review demand curve; make quantity decision (Q1).
Quantity and price sold revealed to both managers; performance measures calculated and revealed to both managers.
Unidirectional Communication Condition
Merchandising
Purchasing
Review demand curve; make price decision (P1).
(P1)
Review demand curve; make quantity decision (Q1).
Quantity and price sold revealed to both managers; performance measures calculated and revealed to both managers.
Bidirectional Communication Condition
Merchandising
Purchasing
Review demand curve; make initial price (P1) and quantity (Q1) decisions.
Q1
Make initial decision on quantity to order (Q2).
Q2
Make revised price decision (P2).
P2
Make final quantity decision (Q3).
Quantity and price sold revealed to both managers; performance measures calculated and revealed to both managers.

FIGURE 3

ANALYSIS SCREEN: DISPLAY ACTIVATED

ANALYSIS | DECISION | HISTORY | Merchandising Manager | PERIOD 10

ORDER QUANTITY CONSIDERED

100 | 150 | 200 | 250 | 300 | **350** | 400 | 450 | 500 | 550

DISPLAY MODE

- **DEMAND UNITS**
- SALES UNITS
- GROSS MARGIN
- LOST SALES UNITS
- ENDING INVENTORY
- INVENTORY TURNOVER

LEVEL OF MARKET DEMAND

PRICE	LOW	MEDIUM	HIGH	EXPTED
$120		98		
$115		141		
$110		193		
$105		246		
$100		300		
$95		356		
$90		413		
$85		472		
$80		532		
$75		595		

Status:
Click the HISTORY box to review results of previous periods. Click the DECISION box when ready to enter planned selling price and order quantity request.

ANALYSIS | DECISION | HISTORY | Merchandising Manager | PERIOD 10

ORDER QUANTITY CONSIDERED

100 | 150 | 200 | 250 | 300 | 350 | 400 | **450** | 500 | 550

DISPLAY MODE

- **DEMAND UNITS**
- SALES UNITS
- GROSS MARGIN
- LOST SALES UNITS
- ENDING INVENTORY
- INVENTORY TURNOVER

LEVEL OF MARKET DEMAND

PRICE	LOW	MEDIUM	HIGH	EXPTED
$120				
$115				
$110				
$105				
$100				
$95				
$90				
$85	417	472	527	472
$80				
$75				

Status:
Click the HISTORY box to review results of previous periods. Click the DECISION box when ready to enter planned selling price and order quantity request.

FIGURE 4

DECISIONS MODE

ANALYSIS	DECISION	HISTORY	Merchandising Manager	PERIOD 10

Click below to select a planned selling price (not transmitted to purchasing):

75	80	85	90	95	100	105	110	115	120

Click below to select an order quantity request to be transmitted to purchasing:

100	150	200	250	300	350	400	450	500	550

You have entered a planned order quantity of 450.
Click below to confirm your entries and transmit your
order quantity request to purchasing or to cancel.

CONFIRM AND TRANSMIT | CANCEL

An order quantity request of 450 confirmed.
Quantity request has been transmitted to purchasing.

Status:
Decision mode temporarily inactive. You may continue
to view the analysis or history modes.
Awaiting planned order quantity from purchasing.

ANALYSIS	DECISION	HISTORY	Purchasing Manager	PERIOD 10

Click below to select a planned order quantity to transmit to merchandising:

100	150	200	250	300	350	400	450	500	550

You have entered a planned order quantity of 400. Click below to confirm and
transmit your entry to merchandising or to cancel.

CONFIRM AND TRANSMIT | CANCEL

Planned order quantity of 400 confirmed and transmitted to merchandising.

Status:
Decision mode temporarily inactive. You may continue
to view the analysis or history modes.
Awaiting final selling price from merchandising.

FIGURE 5

RESULTS SCREEN

ANALYSIS | DECISION | HISTORY | · Purchasing Manager   PERIOD 10

RANDOM NUMBER DRAWN	14
LEVEL OF MARKET DEMAND	LOW
PURCHASE QUANTITY	450
PRICE	$85
DEMAND UNITS	417 L
SALES UNITS	417
GROSS MARGIN	14595
LOST SALES UNITS	0
ENDING INVENTORY	33
INVENTORY TURNOVER	5.024
YOUR COMPENSATION	5024
MERCH. COMPENSATION	7298

Status:
Click the ANALYSIS or HISTORY box to proceed to the next period.

FIGURE 6

HISTORY MODE

ANALYSIS	DECISION	HISTORY	Purchasing Manager	PERIOD 11

RESULTS OF COMPLETED PERIODS

	10	9	8	7	6	5	4	3	2	1
PURCHASE QUANTITY	450									
PRICE	$85									
DEMAND UNITS	417 L									
SALES UNITS	417									
GROSS MARGIN	14595									
LOST SALES UNITS	0									
ENDING INVENTORY	33									
INVENTORY TURNOVER	5.02									
YOUR COMPENSATION	5024									
MERCH. COMPENSATION	7298									

Status:
Click the ANALYSIS box to view current period data.

Awaiting order quantity request from merchandising.

ANALYSIS	DECISION	HISTORY	Purchasing Manager	PERIOD 11

RESULTS OF COMPLETED PERIODS

	10	9	8	7	6	5	4	3	2	1
PURCHASE QUANTITY										
PRICE										
DEMAND UNITS	417 L	411 H	527 H	532 M	532 M	650 H	650 H	413 M	358 L	472 M
SALES UNITS										
GROSS MARGIN										
LOST SALES UNITS										
ENDING INVENTORY										
INVENTORY TURNOVER										
YOUR COMPENSATION										
MERCH. COMPENSATION										

Status:
Click the ANALYSIS box to view current period data.

Awaiting order quantity request from merchandising.

FIGURE 7

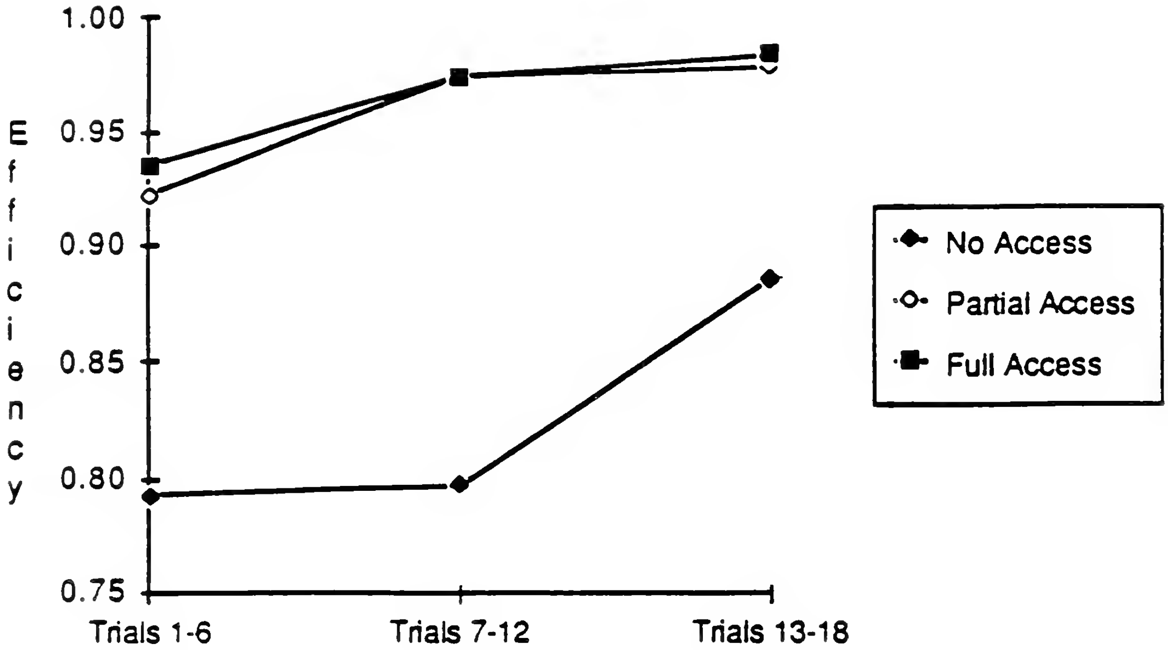

Figure 8
Effciency across Blocks of Trials:
Nonconflicting Incentives Condition

APPENDIX A
Excerpts from Ackoff, R. L., "Management Misinformation Systems,"

Management Science, (December 1967), pp. B147-156

...For example, consider the following very much simplified version of a situation I once ran into. The simplification of the case does not affect any of its essential characteristics.

A department store has two "line" operations: buying and selling. Each function is performed by a separate department. The Purchasing Department primarily controls one variable: how much of each item is bought. The Merchandising Department controls the price at which it is sold. Typically, the measure of performance applied to the Purchasing Department was the turnover rate of inventory. The measure applied to the Merchandising Department was gross sales; this department sought to maximize the number of items sold times their price.

Now by examining a single item let us consider what happens in this system. The merchandising manager, using his knowledge of competition and consumption, set a price which he judged would maximize gross sales. In doing so he utilized price-demand curves for each type of item. For each price the curves show the expected sales and values on an upper and lower confidence band as well. (See Figure A1.) When instructing the Purchasing Department how many items to make available, the merchandising manager quite naturally used the value on the upper confidence curve. This minimized the chances of his running short which if it occurred, would hurt his performance. It also maximized the chances of being overstocked but this was not his concern, only purchasing manager's. Say, therefore, that the merchandising manager initially selected price P1 and requested that amount Q1 be made available by the Purchasing Department.

In this company the purchasing manager also had access to the price-demand curves. He knew the merchandising manager always ordered optimistically. Therefore, using the same curve he read over from Q1 to the upper limit and down to the expected value from which he obtained Q2, the quantity he actually intended to make available. He did not intend to pay for the merchandising manager's optimism. If merchandising ran out of stock, it was not his worry. Now the merchandising manager was informed about what the purchasing manager had done so he adjusted his price to P2. The purchasing manager in turn was told that the merchandising manager had made this readjustment so he planned to make only Q3 available. If this process--made possible only by perfect communication between departments--had been allowed to continue, nothing would have been bought and nothing would have been sold. This outcome was avoided by prohibiting communication between the two departments and forcing each to guess what the other was doing.

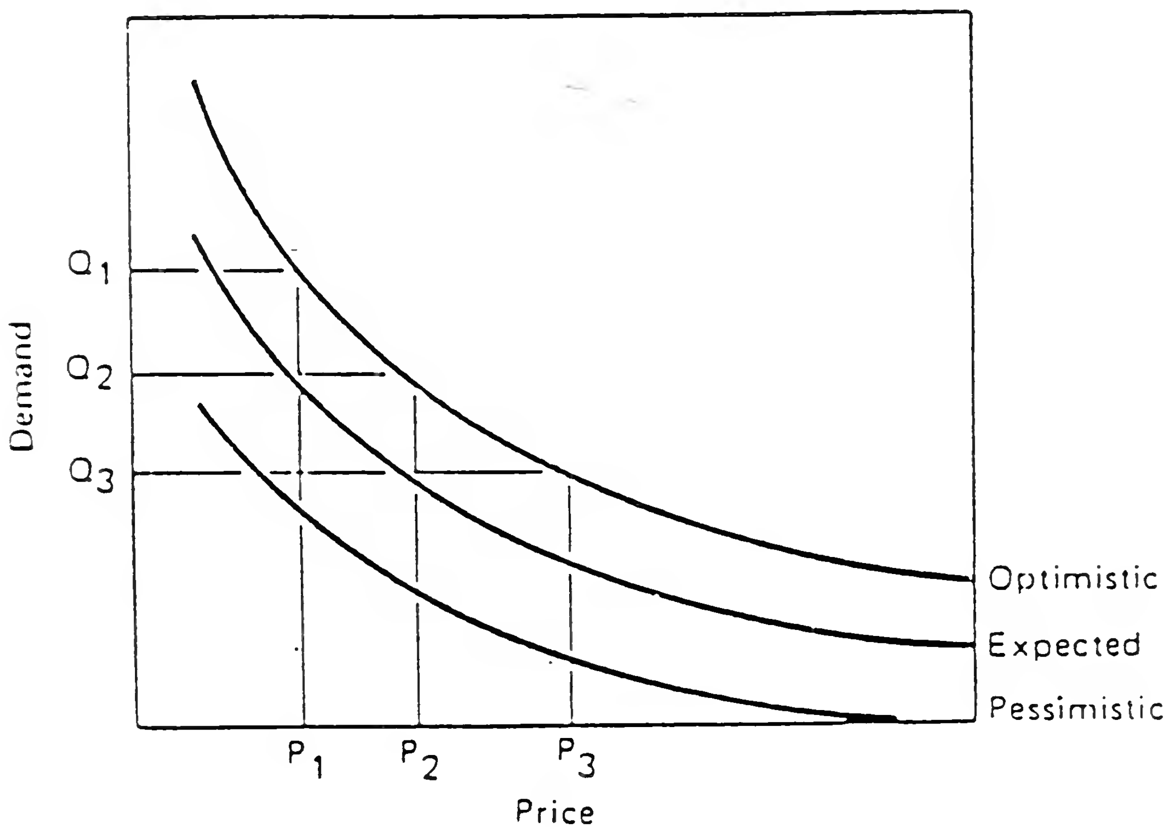

Fig A1 *Price-demand curve*

APPENDIX B
A Game-Theoretic Analysis of Ackoff's Scenario

Basic Parameters

Assume that sales demand (d) is jointly dependent on selling price (p) and on a random state of nature. Nature has three possible state realizations, which occur with equal probability. They represent high, medium, and low sales demand. The demand functions for each state are:

High demand: $d = 2555 - 220(p^{1/2})$

Medium demand: $d = 2500 - 220(p^{1/2})$

Low demand: $d = 2445 - 220(p^{1/2})$

If demand is greater than the quantity ordered by purchasing (q), the units sold for the period are equal to q, that is, no backorders are allowed. If demand is less than the quantity ordered by purchasing, the units sold for the period are equal to d. Remaining units are not carried over to the next period; it is assumed these are disposed of at cost. The cost for each item is 50, therefore, the gross margin for each period is:

(p - 50) x number of units sold

Merchandising's compensation for each period is one-half of gross margin. Purchasing's compensation is based on a modified version of the traditional inventory turnover ratio, specifically:

$$\frac{\text{number of units sold}}{\text{ending inventory} + 50} * 1000$$

Merchandising may set a selling price anywhere from 75 to 120, in increments of 5. Purchasing may order from 100 to 550 units, in increments of 50. The expected values for each manager for each combination of selling price and order quantity are shown in Figure B1.

Game-Theoretic Analysis: No Communication Allowed

If one were to show the extensive form of this game, the diagram would look like Figure 1, except that it would have ten branches coming out of merchandising's initial decision node and another ten branches coming off of these branches, at each of purchasing's decision nodes. Figure B1 shows the strategic form of the game. By successively eliminating dominated strategies (starting with p = 120, q = 100, and so forth), one can show that this game has a unique equilibrium point (EP) at p = 105, q = 250. The expected payoffs at this point are 6298 to merchandising and 3769 to purchasing.

Game-Theoretic Analysis: Communication Allowed

In the case where communication from merchandising to purchasing is allowed, the game can be represented in extensive form by a diagram similar to Figure 2. The actions which yield the highest expected payoffs for merchandising in this game are p = 85 and p = 90. At p = 85, purchasing should choose q = 400, yielding expected payoffs of 7000 for merchandising and 8000 for purchasing. At p = 90, purchasing should choose q = 350, again yielding an expected payoff of 7000 for merchandising, but only 8000 for purchasing. Note that in either case, the expected payoffs to both managers are higher than without communication.

The predicted outcomes for the game with communication, however, are but two of many EPs. Also, note that the EP of the game without communication is one of the EPs of the game with communication. In fact, Dubey and Shubik (1981) have shown that for two games which are identical, except for the information sets of the players, the set of pure strategy EPs for the game with less information will be a subset of the set of pure strategy EPs of the game with more information.

In the Ackoff scenario, this means that the merchandising manager will be at least as well off with communication as without. His choice set of EPs with communication will always include the no communication EP(s), and in many cases, will also include an EP where the expected payoffs are greater than without communication. This does not by itself guarantee an increased expected payoff with communication for the purchasing manager. However, in cases where the payoff structure is similar to the one shown here, the action with the highest expected payoff for merchandising under communication is to set a lower selling price than without communication. Purchasing's best response to this is to order a higher quantity than without communication. This will yield a higher expected inventory turnover for purchasing than without communication and therefore, higher expected payoffs.

p \ q	100	150	200	250	300	350	400	450	500	550
75	1250	1875	2500	3125	3750	4375	5000	5625	6250	6833
80	1500	2250	3000	3750	4500	5250	6000	6750	7385	7795
85	1750	2625	3500	4375	5250	6125	7000	7683	8103	8260
90	2000	3000	4000	5000	6000	7000	7720	8140	8260	8260
95	2250	3375	4500	5625	6750	7508	7928	8010	8010	8010
100	2500	3750	5000	6208	7042	7458	7500	7500	7500	7500
105	2750	4125	5418	6298	6756	6765	6765	6765	6765	6765
110	3000	4380	5310	5790	5790	5790	5790	5790	5790	5790
115	3098	4084	4583	4583	4583	4583	4583	4583	4583	4583
120	2625	3150	3150	3150	3150	3150	3150	3150	3150	3150

Expected Value of Payoffs for Merchandising Manager
(Gross Margin / 2)

p \ q	100	150	200	250	300	350	400	450	500	550
75	2000	3000	4000	5000	6000	7000	8000	9000	10000	10333
80	2000	3000	4000	5000	6000	7000	8000	9000	8845	7567
85	2000	3000	4000	5000	6000	7000	8000	7675	6396	4395
90	2000	3000	4000	5000	6000	7000	6630	5423	3529	2411
95	2000	3000	4000	5000	6000	5680	4602	2868	2000	1547
100	2000	3000	4000	4818	4778	3860	2311	1636	1275	1046
105	2000	3000	3746	3769	3189	1851	1321	1033	850	723
110	2000	2742	2873	2475	1437	1030	807	665	566	492
115	1781	2048	1816	1058	758	593	488	415	361	320
120	1268	1222	702	499	388	318	270	234	207	186

Expected Value Payoffs for Purchasing Manager
(Inventory Turnover * 1000)

Figure B1
Expected Values to Managers with Conflicting Incentives

APPENDIX C
The Nonconflicting Incentives Condition

The demand functions and game rules used in the nonconflicting incentives condition are the same as with conflicting incentives, with the exception of how the payoffs to the managers are defined. Under nonconflicting incentives, each item remaining in ending inventory is assumed to have a holding cost of ten units. Payoffs are an equal division of gross margin less holding costs. Expected payoffs for each combination of selling price and order quantity are shown in Figure C1. By inspection, one can see that the highest expected payoff, 7925, occurs at p = 90, q = 450.

		q									
		100	150	200	250	300	350	400	450	500	550
	75	1250	1875	2500	3125	3750	4375	5000	5625	6250	6817
	80	1500	2250	3000	3750	4500	5250	6000	6750	7347	7643
	85	1750	2625	3500	4375	5250	6125	7000	7628	7918	7870
	90	2000	3000	4000	5000	6000	7000	7650	7925	7825	7575
p	95	2250	3375	4500	5625	6750	7426	7689	7540	7290	7040
	100	2500	3750	5000	6200	6950	7200	7000	6750	6500	6250
	105	2750	4125	5403	6193	6484	6245	5995	5745	5495	5245
	110	3000	4360	5195	5505	5255	5005	4755	4505	4255	4005
	115	3075	3963	4288	4038	3788	3538	3288	3038	2788	2538
	120	2500	2850	2600	2350	2100	1850	1600	1350	1100	850

Figure C1
Expected Values: Nonconflciting Incentives