COMMUNICATING THE INTENTION: A COMMUNICATION CHANNEL DESIGNED FOR EXCHANGING INFORMATION ABOUT INTENTIONS IN COLLABORATIVE SYSTEMS

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Abstract
In collaborative systems, both technical and social factors influence decisions. While collaborative options may yield desired outcomes, a lack of understanding between parties can hinder collaboration. Effective communication facilitates information exchange and comprehension of partners' intentions, guiding designers toward collaborative decisions. This study examines the impact of a communication channel designed to share actors' collaboration intentions on the accuracy of information exchange and strategic decisions in a collaborative design process. The research uses secondary data from a human experiment involving a collaborative system design problem to assess the intervention's effects. The experimental procedure involves actors completing 30 paired tasks, earning or losing points based on joint decisions with their partners. Participants represent decision-makers from different car manufacturing companies. The experimental data includes 28 junior-year plus STEM undergraduate and graduate students completing paired decision-making collaborative tasks allowed to exchange verbal information and have an additional communication channel to share intentions. The usage of the communication channel is investigated using multiple statistical tests. Results indicate that actors share their intentions accurately and honestly via the communication channel. Even in inaccurate cases, actors' decisions shift significantly due to their partner's reported strategic intentions. This research underscores the importance of communication for better management of collaborative systems.

Keywords
Collaborative Systems, Communication, Decision-making, Game-Theory, Human Experiments

Introduction
Boeing, a leading aircraft designer and producer, manufactures only a few parts of its designs, while Apple, a top technology company, relies on partners to produce most of its products. These examples illustrate that engineering has evolved from a cooperative to a collaborative process, making the management of collaborative systems critical.

Collaboration is a strategic agreement between actors to work together in ways that surpass the capabilities of a single actor (Rechtin, 1992). Despite their significance, about half of collaborations fail (Kale, Dyer, & Singh, 2002). In collaborative design systems, outcomes depend not only on one's decisions but also on a partner's actions, making risk inseparable from the process (Avsar, Grogan, & Stern, 2022; Avsar, 2023). Even if collaboration promises higher gains, lack of understanding, insufficient common knowledge, and the bounded rationality of the participants due to suspicion and distrust towards their partner can lead decision-makers to choose individual options (Zajac & Bazerman, 1991; Agarwal, Croson, & Mahoney, 2010). Enhanced communication is shown to increase successful collaborative outcomes (Agarwal, Croson, & Mahoney, 2010; Shin, Park, & Ingram, 2012; Rodan & Galunic, 2004; Adner & Helfat, 2003; Kogut, 2000). This paper investigates whether actors use an information channel accurately to communicate their strategic intentions, provided it is present in the collaborative system.

The paper uses secondary data from a dissertation study (Avsar, 2023) involving a human experiment on a collaborative system design problem. It investigates the effects of an intervention on outcomes, with participants representing decision-makers of different organizations aiming to increase their revenues through paired collaborative tasks. Participants can gain more by collaborating but face downside potential if it fails. Actors report their collaboration beliefs in each task via a slider, and the communication channel provides information on the strategic intentions of both actors and the minimum required collaboration beliefs to choose collaboration.

While results of the thesis focus on effects of the intervention on collaborative task outcomes (whether it helps for more successful collaborations), this paper investigates the usage of the collaboration belief slider as a communication channel between pairs. Results show that actors share accurate information about their strategic intentions via the communication channel. Actors' final decisions can change after learning about their partner's strategic intentions, especially in cases when actors report they intend to choose individual options; they decide to collaborate after they learn their partners intend to collaborate. Finally, results show that the majority of actors do not share manipulating information via the communication channel. This study shows that communicating the intentions in a collaborative system is one of the critical elements for a more efficient process because as the actors prefer to use the channel honestly, their understanding of their partners' intentions increases, reducing their perceived risk towards choosing a collaborative design option.

Background

Collaborative Systems

Rechtin defines a *system* as "a set of different elements so connected or related so as to perform a unique function not performable by the element alone" (Rechtin, 1992). He states that each part in a system has its value, but the essential value comes from the relationship between the parts and how they all form a system. A system is a collection of different entities composing an outcome that cannot be achieved by an individual entity (Rechtin, 1992).

Collaborative systems can be defined as large systems that assemble two or more complex systems. Collaborative systems possess both operational and managerial interdependence (Maier, 1998). In collaborative systems, each sub-system can perform independently but choose to form a collaboration because, as a single system, they cannot perform the function of a collaborative system (Maier, 1998). Normatively, actors choose collaboration when the benefit of the collaboration outweighs its costs. Maier states that the mechanisms and incentives for collaboration must be designed in the system (Maier, 1998).

Research on collaborative engineering design emphasizes highly human dependent engineering systems with multiple interdependent participants (Klein & Sayama & Faratin, 2003). Collaborative system problems have several self-interested agents who must work together towards a common system-level goal despite different local objectives (Safarkhani & Bilionis & Panchal 2018). Social dilemma can arise in collaborative design problems from conflicts between collective benefits and self-interest (Takai, 2016, Valencia-Romero & Grogan, 2020) that adds uncertainty to the system. Decision-making actors can share or retain information for their self-benefit, so actors need to make strategic decisions only with the limited available information to maximize their expected gains (Grogan & Valencia-Romero, 2019).

Game theory provides methods to model strategic dynamics in a collaborative system (Grogan, 2019). Even though the prisoner's dilemma has been widely discussed in the research literature, a stag hunt game better captures and models the dynamics in a collaborative system (Agarwal & Croson & Mahoney, 2010, Grogan, 2019). In a stag hunt game, there exist two hunters who can either hunt hare individually or collaborate and hunt a stag together. Although stag-hunting provides greater gains for both hunters, it is also risky because the hunter would face downside losses if their partner defects and decides to go with the individual option of hunting a hare. It is normatively expected from actors to choose stag-hunting when they have a stronger belief about their partner's intention to cooperate (Skyrms, 2004) by decreasing their perceived risk towards the collaborative option (Avsar, Grogan, 2023).

Communication in Management Systems

In management science, communication holds an essential place in the literature on strategic alliances (Shin & Park & Ingram, 2012). In a strategic alliance, communication can shift partner perceptions from competitive to cooperative (Agarwal & Croson & Mahoney, 2010). Research on strategic alliances acknowledges the significance of interpersonal communication among decision-makers as a pathway to fostering collaboration and alignment (Rodan & Galunic, 2004, Zaheer & Venkatraman, 1995). Communication can prevent problems arising from bounded rationality and decision biases. Management literature shows that improved communication in strategic alliances also improves economic returns (Adner & Helfat, 2003) by ensuring better information flow (Kogut, 2000).

As in strategic alliances, there exists fear related to partner misconduct; having further knowledge about other parties' incentives and orientation toward the strategic alliance can reduce perceived risk. Communication also reduces the chances of surprises and minimizes the chances of unexpected developments, fostering shared expectations that improve group coordination and unity. Previous research on alliances has established a notable correlation between communication among partners and enhanced performance in strategic alliances (Doz, 1996). Consequently, effective communication fosters the cultivation of social capital and trust among partners in strategic alliances (Gulati, 1999).

The literature in economics shows that in prisoner's dilemma context, communication does not increase the probability of cooperation (Farrell & Rabin, 1996). However, strong evidence shows that enhancing communication increases cooperation outcomes in assurance games (such as stag hunt game) with multiple Nash equilibria, which are better representations of strategic alliance context (Ledyard, 2020). Agarwal et al. investigate the effects of communication in strategic alliance by conducting a human experiment (Agarwal & Croson & Mahoney, 2010). In their experiment, each participant represents a firm that makes a decision about the extent to which to engage in cooperative activities within their strategic alliance, and participants can communicate via a chat-box in the treatment groups. Their experimental results support significant evidence that the ability to communicate approximately doubles the rate of successful cooperation in strategic alliances.

Research Objective

The literature shows how collaborative systems can provide greater benefits for all actors if they are successful but are fragile due to complexities arising from actor interactions. Management science literature shows the importance of communication in strategic alliances for more successful outcomes. Accordingly, this study investigates the usage of a communication channel by actors in a collaborative system using secondary data from an experiment that investigates the addition of a system mediator as an intervention to re-design the system (Avsar, 2023). In the original study, the system mediator enables the exchange of necessary technical and social information. This paper only focuses on the usage of the communication channel as an information exchange tool to report strategic intentions of actors in a collaborative system. This paper investigates the following research questions:

- **RQ1:** Do actors share accurate information about their strategic decisions via the communication channel?
- **RQ2:** Does the partner's reported strategic intention via the communication channel affect an actor's final decision when there is an inaccuracy between their initial strategic intention and final decision?
- **RQ3:** Do actors share manipulating information via the communication channel for strategic purposes?

Methodology

This paper uses secondary data from an experiment that investigates the effects of an intervention in a collaborative system by re-designing the system with the addition of a system mediator (Avsar, 2023). The system mediator is a communication channel that enables the exchange of necessary technical and social information. This paper only focuses on the effects of the communication channel for social information exchange in a collaborative system.

Design Task

The experimental design includes tasks with two paired actors completing decision-making tasks. All design tasks incorporate Stag-Hunt strategy dynamics to capture the collaborative system's strategic dynamics and re-frame the problem to include three collaborative and one individual option as in real world problems there exist multiple design options. Exhibit 1 shows example payoff value (V) options for Actor A as a function of the decisions of Actor B for a stag-hunting problem. In each task, actors must choose an option among the four designs (D) based on the possible payoff values of designs (V_D). The payoff values received by each actor ($V_D^{S_A S_B}$) depends on the strategic decision (S) of the pair. Accordingly, even though actors make one decision in each task, they first make a strategic decision between collaborative and individual options. If they choose to cooperate, they then evaluate the tradeoff among three cooperative options: the higher potential rewards with higher risk against the lower potential rewards with lower risk.

Exhibit 1. Payoff Matrix Example for Bi-Level Stag Hunt Game

		Actor B	
		Cooperation (C)	Individual (I)
Actor A	Design K (C)	$V_M^{CC} = 111$	$V_M^{CI} = -90$
	Design L (C)	$V_K^{CC} = 92$	$V_K^{CI} = -45$
	Design M (C)	$V_L^{CC} = 77$	$V_L^{CI} = -15$
	Design Y (I)	$V_Y^{IC} = 50$	$V_Y^{II} = 50$

Design tasks are categorized into six levels based on different difficulty levels and five levels of payoff magnitude range (detailed explanation in experiment design section). Each design alternative in a task has the same difficulty level, and the cooperative design options have different payoff magnitude ranges. The three payoff ranges for each task provide greater control over cooperative design implementation, which can shift the risk-dominant equilibrium toward collaboration due to shift in their risk perception (Avsar, Grogan, 2023).

Exhibit 2. Experimental Interface for Training Task 1

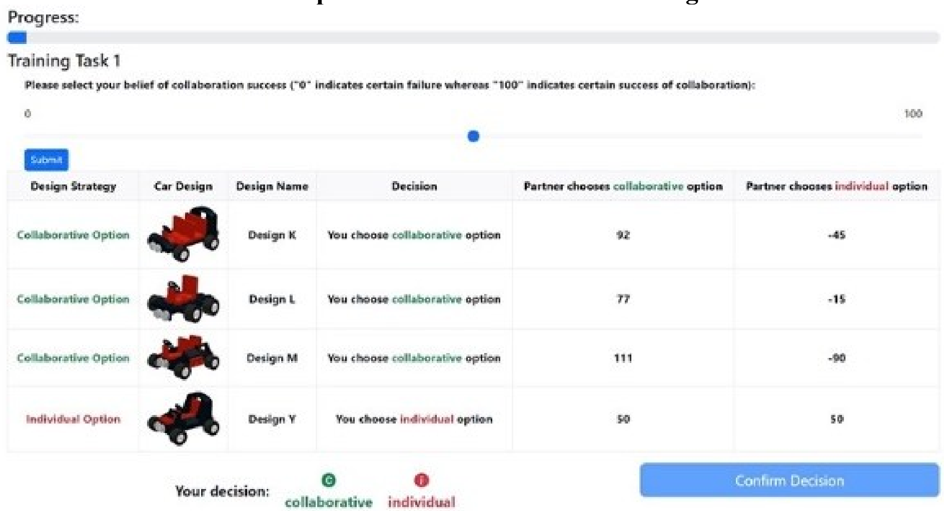


Exhibit 2 illustrates the interface for the first training task. Each task has three collaborative design options (designs K, L, and M) and one individual design option (design Y). More advanced collaborative design options yield higher revenues if collaboration is successful but result in bigger losses if the partner defects (e.g., option M: upside potential = 111, downside potential = -90 points, option L: upside potential = 77, downside potential = -15 points). Each experimental task includes a question that asks about the participants' beliefs about the success of the collaboration. Participants select a value from a slider from 0, indicating a certain belief of collaboration failure, and 100, indicating a certain belief of successful collaboration. After seeing each task, participants must select their collaboration belief from the slider before making a final decision in the design table.

Experiment Design

The difficulty levels (L) of tasks are calculated using economic theory principles based on normalized deviation loss (u). Normalized deviation loss measures the minimum probability of cooperation (p_j) of one's partner required to pursue the collaborative strategy (C) from an expected value perspective (Harsanyi & Selten, 1988). Equation (1) shows the u-value calculation and an example u-value for design L (C) and design Y (I) in Exhibit 1:

$$\mathrm{u} = \frac{V_Y^{II} - V_L^{CI}}{(V_Y^{II} - V_L^{CI}) + (V_L^{CC} - V_Y^{IC})} = \frac{50-(-15)}{(50-(-15))+(77-50)} = 0.7 \qquad (1)$$

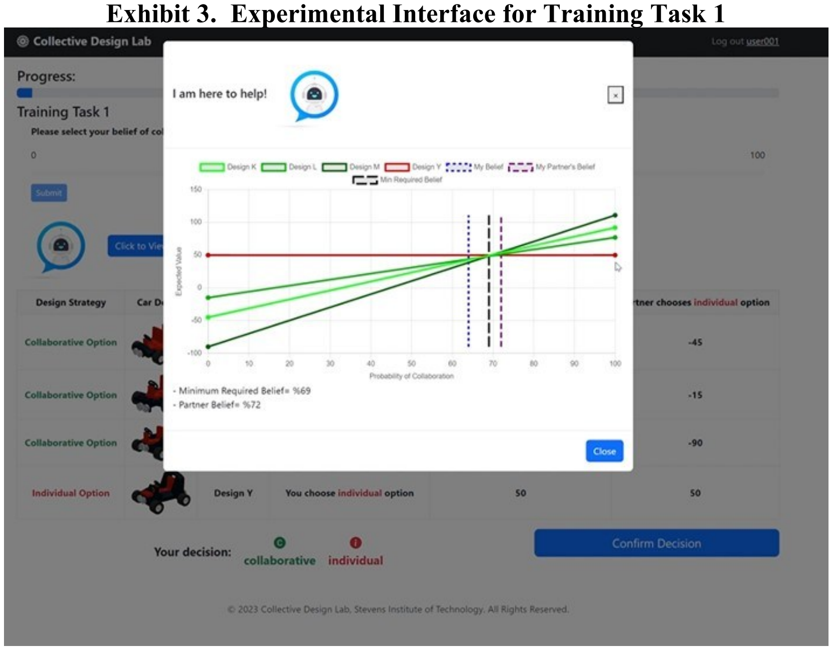
The six difficulty levels are as follows: Level 1: u = 0.55, Level 2: u = 0.60, Level 3: u = 0.70, Level 4: u = 0.75, Level 5: u = 0.80, Level 6: u = 0.85. For instance, an actor requires 55% cooperation probability from their partner for level 1 and 85% for level 6. Design tasks include five tasks from each difficulty level for a total of 30 design tasks.

The experimental design includes five different payoff magnitude ranges (G) and cooperative design options have consecutive payoff ranges such that option A always has the highest range, option B always has the mid-range and option C always has the lowest range (e.g., $V_A^{CC} = 130$ and $V_A^{CI} = -48$, $V_B^{CC} = 115$ and $V_B^{CI} = -27$, $V_C^{CC} = 105$ and $V_C^{CI} = -17$ for L=1 and G=5). Through an experimental session, cooperative design option A ranges from a maximum of 130 points to a minimum of -400 points, design option B ranges from a maximum of 115 points to a minimum of -280 points, design option C ranges from a maximum of 105 points to a minimum of -250 points. The order of design options A, B, and C is randomized as design K, L, and M. There are five tasks for each difficulty level with five payoff magnitude ranges Each task includes three collaborative options with the same difficulty level but different payoff magnitude ranges (e.g., $V_A^{CC} = 100$ and $V_A^{CI} = -9$ for L=1 and G=1, $V_A^{CC} = 130$ and $V_A^{CI} = -400$ for L=6 and G=5 while V_Y is constant at 50 for all tasks). Each pair of participants encounters all possible combinations of difficulty levels and payoff ranges. Also, pairs face asymmetric tasks, meaning that partners do not face the same payoff values.

According to the experimental design, the **communication channel** has two roles. 1- **Providing technical information:** Experimental tasks include different difficulty levels, and participants might not be able to process a complex calculation of normalized deviation loss in a one-minute task period; the communication channel illustrates the u-value of the specific task. 2- **Exchanging social information between partners:** The communication channel shows the participants their and their partner's selected collaboration belief for each task, enabling the communication of intentions.

Exhibit 3 illustrates the interface for the treatment group with the communication channel window. The black vertical line in the plot shows u-value of the task, the purple dashed line shows the collaboration intention of the partner, and the dotted blue line shows the collaboration intention of the actor from the collaboration belief slider.

Exhibit 3. Experimental Interface for Training Task 1



Experimental Protocol

The source study includes two study groups: the control group without the system mediator (communication channel) and the treatment group with the system mediator. All experimental sessions were conducted in person at the Stevens Institute of Technology campus. The procedure includes a demographics survey, a pre-survey, and a post-survey. Participants are given one minute per task, three minutes for each survey, and 10 minutes for instructions, making each session approximately 60 minutes long.

Each session includes four participants randomly paired by the experimenter before the session begins. Each participant completes 30 decision-making tasks from which they earn/lose points (points are the possible payoff values) based on joint decisions with their partner. Even though participants need to complete the tasks with their partner, they earn/lose points individually. At the end of the session, participants receive gift cards based on their individual ranking calculated by their cumulative points. Participants are informed that they represent decision-makers from different car manufacturing companies, making each session a competition among four companies.

In each task, participants choose from four car design options, and they must strategically decide whether to collaborate or defect to maximize their company's revenues. Additionally, participants are informed that collaborative designs have a 5% chance of a technical error occurring, which would cause the collaboration to fail and result in losses. This technical error is included to simulate real-life scenarios where collaborations might fail not only due to social conflicts but also due to technical incompetence. However, this technical error was not actually implemented in resulting payoffs. The experimental sessions also include six distraction tasks with prisoner's dilemma distributed throughout the task sequence in a fixed order to introduce a variety of strategic dynamics during the experiment.

In each session, four participants attended the same room, and pairs sat face to face, allowing them to communicate verbally but restricting them from seeing each other's screen. During the experimental tasks, participants were free to share verbal information with their partners, such as their intentions, the payoff value they face, or their chosen design options. However, it was their choice whether to share honest or misleading information. Since all four participants (two pairs) were in the same room, they could also hear the conversations of the other pair but each participant in the room faces different set of tasks at a time. The experimental tasks sequence is randomized for four participants within a session but remains fixed across different sessions. The experimenter monitored the progress of each task and automatically moved on to the next task once all participants had made their final decisions.

Experiment Data

The experiment data for this paper includes a total of 28 subjects (8 women, 20 men) participated in the experiment. Subjects ranged from 20 to 33 years of age. All participants either completed or were in their junior year of STEM undergraduate studies, and over half were pursuing a graduate engineering degree. Participants reported their English proficiency one to six scale, six meaning fluent/native, five meaning high (TOEFL > 95 or IELTS > 7.0) and one meaning low (TOEFL≤60 or IELTS < 6.0). Participants average reported English proficiency was 5.6 with all participants reported an English proficiency above or equal to level 3. Subjects reported their social closeness with their pair on a one to five scale, with one meaning lowest social closeness (the first-time meeting) and five meaning highest social closeness (relative, partner, very close friend). The average reported social closeness was 2.2 with a minimum of level 1 and maximum of level 5. The experimental design yields observations (strategic decisions, points earned/lost and collaboration beliefs) from 420 design tasks (14x30=420).

Results and Discussion

Analysis considers the treatment group consisting of 420 experimental tasks. Observed data includes final strategic decisions and strategic intentions (both the actor's and their partner's) reported via the collaboration belief slider, resulting in 840 observations. Exhibit 4 summarizes all variables and their definitions used in the analysis and results.

Exhibit 4. Abbreviation Table for Results and Analysis

Variable	Equation	Range	Definition
u_i	n/a	[0, 100]	Normalized deviation loss (task difficulty) for actor i.
D_i	n/a	[I, C]	Final decision (C: collaborative, I: individual) for actor i.
P_i	n/a	[0, 100]	Collaboration belief reported via slider for actor i.
Q_i	$P_i - u_i$	[-100, 100]	Modified collaboration belief for actor i.
W_j	$P_j - u_i$	[-100, 100]	Actor j's modified collaboration belief perceived by actor i.
S_i	C if $Q_i > 0$ else I	[I, C]	Implied strategic intent for actor i.
R_j	C if $W_j > 0$ else I	[I, C]	Actor j's implied strategic intent perceived by actor i.

Results and Analysis for RQ1

RQ1: *Do actors share accurate information about their strategic decision via the communication channel?*

The first research question investigates whether actors use the collaboration belief slider to accurately communicate strategic intentions with their partner. As explained in the methodology section, actors report their collaboration belief on a scale from 0 (certain belief of collaboration failure) to 100 (certain belief of collaboration success) prior to making a final decision. Further, each task has a different difficulty level based on the task's *u*-value. The actor's reporting a collaboration belief of $Q_i > 0$ indicates that they intend to collaborate (S_i = C), and $Q_i \leq 0$ indicates they intend to choose individual option (S_i = I). Actors' shared information is accurate if their reported strategic intention and final decision match (accurate if $S_i = D_i$, inaccurate if $S_i \neq D_i$).

Results show actors use the collaboration belief slider accurately in 83% (703/840) of tasks. Exhibit 5 illustrates information sharing accuracy using the collaboration belief slider. The data shows that actors intended to collaborate and followed through in 74.4% of tasks; intended to collaborate but chose the individual option in 6.4% of tasks; intended to choose the individual option and followed through in 9.3% of tasks, and intended to choose the individual option, but chose the collaboration instead in 9.9% of tasks.

Exhibit 5. Experimental Data for Accuracy of Collaboration Belief Slider

Collaboration Belief Slider Usage Accuracy	Strategic Intention of Actor i (S_i)	Final Decision of Actor i (D_i)	Occurrence Percentage	Observed Occurrence/Total Task #
Accurate	Collaborative (C)	Collaborative (C)	74.4%	625/840
	Individual (I)	Individual (I)	9.3%	78/840
Inaccurate	Collaborative (C)	Individual (I)	6.4%	54/840
	Individual (I)	Collaborative (C)	9.9%	83/840

Statistical analysis investigates the relationship between the reported strategic intentions via the collaboration slider and final decisions. Analysis uses Q_i to understand the magnitude and direction of the actors' reported strategic beliefs. A greater Q_i indicates a stronger belief in collaboration, as reported by the actor, whereas, as Q_i gets smaller, the strategic intention of collaboration decreases. The analysis encodes the actor's final decisions as a binary variable (D_i=C encodes as 1 while D_i=I encodes as 0).

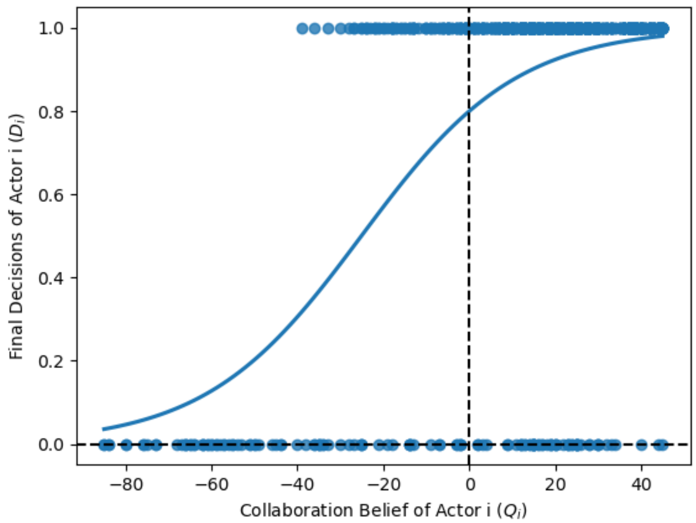
Point biserial correlation investigates the relationship between Q_i and D_i, because D_i is a binary variable and Q_i is a continuous variable. Results show a statistically significant moderate correlation with correlation coefficient 0.555 and p-value $3.52\ x\ 10^{-69}$.

The logistic regression test is selected for further analysis of the effects of Q_i on D_i, because the dependent variable D_i is binary, and the independent variable is continuous. The logistic regression model is $D_i = \beta_0 + \beta_1 Q_i$ and results in Exhibit 6 show that Q_i has a statistically significantly effect on the final actor decisions. Exhibit 7 also illustrates the relationship between Q_i and D_i in a scattered plot with the logistic regression curve.

Exhibit 6. Logistic Regression Results Investigating Effects of Q_i on D_i

Variable	Coefficient	Std. Error	z-value	p-value
intercept	1.3787	0.117	11.818	$3.151\ x\ 10^{-32}$
Q_i	0.0551	0.005	11.795	$4.132\ x\ 10^{-32}$

Exhibit 7. Scatter Plot of Q_i and D_i with the Logistic Regression Curve



Discussion of RQ1

Analysis results reveal a statistically significant relationship between the actors' reported strategic intentions and final decisions, suggesting that actors accurately share information about their strategic intentions using the collaboration belief slider. Results indicate that as the collaboration belief value reported by the actors increases, the chance of the final decision being a collaborative option also increases. The temporal separation of the two events (i.e., actors always enter a collaboration belief prior to selecting a final decision) which strengthens the causal relationship.

During the experiment, even though actors are allowed to share any verbal information, they have different preferences over communication. Some actors prefer to share information willingly, whereas others prefer to retain information or feel uncomfortable sharing information verbally. Accordingly, some pairs do not communicate effectively or have miscommunication issues, meaning they cannot obtain essential information. The communication channel addresses this issue by allowing actors to communicate the relevant information about the task without any verbal communication, thereby increasing transparency. More specifically, actors share their collaboration beliefs with their partners via the communication channel, and experimenter observations show that many actors are more comfortable and honest when sharing their beliefs about collaboration technically rather than verbally. The communication channel enables actors to share their strategic intentions and results show that actors are willing to share accurate information about their intentions via the communication channel.

Results and Analysis for RQ2

RQ2: *Does the perceived strategic intention of partner via the communication channel affect an actor's final decision when there is an inaccuracy between their initial strategic intention and final decision?*

The second research question investigates if inaccuracy between reported strategic intentions and final decisions can be attributed to the partner's strategic intentions available through the communication channel. After an actor reports their strategic intention, they can use the communication channel to view their partner's strategic intention (illustrated in the methodology section Exhibit 3, the purple vertical line). Accordingly, final decisions are made after learning about their partner's strategic intentions. If partner's strategic intention $P_j > u_i$, the actor perceives a positive collaboration belief from their partner but if $P_j < u_i$ the actor perceive collaboration risky. This research question focuses on the relationship between partner's perceived collaboration belief (W_i) and final decisions of the actor (D_i), hypothesizing that an actor may be expected to change their decision if R_j does not match S_i.

This section of analysis only considers the population with inaccurate strategic intention reports for the specific purpose of the research question (data includes only $S_i = C$, $D_i = I$ or $S_i = I$, $D_i = C$). Exhibit 8 shows that for actors who reported $S_i = C$ but acted $D_i = I$, 64.8% of the time their partner reported $R_j = I$ and for actors who reported $S_i = I$ but acted $D_i = C$, 96.4% of the time their partner reported $R_j = C$.

Exhibit 8. Experimental Data for Partner Responses for Inaccurate Actions

Collaboration Belief Slider Usage Accuracy	Strategic Intention of Actor i (S_i)	Final Decision of Actor i (D_i)	Strategic Intention of Actor j (R_j)	Occurrence Percentage	Observed Occurrence/Total Task #
Inaccurate	Collaborative (C)	Individual (I)	Individual (I)	64.8%	35/54
	Individual (I)	Collaborative (C)	Collaborative (C)	96.4%	80/83

The logistic regression test is again selected to investigate effects of the continuous variable, W_j, on the binary variable D_i within the set of tasks labeled as inaccurate. Logistic regression model ($D_i = \beta_0 + \beta_1 W_j$) results in Exhibit 9 show that W_j has a statistically significant effect on actor decisions.

Exhibit 9. Logistic Regression Results Investigating Effects of W_j on D_i for Cases with $S_i \neq D_i$

Variable	Coefficient	Std. Error	z-value	p-value
intercept	-0.0071	0.241	-0.030	0.976
W_j	0.0545	0.011	5.069	4×10^{-7}

Discussion of RQ2

Analysis results for RQ2 indicate that inaccuracy between reported strategic intentions and final decisions can be partially attributed to their partner's strategic intention. To be more specific, the analysis supports that an actor can change their decision after learning about their partner's strategic intentions. Results are especially exciting for cases when an actor intended to choose the individual option and their partner reported their intention is collaborating because in those cases, actors shift their decision from individual to collaborative approximately 96% of the tasks.

The communication channel makes the collaborative process more transparent by providing social information about the partner's collaboration intent. Collaborative systems include both risk-taking and risk-averse actors, and risk-averse actors perceive collaboration even riskier compared to risk-taking actors due to their utility functions. Experimenter observations show that the communication channel can show risk-averse actors that collaboration is not as risky as they perceive it to be because their partner has a high probability of collaborating, increasing their perceived trust levels. This significant result indicates that by enabling a more transparent social picture, the communication channel can lead to higher rates of collaborative decisions and successful collaborations.

Results and Analysis for RQ3

RQ3: *Do actors share manipulating information via the communication channel for strategic purposes?*

Introducing a communication channel in a collaborative process for communicating strategic intentions holds a great risk because actors can use the channel to manipulate their partners toward their strategic gains. The basic stag hunt game does not incentivize this type of manipulative behavior; however, because points are accumulated individually in the experiment, participants have some incentive to harm their partner to improve their own relative position. That said, manipulation has significant limits in this setting because actors can generally out-perform competing pairs through successful collaboration. Still, this research question investigates if actors report they have high intentions towards collaboration, knowing that this information would be available to their partner, and they choose individual design option, meaning they used the communication channel for deceiving their partner.

This section focuses on only scenarios where $S_i = C$ and $D_i = I$, because this is the setting where manipulation is easiest to identify, which is only 6.4% of the total observed scenarios (54/840 tasks). Furthermore, in 65% of these scenarios, the partner's perceived strategic intent is to choose the individual option, which might have shifted the actor's decision from collaboration to individual (following RQ2). The subset in which both $S_i = C$ and $R_j = C$, but the actor chose the individual option, is only observed in less than 3% of the cases (19/840 tasks).

However, even though manipulative behavior has not been observed in the communication channel in many cases, there may be specific actors who follow the manipulative strategy. The analysis first aims to investigate if the mean values of final decisions are equal for all actors for the scenarios where both actors reported their strategic intentions is to cooperate (S_i = C and R_j = C). Accordingly, the analysis first runs a one-way ANOVA test for 50 actors with the null hypothesis that the mean D_i value is equal for all actors when both S_i and R_j equal C (sample size is 560). The results of the ANOVA test indicates that there is at least one actor whose population mean is different from the rest for the D_i values (F-statistics = 4.304 and p-value = $4.62 \ x \ 10^{-19}$).

From the results of the ANOVA test, the next goal is to investigate which actors have different mean D values from the population. Accordingly, the analysis runs a one-population one-tailed t-test to compare actor decisions to the expected population mean of D_i =1. After running the t-test for all actors, results show that there are five actors, whose population mean is statistically significant (p-value < 0.05), results are shown in Exhibit 10.

Exhibit 10. T-Test Results: Actors with D_i < 1 for Cases with S_i = C and R_j = C

Actor ID	t-statistics	p-value	df	Mean D_i
User 13	-1.871	0.041	14	0.800
User 41	-1.852	0.041	16	0.823
User 43	-2.985	0.003	28	0.758
User 44	-2.985	0.003	28	0.758
User 48	-3.873	$7 \ x \ 10^{-4}$	15	0.500

Discussion of RQ3

One of the biggest concerns while designing a communication channel for a collaborative design system is that actors can manipulate the information strategically for their benefit. However, results show a majority of actors within the experiment use the communication channel to honestly communicate their intentions serving to common good, rather than using it as a strategic tool. Analysis results indicate that only a few participants' behaviors can be grouped as manipulative. Future studies should investigate further ways to detect those actors during the collaborative tasks to eliminate them from the process to preserve the main reason for having a communication channel that is serving the common good.

Limitations

Results from this paper are subject to several limitations. First, it uses secondary data from an experiment on the effect of an interventions, that has more roles than just being a communication channel, on the outcomes of collaborative design systems (Avsar, 2023). The experiment uses a highly simplified collaborative task, representative of a collaborative system only at an abstract level. Although a simplified task helps to better understand the effects of specific factors, it also greatly simplifies the tasks by neglecting factors such as domain knowledge and creativity. Constraints on session duration limited the number of tasks to keep the total experiment time less than one hour and retain participant attention. Additionally, experimental resources only allowed for thirteen sessions, limiting the amount of data collected. Finally, experimental tasks consider interactions between two participants at a time, take place over a short period (minutes), have a small number of design variables without any domain-specific design context, and incentivize behavior using a financial reward tied to relative ranking in a design session. These limitations indicate that the results of this experiment might show variations when domain-specific knowledge or greater design space is included in the system.

Conclusion

In collaborative systems, actors not only make decisions based on technical information but also evaluate their partners' intentions toward collaboration. Even though partners can exchange verbal information about their beliefs, constraints might prevent successful communication. This paper investigates a communication channel where actors share their collaboration beliefs through this channel with their partners. The paper provides three significant results: 1- Actors accurately share information about their strategic intentions using the communication channel. Experimenter observations suggest that many designers are more comfortable and honest when communicating their beliefs technically rather than verbally. 2- An actor can change their decision after learning about their partner's strategic intentions. By enabling a more transparent social picture, the communication channel can shift individual decisions to collaborations by showing an actor that their partner has high intentions towards collaboration. 3- Manipulative communication channel usage has not been observed widescale cases; only a few participants' behaviors can be grouped as manipulative.

To sum up, this study contributes to the literature by showing that communicating the intentions in a collaborative system is one of the critical elements for a more efficient process because as the actors prefer to use the channel honestly, their understanding of their partners' intentions increases, reducing their perceived risk towards choosing a collaborative design option.

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